Paper 152 - Galheta Canal Capacity Analysis - Port of Paranagua

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ABSTRACT: There is a strong interconnection between the inland waterway transport and the cabotage navigation in Brazil. The main cabotage routes of the country navigate the Amazonas River by more than 1000 km before reaching the ocean. This paper aims to determine the capacity of one the maritime/inland waterway arrangement component, the Paranaguá port maritime configuration. More specifically, the capacity of its harbour approach channel, tuning basins and anchorage areas of receiving safely the vessels used in these cabotage routes, based on the application of the PIANC's Report n°121-2014

1 INTRODUCTION

Navigation, since the beginning of times, has been shaping the human organization. The expansion of maritime knowledge, materialized in caravels, was one of the main reasons for Portugal's success in colonizing America [8]. It is believed that the first navigable channel was the China's River Port, built in the VI century. In 1515 Leonardo da Vinci, projecting Channels and Locks, solved a flood problem in the region of Milan. Those facts are just examples, among hundreds of others, which provide historical basis to the navigation sector relevance in human organization [13].

It is estimated that maritime routes transport 80% of the exterior commerce, based in tons. It has represented, in the year of 2012, a little more than 9 billion tons [19]. Also in the year of 2012, it was reached the mark of 600 million TEUs (twenty-foot equivalent unit) transported. Except for 2008, due to the economic crisis, when the exterior commerce decreased, the prognostic is of constant expansion.

The waterway transport is, in itself, characterized by some inherent advantages of its utilization, since it is, compared to other transport options, clean and eco-friendly, besides having a great energetic efficiency [11].

Furthermore, according to [18], mega containers arise is a trend in development and there is, consequently, a pressure on the already existing maritime configuration. Comprised by this expansionist and globalized context, entrepreneurs are looking for new alternatives to make the transport of products among countries economically viable, such as the Panamá Canal expansion and the new maritime routes of the Arctic.

The development of a safe and efficient transport is fundamental, taking into account the benefits of such reality. Transportation corresponds to, on average, 60% of the logistical costs; therefore, any obtained reduction in this sector is relevant. Yet, human mistake causes from 70% to 80% of all maritime accidents [14].

According to the Economic World Forum, in its report "Global Competitiveness 2013-2014" [18], competitiveness is a set of factors, policies and institutions that determine the productivity level of a nation. The report analyses 114 factors in its evaluation and, when it comes to port infrastructure, among the 148 nations that were researched, Brazil ranks the 131 ª position, far from the ideal of a country with more than 7.000km of coast.

When the Brazilian trade balance is analyzed, from 2003 to 2012, it is possible to observe that, according to data from ANTAQ [5] (National Agency of Waterway Transports – Agência Nacional de Transportes Aquaviários), there is a clear predominance of the of maritime transport mode. Based on the FOB value (Free on Board) of goods, 84% of the transports were made by waterway. Its share reaches 98% if it is based on the quantity by tons.

The basic criterion to define a maritime configuration is the safety of its maneuvers and operations [12].

In Brazil, transoceanic vessels berth in river ports, taking into account the magnitude of those rivers. The greatest shipowners operating in the country have lines that go from north to south, being the most outstanding and reliable example the Manaus-Rio Grande route. An ocean going vessel operating the mentioned route navigates Amazonas River for more than 1.000 kilometers before reaching the ocean.

2 OBJECTIVES

This paper’s goal will be to determine if one of the main components of Brazil’s river-maritime relation; Paranagua port harbor approach channel, turning basin and anchorage areas, will be classified as appropriate or inappropriate for safe navigation of the vessels under analysis.

The work begins with the item 3 presenting the adopted calculus methodology, justifying the choice made and commenting about simulation alternatives. In the item 4, main characteristics will be designated as well as environmental aspects and the vessels analyzed. On item 5, the calculations steps are explained and the obtained classification is displayed. At last, on item 6, the final considerations and recommendations are pointed out.

3 CALCULATION METHODOLOGY OF THE CAPACITY OF A CHANNEL PROJECT

3.1 *Process of a Channel Project*

As stated in [12], channels are projected in a two steps process: conceptual project and detailed project.

The conceptual project is characterized for being quick and for not involving the utilization of very detailed data. An empirical process determines channel characteristics. It is important because in this phase it is possible to evaluate innumerous scenarios [12].

The detailed project exists to refine, improve and validate the conceptual project that was adopted by means of physical and numerical analysis, with the utilization of simulators. This phase requires a further deepening in the data and in the vast experience of the projectionist in analyzing the results. The aid from the navigation professionals, such as maritime pilots and tug masters, is also necessary [12].

Initially, at conceptual project level, the first step is to adopt one or more design ships that are compatible to determined maritime settings, thus defining the analyzed alternatives. In sequence to this work, it is sought to optimize the navigation aspects, the safety, the environmental and economic aspects, among others, reducing the amount of alternatives that are worth analyzing at the level of a detailed project [12].

3.2 *Simulation*

Nowadays there are two models of simulation, which have distinguished objectives: (a) to simulate the capacity of a Channel by means of berthing maneuvers and its viability referred to navigation safety aspects, or (b) to quantify the maximum traffic in the Channel determining, in conjunction with other analysis, the cargoes movement capacity in the port system.

The objective of this paper requires an analysis of the maneuver simulators.

3.2.1 *Maneuver simulator*

There are two types of maneuver simulator: fast-time and real-time. Both are compound by simulation software, mathematical models of vessels maneuvers, a data bank with the geographical characteristics and analysis tools. The main difference between them is that in the fast-time system an algorithm navigates the vessel and automatically places the tugs. In the real-time model, a human being has the responsibility over the navigation, usually the maritime pilot [12].

The maneuver simulators allow a double application: (a) engineering and research, (b) qualifying and training. It is worth noting, however, that they demand different requirements. For research and engineering, the model must faithfully reproduce the physical behavior of the vessel in order to become a reliable extrapolator and allow the analysis of the maneuver security in a certain vessel in a given environmental condition. In the case of training, it must be reproduced qualitatively, transmitting the impressions, challenges, difficulties that the operator would have inserted in the defined environmental situation in a certain vessel [17].

The mathematical models are more reliable if based on data obtained in real scale. Those can be assessed on tanks and wind tunnels, physical models in scale, and then calibrated through real parameters. Nevertheless, it is possible to produce satisfying results with the utilization of numerical modeling and with models previously used in vessels with similar characteristics [12].

The geographic characteristics depend on the gathering of topographical, bathymetric and hydraulic data from the analyzed place and are very important because they influence directly on the hydrodynamic response of vessels [12].

The fast-time alternative might be sufficient for maneuvers considered simple, without many curves, in virtually rectilinear stretches. Various maneuvers are needed in each considered situation, with the response parameters of operators varying within a certain range that allows a statistical analysis of the data and ensures a significant validity to the results. Nevertheless, however simple the project of a Channel might be, the berthing maneuver is not trivial when you are very close to the pier, or when making curves in the turning basin. Thus, a real-time simulation dismissal demands extreme caution [12].

The real-time alternative is the most complete and closest to reality. The sophistication level of a real-time simulator varies very much, ranging from a monitor or projector and only a few controls to a simulation in 360° and all of the available controls in a real situation (Full-Mission Bridge). These bridge simulators are even used for qualify navigation professionals in training. The most advanced simulation is indicated for the final definition of the horizontal dimensions of the Channel and for the proper placement of navigation aids. Undoubtedly, experienced professionals and local connoisseurs, who are the maritime pilots and tug masters, in order to get a really reasoned and knowledgeable opinion, should perform its operation. Only their participation in the real-time simulation provides the guarantee of human factors and error margins inclusion [12].

3.3 *Methodology*

The methodology here adopted is the Deterministic Verification, in conceptual terms due to the nature of the available data and the resources availability, proposed by PIANC. According to it, the maritime configuration will be determined based on calculations where wave conditions, channel bottom, vessel type, among many other characteristics are variables. The results will make possible to determine if the vessel type that was studied navigates safely through that maritime configuration element. The author did not have enough resources to fund a fast-time simulation and therefore could not accomplish it.

4 CASE STUDY

4.1 *Overall Characteristics*

The Galheta Channel, that gives access to the Paranaguá Port, is located in the state of Paraná, in the city of Paranaguá. Paranagua port moved 41.9 million tons in 2013, representing 4.5% of the total amount moved in the country's ports. The aforementioned movement means an increase of 3.6% compared to 2012 [4]. The demand forecast for the year 2030 quantifies the total movement of almost 81 million tons, an increase of almost 100% on the current amount [15].

4.1.1 *Approach Channel*

Millions of tons movement increase allows inferring an increase trend of berthing’s and vessel transit through the ports maritime configuration. In the year of 2012, 2.525 berth maneuvers were made in the port and it is estimated that 5.873 will be made in 2030 [15].

A vessel type oriented analysis of the berthing maneuvers indicates the predominance of volume carriers. For the 2030 demand forecast, considering the 16 types of cargoes projected by the Master Plan of 2012, the Port will be accountable for 3.209 berthings of volume carrier vessels and 2.664 berthings of weight carrier vessels. Paranagua Port Authority (APPA) subdivided Galheta Channel in 3 sections:

4.1.1.1 *Section Alpha*

It is the outermost part of the channel, with an extension of 8.635 meters and 200 meters width throughout its entire extent. It goes through the bank of Galheta, which has the natural depth of about 5 meters. It is the only not sheltered section. It lies between the luminous buoys 1/2 and 9/10 and is almost rectilinear, with only one curvature with a very high radius [15]. It has a project depth of 15 meters [20].

Figure 1: Section Alfa. From Paranaguá port Master Plan (2013).

The section houses the only stretch not considered a two-way stretch throughout Galheta Channel according to Maritime Traffic and Permanence in Paranaguá and Antonina Ports Norm [2], in its Chapter 7 – PROCEDIMENTOS DE MANOBRAS, item 7.1.4.

4.1.1.2 *Section Bravo 1 and 2*

The sections following Alpha are the Bravo 1 and Bravo 2. About Bravo 1, it can be affirmed that it is 6.075 meters long, 13,5 meters deep and 200 meters wide throughout its entire extension. It is considered a semi-sheltered area. It lies between the buoys 9/10 and 15/16 and is completely rectilinear [15].

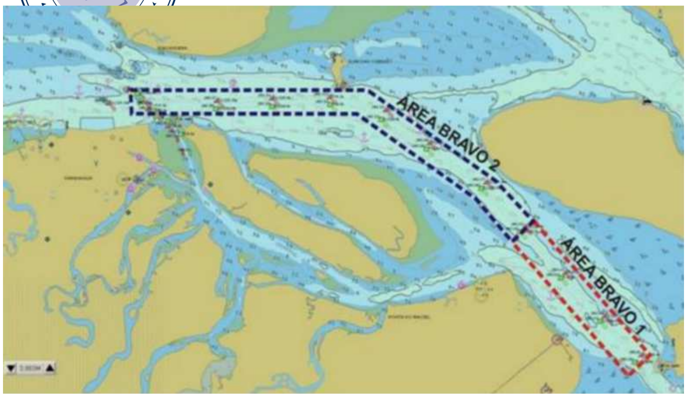

Figure 2: Sections Bravo 1 and 2. From Paranaguá port Master Plan (2013).

The Bravo 2 section extends for 14.471 meters maintaining a width of 150 meters and a depth of 13,0 meters. It lies between the buoys 15/16 and 30/31 and has three curves, all of them with a radius equal or bigger than 2.000 meters [20]. It's completely inserted in a sheltered area [15]. The first curve is considered the most downstream one, the second as intermediary and the third as the most upstream. Between each other, the first and the second curve have a 3.519 meters distance. When it comes to the second and the third curves, the distance is 1.241 meters [20].

4.1.2 *Turning Basin*

Turning basin areas are considered, in Paranaguá port, the entire space placed in front of its quays. The mentioned areas are divided in 3 sections of dimensions ranging from 450 to 550 meters [15]:

4.1.2.1 *Sections Charlie 1 and 2*

Paranagua port public quay places behind sections Charlie 1 and 2. The depths range from 10,0 to 13,0 meters, with a forecast of deepening to 14,5 meters [15][20]. The longitudinal dimension is of approximately 2750 meters and the transversal of 603 meters [20].

4.1.2.2 *Section Charlie 3*

Fospar, Cattalini and the public quays are placed behind section Charlie 3. Its depth is of 12,0 meters with a project of reaching 14,0 meters [15][20]. It has a longitudinal dimension of 2.200 meters and transversal of 343 meters [20].

4.1.3 *Anchorage area*

Paranagua Port has 12 anchorage areas with its utilization coordinated by the Maritime Traffic Norms and Permanence in the Paranagua and Antonina Ports [2].

The depths of each area, obtained from the Nautical Charts 1821 and 1822, provided by CHM (Centre for Marine Hydrography – Centro de Hidrografia da Marinha) and DHN (Directorate of Hydrography and Navigation – Diretoria de Hidrografia e Navegação) [6] [7], the port plan sent by TCP (Paranagua Container Terminal – Terminal de Contêineres de Paranaguá) [20] and PDZPO (Zoning and Development Port Plan – Plano de Desenvolvimento e Zoneamento) [1], allowed the compilation of the following table:

Anchorage Area	Dimensions (m)		Depth (m)
	Transversal	Longitudinal	
2	900	2.680	6 a 14
3	310	830	7 a 9
4	770	2.100	8 a 12
5	550	1.800	11 a 14
6	710	6.620	10 a 19
7	710	1.590	10 a 11
8	660	4.300	9 a 12
9	730	3.170	9 a 12
10	530	1.670	8 a 9
11	760	4.570	9 a 13
12	-	-	12 a 17

Figure 3: Anchorage areas characteristics.

4.2 *Environmental* Characteristics

4.2.1. *Climate*

According to the Department of Agriculture and Supply of the State of Paraná, the local climate regime, based on the Koppen classification, is considered CFA type. This classification means it is a subtropical climate; being the average temperature in the coldest month below 18 ° C (mesothermal) and the average temperature in the hottest month above 22 ° C, with hot summers, infrequent frosts and a tendency of rainfall concentration in the summer months. However, there is not a defined dry season.

4.2.2. Pluviometry

As suggested by Koppen's classification, the rainiest season is summer, and the least rainy is winter, not having a dry season. In the summer, the greatest daily precipitation is of about 100mm and it can reach peaks of 400mm. The average monthly precipitation is 200,5mm [16].

Regarding air humidity, Paranagua has annual monthly averages of about 12,103 mB³. The highest monthly averages occur in the months of June, July and August; and when it comes to the lowest rates, they occur in December, January and February [1].

4.2.3. Winds

The winds in the coastal portion of the state of Paraná, which includes Paranagua, have its dynamic set in its action upon the branch of the Atlantic Polar Mass, through the South Atlantic Anticyclone the Migratory Polar Anticyclone (BIGARELLA et al, 1978; Apud, [1]).

According to the data provided by TCP [20], obtained through a numerical modeling applied to previously collected data for weather forecasts, it's possible to affirm that the predominant wind direction is from northeast (NE) and east-northeast (ENE), with an intensity that does not present any possibility of exceeding 20m/s. Only 22% of registered winds reached 8m/s and less than 3% reached 12m/s.

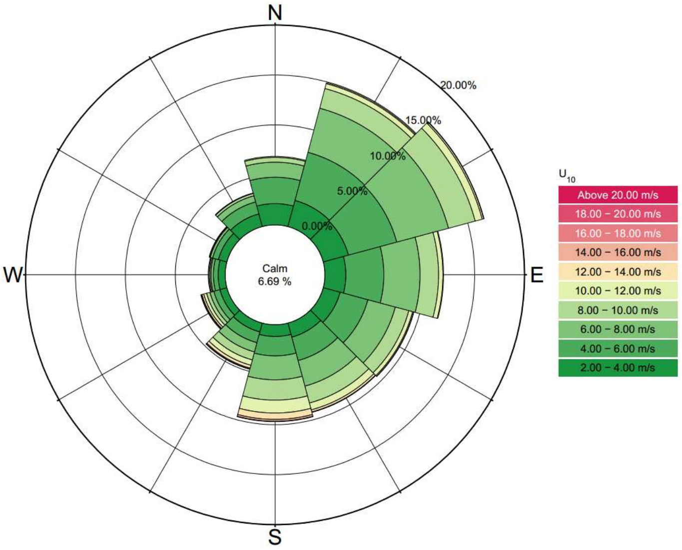

Figure 4: Wind rose. From TCP.

4.2.4. Waves, Tides, Currents and Density

APPA continuously conduct tide height observations through data obtained from automatic tide gauges, which maritime pilots operate, installed in Galheta Channel, Port of Paranagua and Ponta do Félix terminal. By means of these stations, it was possible to observe that the tide in the Galheta Channel region is semi-diurnal with daytime disparities [1].

The tide in the region of Paranagua's Estuarine Complex (CEP) has an average width of 2.2m and a predominantly semi-diurnal within the complex behavior, although there are disparities and nonlinear effects [1].

The wave's regiment, constituted from the collected data, measured by an AWAC (Acoustic Water Current Profiler) and commissioned by TPC, allows affirming that the predominant wave direction is between northeast and a east-northeast, with a height that doesn't surpass 5 meters. The data collection performed by the TCP supports the affirmative from APPA and the information contained in the Maritime Traffic Norms. This data collection was held on 8 stations, which are distributed throughout the studied region and it was mathematically extrapolated to the other regions. Less than 4% of the waves height exceeds 2.5 meters.

According to [1], through the publication of the PDZPO, and through the data provided by the TCP [20], it can be stated that the currents in the channel do not exceed 2.6 knots, except in rare occasions.

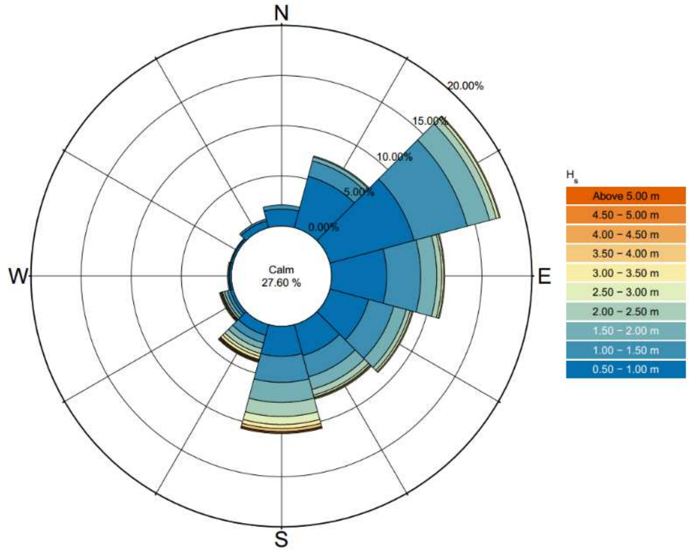

Figure 5: Wave rose. From TCP.

4.2.5 *Geotechnical Condition of the Soil and Siltation*

Terrigenous grain compose 95% of the Galheta Channel bottom, being that fine sand is the average granulometric fraction [3].

The sedimentary stream that moves along the Paraná coast is divided into two main streams, internal and external. Both have a sedimentation rate, which ranges around 20.000m³ / month [1].

The following figure illustrates a siltation monitoring in Galheta Channel from August 2009 until December 2010.

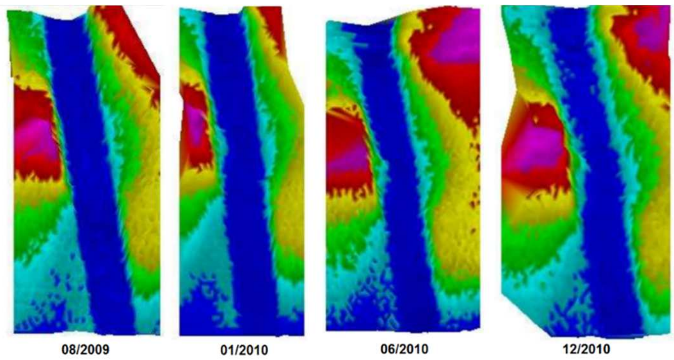

Figure 6: Siltation. From Gustavo Martins.

4.3 Vessel Type

The forecast of demand for berthings at the port of Paranagua, contained in the port Master Plan published in 2013, and the fluvial-maritime integration that exists in Brazil both suggest the analysis of a volume carrier vessel, which will be represented by a container vessel.

The volume carrier vessel with the biggest dimensions that currently navigates the channel (VC1), according to TCP, has the characteristics informed in the following table. Given that the aim is to assess the current fluvial-maritime interconnection in the country, materialized by the cabotage routes, the largest vessel engaged in this activity is Bartolomeu Dias, from Aliança. This vessels' (VC2) main characteristic are also available in the image below:

	L_{oa} (m)	L_{pp} (m)	B (m)	T (m)	DWT (ton)	TEUs
VC1	332,2	318,0	48,2	14,0	123.843	10.595
VC2	255,0	242,0	37,3	12,5	57.818	4.848

Figure 7: Vessel's characteristics.

5 CALCULATIONS AND RESULTS

5.1 *Vertical Dimensions*

5.1.1 *Harbor Approach Channel Vertical Dimensions*

Information obtained from Gustavo Martins [10], a port's maritime pilot, regarding berthing maneuvers allowed the author to adopt the speed range of 10 to 15 knots for both container vessels.

The waves were considered moderate since, during the observation, less than 4% exceeded 2m. Soils' geotechnical characteristic is sandy. Section Bravo 2 was considered an inner channel while Alfa section an outer channel. Section Bravo 1 has influence of both possibilities, being a transition section. Air draught analysis is not necessary since there are no structures above the channel.

There are no exact specifications for Bravo 1 section condition. The values utilized to multiply the vessel's draft calculations were, to maximize safety, the outer channel's interval smaller value. Channel bottom geotechnical condition related, concerning the additional security factor, an average value between the inner and outer channel situations was adopted.

Yet, is necessary to adopt a value to the factor (F_K), which will be 0,76 for both vessels. Since the conceptual project is naturally conservative, the use of a bigger value would make the results excessively high. The roll angle considered was 2º.

The resulting depths for each Galheta channel section are:

h_{CD} (m)	Section		
	Alfa	Bravo 1	Bravo 2
VC1	19,34m	17,89m	16,74m
VC2	17,24m	15,94m	14,89m

Figure 8: Approach channel depths.

Based on the results displayed above compared with each section's current depth it can be said that sections Alpha, Bravo 1 and 2 are not in conformity.

5.1.2. *Anchorage area vertical dimension*

Its recommended for anchorage areas to have 1,1 T of depth. The resulting depth for each vessel is:

	VC1	VC2
Depth (h_{CD}) m	15,4	13,75

Figure 9: Vessels.

Which implies nearly all anchorage areas are inadequate for the vessels in question.

5.1.3. *Turning Basin Vertical Dimension*

All turning basins, Chalie 1, 2 and 3, should have the conducting harbor approach channel's depth, therefore, Bravo 2 depth.

Therefore, no turning basin is considerate adequate.

5.2. *Vertical Dimensions*

5.2.1. *Harbour Approach Channel Horizontal Dimensions*

5.2.1.1. *Galheta Approach Channel width*

Initially, the basic maneuver lane is determined (W_{BM}). Its dimension depends on the ships beam (B). Both vessels maneuverability were considered moderate resulting in the following dimensions for each channel section:

W_{BM} (m)	Section		
	Alfa	Bravo 1	Bravo 2
VC1	72,3	72,3	72,3
VC2	56,6	56,6	56,6

Figure 10: Basic maneuver lane.

Related to vessel's speed, it was considered between 8 to 12 knots for both vessels due to maritime pilot Gustavo Martins considerations [10].

Prevailing cross wind category was considered mild. As for cross currents, low category was adopted. Bravo 1 section had its situation contemplated assuming a medium value between internal and external recommendations. The prevailing longitudinal currents were considered moderate.

Beam and stern quartering wave height was considered moderate. For Bravo 1 section, a value of 0,2 beams (B) was considered.

Since there are DGPS, paired lighted buoys with radar reflectors and lighted leading lines the aids to navigation were considered good. They do not fit in the excellent condition because there is no VTMIS.

The depth draft ratio $({}^{h}/_{T})$ is lower than 1,5 for all considered vessels. The bottom was considered smooth and soft. Ratios lower than 1,0 suggest the hull hitting the bottom. However, the dimensions considered were always in favor of security, and the conditions are the least favorable. Yet, there are possible navigation windows due to tidal differences that could allow the operation of the chosen vessels. For Bravo 1 section a multiplying factor of 0,3 beams was considered, a medium value between internal and external condition.

The last item was not considered since any of the vessels analyzed in this study carry high cargo hazards.

Further, widths regarding red (W_{BR}) and green (W_{BG}) sides were evaluated. The channel edges were considered sloping given a 1:4 ratio.

In Bravo 1 and 2 sections, which allow two-way traffic, it is important to consider the term width for passing distance (W_P). For Bravo 1 section a medium value between internal and external conditions of 1,5 was considered.

Additional dimension regarding large tidal range does not apply for Galheta Channel.

Resulting widths are available in the figure below:

W (m)	Section		
	Alfa	Bravo 1	Bravo 2
VC1	171,11	329,00	318,12
VC2	148,77	287,27	278,88

Figure 11: Resulting widths.

Alfa section is considered adequate and Bravo 1 and 2 are not.

5.2.1.2. *Curves and alignment*

The three existing curves in Bravo 2 section are geared to the same direction; therefore, need 3 considered vessel's length overalls (L_{oa}) between them. The following figure gives the resulting lengths:

	Straight section minimum length (m)
VC1	996,6
VC2	765,0

Figure 12: Minimum length between straight sections.

Considering the above shown results, the two straight sections between the three existing curves are considered adequate.

The minimum adequate curve radius for VC1 and VC2 are 7 length overalls (L_{oa}). Therefore:

	Curves minimum radius (m)
VC1	2325,4
VC2	1785,0

Figure 13: Curves minimum radius.

Besides that the curve radius is bigger than 2.000 meters, there is no further information. In any case, they are certainly adequate for vessel VC2.

5.2.2. *Anchorage Area Horizontal Dimension*

The anchorage area horizontal dimension is defined by the addition of six parcels. The first correlates directly to the considered vessel, dispensing explanations.

Paranagua port Anchorage areas, except number 12, were considered well protected. Since the time staying to berth varies, a medium value of 3,5 high tide depths was considered. Area 12 is external and the worse conditions applied, being considered 6 high tide depths.

The additional safety margin adopted was 25% of the length overall.

Soil geotechnical conditions were considered good for anchoring being possible to fit that portion in 0m condition.

The last parcel was defined as 10% of the lengths overall for the two evaluated vessels.

Results obtained for the vessels characteristics (L_C), available in the following figure considered the deepest value of the displayed in the figure that contained anchorage area dimensions. Horizontal dimensions per vessel and per anchorage area are also available.

AA	L_C (m)	*HD* (m)	
		VC1	VC2
2	49,0	497,47	382,67
3	31,5	479,97	369,20
4	42,0	497,47	382,67
5	49,0	497,47	382,67
6	66,5	514,97	396,20
7	38,5	486,97	374,20
8	42,0	490,47	377,67
9	42,0	490,47	377,67
10	31,5	479,97	369,20
11	45,5	493,97	379,20
12	102	550,47	423,67

Figure 14: Anchorage area horizontal dimensions.

Comparing the results obtained and presented in the figure above with the existing dimensions it is possible to assert there is partial conformity.

5.2.3. *Turning Basin Horizontal Dimension*

Chalie 1, 2 and 3 nominal diameter can be considered of 2 length overalls (L_{oa}) since there is no special treatment demanding characteristic and Paranagua port has tugs to aid the maneuvers.

Therefore:

Vessel	Charlie 1, 2 e 3 minimum nominal diameter (m)
VC1	664,4
VC2	510,0

Figure 5: Turning basin horizontal dimensions.

The longitudinal dimensions are adequate for both vessels; however, the transversals are not. Since the two dimensions need to be in accordance, the turning basins are considered inadequate.

6 CONCLUSION

6.1. *Final Considerations*

The results obtained by this study enable comments and further studies suggestion.

Based on maritime and port professional comments, and also previously done academic research, the investments shortage on the sector repercussions until today. Simple indispensable environmental data are missing for many ports in the country, situation that implicates on the adoption of less secure and efficient maritime configurations. In addition, there is a lack of professionals and research centers dedicated to this subject.

Paranagua port maritime configuration evaluated in conceptual design guidance was considered adequate in rare occasions even for the smallest considered vessel. Detailed design evaluations would most probably approve the maneuvers since they already happen frequently and there is no registration of incidents. Anyway, this study allows inferring that maritime professionals, pilots and tug masters, working in the area perform an excellent job due to the fact that they do not fail even when the most respected and up to date guideline available suggest higher dimensions for a safe condition.

6.2. RECOMMENDATIONS

The author supports PIANC recommendations with the following considerations.

Vessels selected in this work were chosen based on suggestions received from port, more specifically TCP, and maritime, pilot Gustavo Martins, professionals. However, a broader evaluation including a full hinterland economic analysis, different port terminals and shipowners consultation, among other possible actions could have pointed the consideration of more ships and situations. Since that is exactly what this stage of the work is designed for, deepening the deterministic process is recommended.

Possessing the calculations available on this work together with the ones resulted from the deepening effort, fast-time simulation is endorsed to reduce the number of possibilities before proceeding to detailed project stage.

Lastly, head on to the detailed project stage, that demands complete evaluation of each maritime configuration intervener aspect. Real-time simulation is highly recommended at this stage to insert practical experience and the human factor in the project. This complete process not only achieves the main maritime configuration design goal, which is the safe navigation of vessels, but also indicates what is the best economic, commercial, environmental, social alternative.

Based on the results obtained so far, Galheta Channel deepening and widening, Anchorage Area and Turning Basin transversal dimension extension together with its deepening are recommended interventions. Notwithstanding, specific comments apply.

Operational solutions could be discussed for the Anchorage Areas since a direct berthing could occur. Considering its horizontal dimension, this work considered vessels dropping just one anchor ahead, thus multiplying the need for space. The drop of one bow anchor a and one stern anchor could reduce the need for space and consequently reassess the recommendation of a costly intervention.

Pier 217, located ports downstream and next to Surdinho Canal, could have its maneuvers greatly facilitated if Palangana and Surdinho rocks were demolished. Besides increasing safety margins, that work would enhance harbor approach channel flow capacity, being also a recommended intervention.

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