Simulation of a door-to-door maritime transport chain between seaports of Leixões and Luanda

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Abstract

Currently, there is no transportation service door-to-door between Portugal and Angola. Thus, ships make several stops before reaching the destination regardless of the services offered. However, given the importance of commercial exchanges carried out between Portugal and Angola, evaluating the feasibility of a door-to-door service between these two countries became quite relevant.

A macroeconomic framework of the two countries was developed in order to highlight the importance of this dissertation, followed by a review of relevant concepts in literature, emphasizing the concepts of logistics and simulation, ending with the analysis of similar studies to this work. It is also presented the development of the simulation model in SIMUL8, able to assess what factors are necessary to get a regular and effective transport service between the two seaports.

Four experiments, varying the number of ships to consider, its speed and the frequency of transport, were performed. The results show that to obtain a regular service, two ships are required, with fortnightly and capacity of 2000 TEU. However, although it gets a regular and efficient transport, the occupancy rate of the ship on the journey between Luanda and Leixões could jeopardize the viability of the service.

Key words: Logistics; Discrete-Event Simulation; SIMUL8; Regular transportation; Door-to-door transportation

1 Introduction

The development of commercial exchanges between two countries is strongly correlated with the existence of economic, regular and efficient transport services, preferably door-to-door, between them. Given the potential of bilateral relations between Portugal and Angola, where in recent years Portugal has become the main supplier of Angola, while Angola became the main extra-UE client and provider of Portugal, it is quite relevant to assess the feasibility of a door-to-door maritime transport chain between these two countries in order to foster their trade relations.

In turn, the discrete simulation is a traditional technique of operational research with evidence of its usefulness in the operation analyzing of complex and random systems. Thus, using simulation, the goal of this research regards testing and validation, considering the regularity of service, the number of ships to use and their speed, possible configurations of a door-to-door maritime transport chains that will ensure an efficient service between the seaports of Leixões and Luanda.

The methodology adopted in this work consisted, initially, in a relevant data collection and analysis in order to create an adequate model wich represents the current reality. After the problem identification, a model was created using the SIMUL8 software. Lastly, and after model validation/verification, experiments were performed in order to draw conclusions.

2 Literature review

2.1 Logistic and Supply Chain Management

Accordingly with Ellram et al. (2006), logistics is a network of related activities together with the purpose of managing, in an orderly manner, the flow of material and personnel with the objective of adding value to the activities carried out within the logistics channel.

For Supply Chain Management (SCM), several authors have similar definitions. One of the most relevant is the definition presented in the Council of Supply Chain Management Professionals (2013): "*Supply chain management encompasses the planning and management of all activities Involved in sourcing and procurement, conversion, and all logistics management activities*."

Therefore, the focus of companies in recent years has been the efficiency of their operations since, according to Simchi-Levi et al. (2007), the reduction of costs in activities such as the purchase of raw materials or transportation (logistics activities) has a far greater impact on profit compared with an increase in sales.

2.2 Transportation activity

Accordingly with Ellram et al. (2006) there are many logistics activities, such as the selection of plants and the acquisition of raw material. However, as Simchi-Levi et al. (2007) emphasizes, the costs of transportation take the biggest share of the logistics costs enterprises, representing typically more than 50% of these costs.

Transport activity is responsible for the transportation of goods from an origin to a destination. It can be done by road, rail, air or sea. This work considers the maritime transport, which according to David & Stewart (2010), is characterized by being a long-distance transport, making transportation from one seaport to another, and because the ships can to carry large amounts of cargo can be considered a low cost tansport.

2.3 Simulation

Porta Nova (2008) states, informally and in a very generic manner, which simulate is often presented in the literature as a process including the following steps: develop a model of a real system, "feed it" with data and observing the corresponding results.

The core objective of simulation is to improve or optimize the performance of a system when exposed to variations of a number of factors. Because simulation is an experimental method, its success is highly dependent on the credibility of the model (Pidd, 1998). Like Miyagi (2006) explains, a model is a simplification of the real system in order to make their study manageable.

The development of a simulation is made, according to Porta Nova (2008), by process with different phases: 1) Problem Formulation; 2) Development a model; 3) Collection and analysis relevant data; 4) Construction of the model in appropriate language; 5) Verification of the computational model; 6) Validation of the simulation model; 7) Planning experiences; 8) Analysis of the results; 9) Implementation of the study. These phases were adopted in the present work.

2.4 SIMUL8

According to Shalliker & Ricketts (2002), SIMUL8 is a computer program that allows the user to create a visual model of the target system study by drawing objects (typically queues or service points) directly on the screen. The characteristics of the objects may be defined in terms of, for example, capacity or speed. Compared with simulation software developed in previous decades, SIMUL8 has more modern technologies, facilitating its use and reducing development time and analyzing simulation models.

2.5 Relevant studies

Although simulation of door-to-door transport chains is not a common issue, there are several relevant simulation studies can be found in literature. One of them is Persson & Olhager (2002) study, whose main objective is to evaluate alternative supply chains with quality, lead times and costs as key performance parameters. The relevance of this study is on the difficulty encountered by the authors to validate a model of a supply chain that encompasses more than one company. The technique suggested by the authors is the independent validation of each part of the model, thus validating the whole model.

Tsekeris & Ntemoli (2011) also presents a relevant study, which consists of a simulation of a chain of automotive industry, large-scale intermodal supply. To this end, the authors are based on discrete event simulation using the software SIMUL8. The overall procedure aims to discover the combination of the most promising modes of transport in terms of total cost subject to various constraints, such as delivery times, capacity, and financial budget. The simulation results show that the developed model can be used to easily and efficiently compare and evaluate alternative configurations of the supply chain, showing once again the versatility of the simulation.

In addition to the aforementioned studies, it is worth noticing the studies of Cartenì & Luca (2012) and Carôco (2013). The general conclusion to be drawn from these studies concerns the versatility of discrete event simulation and SIMUL8 software. Both are used in several different fields, such as the simulation of production processes, simulation of supply chains performance, or as is the scope of this dissertation, the simulation of transport chains. The authors of the studies reviewed state that high importance should be given to the development of the model, with emphasis on defining parameters, and verification/validation.

3. Model development

3.1 Problem identification

The system to be simulated concerns the transport of containers between the seaports of Leixões and Luanda. Thus being, two kinds of containers are considered in this model, defined as "container 1" and "container 2":

- **Container 1** - enter the system at the Leixões seaport before being inspected and leaving the system at the port of Luanda after being verified;
- **Container 2** - enter the system at the Luanda seaport before being inspected and leaving the system at the Leixões seaport after being verified.

Notice that only a percentage of containers are inspected / checked.

The transportation of containers is ensured by a ship that is dedicated exclusively to this transport with no further stops besides Leixões e Luanda. The scheme of figure 1 aims at clarifying the system that is intended to simulate.

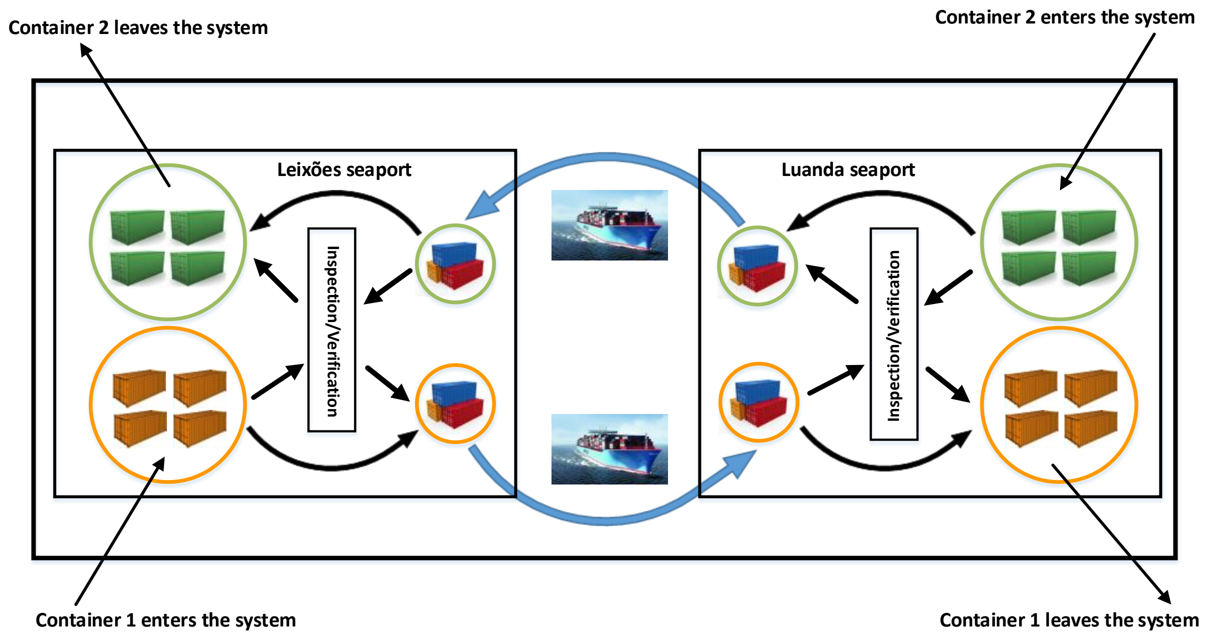

Figure 1: Scheme with problem identification

Currently, the process of customs in both seaport of Leixões and Luanda is done on the website of the Tax Authority after the file being transferred to the *Janela Única Portuária*[1]. This system came expedite the process of customs, and is now possible a container arriving at seaport already bonded. Thus, the activity of customs is no longer relevant for the model to develop. So, with the purpose of the model being closer to the current reality, the activity of inspection and verification was the only considered.

[1] Electronic platform that implements the concept of virtual one-stop shop, being the single point of contact at the port where economic agents deliver information in electronic format and it streams all related entities.

3.2 Simulation development

It is quite necessary to first define the relevant entities in order to model the system that is intended to simulate. Furthermore, there are two types of entities according to their interactions with the system: the permanent entities, who are always in the system, and temporary entities, that enter and leave the system during the simulation time. Thus the following entities were identified:

Permanent entities

- Ship

Temporary entities:

- Container 1
- Container 2

After identifying problem and relevant entities becomes necessary to collect relevant data. Please note that all data used is real (or realistic), because it is the only way possible to obtain a reliable model.

Thus, the data / assumptions used to "feed" the model were as follows:

Table 1: Collected data

Activity	Leixões (time in minutes)	Luanda (time in minutos)
Container entry	Distribution: Exponential Average: 5	Distribution: Exponential Average: 40
Inspection	(1% of containers) Distribution: Normal Average: 300 Std Dev: 60	(2% of containers) Distribution: Normal Average: 480 Std Dev: 240
Verification	(4% of containers) Distribution: Normal Average: 300 Std Dev: 180	(2% of containers) Distribution: Normal Average: 480 Std Dev: 240
Seaport entry	Distribution: Average Average: 90	Distribution: Triangular Upper: 1440 Lower: 120 Mode: 420
Seaport exit	Distribution: Average Average: 90	Distribuição: Triangular Upper: 600 Lower: 120 Mode: 240

Additionally, it was considered that the rate of containers loading and unloading is an average of 40 containers per hour in Leixões seaport and 30 containers per hour in Luanda seaport. The seaport works everyday, 24 hours a day, 7 days a week. However, the time of containers receipt are Monday through Friday, from 08:00 to 24:00. Regarding the characteristics of the ship: in an initial phase it was considered that the ship has a capacity of 4000 TEU and sailing to 23 knots, so that, in average, traveling between Leixões and Luanda takes 10 563 minutes (the distance between Leixões and Luanda is 7500 km).

With the collection of data was performed, in SIMUL8, an appropriate model shown in figure 2.

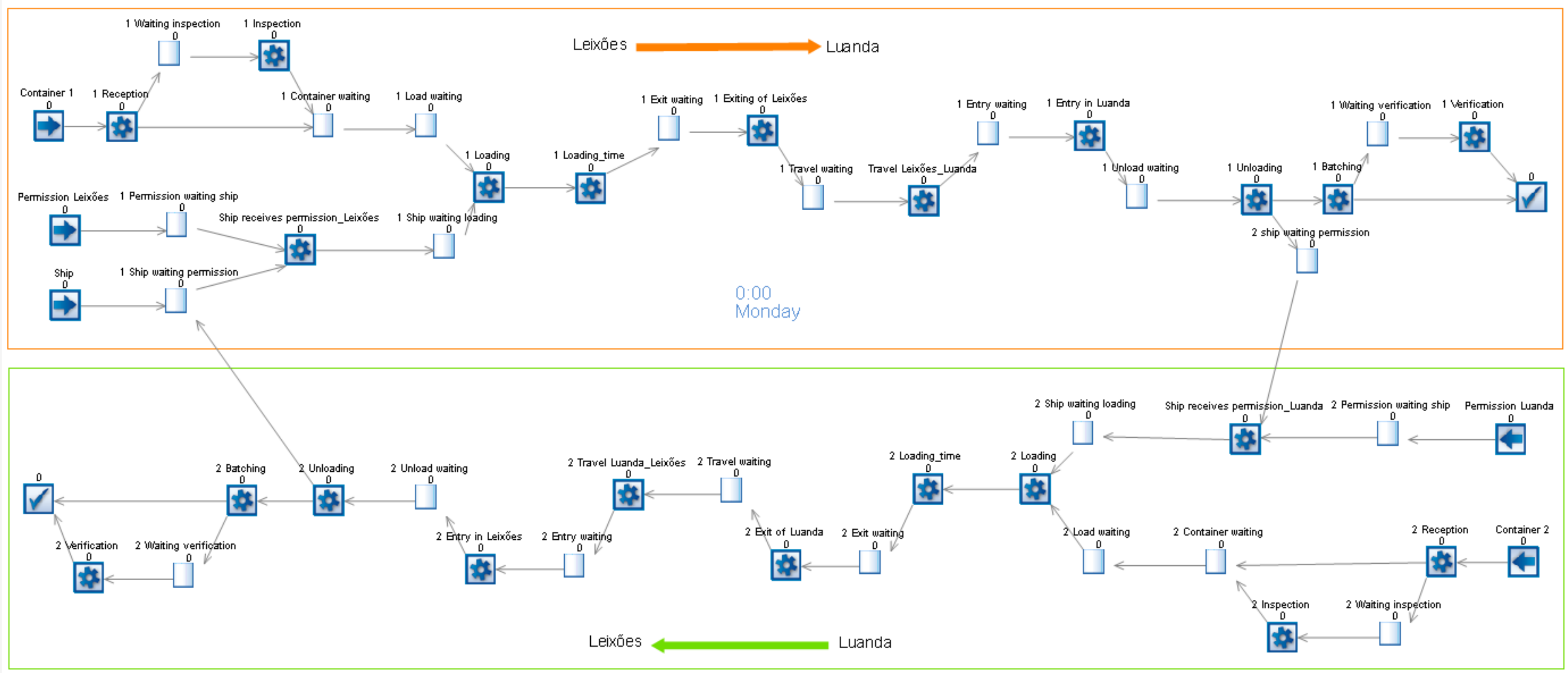

Figure 2: Developed model in SIMUL8

As the figure 2 suggests, the developed model has two distinct components: a trip to Luanda with origin in Leixões, and the trip to Leixões with origin in Luanda. In each paths the container enters the system and may, or may not, be inspected. After this activity, the containers awaits loading in the ship in queue "Load waiting". This queue defines the maximum capacity of the ship. If the number of containers to be transported exceeds the capacity of the queue, so they wait in queue "waiting Container".

At the beginning of the simulation process, one (or more) ships enter, and they remain in the system throughout the simulation time (it is a permanent entity). Departure ship times are set in the start point "Permission". A ship can only start loading activity after receiving this authorization. Therefore, after the ship becoming available, loading is the following activity, which is where the main problem in the development phase of the model was observed. At this stage it is necessary to collect a certain amount of containers to be transported. However, the number of containers to be transported is a variable, and the collect function of SIMUL8 only accepts a fixed number. Similar problems in literature were sought, although none were found.

Thus, in order to solve this problem Visual Logic tool was explored. This is an alternative approach for adding SIMUL8 controls through the Visual Basic programming language. Through this tool, it is possible to set the number of items to be collected using the number of items that are in queue "Load waiting". It was concluded that Visual Logic tool allowed to solve a complex problem in a very simply manner.

After the loading activity, the ship leaves the seaport and begins the journey to the destination seaport. The entry into seaport and unloading are the follows activities. Here, the work item shipped on the trip is divided in two: in containers, or they come out of the system or are checked, and the ship, which goes to the queue "ship waiting permission" where, after receiving permission, begins a new journey.

3.3 Model validation

The literature review conducted in this study suggest that the authors give utmost importance to the model validation. This is a very important stage, from where one may conclude that the model adequately represents the reality wich is intended to simulate, or not.

Thus, the validation of the model was done in two phases: initially critical components of the system were analyzed, with fixed values. Note that critical components are "load waiting" queue, where ship capacity is defined, the activity of "loading", due to the problem identified with the collect, and the "unloading" activity, where a wok item becomes into two: one containing all containers transported, and another that is the ship.

It was concluded that all components operated correctly, so in phase 2 stabilization system is made. To achieve this it is necessary to set stabilization parameters to find a reliable simulation time, in other words, that results are representative of the operation of the system at a stage where it shows stability and efficiency. The parameters to consider are: 1) Do not overload the system; 2) Warm Up; 3) Simulation time; 4) Number of runs to be considered; 5) Conditions imposed on the system.

The first parameter was validated through "load waiting" queue, where the ship capacity is defined. If the ship does not have enough capacity to carry containers, then the "Container waiting" queue and the average time in system of containers will grow indefinitely. It was considered a ship with 4,000 TEU, and it was concluded that there is no congestion of the system.

The warm-up period is the time interval in which SIMUL8 not use simulation results, in other words, the interval that model needs to achieve stability. This time interval was defined using the average number of containers waiting to be loaded, and the average time of containers in system. It was concluded that warm up period should be 4 months.

To set the simulation time the same measures of performance to set the warm up were used. The simulation time is set by performing a series of runs with the warm-up period set in order to find out the instant at which the system begins to stabilize. It was concluded that the system began to stabilize from 18 months, so this was the simulation time chosen.

To ensure the reliability of the results is also important to determine the number of runs that provide an acceptable deviation from the mean value. To obtain suitable results the average number of containers entering the system was considered. We conclude that even for a little number of Runs the deviation from the mean value was negligible, so was defined the number of runs as 5, which revealed a deviation of 0.54%.

Finally it is necessary to verify that the results obtained are consistent with the conditions imposed on the system. To evaluate this component was used a comparison between the results obtained for the entry and exit of containers with the theoretical value. The maximum error obtained was 5.84%, so it is concluded that the model adequately simulates reality.

4 Results

Four experiments were performed. At first the use of a ship, with a capacity of 4000 TEU, speed 23 knots, and monthly departures in the seaport of Leixões and Luanda, Monday at 08:00, was considered. Thus, there are 14 days for the transport activity between Leixões and Luanda, and 14 days for the transport activity between Luanda and Leixões. Given the constant delays in departures in Luanda, it was concluded that the activity transport between Leixões and Luanda takes longer. This happens due to the larger number of containers to be transported in Leixões route Luanda.

Thus, in the second experiment ship leaves Leixões, monthly, Monday at 08:00. However, ship leaves Luanda, monthly, Thursday at 08:00. So there are 17 days to the transport activity between Leixões e Luanda and 11 days for the transport activity between Luanda and Leixões.

For the third and fourth experiments two ships with a capacity of 2000 TEU, and fortnightly departures was considered. The difference between these two experiment was the speed of the ship: in the third experiment it was considered that the ship sailing at 23 knots, while in the fourth experiment sailing at 18 knots. The results obtained are shown in table 2.

Table 2: Results of experiments

Resume	Experience 1	Experience 2	Experience 3	Experience 4
Periodicicity	Monthly	Monthly	Fortnightly	Fortnightly
Number of journeys during the simulation	36	36	72	72
Departures on time	14	20	67	53
Delayed departures	22	16	5	19
% Departures on time	38,89%	55,56%	93,06%	73,61%
% Delayed departures	61,11%	44,44%	6,94%	26,39%
Average delay of departures in Leixões (days)	0,29	0,28	0,00	0,56
Average delay of departures in Luanda (days)	3,72	1,25	0,11	0,68
Global average delay of departures (days)	2,01	0,77	0,06	0,62
Ship capacity (TEU)	4000	4000	2000	2000
Average occupancy rate (Leixões -> Luanda)	95,46%	95,46%	95,49%	95,63%
Average occupancy rate (Luanda -> Leixões)	12,03%	12,00%	12,03%	11,97%
Global occupancy rate	53,75%	53,73%	53,76%	53,80%
Container 1: Average time in system (days)	45,67	45,65	29,31	32,27
Container 2: Average time in system (days)	37,09	36,86	22,47	24,40

Given these four scenarios, there is no doubt that the third option, in terms of level of service, is the most advantageous, where 93.01% of departures of the ship occurred at the expected time. For this option the average time of containers 1 in system is 29.31 days, although there are currently ship owners that ensure journey time between Leixões and Luanda in just 17 days. However, these 29.31 days also consider the possibility of a container to be inspected / checked during the journey, though, still does not seem to be very advantageous compared to the current service. But if the journey between Luanda and Leixões seems to be no major improvements, in journey between Luanda and Leixões the situation is reversed. The service available with option 3 would reach an average time in system, of containers 2, of only 22,47 days compared to 30 days (these 30 days only consider the journey, attention) that currently the majority of owners present. Thus, evaluating these components, the rated service is viable.

Finally mention an important factor: the occupation of the ship. The occupancy rate recorded in any of the options on the journey between Luanda and Leixões was only 12%. In economic terms, which are outside the scope of this research, this factor may jeopardize the viability of the service. However, this process was done, for lack of data, not considering transaction of empty containers between the two seaports. In future work it may be a factor to consider.

5 Conclusions

Portugal and Angola are important trading partners: Portugal is the main goods supplier country of Angola, and Angola is the main export and import extra-EU partner of Portugal. This was the main motivation for to develop this work, wich aims to evaluate the feasibility of a door-to-door maritime transport chain between these two countries in order to foster their trade relations.

Although simulation of door-to-door transport chains is not common, a discrete event simulation, coupled with SIMUL8 software, revealed itself as an important tool to assess the problem in question. During the phase of the simulation model were encountered several problems, with the highlight the difficulty, at first, to make a collect of a variable number of work items. However, the versatility of the software used, which allows, through Visual Logic function, the introduction of basic lines of code in Visual Basic language, has solved the problem.

Four experiments were performed, and it was concluded that to obtain a regular service, two ships are required, with fortnightly, capacity of 2000 TEUs and speed of 23 knots. For this option, there was an overall average delay of only 1,44 hours, which is totally acceptable. Major improvements were observed in journey between Luanda route Leixões, where the average time in the system observed was about 22 days, while today most owners announced 30 days just for the journey. However, the occupancy rate of the ship, between Leixões and Luanda, could jeopardize the viability of this service, where the average occupancy rate of the ship stands at 12%. On the one hand, this rate can, and should, be increased in the future with the increase of imports from Angola. Moreover, it can be interesting, in a future work, to evaluate the transaction of empty containers between these two countries. If this is a significant number, it is possible to obtain an average occupancy rate of the ship more acceptable.

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