Progress in Maritime Technology and Engineering

Editors:
C. Guedes Soares
T.A. Santos

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Progress in Maritime Technology and Engineering

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Table of contents

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Preface

Since 1987, the Naval Architecture and Marine Engineering branch of the Portuguese Association of Engineers (Ordem dos Engenheiros) and the Centre for Marine Technology and Ocean Engineering (CENTEC) of the Instituto Superior Técnico (IST), University of Lisbon (formerly Technical University of Lisbon) have been organizing national conferences on Naval Architecture and Marine Engineering. Initially, they were organised annually and later became biannual events.

These meetings had the objective of bringing together Portuguese professionals giving them an opportunity to present and discuss the ongoing technical activities. The meetings have been typically attended by 150 to 200 participants.

At the same time as the conferences have become more mature, the international contacts have also increased and the industry became more international in such a way that the fact that the conference was in Portuguese started to hinder its further development with wider participation. Therefore, a decision was made to experiment with having also papers in English, mixed with the usual papers in Portuguese. This was first implemented in the First International Conference of Maritime Technology and Engineering (MARTECH 2011), which was organized in the year that Instituto Superior Técnico completed 100 years. Subsequently, two more MARTECH conferences have been organized, namely in 2014 and 2016, always with a broadening of scope.

In this Fourth International Conference of Maritime Technology and Engineering (MARTECH 2018), a total of around 130 abstracts have been received and 80 papers were finally accepted.

The Scientific Committee had a major role in the review process of the papers although several other anonymous reviewers have also contributed and deserve our thanks for the detailed comments provided to the authors allowing them to improve their papers. The participation is coming from research and industry from almost every continent, which is also a demonstration of the wide geographical reach of the conference.

The contents of the present books are organized in the main subject areas corresponding to the sessions in the Conference and within each group the papers are listed by the alphabetic order of the authors.

We want to thank all contributors for their efforts and we hope that this Conference will be continued and improved in the future.

C. Guedes Soares & T.A. Santos

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Port performance I

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Comparative analysis of port performances between Italy and Brazil

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ABSTRACT: The State of Bahia has one of the largest port complexes in Brazil, that consists of public ports and private use terminals. One of which is specialized with a cargo carrying capacity of about 530 thousand TEUs (Twenty-foot Equivalent Unit) per year. On the other hand, the container terminal at the port of Genoa, Italy, has a similar capacity but has been performing better than the Brazilian one. The present study evaluates the differences and similarities between these ports, in the context of engineering, environmental sustainability and some topics of the port regulatory framework that can influence productivity. Based on the arrival and service rates of the ships and their respective probability distributions, a mathematical model of queuing theory was developed that indicates the port occupation rate, the time and the average number of ships in the queue, in a process with which one can assess the environmental impact of these terminals.

1 INTRODUCTION

The Container Terminal of the Port of Salvador (TCS), located in the northeast of Brazil, is a medium-sized structure port, with two berths (pier 1 and 2). Pier 1 is the most modern, with a greater depth and extension, is equipped with cranes which are able to serve ships of the super-postpanamax class, serving almost all the demands of the terminal. On the other hand, pier 2 has smaller extension and depth, operates with cranes which can serve ships of the panamax class only, meeting the needs of a small part of the terminal demand.

With similar characteristics to TCS, although with greater capacity, the Container Terminal of Genoa (TCG) is a benchmark in this work. It is located in the region of Liguria, Italy, having a modern structure, with berth length, seaport depth and cranes able to serve ships of the super-post-panamax class.

It should be noted that, not always, the entire cargo of the ship is destined for the port at which the vessel is arriving. Therefore, both loading and unloading may occur. Cargo may also be only loaded or unloaded, in whole or in part.

The Port of Salvador has a single container terminal, while in Genoa there are two important terminals. The results of the studies published here relate only to one of these Genoa´s Terminals. Referring to the designation adopted—TCS and TCG—do not represent the commercial name of the companies involved herein.

Based on the study of these two port structures, this paper evaluates the differences and similarities of both maritime terminals, both in the engineering (naval-port infrastructure and queuing theory) and in environmental sustainability, as well as in some points of the regulatory framework and logistical infrastructure of both countries that can influence and reveal the competitiveness of these ports. Based on vessel arrival and service rates and their consequent probability distributions, in addition to other constraints, the queuing model reveals the time and average number of ships in process, the port occupation rate, and the expected probability of this finding variable, may provide a possibility of fine payments for delay in services, thus serving as the efficiency indicators of port operation.

The results obtained here, and their interpretations, are limited to the time of their respective data collection, as well as to the reliability of information that was possible to obtain at the time of the technical visits and professional meetings held. They are also limited to the consultations made to the electronic pages of the terminals and institutions that control local port operations.

The present work is in the context of other researches already carried out. Camelo et al. (2010), used queuing theory to simulate the behavior of the row of iron ore vessels in the port of Ponta da Madeira, Brazil, with the aid of the Arena® software and found high berth occupation rates, recommending investments in the expansion of its capacity to meet the expectations of growing demand for ores in the world market. In this same direction, Schoreder (2014) simulated the operational behavior of the container terminal at the port of Durban, South Africa, based on the operation of the queue system of the container terminal at the port of Rotterdam from the logic of model construction simulated with Simio® software. It is concluded, after validation, that the model represents appropriately the operational reality of the terminal. Navarro et al. (2015), on the other hand, applied a queuing network model in the container terminal of the port of Manila involving both the queue of container haulers to the port and the queue of ships awaiting loading with the aid of the software Promodel®. By demonstrating the usefulness of the model used, concludes by the adoption of vehicle reserves to support variability in the ship loading rhythm.

2 METHODOLOGY

The primary data for the construction of the queuing model, based on vessel movement in the TCS, was obtained in the statistics sector of the Docks Company of the State of Bahia—CODEBA, in the format of Excel® spreadsheets, comprising the years 2012 to 2016, except for the year 2015 that was excluded from the statistical database because of inconsistencies, resulting in 1,597 events exclusively for pier 1, the most important of this port. The pier 2, because of its smaller depth (only 12 m) as compared to pier 1 (14 m) and the available infra-structure, including the length, does not allow the docking of the ships planned to dock at pier 1. Hence, it configures a single server queue system (S = 1) since only the vessel movement data on pier 1 was considered for the purpose of comparison with the TCG in this article, highlighting that this specific terminal of Genoa has only 1 berth (S = 1). The Table 1 presents a brief of CODEBA data.

From this data, statistical tests were performed to evaluate adherence to certain probability distributions, according to Hillier, FS & Lieberman G. J. 1995, as a requirement to select the correct mathematical form for modeling the ship queue. Consequently, tests were applied for Poisson, exponential, Erlang and range, among others, for arrival and service time of the ships. The computational assistance for these tests was software R, version 3.4.1, and Quantitative Systems Business Plus (QSB+), as well as Excel® spreadsheets (Microsoft Corporation) were used for queuing system behavior calculations.

Based on this data with an aim to implement the mathematic model of queues, the average ship arrival rate (λ) and the average service rate (μ) were calculated. After calculating these input variables and evaluating their respective statistical behaviors (arrivals and services), the parameters of this queuing model were calculated using the QSB+, which are:

- L: Number of ships in the system (waiting and in service);
- Lq: Number of ships in queue (waiting to be attended);
- W: Waiting time in the system (waiting andin service);
- Wq: Waiting time in queue (waiting to be attended;
- ℓ: Terminal occupancy rate;
- Po: Probability of the terminal being idle;
- Pw: Probability of waiting to be attended.

The parameters implicit in Kendall's notation (A/B/s/N/m/Z), which together with (λ) and (μ), complete the information required for modeling, are selected by the QSB+ software and are adopted for this work. They can be defined as:

- A describes the statistical distribution of the number of arrivals;
- B describes the statistical distribution of the time of service;
- s is the number of servers (Berth)
- N is the maximum capacity (maximum number of vessels allowed in the system);
- m is the size of the population that provides customers (ships);
- Z is the row discipline (how they are selected to be attended).

Considering an unlimited capacity of a given system (N), the population of clients that demand a single service of this system is also infinite (m), and its service is in order of arrival (Z): the notation of Kendall can be summarized as A/B/1. Thus, the notation of the type M/M/s, Markovian, is denoted as Poisson input and exponential service time with s servers. If it is M/G/1, it implies Poisson input and a general service distribution with 1 server (S = 1). However, it should be noted that the queuing models that are closest to reality, register values for ℓ <1.

During the survey, visits were made to the port of Salvador, Brazil, both to observe, in-situ operations and to discuss with them the details of the studies being carried out. Further to analyze the technical validation by experienced professionals, as well as

Table 1. Summary of data collected at CODEBA.

		Hour and day				
Vessel's Name	Pier	Input H:M/D	Exit H:M/D	Td H	C Σ	P C/H
ALIANÇA MANAUS	611	13:30/01	21:10/02	31.67	982	31.01
MONTE VERDE	611	22:40/02	6:45/03	8.08	255	31.56
LUTETIA VIAGEM	611	2:30/01	10:10/01	6.67	128	19.19
ER LONDON	611	9:30/03	4:35/04	19.08	723	37.89

H = Hour; M = Minute; D = day; Td = Time docked; C = Container; P = Productivity.

for data collection. As for the TCG, a general visit was made by the sea, accompanied by a representative of the Port Authority for an annotated observation of the infrastructure of the Genoa terminals. Data was also collected from queries to the public electronic pages of these terminals.

In addition to modeling the current state of the queuing system, two new simulations were carried out, one with a 50% increase in container demand in Brazil, based on the perspective of international trade growth in the next 10 years according to the Ministry of Mines and Energy of Brazil, 2016. The other simulation considered the possibility of unavailability of one of the cranes for both terminals due to machine failure.

The statistical treatment of this article was structured and started in the Laboratory of Integrated Production Systems—LABSIP, linked to the Department of Mechanical Engineering / Polytechnic School of the Federal University of Bahia (UFBA), and finalized in the Department of Civil and Environmental Engineering/Polytechnic of Milan (POLIMI).

As a consequence of the queuing model, the present study used scientific references and technical coefficients to calculate the mass of gaseous emissions generated by ships in the queuing system. Further it compared quantitative data in the regulatory frameworks and the World Bank in both countries (Italy and Brazil), to compare their performance.

3 OBTAINED RESULTS

3.1 *Results for the infrastructure*

The operational capacity of these terminals can be summarized as shown in Table 2.

According to Table 2, and due to the combination of factors such as water density, suction that the hulls of vessels are subjected to in squat, wave effects, background irregularities and sedimentation, the PIANC standard (PIANC, 1997) recommends a slack due to the squat that can be determined by the expression:

$$S_b = \left(C_z + 1/2C_\theta\right)\frac{V}{L_{pp}^2}\left(F_{nh}^2\right)\sqrt{\left(1-F_{nh}^2\right)}, \quad (1)$$

where:

Table 2. Infrastructure of the container terminals.

	Berth (m)	Depth (m)	Portainer[1] (unity)	Area (m^2)
TCS	377	14	3	120,000
TCR	526	15	5	174,000

1. Super-*post-panamax*.

S_b = maximum vertical displacement due to squat;

C_z and C_θ = coefficients recommended by the standard, with: $C_z = 1.46$ (due to heave) and $C_\theta = 1$ (due to pitch).

V = buoyance volume in m^3;

L_{pp} = length between perpendiculars in m;

F_{nh} = Froude's number relative to local depth, given by:

$$F_{nh} = V_{ms}\sqrt{(gh)}, \quad (2)$$

where:

V_{ms} = speed of evolution in m / s;

g = acceleration due to gravity, 9.81 m / s^2; and

h = local depth in m;

To measure the clearances, vessels of the post-panamax type were adopted (PIANC,1997). Due to the similarity in terminal infrastructure, their gaps are equal (Sb = 1.15 m) and so the recommended maximum draft (T) for ships is: T = 12.85 m for TCS and T = 13.85 m for Genoa.

The maximum range for the booms of the cranes at both ports is 55 m, with 50 m being the maximum permissible molded breadth for ships.

Considering these dimensions, the berth lengths (Table 2), operating clearances and maximum length-to-beam ratio of 8, the maximum lengths for ships for these terminals are as follows: L = 350 m (TCS) and L = 400 m (TCG). Adopting the average block coefficient of 0.65 (PIANC, 1997), one can reach the full load displacements of:

$$\Delta_{TCS} \cong 1{,}298{,}881\ kN;\ \Delta_{TCG} \cong 1{,}601{,}360\ kN. \quad (3)$$

Assuming now the average recommended ratio (PIANC) for the relationship between the deadweight and the full displacement of 0.70, we arrive at the gross deadweights:

$$DWT_{TCS} \cong 907{,}437\ kN;\quad \mathrm{DWT}_{TCG} \cong 1{,}120{,}952\ kN. \quad (4)$$

Considering that the variability of the load causes the actual net weight of the containers to vary, hence the average value of the gross weight of 133.k kN was adopted, thus estimating the following maximum ship loads at these terminals (measured in TEUs):

$$DWT_{TCS} \cong 6{,}800\ TEUs;\quad \mathrm{DWT}_{TCG} \cong 8{,}400\ TEUs. \quad (5)$$

In addition to this dock infrastructure, the TCS and TCG have the following equipment for movement in the back area, as shown in Table 3.

With this infrastructure, the TCS informs the capacity of 530,000 TEUs/year, while the information of the TCG is 550,000 TEUs/year. In 2016 TCS moved 200,000 TEUs while TCG moved 300,000 TEUs.

3.2 *Results for statistical tests*

The application of the adhesion test to the number of ship arrivals proved to be validated for the Poisson distribution. The raw data was systematized for the application of the test and summaries of the results are available in Table 4.

The non-parametric *Kolmogorov-Smirnov* test was used for the time of service of the ships for different statistical distributions, including the gamma distribution. In this case, the shape parameter (α) and the rate parameter (β) are modeled by the probability density function given by Eq. (6)

$$f(x) = \begin{cases} \dfrac{\beta^{\alpha} x^{\alpha-1} e^{-\beta x}}{\gamma(\alpha)} \text{ if } x \geq 0 \\ 0 \text{ if } x < 0 \end{cases} \tag{6}$$

where 'x' is the assumed value of the independent variable of the problem and the gamma function $\gamma(\alpha)$, on the other hand, is given by Eq. (7):

$$\gamma(\alpha) = \int_0^{\infty} x^{\alpha-1}.e^{-x}.dx \tag{7}$$

Based on this model, the adhesion test for the service time was applied, which was validated for the gamma distribution. It is reported that the treated data was imported from the Excel® worksheet into software R, which did not reject the null hypothesis of adherence between theoretical and observed behaviors. The results obtained can be seen in Figure 1.

As shown in Figure 1, the observed and theoretical (gamma) behavior results for significance of 5% and

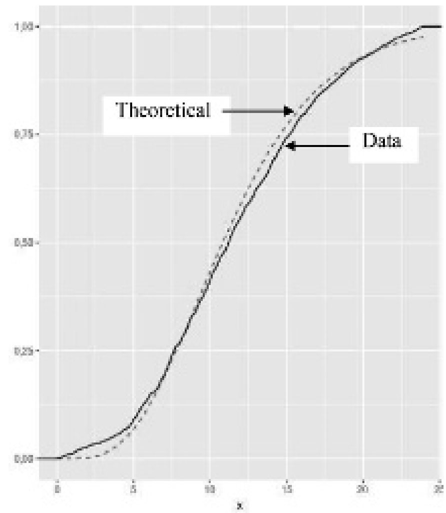

Figure 1. *Kolmogorov-Smir nov* test (working time)[1]. 1. Pier 611 for years 2012, 2013, 2014, 2016. p-value (0,983); test statistic (0.0577); observations (1597); shorter time (0.1667); maximum time (23.92); average time (11.60); Parameter shape-gamma (4.95); parameter rate-gamma (0.4264).

Table 3. Devices of moving (retro area).

	RTG	RMG	Reach Stackers	Access way
TCS	8	1	8	Road
TCR	8	6	17	Rodo-rail

Table 4. *Chi-squared* test for Poisson[1].

H_0: Is Poisson			<== adhered to Poisson distribution	significance levels (α)	
H_1: Is not Poisson				5%	degrees of freedom
					18
min	max	mean	standard deviation	sum χ^2	p-value
24	43	33.27083	4.76856	0.33581	0.9999999999997
		ships per month			
Ships	Events	Relative Observed Frequency	Poisson Relative Frequency	χ^2	Theoretical Expected Frequency
24	2	0.04167	0.01939	0.02561	0.64498
25	0	0.00000	0.02580	0.02580	0.85836
26	3	0.06250	0.03301	0.02634	1.09840
27	2	0.04167	0.04068	0.00002	1.35351
28	3	0.06250	0.04834	0.00415	1.60830
29	0	0.00000	0.05546	0.05546	1.84515
30	5	0.10417	0.06151	0.02959	2.04633
31	2	0.04167	0.06601	0.00898	2.19622
32	5	0.10417	0.06863	0.01840	2.28344
33	2	0.04167	0.06920	0.01095	2.30218
34	3	0.06250	0.06771	0.00040	2.25281
35	2	0.04167	0.06437	0.00801	2.14151
36	6	0.12500	0.05949	0.07215	1.97916
37	4	0.08333	0.05349	0.01665	1.77969
38	2	0.04167	0.04683	0.00057	1.55820
39	3	0.06250	0.03995	0.01272	1.32930
40	1	0.02083	0.03323	0.00463	1.10567
41	1	0.02083	0.02697	0.00140	0.89724
42	1	0.02083	0.02136	0.00001	0.71076
43	1	0.02083	0.01653	0.00112	0.54994

test statistics of 0.057, the p-value resulted in 0.983, indicating that there is no evidence to reject the null hypothesis. This test was applied to a gamma distribution with a shape parameter of approximately 4.95 and a scale parameter of approximately 0.43

3.3 *Results for queue output data*

Complementing the statistical results with the characteristics and infrastructure of the terminals, and considering unlimited vessel mooring capacities, it is possible to assume, for the purpose of the queuing system, and in the context of Kendall's notation, the M / G / 1 for the TCS, which is:

- A (distribution of number of arrivals): Poisson;
- B (distribution of time of service): gamma;
- s (number of berths): 1 (restricted to types of vessels);
- N (system capacity): unlimited (bay);
- m (size of ship population): infinite;
- Z (row discipline): FIFO / order of arrival

To compare the performance of the queue between the terminals, it was assumed that the statistical behavior for the TCG is equivalent to the TCS, i.e. M / G / 1. With the TCS data treatment the average arrival (λ) and service (μ) rates were calculated. For the TCG, inferences and calculations were made from the infrastructure and arrivals of ships in this terminal, available on the website in the global computer network of the Port of Genoa, 2017. The results, in ships/day, are: $\lambda_{TCS} = 1.10$; $\mu_{TCS} = 2.10$; $\lambda_{TCG} = 1.44$; $\mu_{TCG} = 2.88$.

With this data and through the QSB+ software, the behavior of the queue for both terminals was calculated, as shown in Figure 2, which represents the screen of the results of the application for the TCS.

Figure 2. Results for the TCS1 Queue System[1].
1. Arrival rates and service period 2012, 2013, 2014, 2016. Standard deviation for service time equal to 5.22.

Table 5. Results of queue output parameters[1].

	ℓ (%)	L	Lq	W (h)	Wq (h)	P_0 (%)
TCS	52	1	0.5	19	7.5	48
TCG	50	1	0.5	14	6.0	50

1. It is observed that with S = 1, we have $P_w = \ell = 52\%$.

The summary of the approximated results, by QSB+, is in Table 5.

In order to forecast a 50% increase in demand, new calculations were made for the queuing system, maintaining service rates (μ), but assuming the following arrival rates (ships/day): $\lambda_{TCS} = 1.65$ e $\lambda_{TCG} = 2.16$. Table 6 summarizes the results obtained by QSB+ for this new scenario.

Considering the possible unavailability of one of the cranes at the terminals, it results in a proportional reduction of 1/3 of the service capacity for the TCS and 1/5 for the TCG, and new service rates of 1.4 ships/day and 2.30 ships/day, respectively for TCS and TCG. With this new input data, we get the results of Table 7.

With this data, other results are generated, such as the comparison between the two scenarios for the waiting time in the system (W) and the occupancy rate of the terminals (ℓ), as can be seen in Figures 3, 4 and 5.

The reduction in capacity over the service time of these terminals can be seen in Figure 5.

3.4 *Results of the impact of queuing on the environment*

While waiting in the queuing system, the ship's engines generate emissions that impact the environ-

Table 6. Result of queue with new demand[1].

	ℓ (%)	L	Lq	W (h)	Wq (h)	P_0 (%)
TCS	79	3	2	37	24	21
TCG	75	3	2	26	18	25

1. Considering the arrival rate 50% higher.

Table 7. Impact on queue with reduced capacity[1].

	ℓ (%)	L	Lq	W (h)	Wq (h)	P_0 (%)
TCS	77.5	3	2	50	32.5	22.5
TCG	62.5	2	1	21	11	37.5

1. Considering unavailability of 1 crane.

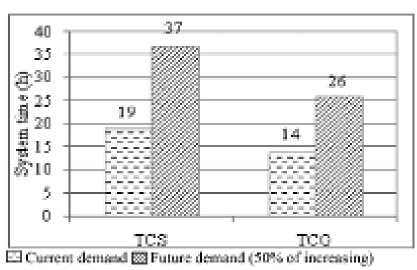

Figure 3. Impact of demand on waiting time.

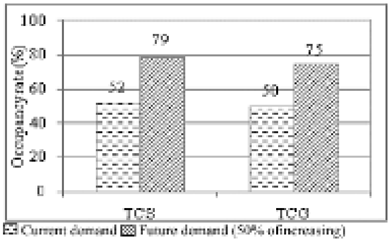

Figure 4. Impact of demand on the occupancy rate.

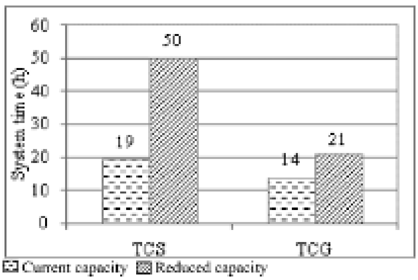

Figure 5. Effect of capacity reduction of ships in service.

Table 8. NOx emissions caused by the demand[1].

	Current demand (tNOx)	Future demand (tNOx)
TCS	0.033	0.197
TCG	0.024	0.138

1. EN = 320 kW·h; FP = 0.4; FE = 13.9 g/kWh.

ment, as reported by the International convention for the prevention of pollution from ships—MARPOL, 2005, highlighting nitrogen oxides among the pollutants. The mass (t) of combustion gases emitted by ships can be calculated by means of Eq. (8), as provided by the Environmental Protection Agency—EPA, 2009:

$$EG(t) = L \cdot [EN \cdot FP \cdot W \cdot FE], \tag{8}$$

in which: EG = gaseous emissions (t); L = number of ships in the queue system; EN = energy consumed (kW·h); FP = power factor (%); W = ship waiting time (h); FE = emission factor (g/kWh).

Based on Eq. (8) and considering the results of the queues for the TCS and the TCG, along with the NOx gas emission factor of 13.9 g/kWh, we get the following synthesized results in Table 8, with an aim to meet current and future demands.

The impact of this data can be best seen in the graphical comparison of Figure 6.

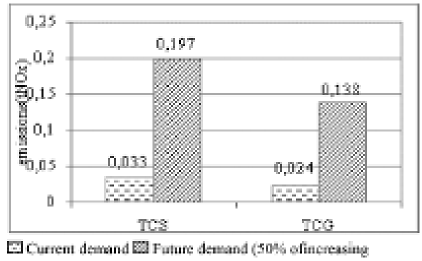

Figure 6. Gaseous NOx emissions caused by the demand.

Table 9. Accessibility and regulatory indicators.

	Railroad[1] (Km)	Highway[1] (Km)	Contract[2] (years)	Oversight[2] (agents)
TCS	0	4.3	25	7
TCG	1[3]	0.5	30	6

1. Available on the terminals web pages; 2. Provided in the Ports Act 12.815/2013 (Brazil) and Act 84/1994, updated by DL 169/2016 (Italia). 3. Ways: 3 × 370 m, and access by Italian railroad.

3.5 *Results of regulatory and logistical aspects*

Regarding the regulatory aspects and port accessibility, the data are shown in Table 9.

Another important result is available as a general logistics performance indicator, where Italy ranks 21st, and Brazil ranks 55th in the world ranking, according to the World Bank, 2016.

4 DISCUSSION OF RESULTS

From the results obtained, it can be observed that both terminals have similar characteristics, are housed inside a bay and have relatively close infrastructures, but with advantages for the TCG, which has more resources, and can serve larger vessels (8,400 TEUs) against 6,800 TEUs in the TCS, almost 25% higher, with better logistical accessibility.

However, it should be noted, that in this last resort, the TCS only has road access for container movement, an important exclusive logistics via (4.3 km). The TCG, in turn, has both a highway, just 500 m from the freeway, and trails (3 trails of 370 m) with access to the Italian railway network, which is an important and outstanding logistical advantage. With this infrastructure, the reported capacity of the TCG (550,000 TEUs) is approximately 4% higher than the capacity of the TCS (530,000 TEUs).

Regarding the demands for the terminal and the service capacity, it can be observed that while the TCS serves 2 vessels/day, the TCG can serve up to 3 vessels/day. Even though its arrival rate is approximately 1/3rd higher than the rate of TCS arrivals. This happens because the infrastructure of the Genoa terminal is more imposing than the terminal in Salvador. The availability of 2 more cranes than the TCS enables the TCG to handle a ship at around 8 h, while the TCS needs an average of 11.5 hours to process it. Thus, while in Genoa a ship waits at the terminal for an average of 14 hours between its arrival and departure, the same time in Salvador would be 19 hours, i.e. 5 hours more.

It can also be observed that due to their current arrival and service rates, at both terminals, two vessels will be present on average, one in service and the other coming to the queuing system. Of course, the service capacity makes the difference both in the waiting time at the terminal and in the load factor of the terminal. So, waiting in line at the TCG (6.0 h) would be 1.5 h less than at the TCS (7.5 h). This is linked to the infrastructure of these terminals and affects the results of their respective occupancy rates, making Salvador with 52%, a little higher than that of Genoa (50%).

Now, analyzing the results of the simulation with 50% increase in the arrival rate, a similar behavior was observed for both vessels in their respective systems, that is, 3 units, 1 ship in service and 2 ships in the queue. However, once again, the TCG presents advantages in attending these units. While the impact of this simulation causes the waiting time in Salvador to increase approximately by 95%, going from 19 h to 37 h, the impact in Genoa would be an increase of 86%. This would be a smaller increase in waiting time, jumping from 14 h to 26 h. In the same context, the occupancy rate in Genoa would also have less impact, jumping from 50% to 75%, thus a difference of 25%, while in Salvador the impact would be of 27%, jumping from 52% to 79%.

On the other hand, analyzing the results of the simulation with the reduction in service capacity, there is an even greater advantage for TCG. While at TCG the increase in the waiting time of a ship is 7 h, jumping from 14 h to 21 h, the impact on the TCS would be more significant, an increase of 31 h from 19 h to 50 h, i.e. double the current time. Also in this simulation, the impact on the queue is better absorbed by the TCG, which would have only 2 ships in the system, 1 more than in the current queuing state, while TCS would retain 3 ships, 2 more than its current operation.

Regarding the impact of the queue on the environment (NOx emissions), the results calculated for the TCG would once again have advantages on the TCS. At TCS, in the current state of operation 33 Kg is emitted, while in the TCG it is 27% smaller i.e. 24 Kg. However, this proportional difference would jump to 30% in favor of the TCG, with the increase of the demand in the terminals.

Regarding the normative regulatory aspects, it is observed that in Italy a revision in the port regulations occurred recently with the addition of Legislative Decree 169/2016, although Law 84/1994 is still in force. In Brazil, the complete legal framework is more recent and is based on Law 12,815 / 2013. The Italian regulatory revision implemented a service called "sportelo unico" which anticipates the services for the fulfillment of the documentary demands of the ship cargoes destined to Italian ports, 24 hours before arriving in the country. This already reduces the estimated time by 30% and 40%, indicating that in the port of Genoa the wait would have already been reduced from 4 to 5 days. Obviously, the queuing model presented here considers only vessels capable of being served in the system, disregarding the time of document processing. In this context, Brazil instituted in 2011 the procedure entitled "Paperless Harbor" to group together the necessary documentation for the processing of cargo ships in the so-called Virtual Single Document. Also in this legal aspect other operational similarities appear, so that in Brazil the concession contracts are of 25 years while in Italy the term is a little longer, of 30 years; the number of agents involved in ship liberations is also very close, with 7 in Brazil and only 6 in Italy.

As per the World Bank's logistic performance indicator (2016), evidenced in the ranking, Brazil is in a much less competitive position (55th) as compared to Italy (21st), i.e. an equivalent of 34 disadvantage positions. This indicator is part of a study conducted every 2 years and reveals that as compared to the previous edition (2014) Brazil improved 10 positions, while Italy lost only 1 position, and Germany occupies the first place, revealing itself as the country with the best logistics infrastructure. Among the criteria that make up this indicator are reliability of operations, cargo tracking, handling and port infrastructure.

5 CONCLUSIONS

A comparative study was carried out between the container terminal of the Port of Salvador-Brazil (TCS) and the container terminal of the Port of Genoa-Italy (TCG) by the modeling of discrete systems through queuing theory, complemented by aspects—the regulatory and logistical infrastructure of these countries. The queuing theory provides important results for the management of ongoing operations and for the planning of new guidelines that favors the improvement in the functioning of these productive systems.

Both the TCS and the TCG are important ports in both countries with infrastructure capable of ensuring competitiveness in their areas of influence. While the TCG has strong penetration in the markets of northern Italy and southern Europe, the TCS stands out in Brazil acting across the coast of the country and towards the North Atlantic.

The analysis of the data and the results indicate that the Genoa terminal, which has similarities with the Salvador terminal, can be a good reference for the latter. It can be seen that investments in dock infrastructure, such as the size and capacity of container handling, are very sensitive to the operational results. Thus, only one meter more depth in the cradle and the presence of two additional cranes, besides other important logistic complements, can make a significant difference in the operational results of the ports, as verified in this study, showing better yields for the TCG. Significant increases in demand would cause the TCS to operate close to the limits of its capacity with mechanical fatigue risks on the handling equipment, which could lead to interruptions with consequent payments of contractual fines for delay in the service of the ships.

Another aspect that deserves attention is the location of the TCS in a densely populated area of Salvador, an important tourist spot, which casts doubts on the security of the investments needed in the infrastructure to increase the capacity. The possibility of moving the Port to another area is still under evaluation and also its permanence to the present place with the extension of the berth is scrutinized. In Genoa, although the TCG is also located in the outskirts of the city, the railway infrastructure and the easy access to the Italian highways do not seem to present the same problems as for the TCS.

In the environmental context, as TCG presents a more efficient queuing system than the TCS, it releases less pollution in the region, even though these emissions should be below the limits recommended by international organizations.

Concerning the regulatory aspects, both in Italy and in Brazil there have been similar updates of its legal frameworks in order to reduce bureaucracy in the port system, although the effect seems to be faster in Italy than in Brazil (documentation of processing of ships). Also the concession period is similar, although in Brazil it is five years shorter than in Italy, with the idea of imposing a faster return on private investment. In general, Brazil has limited logistics infrastructure in the service of ports, being only served by the road, unlike Italy where the road and rail system show more availability for the transport of containers.

It should be noted that the methodology presented here, although supported by a consistent set of data regarding the port of Salvador, has its limitations due to the uncertainties of the data obtained in reference to the Italian port. Although the results obtained compose a representative model of port operations, very useful for the planning of such facilities.

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Model to forecast times and costs of cutting, assembling and welding stages of construction of ship blocks

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Causal Analysis of Accidents at Work in a Shipyard Complemented with Bayesian Nets Modelling

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Analysis of SME Ship Repair Yard Capacity in Building New Ships

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Shipyards of the 21st century: Industrial internet of things on site

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