Competitive Positioning of Ports based on Total Landed Costs of Supply Chains

by

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ABSTRACT

Nowadays ports play a critic role in the supply chains of contemporary companies and global commerce. Since the ports' operational effectiveness is critical on the development of competitive supply chains, their contribution to regional economies is essential. With the globalization of markets, the traffic of containers flowing through the different ports has increased significantly in the last decades. In order to attract additional container traffic and improve their comparative advantages over the competition, ports serving same hinterlands explore ways to improve their operations to become more attractive to shippers. This research explores the hypothesis that lowering the variability of the service time observed in the handling of containers, a port reduces the total logistics costs of their customers, increase its competiveness and that of their customers.

This thesis proposes a methodology that allows the quantification of the variability existing in the services of a port derived from factors like inefficient internal operations, vessel congestion or external disruptions scenarios. It focuses on assessing the impact of this variability on the user's logistic costs. The methodology also allows a port to define competitive strategies that take into account its variability and that of competing ports. These competitive strategies are also translated into specific parameters that can be used to design and adjust internal operations. The methodology includes (1) a definition of a proper economic model to measure the logistic impact of port's variability, (2) a network analysis approach to the defined problem and (3) a systematic procedure to determine competitive service time parameters for a port.

After the methodology is developed, a case study is presented where it is applied to the Port of Guaymas. This is done by finding service time parameters for this port that yield lower logistic costs than the observed in other competing ports.

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TABLE OF CONTENTS

Page

LIST OF TABLES vii

LIST OF FIGURES viii

CHAPTER

1 PROBLEM DEFINITION 1

Introduction 1

Relevance of Logistics in Modern Supply Chain 1

Problem Statement 9

Specific Objectives 10

Limitations of the Study 11

Thesis Overview 12

2 LITERATURE REVIEW 14

Introduction 14

Relevance of the Logistics Approach 14

Lead Time Variability and the Supply Chain Processes 17

Port Performance and Competitiveness Models 19

Contribution of the Present Research 25

Benefits of Research 26

3 METHODOLOGY 28

Introduction 28

Define the Cost and Variability Model 35

CHAPTER Page

Limitation of the Logistic Network 42

Gathering of Relevant Information about the Logistic Network 44

Gathering of Relevant Information from the Network Users 47

Analysis of Information 50

Comparative Results 59

Summary 64

4 ANALYSIS AND RESULTS: METHODOLOGY IMPLEMENTATION TO THE GUAYMAS PORT CASE STUDY 65

Introduction 65

General Assumptions 69

Application of the Methodology to the Guaymas Port Case Study 76

Results and Parameter Estimation... 92

Conclusions 99

5 METHODOLOGY VALIDATION 102

Introduction 102

Suggested Model for Validation 104

Model Implementation and Results 105

Conclusions 111

6 CONCLUSIONS AND FUTURE RESEARCH 113

Introduction 113

CHAPTER Page

Thesis Summary and Conclusions 113

Thesis Contribution.. 117

Recommendations for Future Research 119

REFERENCES 124

APPENDIX

A MATLAB CODE FOR TLC COMPARISON 128

B ESTIMATION OF PORT OF LOS ANGELES/LONG BEACH

SERVICE TIME VARIABILTY - DATA SUMMARY.............................132

C ESTIMATION OF PORT OF LOS ANGELES/LONG BEACH

SERVICE TIME VARIABILTY - GOODNESS OF FIT...........................135

D VALIDATION ASSIGNMENT MODEL - MPL CODE 137

LIST OF TABLES

Table Page

3.1 - Parameters of the Example Probability Density Function 47

3.2 - Network's User-specific Factors 50

3.3 - Example of Port Service Level in Time (Days) 52

3.4 - Factors Level by Scenario of Evaluation 56

4.1 - Weight Shipped to Guaymas' Hinterland 2007 (U.S. Ports) 70

4.2 - Weight Shipped to Guaymas' Hinterland 2007 (Origin Ports) 71

4.3 - Companies in Guaymas' Immediate Hinterland (Economic Units) 73

4.4 - Basic Data for Simplified Network Arcs 80

4.5 - Statisitcs Summary of Service Time Data 81

4.6 - Fitted Distribution Paramaters (Port of Los Angeles) 83

4.7 - Commodities Distribution of Shipments to Guaymas' Hinterland 84

4.8 - Attributes of Industry's Shipments 85

4.9 - Summary of Case Study Logistic Network Attributes 86

4.10 - Updated Case Study Logistic Network Attributes 88

4.11 - Service Levels for the Port of Los Angeles 89

4.12 - Shipment Scenarios used for Case Study 90

4.13 - Total Landed Costs of Los Angeles Port at 99% Service Level 91

4.14 - Findings of Port of Guaymas vs. Port of Long Beach 99

5.1 - Logistic Network Parameters for Validation 107

5.2 - Results from Validation Iterative Process 110

LIST OF FIGURES

Figure Page

1.1 - Basic Supply Chain Diagram 3

1.2 - Common Transportation Process Example 5

1.3 - Multiple Time Elements throughout Transportation Process..........................8

3.1 - Geographical Representation of the General Network.................................30

3.2 - Outline of Proposed Methodology 34

3.3 - Different Cost Components Behavior as Function of Order Size 39

3.4 - Transportation Process of the Supply Chain 43

3.5 - Example of Segmentation for Analysis..43

3.6 - Example of Input Modeling For Total Lead Time 46

3.7 - Fitted Distribution for Total Lead Time Data Example 46

3.8 - Example Distribution Showing Service Levels...51

3.9 - Simplified Rate Behavior Regions 54

3.10 - Different Rate Behavior...55

3.11 - Graphic Representation of Factor's Levels Based Scenarios.......................56

3.12 - Example of Total Landed Cost Visual Comparison....................................61

3.13 - Annual Savings Differential Graphic for a Shipment Profile......................63

4.1 - Map Showing Geographic Location of Guaymas, Mx. 67

4.2 - Guaymas Port Hinterland 67

4.3 - Network Representation for Guaymas' Case Study.....................................78

4.4 - Simplified Network for Guaymas' Case Study..79

4.5 - Histogram for Port of Los Angeles Total Lead Time..................................82

Figure Page

4.6 - Fitted Distribution for Port of Los Angeles Total Lead Time.......................82

4.7 - Port of Los Angeles Total Time with Service Level Indicators....................88

4.8 - Graphic Representation of Scenarios Comparison.......................................94

4.9 - Annual TLC as Function of Service Time and Shipment Cost.....................95

4.10 - Savings of Guaymas for each Changing Scenario......................................97

4.11 - Graphic Analysis of Port Lead Time..98

5.1 - Alternative Shipments/Port flow for Objective Function............................103

5.2 - Simplified Network for General Problem 106

5.3 - Uniform Sampling from Factor for Shipments...108

5.4 - Logistic Cost and Shipment Assignement by Port 110

1. PROBLEM DEFINITION

1.1 Introduction

The research presented in this thesis is related to port competition. The main objective is to determine how to position a commercial port with respect to other competing ports to best serve the companies located in its hinterland in terms of total landed costs.

The purpose of the following section is to link the main ideas behind this study. The first step is to discuss the concepts and background of the global trade environments in such a way that the relevance of supply chain and logistics is shown. Within these concepts the research is limited to inventory costs and transportation activities. Among these boundaries two major components of the network are selected and reviewed: (1) the port operations as a network node and (2) lead time uncertainty derived from the network variability. The latter's impact on total logistic costs is discussed as a framework upon which to define the problem. Thus the problem becomes how one determines the parameters for a given port, in order to reduce the impact of lead time uncertainty and improve its overall competitiveness.

1.2 Relevance of Logistics in Modern Supply Chain

Companies that operate at a global scale have reached a level at which minimizing supply chain costs has become a challenge that is more than a competitive opportunity, but a necessity for their survival. As a result, certain manufacturing operations have been transferred to countries with lower labor costs; thus forcing these multinational companies to transport goods across international boundaries.

In order to control and achieve efficient and effective flow of goods, several decisions must be made by the multinational companies involved. These decisions range from warehousing strategies to transportation tactics and operations. All these decisions fall in the realm of logistics. Logistics is defined by the Council of Supply Chain Management Professionals (2009) as "…is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements."

For the specific purpose of this thesis, transportation will be considered as the main driver of the logistics and supply chain processes. These processes consist of the movement of goods through a series of echelons in order to achieve a commercial and economic objective. For most firms, transportation usually represents the most important, single element in logistics costs. For instance, freight movement has been observed to account for between one-third and two-thirds of total logistics costs (Ballou 2003). Ballou explains that an effective transportation system contributes to a greater marketplace competition, supports the economies of scale and achieves reduced price (costs) of goods. Therefore, it is obvious that companies consider logistics and transportation as relevant areas, whereas intelligent decision-making creates a competitive advantage and provides a convenient cost-benefit opportunity.

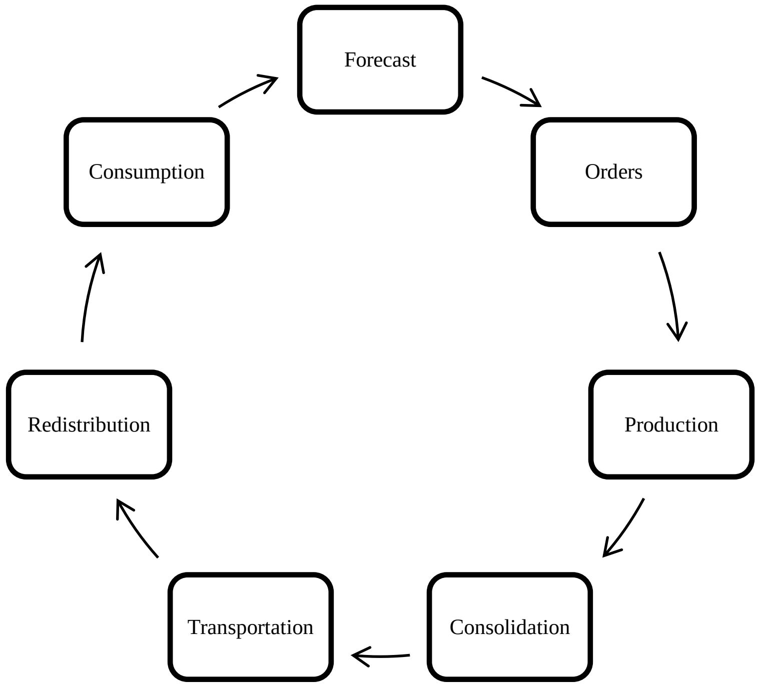


Figure 1.1 - Basic Supply Chain Diagram

Figure 1.1 shows a basic diagram of a modern supply chain. This thesis will focus on the “transportation” echelon of the chain. As it was mentioned before, transportation plays a significant role in a company’s total logistics, and may be a competitive factor when its decisions are made efficiently. Modern multinational companies seek to minimize costs associated to transportation in their quest to improve logistics as a way to achieve competitive leverage.

This thesis is especially concerned with the additional time that a shipment flowing through a port has to spend to be released from the port, in particular the time when a shipment arrives on the vessel to the port until it leaves the port’s premises. Through this thesis we will refer to this time as port’s sojourn time.

Specifically, the impact that this sojourn time has on the supply chain of the customers the port serves.

Furthermore, it is unwise to neglect the role that international commercial ports play on multinational companies and their necessity to transport goods across international boundaries. For instance, sea port traffic in the United States doubled in the last 10 years, especially due to inbound trade from Far East countries into the continental United States territory (USDOT Maritime Administration 2009).

The objective of this thesis is to develop a methodology that can be used to best position a port that would serve companies' supply chains within its area of influence. Specifically, on how to be competitive with respect to other competing ports and other transportation means. The ultimate goal is to provide ports with methodic guidelines to design or reengineer their internal operations to be more competitive within a logistic network. In particular, the thesis will propose a methodology that will be based on an economic comparison of the available ports' within a specific logistic network. The evaluation will provide: (1) inventory costs derived from transportation-related activities and (2) port parameters; both in function of the ports' service time. These costs and port parameters provide a reference of port competitiveness.

To extend the ideas reviewed through this section, a brief summary of some of the relevant concepts of the port's role and transportation lead time variability within the supply chain are presented.

1.2.1 The Port’s Role on the Modern Supply Chain

As previously mentioned, this thesis focuses on the transportation echelon of the supply chain. The purpose of this section is to show the port’s importance on this particular stage of the supply chain.

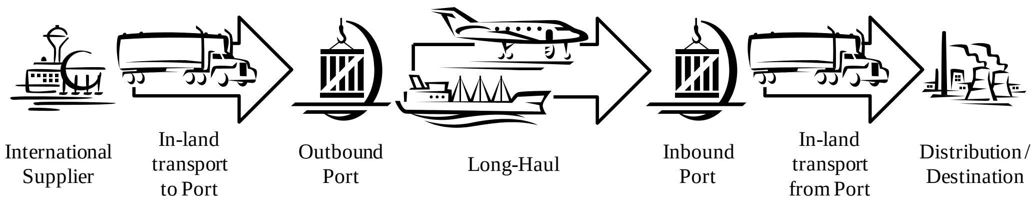


Figure 1.2 - Common Transportation Process Example

Figure 1.2 shows an example of a common transportation process that falls into the scope of the study; that is, the movement of containerized cargo through commercial ports. The interest of the proposed thesis lies in the “Port” stage of the process and its competitiveness in terms of service time.

The impact of sea ports to regional economic development is well known. This is shown in statistics such as in 2003, 8 from the 10 cities with the largest metropolitan area in the world were sea ports (Forstall, Greene, and Pick 2009). The impact is higher for national economies that depend vastly on international trade. Initially sea ports were intended for the economic development of its hinterland (hinterland is applied to the inland region lying behind a port; the area from which products are delivered to a port for shipping elsewhere is that port's hinterland (Chisholm 1897)); nevertheless as modern transportation methods became more efficient, the role of ports in the logistics era became an essential part of the integrated supply chain systems (Song and Panayides 2008). Basically the role of the port within the supply chain has evolved from being the link between maritime/air and in-land transport to being a more active and integral player of the chain. Nowadays, the developed and efficient ports provide a role similar to a logistic platform, where the main objective is to provide to its customers with a reliable and continuous service with high productivity levels (Carbone and De Martino 2003).

Another concept that supports the relevance of the port role within the supply chain is the containerized cargo-related operations. Containerization relates to the system of intermodal freight transport using intermodal containers in a standardized cargo mode (International Organization for Standardization 2010). Containerized cargo has its origins in the late 1700's but its standardization in the 1960's became an innovation for global logistics facilitating the cargo and handling operations throughout the entire transportation channel. The world container international traffic has increased from approximately 85 million twenty-foot equivalent units (TEU's) in 1990 to around 500 million TEUs in 2008 (International Association of Ports and Harbors 2008); this shows an increasing tendency that makes the ability of handling of containerized cargo an integral part of the Port's operations. Since these operations are crucial to modern supply chains, the research scope lies on ports handling containerized cargo. It is then that the focus of the proposed research yields the relevance of a commercial port's efficient service as part of an integrated supply chain.

1.2.2 Importance of Lead Time Variability in Logistics Decision

A relevant concept for this study is the existing relationship between lead time variability and logistic decisions. The design of the supply chain in this modern globalization era has become a very difficult task; mostly because it needs to operate and meet the requirements of uncertain environments. This uncertainty is derived from several factors which include supply/demand alignment, inventory and back-order levels and forecasting errors. Even though demand factors are the most studied within the supply chain management research, they are not the only source of uncertainty; for instance, delivery lead times and its variability can also have significant impact over the whole supply chain (David Simchi-Levi, Kaminsky, and Edith Simchi-Levi 2007).

The term variability for is defined as "subject to variation or changes" (Merriam-Webster, Inc. 2009). Specifically, in relation to transportation processes, variability is associated with the level of sparseness observed in the lead time (LT). As it was previously mentioned, from all segments analyzed of the logistic network, the port is of the utmost interest for the present research. Therefore, it is important to emphasize that for purposes of this thesis, port time variability refers specifically to a shipment's sojourn time in the port; this time is directly related with the amount of time that the port operations –or disruptions- add to the overall lead time of a shipment, from the origin to the destination. Consequently, the term "*service time variability"* when used with respect to the port's service time it refers to the shipment's sojourn time uncertainty in the port.

Examples of the impact of additional sojourn time in ports are seen in the sea ports of Long Beach and Los Angeles (LB/LA). The new environmental policies of California and the saturation of the ports' capacity, altogether with the demand trends -explored in the literature review section- are generating problems in the vessels' service turnaround times. Thus, the service levels commonly required by the port's clients -that rely on its cargo moved almost daily through it- are getting harder and harder to reach. For instance, if a goods' shipment has a mean of 21 days for the long-haul from China to LB/LA and the port increases this time by a variable amount -showed as a standard deviation of 3 days on due port operations-, the shipment's consignee in order to protect from a late delivery backorder would have to stock safety-related inventory for up to almost 7 days to reach service levels of 99% (this and other examples will be discussed in Chapters 3 and 4).

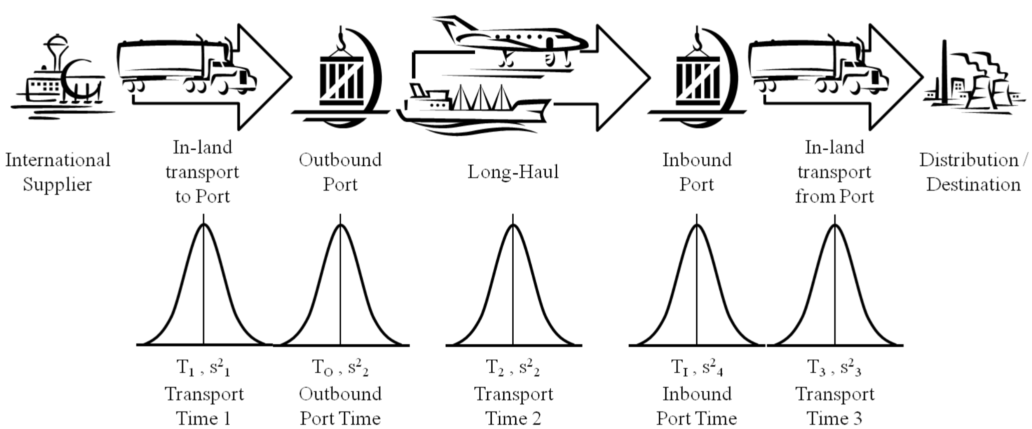


Figure 1.3 - Multiple Time Elements throughout Transportation Process

Figure 1.3 (Ballou 2003) presents the different processing time distributions that can be identified throughout the entire transportation echelons of the supply chain (Ballou 2003). Several elements are unpredictable and capable of adding different intervals of time to the entire process; these behaviors can be combined to affect the overall transportation lead time, which is then interpreted as additional costs to the supply chain. Thus, the effect of lead time variability is addressed as a key component of the explored methodology of this thesis.

The presented study is based on the economic interpretation of lead time variability. A common place to integrate transportation lead time into total cost formulas is within the in-transit inventory cost component, which is basically a t/365 increment relationship for each day (t) the LT is increased and a fractional increment overall. Additionally, the proposed methodology considers lead time variability as the direct linear increment over the holding costs component. The time increment in the common transportation LT cost interpretation is linear and fractional; whereas cost effect due the transportation LT uncertainty is linear but non-fractional.

1.3 Problem Statement

The problem at hand is to determine the impact of port operations' on the transportation lead time and on its clients' total logistic costs; and how to define operational parameters within the port in such a way that this impact is reduced and the port itself becomes more attractive for those companies operating supply chains within its hinterland. Indirectly, the problem is how to position a given port in order to compete against other ports, even other modes of transportation.

The underlying hypothesis to be explored is that if the average sojourn time of a shipment in a given port is low, then the port could be in a better competitive position over other ports that may even have lower tariffs or be geographically closer to a potential customer.

1.4 Specific Objectives

In this section, the specific objectives of the research are presented according to the problem at hand. The problem defined above provides a research opportunity that is yet to be explored. This problem involves specific operative factor of the port's role in the supply chain: the service and operational time as they affect the shipment's sojourn time in port. Thus, it is critical to identify how these changes in the competitors' operations lead times can be used to define competitive advantages for a specific port.

The underlying objective of the thesis is to develop a methodology that can be used by any arbitrary port to determine competitive parameters based on the total logistics costs of the supply chains existing in its hinterland. The resulting method is expected to be practical enough to be used in real life scenarios.

To achieve this, several sub-objectives are identified and developed through the study:

- Define how to delimitate the logistic network to analyze and how to identify the service level provided by the available ports within.
- Develop an economic interpretation of lead time variability in port operations and its impact on Total Logistic Costs.

- Determine average sojourn times for a port to be competitive –or increase competitiveness- in the specific network.
- Include a case study that can support the proposed methodology and that can provide more detailed results.

The effect of port variability on supply lead times is a critical factor in this study. This will be addressed in time units (due to queues, operations, customs, drayage and others related processes) and is to be projected into total landed costs models, which will be represented as inventory costs components for its analysis. It will be the base of comparison for the service levels provided by the network; additionally, it will help identify the competitive service time's opportunities.

1.5 Limitations of the Study

The limitations of the thesis are presented in order to narrow the scope of the present study. In order to define the methodology, some research limits considered:

1. The present study is not intended to solve an operation, production or inventory problem. Even though inventory metrics are considered within the methodology, these are used merely for the economic interpretation of transportation lead time variability and do not intend to identify operation, production or inventory issues for the logistic network.
2. Several factors exist that can be utilized to define competitive parameters for a specific port. The methodology focuses on

determining the competitive parameters from the existing lead time variability of *other* ports and/or transportation channels at the same supply chain level.

3. Requirements or specifics related to the implementation and/or design of the port's operations are out of the scope of this study.
4. The expected results from the methodology are suggested for decision-making support and do not intend to be the single base of the port operations design.
5. The case study presented in section 4 is based on information provided by a specific port administration and complemented by researched statistics. The analysis in that specific section is limited to the information available at the time of the referenced research project. Most of the information is public whereas some was bought through database services. This represents another limitation of the study when related to specific case analyses.

1.6 Thesis Overview

This thesis is divided into six chapters. In Chapter 2, a literature review is presented to frame the relevant subjects of the thesis, including the background theoretical elements, the effect of lead time variability in the supply chain and existing tools used for port comparison. This chapter also includes a perspective on the contribution of this thesis in function of the reviewed material. Chapter 3 describes the methodology and its systematic approach to solving the defined problem. In particular, this chapter aims to describe the proposed solution to its general case. First, the factors considered and the assumptions made are discussed followed by a walk-through of the proposed methodology, and at the end a summary of the proposed procedure to the general case is presented.

Proceeding into the analytical section of the thesis, Chapter 4 demonstrates the application of the methodology in a real case scenario. It describes the analyses and results obtained by implementing the steps described in Chapter 3 to a specific case study. This chapter presents the primary results of the thesis and sets the base for conclusions and future research opportunities. Chapter 5 illustrates a suggested linear model that validates the proposed method. First, the model source and definition are introduced, followed by an explanation and implementation of a modified version of the model, whose purpose is to validate the methodology. Lastly, Chapter 6 contains the conclusions drawn from the previous chapters plus some ideas for future work and research.

2. LITERATURE REVIEW

2.1 Introduction

The objective of this section is to show previous works and studies that are somehow related to the thesis' background and underlying objective. The literature review is divided into three categories: (1) literature supporting the motivation of the thesis, (2) literature focused on the existing relationship between transportation lead time variability and its impact over the supply chain costs and processes, and lastly (3) literature related to models used to measure port performance competitiveness.

The main objective of the literature review is to establish a baseline of development for the proposed study and to identify further research topics.

2.2 Relevance of the Logistics Approach

One of the main ideas of the proposed research is that recent increments in global trade create congestion on the commercial ports, which translates into additional service times that are often overlooked. Trunick (2005) explains the strategies that seaports across the US Pacific followed to alleviate the congestion problem during 2005. However the relevant information for this research is related to the statistics presented in the paper. In the paper the Author mentions that 70% of the all shipments coming from Asia to the US at that time were received through the sea ports of Long Beach and Los Angeles (LB/LA); additionally those shipments showed a 14% annual increment and, while the logistic infrastructure in China and the United States was developing significantly, the congestion in sea ports like Long Beach was not diminishing. The author mentions several examples and cases where shipments coming from Asia have a wait time of up to 8 days to be serviced. The supply lead times for companies that relay in these shipments for their imports from China were severed due these increased waiting times. The author comments that the sea ports terminals along the U.S. Pacific Cost are not prepared for the trade increment in the future years, mostly because of the limited land transportation routes between available Pacific ports and the inland U.S. territories. The strategy of identifying port options along the logistic network is relevant, in order to avoid congestion in similar scenarios.

Rubin (2008) talks about the idea that the increasing fuels prices are not considered on the inflation metrics on the U.S. The Author says that these costs (specifically the ones related to oil) have affected transportation costs; therefore, these represent a bigger threat to the stability of goods prices in the U.S. The established relationship by the author between the increased oil prices and inflation is that these increments are eliminating the economic leverage of the lower cost labor from the Asian countries. The information presented shows that transportation costs for a container moving from Asia to the U.S. will increase in the following years. The author mentions that the average cost of sending one container from Far East Asia to the U.S. has increased threefold since the year 2000 and that it is expected to be double in the following years. This is the reason why the transportation costs from Asia increases the cost of its merchandize, which it is then reflected on price increments for the final user. The most relevant conclusion obtained from the publication is related to the fact the companies that rely on maritime transportation are under pressure to lower their logistics costs.

Mangan et al. (2008) discusses the potential roles of sea ports and present the concept of port centric strategies. The paper explains how sea ports can play a variety of roles in the companies' supply chain strategies, and that are not limited to the basic transshipment operations. The author presents ideas related to the tendency of moving merchandize out of the ports. He mentions that based on the increments on traffic concentration in larger ports, medium size ports are playing a role that is more important from time to time for the shipments' concentration. Other tendencies showed by the author are the increments of environmental and safety regulations in the main international sea ports, and how are they related to port transit congestion. The author speaks briefly on the relationship between ports and supply chain as he shows an example of the port disruption: the case of the labor strikes on Long Beach in 2004. The disruptions caused many vessels to wait a long time for service creating negative effects on the supply chain of the ports' clients. Other comments presented by the author are related to the localization of distribution centers close to ports and its benefits to supply chain. Moreover, the study supports the relevance of the ports as a significant node of the supply chain.

2.3 Lead Time Variability and the Supply Chain Processes

This section describes literature that establishes the relationship between lead time variability and the supply chain processes.

Lair et al. (2004) focuses his paper on the relevance of inventory and transportation on the effective administration of the supply chain. The baseline of the research is related to inventory practices known as Just in Time (JIT), which are logistic tactics used by material managers in modern companies to control issues related to inventory levels. The author suggests that for these JIT practices to be functional and efficient, an efficient transportation method and proper order sizes are required. The paper also analyzes the impact of lead time variability from both factors (transportation and order) over the supply chain performance in a four stage chain, and based on a specific service level. The analysis presented by the author is based on experiments done in simulation models in several scenarios. The results of these effects on the proposed JIT system shows that as transportation time uncertainty increases, the service level offered to the client is reduced. The conclusions of this paper back up the central statement of proposing a comparative framework for the present study; the comparison step of the methodology will be based on the effects of lead time variability and its implications on inventory levels.

Lewis et al. (2006) present a paper on research done on a choice model designed to aide companies quantify the impact of temporal disruptions of a port's container terminal in the productivity of global supply chains. These disruptions, as shown by the author, may be caused by several reasons that range from natural disasters and labor strikes to security-related disruptions. The author specifies that the temporal disruptions result on highly variable lead times, thus increasing the costs related to inventory of the supply chain. The author proposes a Markov decision tool (probability based model) that determines an inventory management policy for supply chains that are subject to temporary disruptions on its most important ports (nodes). With the results of the mathematical analysis the author shows that the impact of long-term port disruptions is higher than the impact of the port closure probability. In other words, the negative impacts on a supply chain of a port subject to few, but long interruptions, are higher than the impacts of a port subject to many, but short interruptions. The research results show the economic relevance of investing on capacity increases for ports that show high utilization, when these are subject to temporary disruptions. The paper also proposes an interesting idea related to the impact of ports' service time uncertainty: any event derived from the port congestion, as observed from the port's client perspective, can be considered as a temporary disruption of the port, thus affecting the supply chain flow.

Chopra et al. (2004) analyze how lead times variability affects the safety stock levels. The author bases the research on the statement that the existing pressure to reduce inventory among the supply chain increases as the competition increases as well. It is mentioned that modern companies try to reduce the costs associated with inventories without reducing the impact of offered service levels;

their main objectives are (1) to reduce the lead times of orders (Order processing time from suppliers), and (2) to reduce the variability on the overall lead time. The author concludes that reducing lead times can have a larger impact that reducing lead time variability. Nevertheless, the paper remarks that the investment and setup cost associated with lead times variability reduction (logistic strategies) are significantly lower than the long term cost of trying to reduce the processing lead times of suppliers (external controlled forces). For this reason is concluded that variability reduction in lead times is a milestone required to achieve a decrease on the overall logistics costs. The author makes an additional recommendation on how long lead times should not be approximated to normal distributions, which is followed during the development of the framework on the following sections.

2.4 Port Performance and Competitiveness Models

This section of the review identifies some of the previous works on port performance and competitiveness models.

The first step on this review was to identify the work related on modeling lead time variability as metric so it can be quantified into an economic model. One of the most appealing ideas is presented by Talluri et al. (2004) in a study that refers to the necessity of managing inventory levels efficiently and its relationship with supply chain management. The author explains how several and different tools and techniques have been developed in academics and in the everyday management practicum, and how these have been used for inventory management along several echelons of the chain. The main objective of these tools is to reduce operation costs and to improve the efficiency of the chain itself. He develops a cost model for pharmaceutical inventory, whose attractiveness is that it incorporates supply and demand variability into a service level-related safety stock analysis. Following the model, the author shows a comparative on cost-benefit between the proposed model and the more common and existent models. The paper concludes with some recommendations for intelligent management of safety stock. The main idea captured from this paper is related to the integration of uncertainty-related safety stock to the analysis models as a measure of supply chain performance, which is intended to be the baseline of the proposed thesis study: the costs associated with safety stock derived from variability in supply lead time.

The following step on this review was to identify what had been done regarding port competitiveness within a given logistic network. The idea is to identify metrics that could be used as a port comparison reference. Bichou and Gray (2004) support the idea of the port's role as a logistics center in the supply chain and suggest that an appropriate port performance measurement has not been developed yet. The authors propose in the paper a framework for port performance measure. The measurement is effectively made through the conceptualization of the port from a supply chain management perspective. The scientific approach presented for measuring the port and terminal performance is considered as reference; the methodology uses action research and exploratory investigation and the results are considerably appealing.

Young and Swan (2004) refer to the use of total landed costs models as support decision tools for purchasing merchandize procedures (mostly raw material) from countries in Far East Asia. The authors explain that as the manufacturing companies start to purchase material from Asia for their operations, the necessity of a sophisticated mechanism for decision making is unavoidable. Their survey shows that most companies use several variants of what is commonly known as "total landed costs" models to make procurement and logistics decisions; unfortunately, the lack of robustness in the models generally used make this decision-making process mostly an informal process. The author of the publication provides different models that include costs that range from material prices and extends up to transportation strategies and customs tariffs. The author upgrades the model up to the point that considers inventory excess, operational risks and not-value-added product costs. The research included on this publication and its satisfactory results shown by the author on the implementation of the models help establish the basis for the total landed cost-based methodology used in the thesis.

Following the idea of using the total landed costs approach as base for the thesis methodology; other papers with the same approach were reviewed. (Leachman 2008) suggests an allocation model for waterborne containerized imports from Asia to the United States. The model defined by the author minimizes total landed cost for a defined set of importers. Specifically, the model considers transportation costs and inventory costs derived from using a given set of transportation channels. One of the most interesting parts of the author's approach is the use of variable lead time and safety stock inventories. The model developed for the paper focuses on determining port's container-handling tariffs per imported TEU via San Pedro Bay Ports. The author's conclusions suggest that a correlation should be presented between the increments on container fees and the port's infrastructure for the port to keep the container transit. The overall suggested model seems accurate and appropriate for the imports allocation especially in regards inventory consideration; but does not consider specific port service variability and its effect on shipment's sojourn time, nor focus the analyses towards port competitiveness. The author's application of total landed cost for port analysis demonstrates the usefulness of the technique as an economic comparison framework.

(Zeng and Rossetti 2003) develop a framework for evaluating logistics costs in the supply chain. This paper deliver yet another suggestion for using total landed costs models for a base of supply chain performance evaluation. The authors suggest the total landed costs are derived from the following categories: transportation, inventory holding, administration, customs charges, risk and damage, and handling and packaging. The previous reviewed studies provide a solid background for adopting total landed cost methods as a competitive measuring model for the network, as long as the required measurement is considered.

The last part of the review was related to optimization models that could be used for validate the methodology results. The validation would focus on demonstrate the relevance of lead time uncertainty reduction as a competitive factor. In the first paper reviewed Chou (2005) made a comparison on several choice models used for port selection. The purpose is to compare the ability of different choice models and their application as port selection tools. The author mentions the relevance of port selection on the current transportation market of containerized merchandize in order to reduce logistics costs. The research focuses on a comparative analysis of several economic choice models used in the past for port selection; the models included are the Equilibrium model, the Stackerlberg-game model and the fuzzy logic model (multiple criteria). Unfortunately, the paper fails to provide a more detailed procedure on how the optimal model for port selection is determined. Furthermore, the author concludes that none of these models are good for port selection on the basis of the analyses and suggest the use of other model types. Additionally, other choice models used by other authors are more of a discrete nature. Malchow & Kanafani (2004) propose a model as function of the port and shipments characteristics. In this study, several fixed routes are assumed on a short time window, and the ports are assigned based on the shipment category and as a function of the port’s geographic location and characteristics. The authors conclude that in base of the model’s results the most important choice factor on port selection is geographic location. Even though the proposed analyses are made mainly for containerized merchandise exportation, the study shows a valid markup on how to categorize and profiling merchandise into the decision models, which is also taken under consideration on the proposed thesis methodology.

Finally, Fan et al. (2009) study the shipments of container imports from China to the United States through optional sea ports other than the heavily concentrated ports of Long Beach and Los Angeles. The author proposes his study on the statement that several routes are being developed to gain access to U.S. markets (South Canada Ports and the expansion of the Panama Canal). The author mentions the use of the Pacific Port of Prince Rupert in Canada and the Atlantic port of Houston, through the Panama Canal. The author estimates a container flow through these new routes logistic channels for containers shipments to the U.S. One of the most interesting contributions from the study is the selection model developed by the author. The selection model considers mostly the port’s congestion and the merchandise’s demand uncertainty. With the proposed model, the researchers determine the optimal route, ship size, port and hinterland shipping channels based on cost minimization. The model is fairly extended and elaborated and may serve as a validation baseline of the proposed methodology (for instance as part of a port selection problem).

2.5 Contribution of the Present Research

In the previous review several papers and past studies were discussed with two objectives: identify previous work related to the topics addressed in this thesis and identify gaps on the approaches presented. By focusing on these objectives it is possible to identify the contribution of the study at hand.

It was observed that most of the analyses shown in the studies related to measure performance focused on the overall supply chain and not on a specific segment; additionally it was observed that those papers related to performance metrics of transportation channels were qualitative rather than quantitative in nature. The scope of the performance measures was either for a single supply channel and/or for internal purposes. That is, these performance measures were not used for the assessment of competitive position, as it is the intention of this thesis. Though competitiveness was highlighted in some of the studies, a technique was not presented to compare transportation channels on basis of the explored measures.

Another relevant notion that was missing in the reviewed papers was the issue of lead time variability on the single elements of the logistic network. This is, a lack of network segmentation was observed through the reviewed studies. This means that the shipment's sojourn time in port was considered as part of the transportation lead time.

From these remarks, the contribution of this study lies on the usage of total landed costs to measure different transportation channels to determine levels of competitiveness within a logistic network. These measurements will quantify the impact of unexpected sojourn time for a given service level. From these comparisons of performance the methodology would be able to provide with competitive parameters to the ports. These parameters are intended to aid the key players within the network to identify strategies, techniques and operations that can reduce the shipments' lead time and improve the level of service provided to their customers.

It also would attempt to show the relevance of transportation lead time variability impact on the costs for the network users by quantifying its effects on economic terms. It is then expected that the methodology would combine supply chain performance metrics with more specific metrics -such as service levels- to increase ports' competitiveness.

Lastly, from this review is relevant to note that for any given commercial port the parameters for the long, mid and short terms activities need to consider the shipments' sojourn time in order to achieve competitive standards. Then, a methodology that incorporates lead time variability to determine port parameters is necessary.

2.6 Benefits of Research

Achieving the specific objectives of this research is expected to benefit ports that may adopt the proposed methodology. Methodic and scientific approaches to improve competitive levels lead the port towards proficient role within the region's supply chains. A port with proper techniques and operations can have positive effects for the port itself; on the other hand, a port with efficient supply chain strategies has positive effects over the entire network (Notteboom and Rodrigue 2005). A competitive port is a key player of an integrated supply chain, which at the end benefit the economic development of its hinterland.

The thesis' study pretends to provide a methodology based on supply chain performance metrics. This methodology will help to determine parameters that can be used as a baseline to develop a competitive port (or increase competitiveness) within a region. Moreover, it would potentially have positive effects for the port's clients, which would benefit of lower service times and lower logistic costs overall.

3. METHODOLOGY

3.1 Introduction

The main objective of this chapter is to outline the methodology to be followed in order to meet the objectives stated in Chapter 1. Also, the background and factors under which the proposed methodology is designed will be presented and described. The primary purpose is to provide an explanation of the systematic approach to be followed.

First an introduction to the methodology is provided, where some factors and assumptions are presented; next, the steps of the methodology are shown to describe the approach to the general problem.

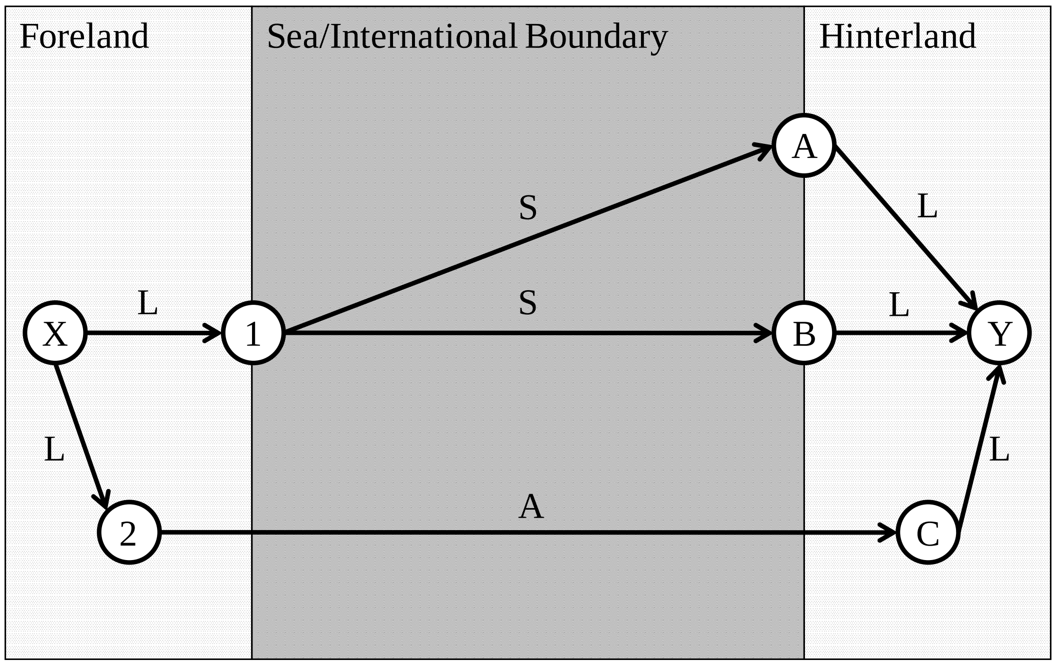
The scope of the study considers a specific node of a logistic network: the port and its service time. This is based on the relevance that it is believed to have over the total landed logistics cost. As it was mentioned on Section 1.4, the objective of the study is to develop a systematic approach to determine competitive port parameters based on existing port-related lead time variability within a given logistic network.

In order to determine the port's competitive parameters, the methodology should address the key elements that were identified during the research. First, it should define the logistic network to be analyzed. Specifically, the methodology must establish the limitation on the network analysis in relation to the entire transportation process within the supply chain. These limits are related to the transportation activities and channels available -for instance, the initial and final points of the network, which are the competing ports and the segments connecting them-. Subsequently, the methodology needs to identify the existing service levels within the network. This refers to (1) the service levels required by the costumers within the defined network, and (2) the service levels provided by the commercial ports to these costumers. Furthermore, one more issue to address relates to the network's shipment traffic, itself. The traffic observed helps estimate the demand generated from the hinterlands to the ports of interest. Lastly, the service levels and identified demands will help determine when the network's lead time variability translates to an opportunity. This opportunity will be later extrapolated to competitive parameters such as the shipment's sojourn time in port needed to attract demands from shippers located within the hinterland.

It is important to underline that the scope of the study is not related to the internal supply chain processes of the port's clients. As it was mentioned before, the intention is not to solve an operation, production or inventory problem, but to support those decisions that can help a port to improve the level of service provided, so that the port can potentially reduce the total landed costs of its customers and become a crucial part of their integrated supply chains.

3.1.1 Description of the General Problem

The general problem is defined as follows: Port A desires to determine the required parameters to be successful in attracting the freight of certain customers in its hinterland who can also be serviced by other ports (i.e. Port B, Port C...Port N), which present uncertainty in the observed sojourn times. These ports also serve the same hinterland and compete with each other for the demand derived from the region. Figure 3.1 shows a geographical representation of the transportation network.



L = Land Transportation
S = Sea Transportation
A = Air Transportation

Figure 3.1 - Geographical Representation of the General Network

In the this network, it is assumed that goods are being transported from region X to a representative company in region Y. Ports A, B and C are available to service the company's supply chain. The primary objective of Port A in this general problem is to position itself as a competitive port for the supply chain of the hinterland, represented in the figure by node Y. The latter has the option of using the available transportation channels to move these goods; thus Port A needs to identify how to attract the demand generated by the industry in the hinterland (node Y). Thus, it is necessary to develop a methodology to identify the shipments' average sojourn time required for Port A to obtain a competitive position over the other available ports and/or transportation methods.

This methodology is to be designed in such a way that it considers the impact of inconsistent shipment's sojourn time in port on the supply chain costs of the hinterland. Several factors need to be considered while modeling this problem. These general factors are discussed next.

3.1.2 Factors under Consideration

Several factors need to be considered in order to achieve the overall research objectives through the methodology. The factors are essential to providing the required guidelines and decision variables to develop the methodology.

The first factor to consider is the existing alternatives available to the targeted companies in the transportation of their freight. Within the logistic network, the alternatives relate to the available transportation channels (including ports) extending from the point of origin to the destination of interest. Other alternatives relate to the goods to be shipped through the network. One expects to identify scenarios for different goods with different attributes. The impact on the safety stock metrics from these different scenarios will be considered in the methodology.

The next factor to consider is the attributes linked to the alternatives defined above. For the transportation channels alternatives, tariffs, distances and specifically port sojourn and service times will be considered. For the goods, one expects to find a proper relationship cost/weight/volume ratio that will serve as the basis for evaluation.

An additional factor is the decision rules. The service levels required by the users of the network will be considered as guidelines to define competitive parameters. This means that if the user requires a specific service level from the port service, the parameters will consider the same level when comparing a port and its competitors. The total landed costs will help identify the average shipments' sojourn time that will set the port as competitive (or not competitive). The inclusion of these factors in the methodology's analyses will help determine the competitive parameters for a given port.

3.1.3 General Assumptions

In order to simplify the proposed analysis, several assumptions are made. Some of the assumptions are:

- Goods are transported from point A to point B for their consumption and their demand is known.
- The rest of the supply chain echelons are considered to have steady and non-variable operations.
- Incorrect decisions or mislead operations from other segments of the chain are not transferred into the segment under evaluation.
- The logistic network has two or more port alternatives (competitiveness).
- The transported goods do not change during the process.

- Some cost components will be assumed to be known and deterministic.
- Transportation will be between two points of interest. That is, direct transportation is available.
- Transit time is assumed to be known and unchanged for each transportation channel; only the observed shipment's sojourn time in port is to be measured.

The list of assumptions for the methodology is not limited to the previous and can be extended in the real life scenarios as required. The overall objective of these assumptions is to maintain the complexity level of the analyses within practical levels.

3.1.4 Proposed Methodology

Once the main factors are identified and the proper assumptions defined, the next section summarizes the methods as they are aligned to the objectives of the study. In order to support the thesis statement, the idea is to develop a methodology that can be used to determine how to get a port into a competitive position. This is based specifically in the lead time variability observed in the port and its effect on the supply chain costs.

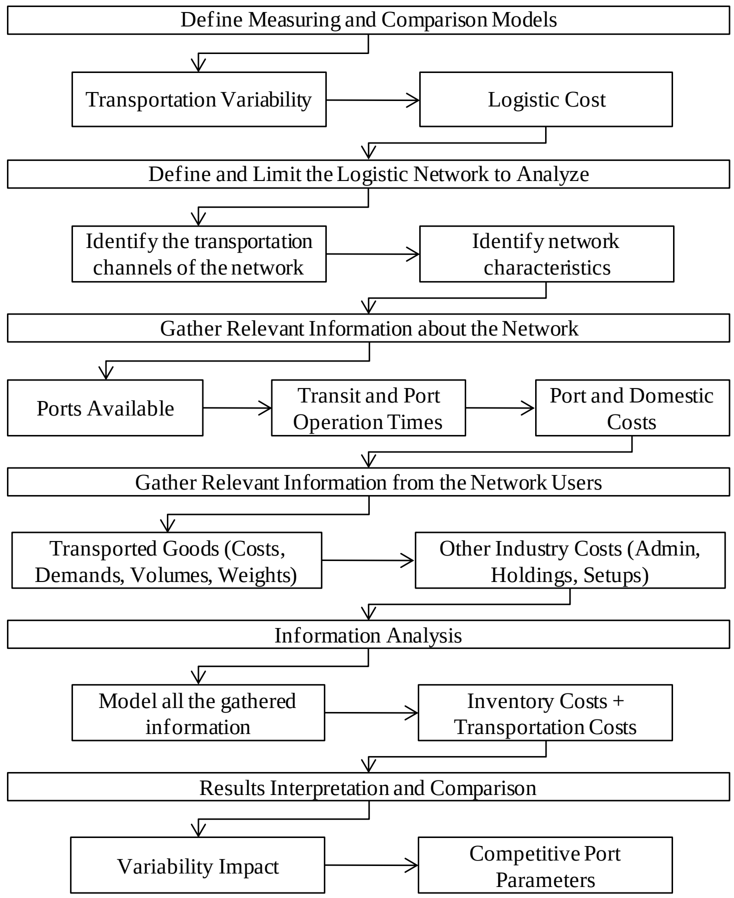


Figure 3.2 - Outline of Proposed Methodology

Figure 3.2 shows an outline of the proposed methodology. The main steps of the sequential method are as follows:(1) set a proper measure of lead time variability and cost model for the problem in hand, (2) set the limitations on the logistic network to analyze, (3) identify the attributes of the supply chains existing within the network, (4) analyze these attributes within the model, and (5) finally, compare them in terms of shipments' average sojourn times in port. These steps are expected to show a clear overview on how transportation lead time variability affects total landed costs and to determine the competitive parameters for a specific port.

3.1.5 Chapter Overview

Each of the steps previously depicted is described in the following sub-sections. Section 3.2 represents the setup of the methodology. It is related to the selection of the Total Landed Cost and a measure of variability that fits the required supply chain comparison. The sections following 3.2 develop the methodology behind the systematic approach to the general problem. Section 3.3 explains the procedure established to delimit the logistic network into the area of interest and how to integrate the transportation channels single measurable units. Next, section 3.4 and 3.5 discuss the information required for the proposed analyses. These are related to the information required to quantify the attributes for each of the transportation channels (ports) to compare. In section 3.6 the information is then analyzed under the selected models. Finally, section 3.7 illustrates the interpretation of transportation lead time variability impact over the Total Logistics Costs and how to determine the competitive parameters from it.

3.2 Define the Cost and Variability Model

Based on the economic models reviewed a cost model was selected for the methodology. The purpose of this model selection is to include a measure of the lead time variability and the corresponding cost in order to compare the different transportation channels (ports and/or transportation means) available in the logistic network. First, the process to quantify the variability in the analysis is shown, followed by the resulting cost model.

3.2.1 Variability

For the transportation and port segment a method for modeling lead time variability is adopted. The method consists of creating different scenarios to model lead time variability in the targeted ports. These scenarios are based on time-based probability distributions that represent the observed shipments' sojourn time in the ports analyzed in the methodology. The level of variability for each scenario is determined by the coefficient of variation of the observed sojourn times' probability distribution. The coefficient of variation (CV) is a normalized measure of the dispersion in a probability distribution. It is defined as the ratio of its standard deviation (σ) to its mean (μ):

$$CV = \frac{\sigma}{\mu}$$

Distributions with small coefficients of variation are considered to have low variability, while distributions with $CV \geq 1$ are considered to have high variability. For instance, an exponential distribution (which has a $CV = 1$) can be used to model the worst case scenario. In this way the lead time variability added by the port segment can be quantified in a matter that can be input into the model as a parameter.

For the case study scenario, real shipments' sojourn time data is used to model the port observed variability. Input modeling techniques are used to identify the probability density functions of the portrayed port times. Once these time distributions are identified, the CV's are computed for each transportation channel in order to have an indicator of variability as a reference. This will be discussed in forthcoming sections.

3.2.2 Total Landed Cost (TLC)

The model used to determine the impact of lead time variability and compare the transportation channels (the different ports and/or transportation means) along the network is the total landed cost model for the goods flowing through a supply chain. This cost model will also provide the reference to determine port parameters. These parameters are required to set the shipments' sojourn time in port in such a way that the total landed cost is minimized for the port user.

As it was observed in the literature review section of this document Total Landed Costs models have been widely used in research as a measure of supply chain performance. The overall definition of the Total Landed Costs also varies from user to user, and can include cost components that range from inventory and administrative costs to custom and taxes components. However, for ease of analysis, the selected model was limited to the components that are common among every company's supply chain regardless of its geographical situation and/or financial size (Ballou 2003).

The cost components related to the stock outs and safety stocks -along the most common transportation costs components- are to be input to a predetermined Total Landed Cost model (TLC) for a wider overview of the transportation lead time variability effects; a comparison will then be made between the differential of savings of the port alternatives. The assumed Cost Components are as follows:

Annual Total Landed Cost =

Ordering Cost: $\left(\frac{D}{Q}\right)*S+$

Transportation Cost: $R(Q)+\beta$

In-transit Inventory Cost: $\frac{ICDT}{365}+$

Carrying Cost of Regular Stock: $\frac{ICQ}{2}+$

Carrying Cost Safety Stock due Demand: $IC*s_d^{'}+$

Carrying Cost Safety Stock due Transportation: $IC*s_t^{'}+$

Stock Out Cost: $\frac{D}{Q}*ks'E_{(z)}$

Where:

D = Annual Demand

S = Order Setup Cost

Q = Order Batch Size

R = Transportation rates

β = Transportation Fixed Charge

I = Opportunity Interest

C = Product Unit Cost

T = Total Time of Transportation

s'_t = Transportation Standard Error

s'_d = Demand Standard Error

k = Stock out penalty factor

$E(z)$ = unit normal loss integral

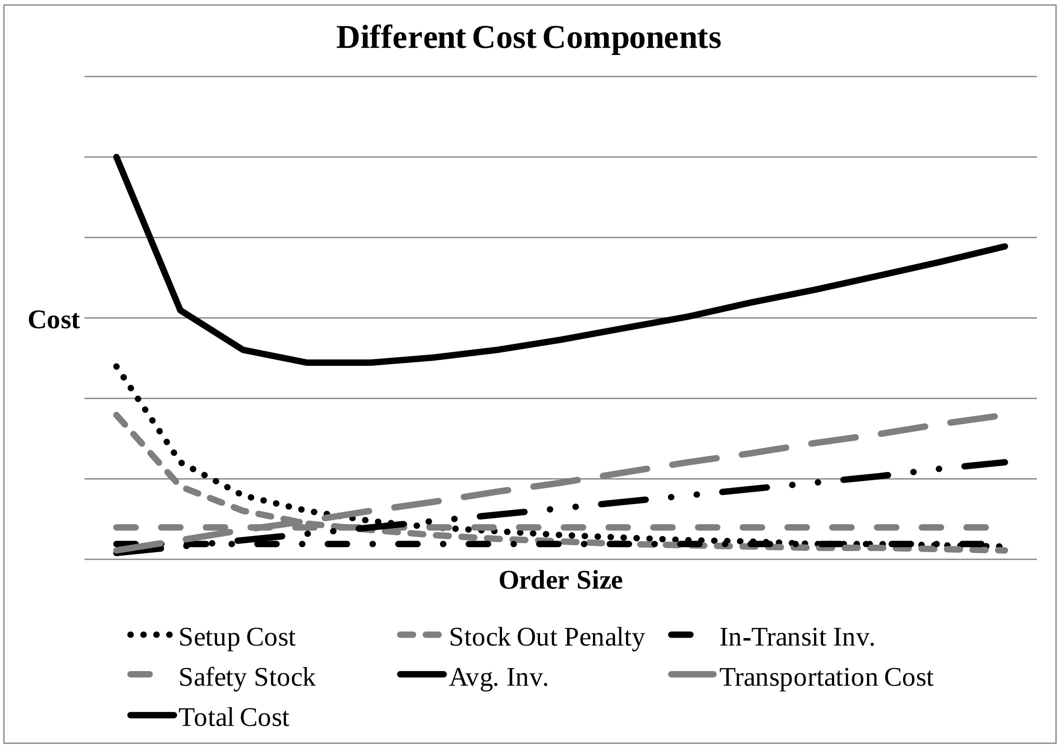


Figure 3.3 - Different Cost Components Behavior as Function of Order Size

Figure 3.3 shows the behavior of each of the cost components specified above as function of the batch size –or order size (Q). Additionally, the sum of all these components is shown as "Total Cost" in the same figure. The next step is to adopt an order policy to estimate the cost components derived from the parameters induced into the presented total cost model. The Economic Order Quantity (EOQ) model is then adopted. This model will be used to determine an optimal goods order quantity (Q*) shown in the TLC equation above. The EOQ formula was developed in 1913 by Ford Harris from a total cost equation involving setup cost and inventory carrying cost. It is used to determine an optimum order quantity such as the total landed cost is minimized (Ballou 2003). The Economic Order optimal quantity considering stock outs and the transportation rates is derived from the TLC equation above. Setting the first derivative of the TLC equation to zero (0) and solving for Q yields its minimum value:

$$Q^{*}=\sqrt{\frac{2D\left[S+ks'E_{(z)}\right]}{IC+2R}}$$

Where:

D = Annual Demand (units)

S = Order Setup Cost (currency units/order)

I = Carrying cost as a percent of item value, per year

C = Item value (currency)

R = Transportation Rate (currency/unit)

k = Stock out penalty factor

E(z) = unit normal loss integral

The re-order point for this quantity is then established as:

$$\text{Re-Order Point: (ROP)}=d^{*}LT+s_d^{'}+s_t^{'}$$

Where LT is the average replenishment lead time for the goods; s'_d is the standard demand error unit and s'_t is the standard transportation error units. These two last terms are dependent on the time probability distribution for demand and lead time variability respectively (in the problem will be addressed specifically for the port service lead time).

It is only fair to mention that there is a broad variety of economic models for inventory analysis that could be used in the methodology, such as periodic revision models. One will use order quantity-based analysis due its convenience and direct relationship to inventory costs. Such costs are intended to be the base of the lead time variability related costs, and it serves as the basis for most pull inventory policies used in industry. In addition, the EOQ policy provides the lowest cost policy as compared to the others. Furthermore, the policy's ability to adjust to the context of the study is helpful to the analyses.

The uncertainty related to time the shipment's stay in the port will influence the total landed costs in several ways. Some of the identified components to be affected by this are: (1) the optimal quantity (Q*). This order quantity will be computed considering the stock out costs and transportation rates that directly affect the size of the order. (2) The cost associated with Safety Stock due Transportation. This cost is a function of the variability observed in the port in terms of time and service level -determined by the port's client-. (3) Stock outs. A stock out cost is added to the model to consider a shortage due port disruption probability. The proposed model is expected to reflect the impact of lead time variability on these components. This will provide a way to compare the overall supply chain costs of using the different ports available in the defined network.

Once the TLC is computed for each transportation channel (port) and by goods profile, a differential between the ports is established based on this computed cost. Different goods profiles are expected to yield different total landed costs among the different ports analyzed. The port showing lower yearly total landed cost for specific goods profile will be the proper selection for the product's logistic network design (or re-design). These will then help to quantify the impact of the variability factor in relation to the other costs components and identify the parameters as those sojourn times in port that yields lower total costs for the network users. More of this is explored in the sections related to information gather and analysis. Beforehand, one will require defining the logistic network to focus the study in.

3.3 Limitation of the Logistic Network

The definition stage of the Logistic Network establishes the limits of the network to analyze. When goods are shipped between two points through a supply chain, the number of variables for this type of analysis can be overwhelming, making it difficult to obtain a practical result. In order to solve practical problems, the logistic network needs to be delimited. The scope of the proposed methodology will limit the study of the transportation network to what is known as the "long haul" and the discharging port in the general problem; this means that pre consolidation and post-distribution operations will not part of the network to analyze. The figure below depicts the network to be studied:

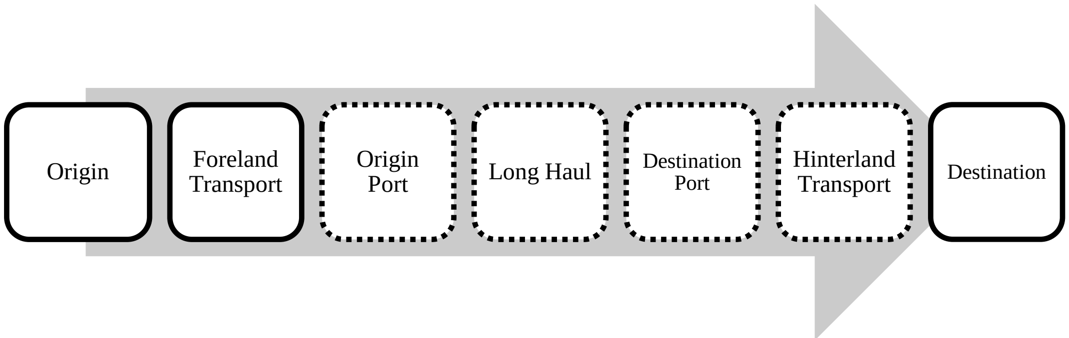


Figure 3.4 - Transportation Process of the Supply Chain

In Figure 3.4, the stages in dotted outline illustrate the scope of the methodology. The “destination port” can be composed by 2 or more ports, one is the baseline port and the other represents the competitor ports.

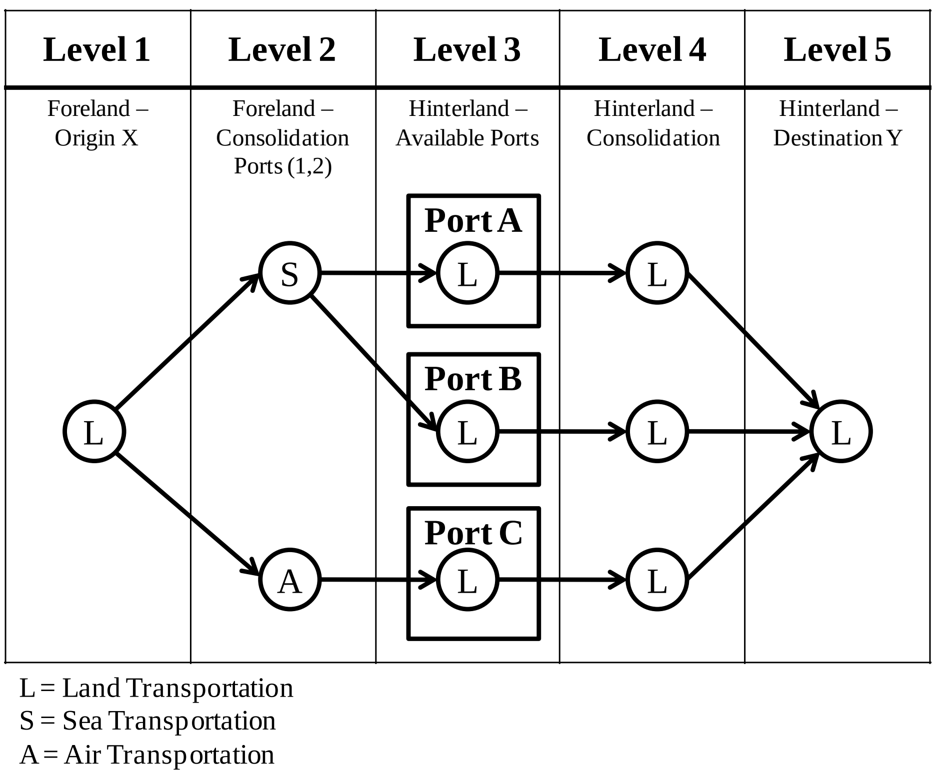


Figure 3.5 - Example of Segmentation for Analysis

Figure 3.5 shows an example of the segmentation of the network shown in the geographical representation of the general problem (Figure 3.1). The segmentation (Sanchez 2007) will serve in the analysis of the transportation channels and the nodes of interest during the implementation of the methodology. The forthcoming sections show how to define the network attributes in a way it can be used within the total logistic cost comparison schema.

3.4 Gathering of Relevant Information about the Logistic Network

In order to compare between the different transportation channels available in the network, it is necessary to identify the logistic attributes of the nodes (ports) and arcs (the single existing connections between nodes). Once these have been identified, it is required to gather specific information of each node and arc segment. This will help quantify the attributes to mathematically model the general behavior of the network. This will allow the comparison of the performance of the available transportation channels in the context of users' (the hinterland companies) requirements.

Historical information about each segment is required to extract appropriate statistics. The information required for quantifying the channel attributes is directly related to the transportation processes. Data related to regular transit times, port distances, transportation tariffs, port operation tariffs among others are to be considered.

There are hundreds of factors that create changes in these cost attributes. For instance while factors like weather, routes availabilities and/or shipment frequencies can affect transit times, others like returns to scale, customs procedures or brokerage can impact tariffs. Since most of these are rather dynamic and stochastic in nature, a rate approximation and average transit times will be used for analytical purposes. On the other hand, other more relevant attributes to the research are known and more realistic quantities will be used (such as observed wait times in port and physical distances connecting the network's nodes).

From all the attributes related to the network, the time the shipments stay on each of the available ports is interpreted using statistical tools of input modeling. The objective of this is to have a mathematical interpretation of the port's operation times in such a way that can be analyzed in the economic context of the methodology. In order to make this modeling for each of the competing ports (level 3 in Figure 3.5) the procedure followed is:

1. Select a random set of observations of shipments through the node.
2. Compute total time in port for each observation as the difference of the time stamp of release from port minus the time stamp of port arrival.
3. Create a histogram of the observed time in port data.
4. Use input model tools to –such as Kolmogorov-Smirnov method- to identify the probability density function that best fits the sampled data.

The last step in the procedure is a common approach used to statistically approximate data behavior into a probability density function. This interpretation allows the use of the data in the mathematical context of the model. Figure 3.6 and Figure 3.7 shows an example of observed lead time modeling as a probability density function.

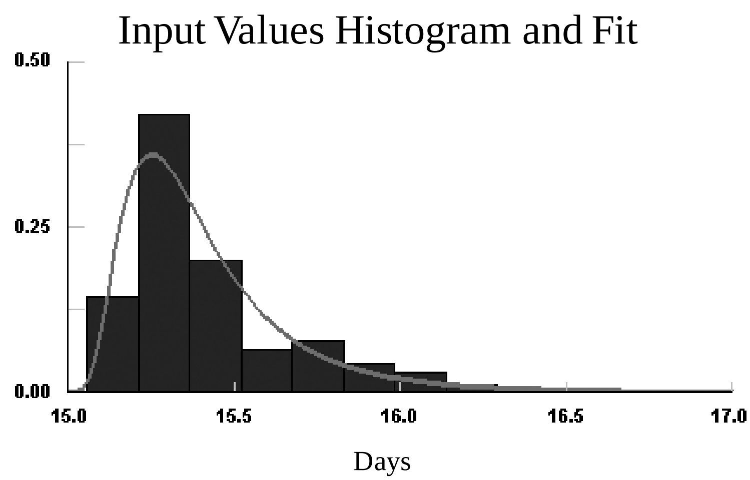


Figure 3.6 - Example of Input Modeling For Total Lead Time

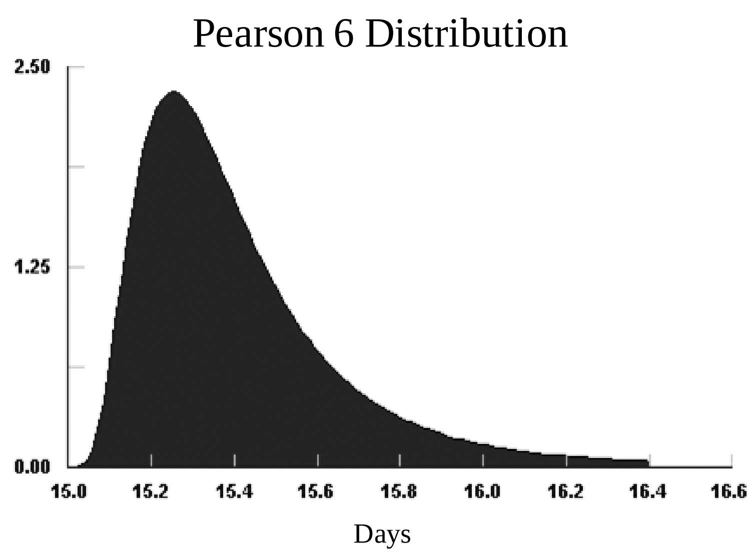


Figure 3.7 - Fitted Distribution for Total Lead Time Data Example

The figures above show how probability density function is fitted to the available data. In this specific example the time is considered a random variable that follows a Pearson 6 probability density function. Table 3.1 shows the parameters of the example function above.

Table 3.1 - Parameters of the Example Probability Density Function

Distribution	*Parameter*	*Value*
Pearson 6	Minimum	15.00
	Mean	15.42
	Standard Deviation	0.286
	Coefficient of Variation	0.01855

Different ports (transportation channels) are expected to show different lead time probability functions with different parameters and coefficients of variation –as mentioned in section 3.2.1.

3.5 Gathering of Relevant Information from the Network Users

For this section of the methodology is necessary to obtain certain information from the network users to establish an overview of their supply chain requirements. Some of the information identified as key to create this base of comparison is related to the user's every day supply chain. Specific details on what goods are being transported through the network and what service levels the users require from the network is necessary. A brief summary of the thesis approach to these relevant concepts is presented below.

The concept of "service level" has been mentioned several times through the document and represents a special interest for this study. The service level required by the user from the network sets a comparison standard between the different transportation channels (or ports) available. This can be interpreted as how the user inventory policies –such as safety stock levels- change due the different transportation channels uncertainty at fixed service levels requirements.

Therefore, this comparison is done from the perspective of the user's supply chain performance.

Service level is a measure of performance for logistics and inventory systems. These can be explained as a metric for certain demand scenarios where no production can be completed due to lack of inventory to meet this demand. This lack of inventory (also known as a backorder) can be derived from several issues. These can be a late delivery, an increase in demand or a quality defect, among other things. Due to the logistical profile of the thesis only cases in which such failures of inventory resulting from variability in shipments' lead time are considered. In other words, it is assumed that the impact on other grounds affect customer equally regardless of the route to follow their shipments.

There are several mathematical interpretations for service level. The most widely used among industry is type 2 (or β) service level, which can be defined in the following equation:

$$\beta = 1 - \frac{\text{Backorders per period}}{\text{Demand per period}}$$

This is a quantitative performance measure that describes the proportion of demand within the period that is covered with no delays. This measure is one of the main contributors to industry's design of safety stock policies. This service level is generally established as an internal guideline for a supply chain. It can be interpreted as the probability that a random demand unit is fulfilled without a delay caused by lack of inventory. To expand the concept, it is necessary to point out that safety stock refers to the additional inventory quantities used in production cycles. This stock is built by companies to protect the aforementioned backorders. These safety stocks have different associated costs which are considered a fundamental part in the economic analysis of this study. The safety stock level to be considered during this methodology is related to backorders caused by the variable shipment's sojourn time observed in a particular port. Therefore, it is precise to identify the service level that the network users receive or expect from the competing ports. This is what percentage of their demand is expected to be covered with no production delay due a good's transportation backorder.

The additional information from the network users that complements the transportation channels parameters is related to the transported goods. This information is related to the goods' demands, unit costs, and physical characteristics such as weights and volumes (or density). These are directly linked with the inventory/cost model used in the methodology. Further indirect costs related to the supply chain need to be included in the methodology. These costs include the administrative costs (indirect costs the industry may have related to general administration and maintenance operations), setup costs (generally purchasing costs), holding costs (these can be financial and related to the inversion rate that is being held with the inventory product) and other physical costs (warehousing, infrastructure, manpower, etc). Table 3.2 shows a segmentation of these factors that are to be considered as direct variables in the cost model.

Table 3.2 - Network's User-specific Factors

Users Metrics	*Shipment's Characteristics*	*Users Indirect Costs*
Transportation Service Levels	Weight	Administrative
Supply Service Levels	Volume	Setup
	Unit Price	Holding
	Year Demand	Warehousing

The supply specifics mentioned above will be used in the landed cost model shown previously to determine total landed cost components related to inventory and transportation.

3.6 Analysis of Information

At this level of the methodology the necessary steps to make the comparisons based on this data are established. To begin with the description of the procedure, it is necessary to recall Figure 3.1. Assuming Port A is seeking to determine competitive parameters for the users of the logistic network; the variability in lead time created by Port B and C is to be measured to determine the service level provided to the users. This would allow Port A to identify an opportunity window to provide better/lower average sojourn time to the network users' shipments. To identify this opportunity and determine the parameters, the information gathered is then analyzed with the suggested models. With this purpose it is required to setup the information in the context of the model; then the computation is made for further analyses.

3.6.1 Setup

In order to initialize the analysis and once the time probability density function is determined, it is required to compute the time values on this function that match the required service levels. These service levels are obtained from the network user's metrics, which are mentioned in the first column of Table 3.2. These refer to what time value (in days) matches each of the service level fixed values. Figure 3.8 shows an example on how the service time window can be obtained from this service level concept.

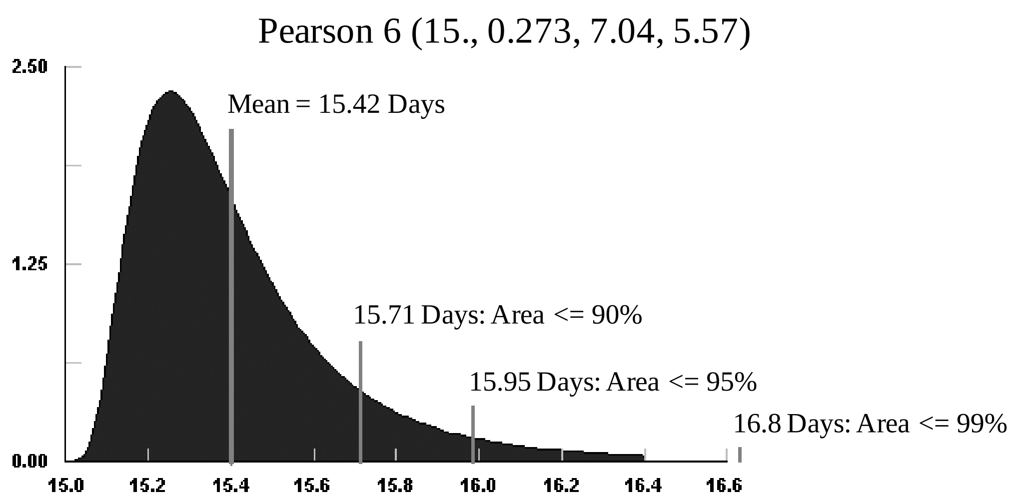


Figure 3.8 - Example Distribution Showing Service Levels

For this example three Type II service levels are assumed (90%, 95% and 99%) and shown in the function. Figure 3.8 shows the probability density function showed in Figure 3.7 with the selected service level indicators included. That is, assuming that a specific port follows the time density function shown, the point up to t = 16.81 days covers 99% of the observed shipments' time through the port.

The shipment's time attributes are summarized in Table 3.3 as parameters of interest.

Table 3.3 - Example of Port Service Level in Time (Days)

P(X<D)	*Service Level*	*In Days (D)*	*D – Mean*
0.90005	90%	15.71	0.29
0.95004	95%	15.95	0.53
0.99002	99%	16.81	1.39

Going back to the assumption that transit time is known, deterministic and not variable (shown in Table 3.1 as the minimum value of 15 days), the "D *minus* Mean" column in Table 3.3 is a numerical interpretation (in days) of the shipment's sojourn time in the port. These quantities represent the additional time to be considered, defined by the required service level, to account for the port's lead time uncertainty. This is, for the example above, the probability that a shipment service time is 0 between and 1.81 days equals 0.99. In other words of 100 shipments, only one is expected to have a time above 1.81 days. These values then are interpreted as additional safety stock for the port user. This means inventory that needs to be held by the user to protect from backorders derived from the observed shipment's sojourn time in port.

The additional data required to setup for calculation purposes is the shipment's attributes shown in the second column of Table 3.2. The necessity of setting this data for analysis relates to the possibility that different values for the identified characteristics may drive on different transportation rates and/or order frequencies, which are considerable cost component of the TLC model presented in Section 3.2.2. Thus, the shipments characteristics are arranged in a way that the entire population is captured somehow. The approach used to create this "shipment scenarios" is to treat each characteristic as a design factor for cost evaluation.

Recalling Section 3.5, four shipment's characteristics are shown as relevant for the landed cost computation. Weight and Volume are considered physical characteristics that may impact transportation rates; unit cost values reflect on changes in holding and inventory cost components; and lastly unit year demand affects the order quantities and/or frequencies. Weight and Volume are combined as a measure for transportation rates. This means that instead of using rates as function of weight and volume separately they are to be defined as function of a combination of both characteristics to approximate rate behavior to reality. This is for instance, transportation rates for a high-weight (heavy) material and/or a high-volume (spacious) material may increase faster than a more balanced material (low-weight/low-volume). Figure 3.9 shows an example of said combination.

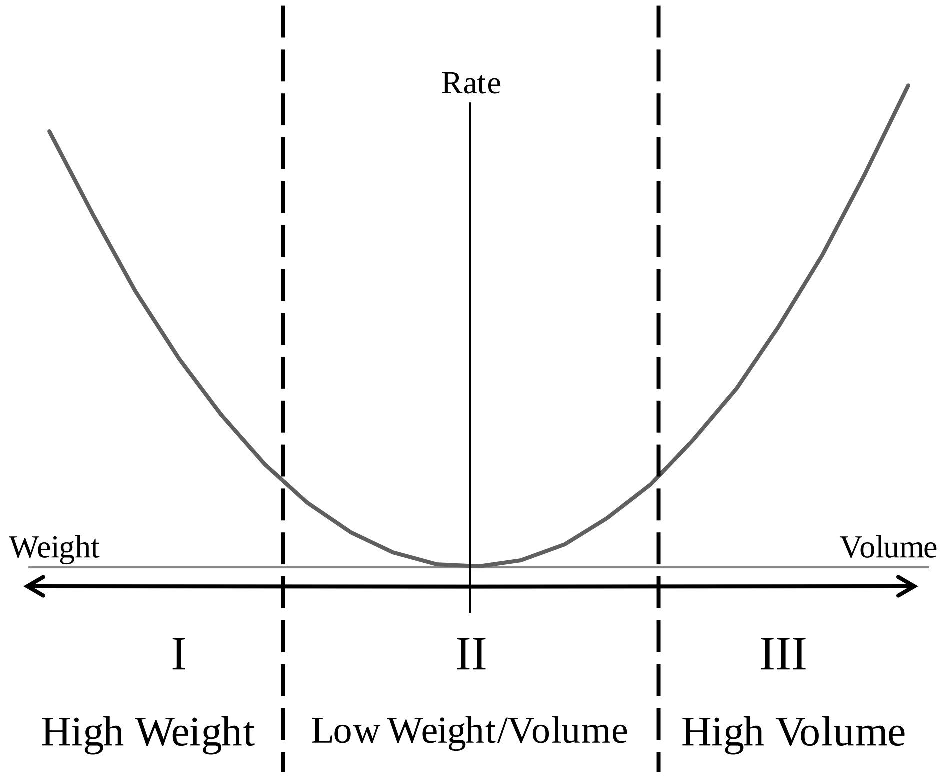


Figure 3.9 - Simplified Rate Behavior Regions

There are three regions identified in Figure 3.9. Region I refers to those heavy shipments constrained by weight and region III refers to the materials constrained by dimensional space. Region II refers to the more balance material which is low in both weight and/or volume. Following this interpretation some shipments will be charged in terms of weight and some in terms of volume. If a linear relationship is assumed between weight and volume we can assume a rapidly increasing rate for those items shown as region I and III, and another steady rate for items in region II. Following this assumption there are two rates behavior to analyze. R_{13} and R_2 are then defined for these behaviors. R_{13} is to be used for those shipments that reach container capacity faster (either by weight or volume) and R_2 for those that reach the capacity in a slower fashion. An approximation of this rate behavior is shown in Figure 3.10. This is known in the freight transportation environment as *dimensional weight*.

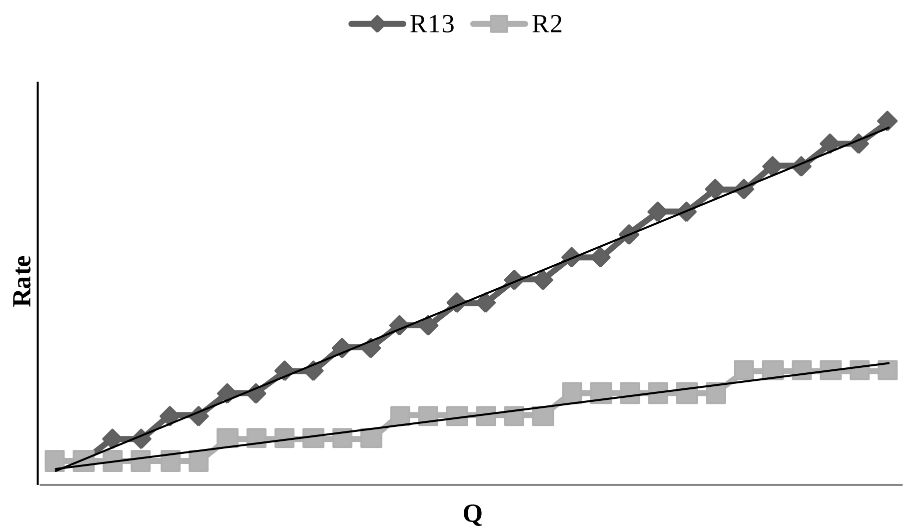


Figure 3.10 - Different Rate Behavior

Using this approach the weight-rate and volume-rate relationships can be modeled as a single categorical factor *"rate"* for ease of analysis. By doing this the physical attributes of the shipment that affect transportation rates can be captured in the computation. Having this settled the shipment scenarios are then defined from the combination of this and the other mentioned previously factors. These scenarios are shown in Table 3.4.

Table 3.4 - Factors Level by Scenario of Evaluation

Scenario	*Rate*	*Unit Cost*	*Demand*
1	R_2	Low	Low
2	R_2	Low	High
3	R_2	High	Low
4	R_2	High	High
5	R_{13}	Low	Low
6	R_{13}	Low	High
7	R_{13}	High	Low
8	R_{13}	High	High

This High/Low factor structuring covers the entire population of the profiles of the goods transported in the context of the characteristics relevant for the total landed cost model analysis. Another perspective of the scenarios shown in the previous table can be seen in Figure 3.11.

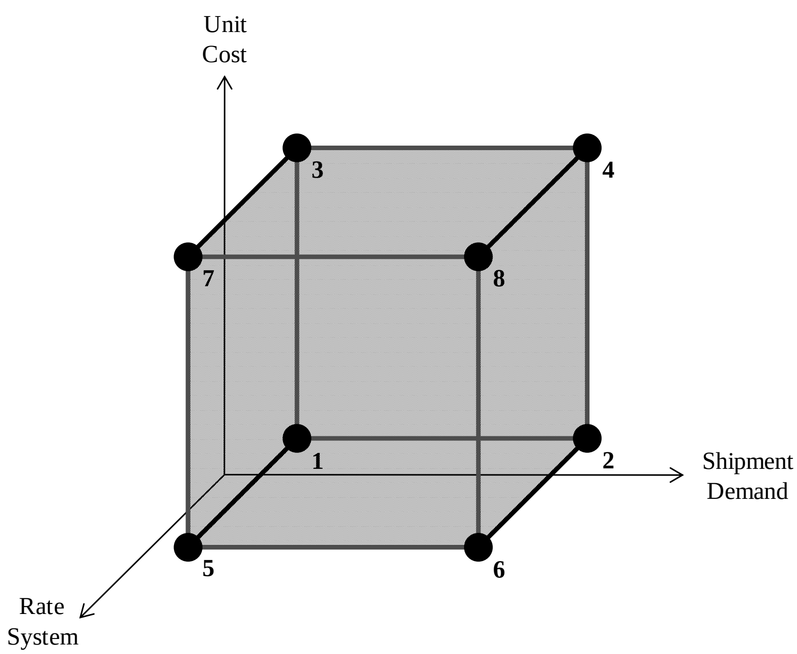


Figure 3.11 - Graphic Representation of Factor's Levels Based Scenarios

This section of the methodology represents a key step of the research. The purpose behind this setup is to easily interpret the overall cost-benefit trade off that may exist on using highly variable ports or transportation channels. For instance, a port may appear less attractive for a specific destination (may be located at a further distance or have less vessel capacity); but at the same time it may provide considerable lower lead time variability, which could drive lower total logistic costs at the end. From sensitivity analysis of this “trade-off” is where the competitive parameters are to be defined.

All these service time parameters are to be considered in the next step of the analysis, which is related to the computation of the suggested total landed costs to benchmark and for their further comparison.

3.6.2 Computation

Once the service time of the competing ports has been established the next step in the methodology is the computation of the cost components. The objective is to determine the total logistic cost of each competing port, and to outline the impact of each cost component. This is done to identify the opportunity windows and the parameters that define that window; for instance, which shipment’s profile is an opportunity to consider, under which circumstances and at what levels of transportation lead time variability.

The modeled service times for each port -as well as the other shipment’s parameters- is input into the Total Landed Cost model described in section 3.2.2.

A general outline of the steps followed to arrive to total landed costs is described as:

Iterative Process A

(1) Set a target service level as defined by the network user (90%, 95%, 99%)

(2) Select a scenario to compute costs

(3) Select the Port (i.e. Port B)

(4) Input Data (lead time variability, shipment scenarios, port and transport tariffs, setup costs, order quantities, etc) into the TLC model

(5) Compute Yearly Total Landed Cost (*TLC_Port*)

Iterations are performed until all costs, service levels and scenarios are obtained for the competition ports (i.e. Port B, Port C).

Once this information is available it is used it to estimate Port A total landed cost as a function of lead time variability. This process consists of the following iterative steps:

Iterative Process B

(1) Set a target service level (90%, 95%, 99%)

(2) Select a scenario

(3) Select the Port to compare with (i.e. Port B, Port C) and its computed TLC

(4) Fix an assumed average sojourn time (in days) for Port A (i.e. 10 days)

(5) Input Data (scenarios, port and transport tariffs, setup costs, order quantities) into Port A's TLC model

(6) Subtract the obtained the two TLCs (i.e. Δ_Savings_A = TLC_Port_B – TLC_Port_A) and record the result

(7) Reduce the assumed average sojourn time for the Port A (i.e. -0.5 days)

(8) Record the results, go back to (5) and recalculate

Once the iterations are exhausted against the competing ports, the data obtained is analyzed to prepare a comparison framework. As it was mentioned previously, the objective is to estimate the parameters where Port A can be competitive within the network. The following section covers the details of this comparison.

3.7 Comparative Results

The objective of this comparison is to quantify the impact of lead time variability on the supply chain of the general problem introduced in this methodology section. The results obtained in the previous iterative steps are to be interpreted in a way the impact in the overall costs can be analyzed to determine competitive time parameters from it. The results of interest –in this generalized case- are those where the total landed cost of Port A are lower to those observed from using the competition ports.

This section is divided into two specific processes; (1) one used to identify the impact of variability and the logistics costs derived from it, and (2) a graphic procedure used to define the competitive parameters from the costs comparison.

3.7.1 Impact of Lead Time Variability

The first interpretation of the results is related to the impact to costs of the shipments' sojourn time in port. The objective of this step is to create a visual interpretation of this impact. For this a graphical representation of the total costs is created. This representation is based on the cost values computed on the previous section of the methodology for each of the port options.

Matlab code was used to create this graphical interpretation based on the results of the previous iterations (the code is shown in Appendix A). Figure 3.12 shows an example of the Matlab graphic output. The Total Landed Costs for the two compared ports are presented in the graph as function of the average shipment's sojourn time in port A and the shipment's unit cost.

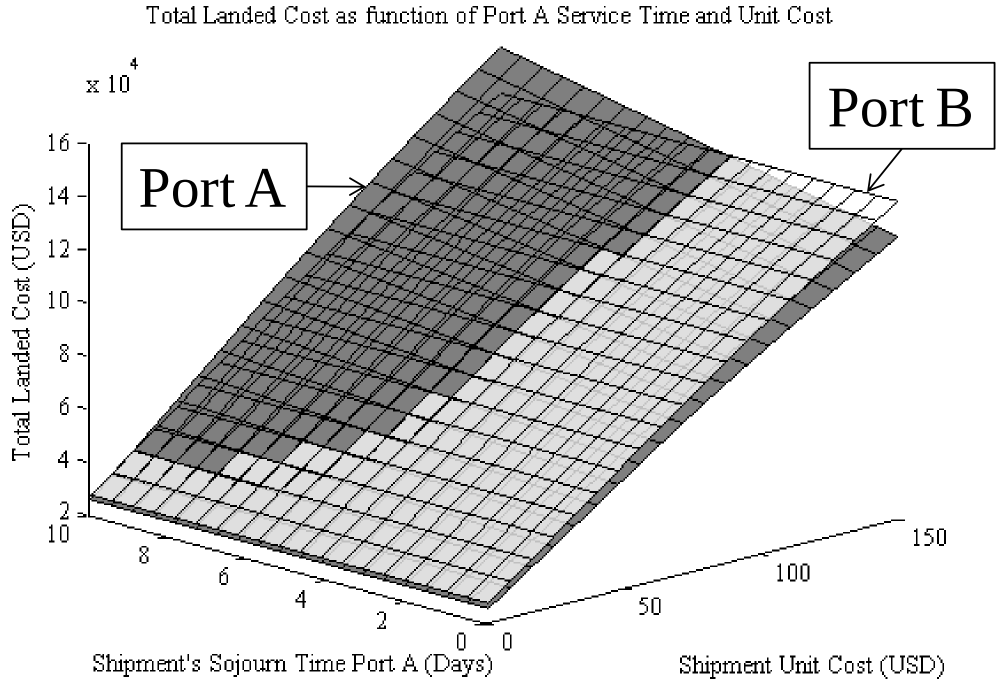


Figure 3.12 - Example of Total Landed Cost Visual Comparison

The graphic in the figure above shows an example of the visual year total landed cost comparison for two given ports. Recalling the problem described in Section 3.1.1 Port A seeks to benchmark itself against the competition's lead time variability to determine those parameters that result in its advantage. Following the perspective of the port under focus (Port A), its average shipment's sojourn time is variable (along the left horizontal axis) while the shipment's sojourn time in port B is fixed -as modeled from observations in the previous step-. The comparison in the total landed cost is done in function of average shipment's sojourn time at Port A's and the price of the transported product. This is, as the average sojourn time for the shipment in Port A changes, the total landed cost for this specific shipment through Port A changes as well. As it can be observed in

Figure 3.12 example, as this time goes over 4 days for a 150 USD unit cost shipment, Port A is no longer competitive for the network user.

From this visual representation, Port A can estimate the impact of lead time variability on the Total Landed Cost of the network users vs. the other alternatives (in this case Port B) for a specific good's profile.

3.7.2 Port's Competitive Parameters

Based on the interpretation of the lead time variability impact on Total Landed Cost from the previous step, the objective is now benchmark the competitive parameters from it. This step the methodology seeks to identify the window of opportunity in which a port cane be competitive –or increase competitiveness- for the hinterland's supply chain.

With this purpose a graphic differential comparison is performed. This is set in terms of inventory savings as function of average sojourn times in port. The graphic differential was easily conducted in Matlab's graphic module. Figure 3.13 shows an example of the resulting savings of shipping a specific shipment profile example through Port B (fixed shipments' sojourn time) vs. Port A (shipments' sojourn time days along the x-axis). This graph shows the range of variability levels for which Port A would be competitive vis-à-vis Port B.

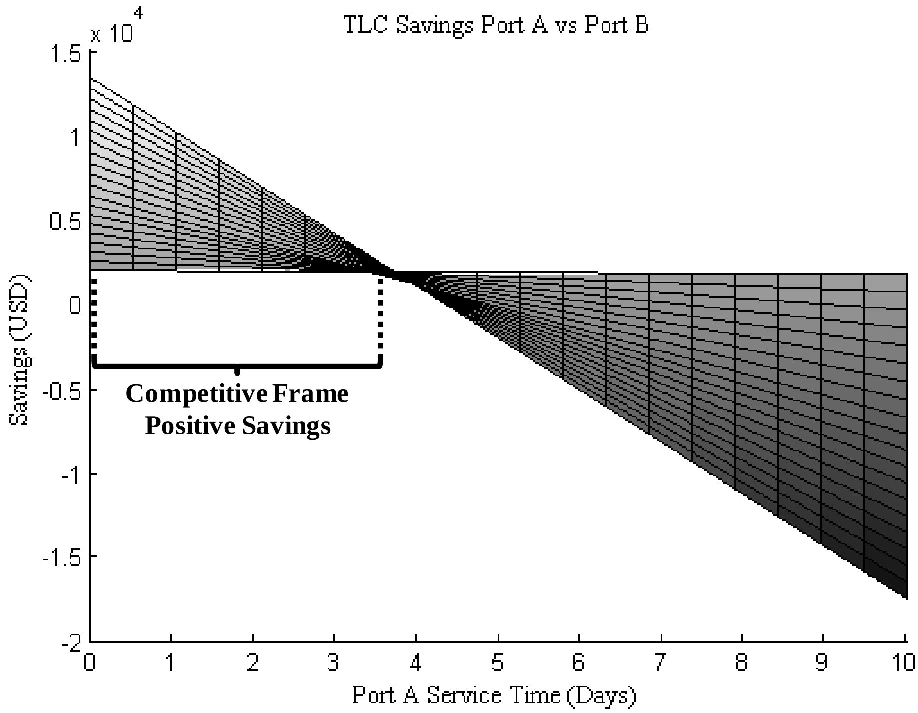


Figure 3.13 - Annual Savings Differential Graphic for a Shipment Profile

The comparison above is done for all the scenarios defined previously in 3.6.1. Once a scenario is "fixed" (fixed port and shipment data) and its savings differential graphic obtained, the lead time conditions under which Port A is a better alternative for this shipment scenario can be determined.

This is how Port A can identify its required lead time levels where it stands over Port B in terms of total landed cost for the network users. These levels are shown in Figure 3.13 as "competitive frame". This frame represents the results where the service time port parameters are obtained. For the shipment scenario shown in the example Port A is required to offer 3 days (or lower) in order to represent a better alternative than Port B. As soon as this breakeven point is crossed the savings derived of using Port A are negative, therefore making it no longer competitive for the shipment scenario.

If Port A service time is confined to the suggested “competitive window” the possibility of attracting more business from the network users is increased. The time values located within the frame refer to the lower and upper bounds of service time required to be considered in the port’s strategic, tactical and operational decisions. While the suggested parameters are maintained the overall costs provided to the hinterland’s supply chain by the Port are improved.

3.8 Summary

This chapter summarized the more relevant aspects of the methodology proposed to position a port competitively in a specific logistic network. This positioning is obtained from the parameters defined in the methodology, which are derived from the lead time variability impact to the network supply chain’s Total Landed Costs. Since this impact is a function of the attributes of the shipments and the port’s operations, the competitive positioning may be only attractive for some shipment scenarios while some other shipments may be out of the port’s competitive reach.

In the following chapter the detailed implementation of the methodology to a case study is presented. The case is related to a port in Mexico that tries to identify how to attract some of the hinterland’s demand already shipped through the commercial port of Long Beach and Los Angeles, CA in the United States.

4. ANALYSIS AND RESULTS: METHODOLOGY IMPLEMENTATION TO THE GUAYMAS PORT CASE STUDY

4.1 Introduction

In the chapter presented previously it was shown that the proactive benchmarking of ports' service times is a viable strategy to identify competitive operation parameters. This was done from the perspective of the shippers. This benchmarking could allow ports seeking to improve their service to the hinterland determine competitive positioning strategies.

The following section relates to the analysis of a case study in the context of the presented methodology. The objective of this section is to develop a solution for a real life scenario which can be used at the same time to support the methods presented in this thesis. For the problem at hand, a logistic segment is to be defined with two available ports and shipments of a set of commodities. These commodities are to be transported from a specific origin to a destination through the available ports. The methodology will be then be applied to the targeted port, commonly the secondary or non-selected port. In this way, the suggested method will show under what lead time conditions the targeted port can be competitive against the primary (or usually selected) port.

In order to maintain the perspective of a real life scenario, actual data is to be used in the present chapter. The information was obtained from a research report titled "Logistics Analysis of the Port of Guaymas in the Supply Chain of Regional Companies" (Villalobos, Sanchez, and Meneses 2010). This information contains real service time data for other ports serving its hinterland and it was conducted for the Port of Guaymas in Mexico.

The following section shows the Case Study background and the specific problematic behind the case study. The subsequent sections provide details on the implementation of the methodology and at the end the results are discussed briefly.

4.1.1 Case Study Background

The Port of Guaymas is located in the Sea of Cortez in the Northern Pacific Coast of Mexico. It is the main sea port in State of Sonora and one of the biggest ports in the Pacific coast of Mexico. Figure 4.1 shows the Geographical position of the port. The port has been active for centuries, and its main activity has consisted of handling inbound and outbound bulk cargo -such as mineral and liquid- (Puerto de Guaymas 2009). Its extended hinterland is composed by the northwestern states of Sonora and Chihuahua in Mexico and parts of the states of Southern Arizona, Southern New Mexico and West Texas (Swift 2008). Figure 4.2 shows the map of the identified hinterland.

Since the Port of Guaymas does not provide container services, the local industry has to use the container services provided by other ports such as the Ports of Long Beach, Los Angeles, and at a lower scale because of connectivity issues, the Port of Ensenada in Baja California, Mexico. This lack of a container services in Guaymas may be affecting the economic development of the region since some companies may prefer to locate in some other places with access to efficient container services. The challenge presented to the Guaymas Port Administration is how to design and offer an efficient and competitive container service to the hinterland.

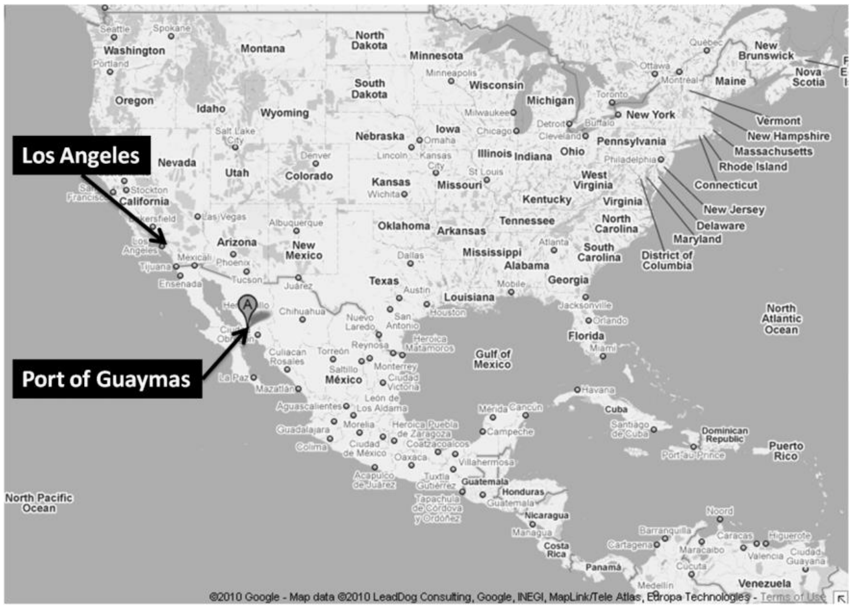


Figure 4.1 - Map Showing Geographic Location of Guaymas, Mx.

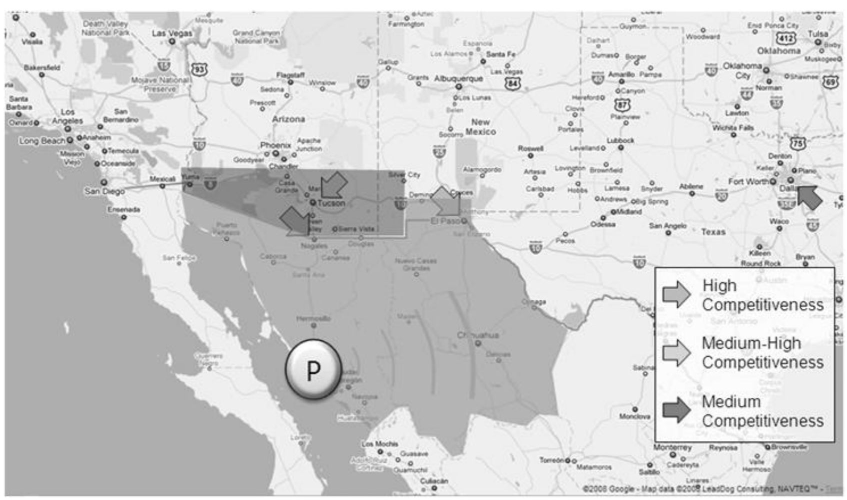


Figure 4.2 - Guaymas Port Hinterland

4.1.2 The Problem in the Case Study

One of the main concerns of the port administration related to starting the containerized cargo service was the attraction of demand. From Figure 4.1 can be observed that the geographic position of the Port of Guaymas represents a significant issue. Blocked by the natural barrier of the Baja California Peninsula, represents a larger travel time from vessels coming from or going to Asia.

Since most of the inbound containerized cargo to the hinterland originates in Far East countries, longer transit times are the usual paradigms impeding the companies in the region not trigger the service in the port. This situation is one of the main concerns of the Port Administration. The administration believes that even though the container service is active, most companies would still not use it for their trade operations. Within the initiatives done by the port administration to trigger the container terminal services, it was concluded that in order to attract demand from the hinterland it was required to offer a service more competitive than the currently available. This presents an opportunity to implement the proposed methodology.

Most companies in the hinterland may only compare factors like inventory transit times and shipping rates when selecting the port (or transportation channel) to be used for their shipments. The methodology explores and identifies the specific circumstances in which the port can create more competitive services based on other factors. This is delimited to the existing gap on lead time variability offered by the other ports (transportation channels) to the hinterland. As it was emphasized in section 3.6 it is necessary to explore the possible trade-offs related to total landed costs and service time in order to identify competitive opportunities. The bottom line is that the lower the shipment’s sojourn time is in the Port of Guaymas, the highest its competitive position is with respect to the hinterland's supply chains.

4.2 General Assumptions

For the present case study some assumptions were done to simplify of analyses. Besides the assumptions shown in section 3.1.3 for the design of the methodology, other more specific to the problem were required to maintain the approach at a practical level. Nevertheless, these are strictly rational in order to stay within the context case study. Even though most of the data is real and retrieved from the aforementioned research project, some other data will be assumed to be known and deterministic. The following sections explain briefly each of these assumptions.

4.2.1 The Competing Ports

The region identified as hinterland is served by a several commercial sea port and airports. Nevertheless, the commercial containerized cargo operations in the port of Los Angeles and Long Beach in the State of California in the United States represents the best port for competition analysis.

The analyses to be presented during this case study will assume the container cargo services of the Port of Los Angeles/Long Beach as the main competition. The reason behind this assumption relies on interviews conducted to companies located within the hinterland and some observed data. Table 4.1 shows the total shipped weight (in kilograms) done to the hinterland in 2007 per U.S. port.

Table 4.1 - Weight Shipped to Guaymas' Hinterland 2007 (U.S. Ports)

Rank	*U.S. Ports*	*Total Shipped Weight (kg)*	*%*
1	Los Angeles CA	192,809,015.64	48%
2	Long Beach CA	121,843,752.09	30%
3	Houston TX	54,259,348.64	14%
4	Charleston SC	9,638,066.36	2%
5	Port Everglades FL	5,479,806.00	1%
6	Oakland CA	4,452,739.09	1%
7	Newark NJ	1,384,362.91	0%
8	New Orleans LA	1,268,655.00	0%
9	Savannah GA	1,022,787.45	0%
10	Jacksonville FL	974,435.00	0%
11	Other (28 Ports)	7,053,976.73	2%
	Total	400,186,944.91	100%

As it can be observed, the port of Los Angeles/Long Beach handles approximately 80% of the total shipments done to the zone. Therefore, it is believed that the main competition for the Port of Guaymas is the aforementioned port. The methodology is then to consider it as the Port to benchmark to define competitive parameters.

4.2.2 Shipments to Guaymas Port's Hinterland

The methodology requires information related to the shipments being done from and to the Port's hinterland. The most relevant details on the shipments are related to the shipment's physical and consumption characteristics, which were discussed in section 3.5 of this document. Most of the data related to those attributes are based on the researched data (Villalobos et al. 2010). Yet another aspect of the shipments that need to be addressed for evaluation is the origin and destination of the shipments. The reason behind this is because one needs to map the logistic network for the application of methodology. In order to map this network, it is required to identify the most representative shipments generated by the region of influence of the Port.

Once the main competition port to benchmark is selected for the case study, the next step was to define if the methodology was to consider shipments coming to the hinterland, or going from it to other zones. The most representative commercial activity of the hinterland supply chain is that related to raw material imports from other countries (J. Rene Villalobos et al. 2006). This raw material is mostly intended for manufacturing of finish goods which final market is the continental Americas.

Table 4.2 - Weight Shipped to Guaymas' Hinterland 2007 (Origin Ports)

Rank	*Origin Port*	*Total Weight (kg)*	*%*
1	Yantian China	72,882,831.45	18%
2	Shanghai China	59,930,268.36	15%
3	Hong Kong Hong Kong	42,484,728.82	11%
4	Bremerhaven Germany	31,450,654.55	8%
5	Busan Korea	26,698,735.45	7%
6	Kaohsiung Taiwan	20,549,514.55	5%
7	Singapore Singapore	16,184,739.00	4%
8	Chiwan China	15,450,507.00	4%
9	Tsingtao China	11,015,666.64	3%
10	Ningbo China	10,014,432.45	3%
11	Other Ports (134 Ports)	93,524,866.65	22%
	Total	400,186,944.91	100%

Table 4.2 shows the main Origin Ports of containerized cargo inbound to the Port of Guaymas hinterland. As it can be observed, the cargo imported from Asia to the region is the main generation of commercial port activity. The

referenced study additionally creates another shipment specification. A center of gravity for all the shipments from Asia to the hinterland done in the last three years is done to create a potential route to include in the analyses. The center of gravity is then identified as the city-port of Shanghai in eastern China.

Based on these premises and for practicality purposes, only *incoming* shipments coming from Shanghai in China to the Guaymas' hinterland through the port of Los Angeles/Long Beach are to be considered for sampling. This means that shipments using this route will be used for lead time variability modeling at the port to benchmark for competitive parameters. In this way is expected to capture the most representative operations of the competing port and the service level provided to the companies of the region.

4.2.3 Market Demand and Consumption

Shipment demands are an important part of the attributes required for the analysis. The demands that are to be used in the implementation of the methodology to the case study are based on several conducted interviews to the users of the port. From these interviews the range on demands was defined.

The first part of this assumption is related to the port users. It is required to identify the profile of the port users. This is because the most representative user profile is then selected for the analyses as part of the assumptions made for the case study. (Villalobos, Sanchez, and Meneses 2010) investigate the profile companies located within the hinterland of the Port of Guaymas. Since the immediate hinterland of the port of Guaymas is Northwestern Mexican territories, industrial census data was used to sample these companies (INEGI 2010). Table 4.3 shows how the companies in the region are distributed in terms of their economic units.

Table 4.3 - Companies in Guaymas' Immediate Hinterland (Economic Units)

Type of Economic Unit		*Percentage*	*Total*
Machinery and Equipment	M	20.19%	87
Automotive	M	14.62%	63
Food Industry		14.15%	61
Electronics	M	12.76%	55
Construction		10.90%	47
Textile	M	8.35%	36
Aerospace-Aeronautic	M	5.80%	25
Plastics	M	4.41%	19
Metal	M	3.25%	14
Packaging	M	2.55%	11
Wood		2.32%	10
Leathers		0.46%	2
Other		0.23%	1
Grand Total			431

As it can be observed in the information from the table above the companies within the hinterland consists mostly of manufacturing industry. Table 4.3 marks this specific type of economic unit with an *M.* These represent the 72% of the total industrial activity. As per this information, the assumption made is that the manufacturing companies are the most representative industry and therefore, the shipments to be sampled for the analyses are related to this specific industry. Additionally, the characteristics to be used to create the shipment scenarios are related with the raw material used in manufacturing.

The demand levels that are used in the case study are considered to be representative of the users. Other assumptions consider the demand to be deterministic and its consumption to be linear. Additionally to this assumption, none of the demand shown is to be wasted due to delays in transportation (or service variability); therefore there are no additional costs implied other than the ones shown in the total cost model (section 3.2.2).

4.2.4 Factors Affecting Logistic Costs

In the same of manner than the previous assumptions, most of the transportation and logistics costs were obtained from interviews done with the port users, as well as quotes. A large quantity of factors affect these logistic costs for the port user (i.e. economies of scale, contract rates, long term engagements); but in order to simplify the analysis, some assumptions were made to determine cost factors for the case study.

The cost factors used during this case study were simplified to meet the cost model shown in section 3.2.2. The cost factors to be considered are those of inevitable nature, such as those related with port distances, travel times and minimum surcharges. These factors are used in the same fashion among the compared ports. For instance, the distances from different ports to a specific region are not equal. These assumptions allows the model to compare the costs based on factors more related to the port itself, and not on factors that fall out of the port’s reach (i.e. the size of the user’s operations).

4.2.5 Other Factors Affecting Variability

Lastly, there is another assumption that needs to be addressed. As it was mentioned previously in this document, there are multiple time elements through the supply chain that may affect the overall variability of the shipment's lead time. Nevertheless, those elements are considered to be out of the scope of thesis; therefore the lead time variability derived from the rest of the nodes in the defined logistic network is not to be considered in the methodology computations.

One of the main reasons behind this assumption relates to the interviews done to the hinterland companies' representatives in (Villalobos, Sanchez, and Meneses 2010). The supply chain and inventory managers interviewed mentioned that the segment of their supply chain where the most variability was observed for their containerized cargo was the commercial ports. The other identified sections within the chain presented little to none considerable effects. Additionally is of interest of this thesis to study only the lead time variability related the containerized cargo in commercial ports. The effect on transportation lead time of other nodes in the network is considered to be none or minimal and uniform throughout the different transportation channels in the network. Thus, it is assumed to have an insignificant effect on the overall lead time.

Some other factors that need to be addressed in this assumption are those related to shipping and receiving operations. Some of their strategies and tactical activities affect the supply chain performance. Factors like late orders, change in demands, communication and system issues affect the supply operations (for instance *the bullwhip effect* in demand signals). However, these factors are to be addressed the same way that the other network segments. These shipper-receiver factors are assumed to have no negative impact (or will equally impact) on the shipments the transportation channels and ports under comparison.

The last factor assumption to be addressed is the inventory impact of early deliveries. In the forthcoming sections, it will be shown that probability of the modeled port lead times presents higher values for those that represent delays, as compared to those representing early deliveries. This means that most of the times the shipment's sojourn time in port will exceed the expected values -rather than being earlier.

4.3 Application of the Methodology to the Guaymas Port Case Study

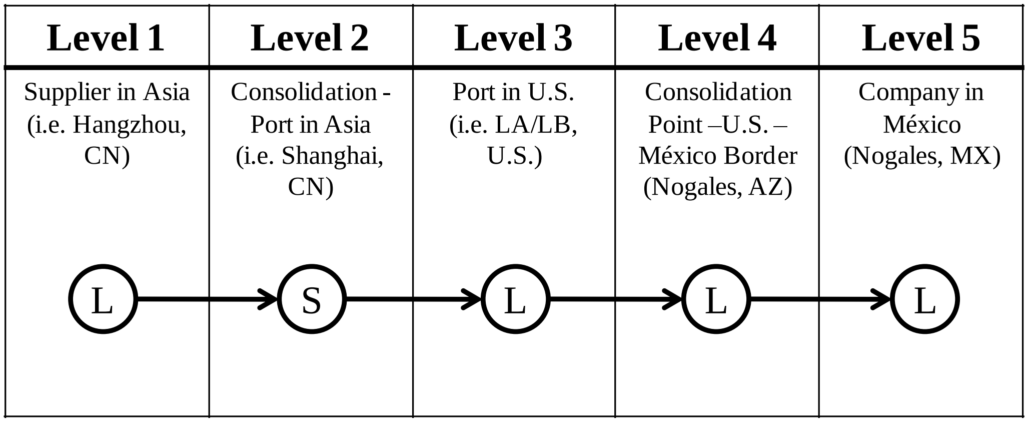
The present section of the thesis shows the direct application of the proposed methodology to the case study. As it was previously mentioned, the objective of this section is to use the approach suggested in this thesis to solve a problem defined from a real life scenario. This section of the chapter goes over each of the steps of the methodology as it approaches the problem in hand. Again, the problem is to identify under what circumstances the port of Guaymas in Mexico can be competitive over the Port of Los Angeles/Long Beach. From the proposed benchmark technique, the port is expected to determine the service time parameters to achieve a competitive position in the region.

The assumptions mentioned in the previous part of the chapter are implied to the procedures followed during the entire analysis. This section is divided in the same manner as the procedure presented in the chapter 3. At the end, the Total Landed Cost model is used as the frame of comparison and to determine the parameters of competition required for the port of Guaymas, Mexico.

4.3.1 Limitation of the Logistic Network

Following the proposed methodology, the first step is to delimit the logistic network for evaluation. As it was mentioned in this chapter's assumptions section, the Port of Los Angeles/Long Beach is the port to be used as benchmark of available port lead times. Additionally, the routes to be considered are those originating in Far East Asia and shipped through the port-city of Shanghai in Eastern China. This supply chain network for the case study is to be defined in this step of the methodology.

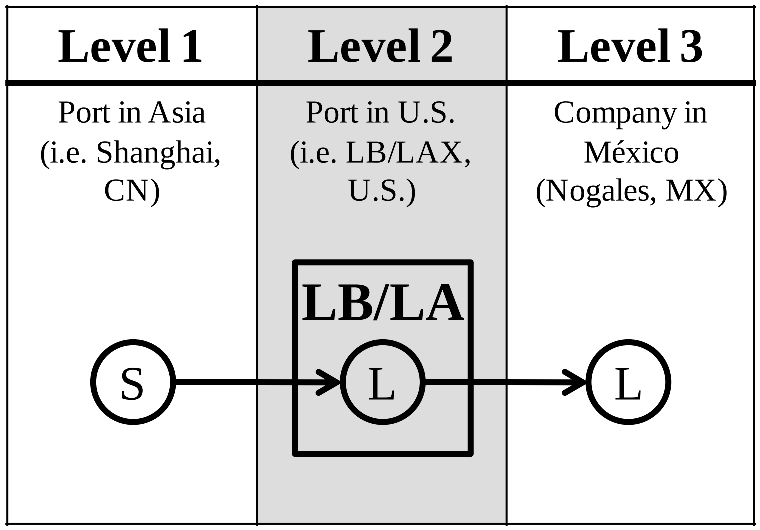
Once the port to benchmark is identified and the hinterland sampled the next step is to define the logistic segment to be analyzed. The node-arc representation of the geographic supply network is shown in Figure 4.3.



L = Land Transportation
S = Sea Transportation

Figure 4.3 - Network Representation for Guaymas' Case Study

The nodes represent each segment of the network and the arcs represent the existing transportation link between each of them. Each of the nodes and arcs has specific attributes which are to be addressed and set as parameters in the forthcoming steps of the methodology. As it was previously mentioned, the node of interest for the present study lies on the commercial port serving the same hinterland as the Port of Guaymas. Since the effect of the other nodes is not of interest of the study, the last assumption mentioned in Section 4.2.5 is followed. Therefore, the network is simplified to show only the nodes and segments of interest.



L = Land Transportation
S = Sea Transportation

Figure 4.4 - Simplified Network for Guaymas' Case Study

Figure 4.4 above shows the simplified representation of the analyzed logistic network to determine the competitive parameters. The node of interest is marked in gray in the figure above (level 2). Once this logistic network is defined, the next step is to quantify the proper attributes for each node and segment that would allow the cost comparison.

4.3.2 Information from the Network Attributes

Following on the methodology implementation, the next step was to gather the relevant network information to crate the attributes needed for the analysis. As it was mentioned in section 3.4, the information required is related to the attributes of each of the individual arcs and segments of the network. A summary of the basic data gathered for the arcs in the research (Villalobos, Sanchez, and Meneses 2010) is shown in Table 4.4.

Table 4.4 - Basic Data for Simplified Network Arcs

Metric	*SHA-LB/LA*	*LB/LA-NOG*
Distance (miles)	6,592	557
Rate (USD/mile)	$0.31	$1.67

The data gathered for the arc relates to the travel times and distances, while for the Los Angeles/Long Beach port the information was more detailed. The reason of the detail level was explored in section 3.4 as well. There is a specific requirement of information related to the service time operations of the Port that the methodology is benchmarking. The objective is to quantify the operations service time for the proper analysis. Specifically for the port of Los Angeles/Long Beach several observations were done. Table 4.5 gives a brief summary of the service time data.

Table 4.5 - Statisitcs Summary of Service Time Data

Source of Random Data	
Port of Origin:	Shanghai CN
Port of Entry:	Long Beach/Los Angeles
Weight of Shipments:	>500 kg
Destination:	Nogales, (MX) and El Paso (U.S.)
Year:	2007

Descriptive Statistics	
Count of Random Observations	52
Lowest Time Observation	12
Highest Time Observation	18
Average	14
Mean	14
Mode	13
Standard Deviation	1.66863
Variance	2.78431
Coefficient of Variation	11.9188

The input modeling techniques mentioned in section 3.4 were used to fit the data above into a random variable probability density function. The histogram of the observed times is shown in Figure 4.5. The resulting probability density function is shown in Figure 4.6.

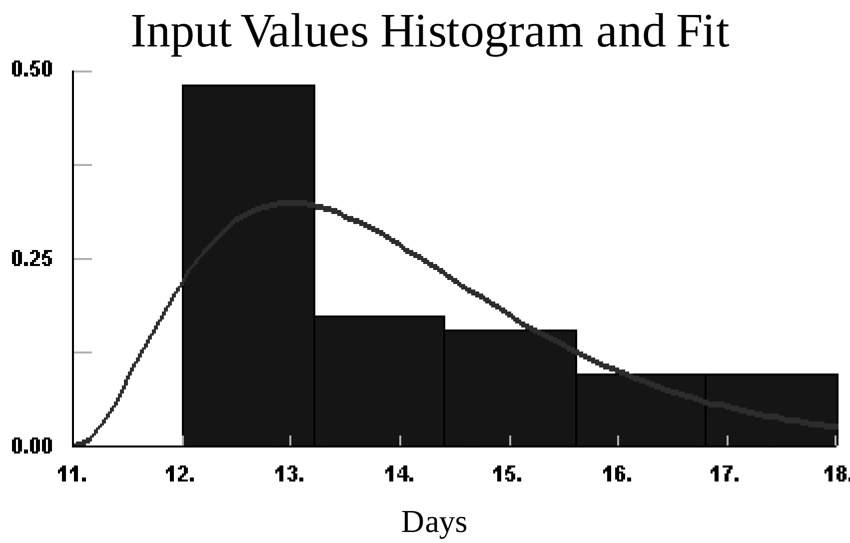


Figure 4.5 - Histogram for Port of Los Angeles Total Lead Time

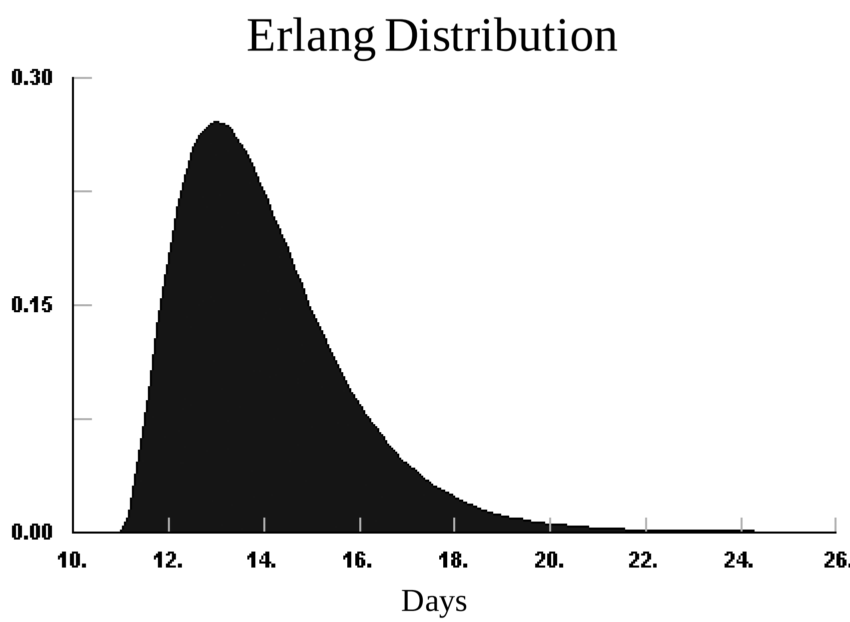


Figure 4.6 - Fitted Distribution for Port of Los Angeles Total Lead Time

The parameters of the fitted distribution are shown in Table 4.6. Appendix B and Appendix C gives more detail on the data collected and gives some reference in the input modeling techniques used as well.

Table 4.6 - Fitted Distribution Paramaters (Port of Los Angeles)

Distribution	*Parameter*	*Value*
Erlang	Minimum	11.00
	Shape	3.00
	Rate	0.999981
	Mean	14.00
	Standard Deviation	1.73
	Coefficient of Variation	0.123571

The information gathered from the arcs and nodes will be used as the network attributes in the analysis step of the methodology. The next section explores the requirements of the overall requirements of the users located within the hinterland of the Port of Guaymas.

4.3.3 Information from the Network Users

This step focuses on quantifying the service received by the users of the port of Los Angeles/Long Beach. The objective is to have the proper reference under which the port's lead time variability is to be evaluated. As it was mentioned in the previous step of the methodology, it is assumed that the objective of the Port of Guaymas is to attract the market generated by the manufacturing industry in the immediate region. Additionally, section 3.5 highlights that the port user would use type II service level as a standard to measure transportation channels' performance. Thus, it is assumed that manufacturing companies in the Port of Guaymas' influence region refer to this policy to compare the ports available for their container operations. This comparison is done by the safety stock required to protect production from shortages derived from each shipment's unexpected sojourn time in port. This means that a manufacturing company will seek a port that requires lower safety inventory at a predetermined type II service level; which by consequence lowers operational costs.

Based on the previous statements the information from the network users along with other required costs were obtained in a similar way (Villalobos, Sanchez, and Meneses 2010). Interviews and the information gathered from the industrial operations provided costs, demands, rates, and shipment weights data; additionally, provided the type II service level requirements. According to the data gathered, the commodities shipped from Asia to the Port of Guaymas' hinterland are shown in Table 4.7. Also a summary of the most relevant attributes used in the analyses is shown in Table 4.8.

Table 4.7 - Commodities Distribution of Shipments to Guaymas' Hinterland

Commodities	*%*
Automotive	18%
Electronic Components	15%
Computers and Accessories	8%
Electric Assemblies	7%
Mechanic Assemblies	6%
Plastics	9%
Electronic Equipment	9%
Appliances	6%
Specialized Equipment	5%
Metals	4%
Harnesses and Wire	4%
Machinery and Accessories	3%
Leathers	2%
Textiles	2%
Chemicals	1%
Furniture	1%
TOTAL	100%

Table 4.8 - Attributes of Industry's Shipments

Industry	*Shipment's Data*	*Values*
Manufacturing Industry	Origins	East Asia
	Costs (USD)	From 5.00 to 150.00
	Demands (Unit/Yr)	From 10,000 to 500,000
	Shipment Type	Containerized
	Service Levels	90%, 95% and 99%

The information shown above is used basically for two purposes. First, the data related to regular shipments operations is used to create the shipment profile scenarios. Second, the data related to the service levels help create the baselines where the lead time variability effects are to be measured. This is how variability is then translated into logistic costs for the companies in the port's hinterland. As it was mentioned before these service levels are used (along with other factors) as a way to create inventory policies such as safety stock levels which are direct costs for the companies. The next step in the methodology is to analyze the collected data. The following section shows the setup and the computation.

4.3.4 Analysis

The following step is related to the setup and computation of the gathered data under the proposed total logistic costs model. Based on the information gathered Table 4.9 shows a summary of the defined logistic network attributes. This is for the shipments from Shanghai through the port of Los Angeles/Long Beach and with a destination within the Port of Guaymas' hinterland.

Table 4.9 - Summary of Case Study Logistic Network Attributes

Origin	*Port*	*Max Vessel Size (TEU)*	*Ave. Time at Sea*	*Time at Port*	*Distance to Nogales (High Influence)*	*Distance to Dallas (Medium Influence)*
Shanghai	Los Angeles/ Long Beach	14,000	14	Variable (Erlang Dist.)	557 mi	1,430 mi
Shanghai	Guaymas	**N/A**	16	**Unknown**	258 mi	1,231 mi

As it can be observed from the table summary there are some parameters where the Port of Guaymas appears to be a better choice over the Los Angeles port (i.e. total distances). Still the Port of Los Angeles/Long Beach is known to be used more often due the vessel capacity available, its operation standards and location. Then, the Port of Guaymas is forced to find opportunity windows through which it can gain a competitive edge for its region's container demand. The opportunities explored by the analysis are defined in terms of faster turnarounds for specific shipment's profiles. Moving on with the ports attributes, there are two shown as unknown for the port of Guaymas in Table 4.9: the *maximum vessel size* and the *time at port*. Vessel size capacity can be hardly a competitive attribute for the Port of Guaymas, which is a medium-sized port. This means it presents some limitations like channel draft, which constraints the maximum vessel size. Additionally the dock positions are limited due the natural characteristics of the port. On the other hand, time at port can be a competitive advantage if defined properly. For this it is required to determine the average shipments' sojourn time that the port needs to offer to its clients in order to be cost competitive.

The present section goes over briefly on the analyses done to obtain the proper results from which the competitive parameters are to be identified. First the gathered data is setup for its interpretation on the model and then the iterative computation processes are shown where the model is implemented.

4.3.4.1 Setup

According to the methodology guidelines, the data is required to be setup for its utilization. First the observed shipments' sojourn times are identified from the Port of Los Angeles/Long Beach distribution (Figure 4.6), and then the scenarios to analyze are defined. This is done following the setup described in section 3.6.1.

Following the service levels required by the network users, the service time values equivalent to these levels are determined. Then the information from the sampled service time data of the Port of Los Angeles/Long Beach is compared against the service levels required by its users. Figure 4.7 shows the port's lead time probability density function with the service levels values marked.

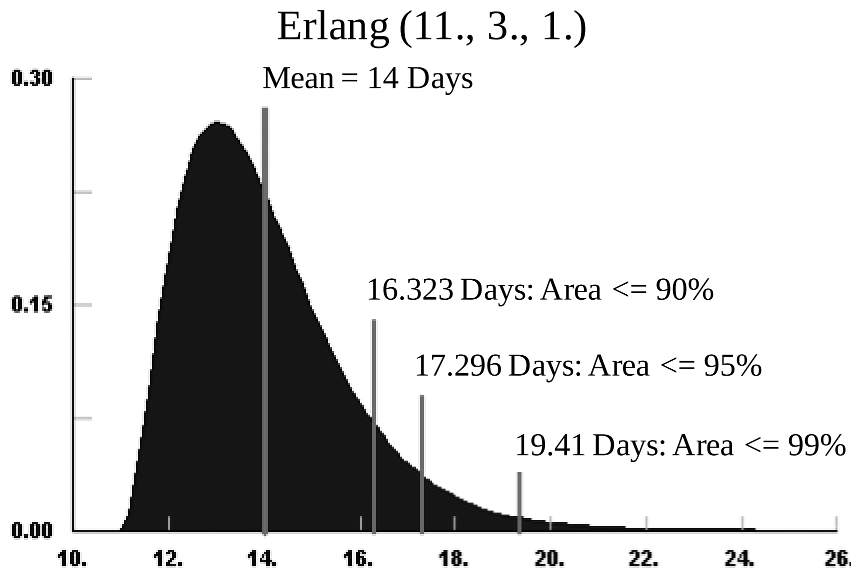


Figure 4.7 - Port of Los Angeles Total Time with Service Level Indicators

For this distribution the three Type II service levels defined previously are used (90%, 95% and 99%) and marked in the distribution. This is for instance, following the lead time density function fitted for the Port of Los Angeles, the point shown up to t = 19.41 days covers 99% of the time probability. Table 4.10 is now updated with the observed shipments' sojourn time probability in the Port of Los Angeles as parameters of interest.

Table 4.10 - Updated Case Study Logistic Network Attributes

Origin	*Port*	*Time at Port (w/Service Levels)*			*Distance to Nogales (High Influence)*	*Distance to Dallas (Medium Influence)*
Shanghai	Los Angeles/ Long Beach	90% 2.32	95% 3.30	99% 5.41	557 mi	1,430 mi
Shanghai	Guaymas	**Unknown**			258 mi	1,231 mi

This setup will provide the required safety stock levels for the computation of the total landed costs on the following part. The information is detailed in Table 4.11.

Table 4.11 - Service Levels for the Port of Los Angeles

Data	*LA/LB*	
Mean Transit Time	14 days	
Service Level [P(X<D)]	Additional Days	Total Days
90%	2.32	16.32
95%	3.30	17.30
99%	5.41	19.41

As a reminder on how to interpret this data an example is provided. For instance if the required service level by the user for the shipments coming from Shanghai through the port of Los Angeles/Long Beach is 99%, then the safety stock required as protection from delays due service times is the equivalent to 5.41 days of production. This is because 19.41 covers the total 99% chances of the total observed time.

The next step is to setup the shipment scenarios from the information gathered from the network users. The scenarios are created based on the shipments supply factors shown in section 3.5. These attributes refer to the shipments' demand, density (volume/weight relationship) and unit cost. The setup is done following the scheme shown in section 3.6.1. The attributes are assigned to each scenario on a high/low combination of the factors involved. These scenarios are shown in Table 4.12.

Table 4.12 - Shipment Scenarios used for Case Study

Scenario (Profile)	*Rate*	*Cost of unit(USD)*	*Demand (Units/Year)*
1	R_2	$5.00	10,000
2	R_2	$5.00	500,000
3	R_2	$150.00	10,000
4	R_2	$150.00	500,000
5	R_{13}	$5.00	10,000
6	R_{13}	$5.00	500,000
7	R_{13}	$150.00	10,000
8	R_{13}	$150.00	500,000

The objective of these scenarios is to sample the representative shipments from Far East Asia to the Port of Guaymas' hinterland. The reason behind this is to identify under which port's lead time variability circumstances these scenarios can be attracted to the Port.

4.3.4.2 Computation

In this stage the total landed costs for the scenarios are iteratively computed to determine total landed costs as they are shipped through the port of Los Angeles/Long Beach. Additionally, the same landed costs are compared with the costs associated to the port of Guaymas. The analysis is performed over the Guaymas sojourn time (noted as "unknown" in Table 4.10) to determine the values that render the lower total landed costs.

For these computations the iterative processes described in section 3.6.2 of the methodology is followed. Table 4.13 shows the values obtained from the **Iterative Process A** at a 99% service level (for the case study the requested service level is set to 99%). These values reflect the total landed costs of the scenarios as they are shipped through the competing port.

Table 4.13 - Total Landed Costs of Los Angeles Port at 99% Service Level

Scenario	*Total Landed Cost Port of Los Angeles - SL:99%*
1	$ 6,925.70
2	$ 83,300.24
3	$ 47,714.19
4	$ 851,037.92
5	$ 22,250.97
6	$ 1,088,109.70
7	$ 48,280.95
8	$ 1,680,885.10

The next step is to perform **Iterative Process B** as defined in 3.6.2. The process consists on iteratively change the value of average shipment's sojourn time in the Port of Guaymas for the scenarios and compute the total landed costs for these changes. Then the difference between those values and the fixed values of the Port of Los Angeles/Long Beach is obtained and logged. This savings are defined as:

$\Delta\_Savings\_Guaymas_{sl,j,i} = TLC\_Los\_Angeles_{sl,j} - TLC\_Guaymas_{sl,i}$

Where:

sl = Required Service Level (90% , 95%, 99%)

i = Average Shipment's Sojourn Time Guaymas (change iteratively)

j = Observed Shipment's Sojourn Time Los Angeles (fixed by service level)

The resulting savings from using Guaymas are logged into a Matlab graphic module. These results are graphically inspected in the forthcoming step to identify the shipment's sojourn time values in which the use of the port of Guaymas results in lower total costs. This is, at what point does this Port offers a Lower Total Landed Cost for those users being serviced by the Port of Los Angeles/Long Beach.

4.4 Results and Parameter Estimation

The objective of the comparison of these results is to quantify the impact of port's lead time variability. In this specific case the focus lies on the impact of the port of Los Angeles/Long Beach service. The results of interest are those scenarios where the Total Landed Cost of the Port of Guaymas is lower to the ones observed in the port of Los Angeles/Long Beach. This section follows the result interpretation procedures shown in section 3.7 and is divided in the same fashion: First the impact of variability through the logistic costs derived from it and the definition of the competitive parameters for the Port of Guaymas.

4.4.1 Impact of Lead Time Variability

A significant part of the case study is to identify the impact of port's lead time variability. The underlying idea is to confirm how this variability cannot be overlooked by the Port of Guaymas Authority on their guidelines to provide a competitive container service to the region. This impact is to be determined by showing how the competitive position of the Port of Guaymas is affected as compared to the existent service level in the competing port.

For this purpose, Figure 4.9 shows the impact of the changes in average shipment's sojourn time on an assumed container service in the port of Guaymas, as the one in the Port of Los Angeles/Long Beach is fixed. The graphics in this section show the scenarios in which the total landed cost changes as function of the time the shipment's stays at the Port of Guaymas and the shipment's unit cost.

Before proceeding with the graphical interpretation of the results it is important to describe how the graphics are presented to reflect the whole scenario spectrum. Figure 4.8 shows the scenarios defined in Section 4.3.4.1 and how they are to be presented in the forthcoming graphics. The scenarios that represent all the high-low mix possibilities of the factors chosen are shown as black dots on the Figure 4.8. In order to make the interpretation more visual-friendly, the upcoming total cost graphs show the scenarios as a change from low to high *average shipment sojourn time in port* and *shipment unit cost* factors, while the other (*rate system* and *shipment demand*) are held constant. This means that the shift in scenarios is done within the same graphics, and it's shown in Figure 4.9.

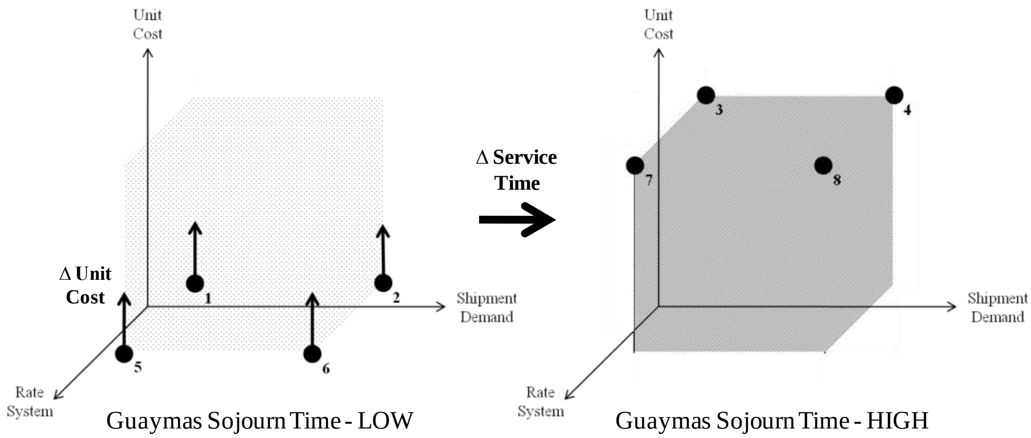


Figure 4.8 - Graphic Representation of Scenarios Comparison

The resulting values from Iterative Processes for the two competing ports are shown in Figure 4.9. Each of the scenario changes are shown separately; a) shows change from 1 to 3, b) is the change from 5 to 7, c) shows the change from 2 to 4 and lastly, d) the change from 6 to 8. This was done so that the visual interpretation of the changes in costs due port's lead time variability was easier to visualize.

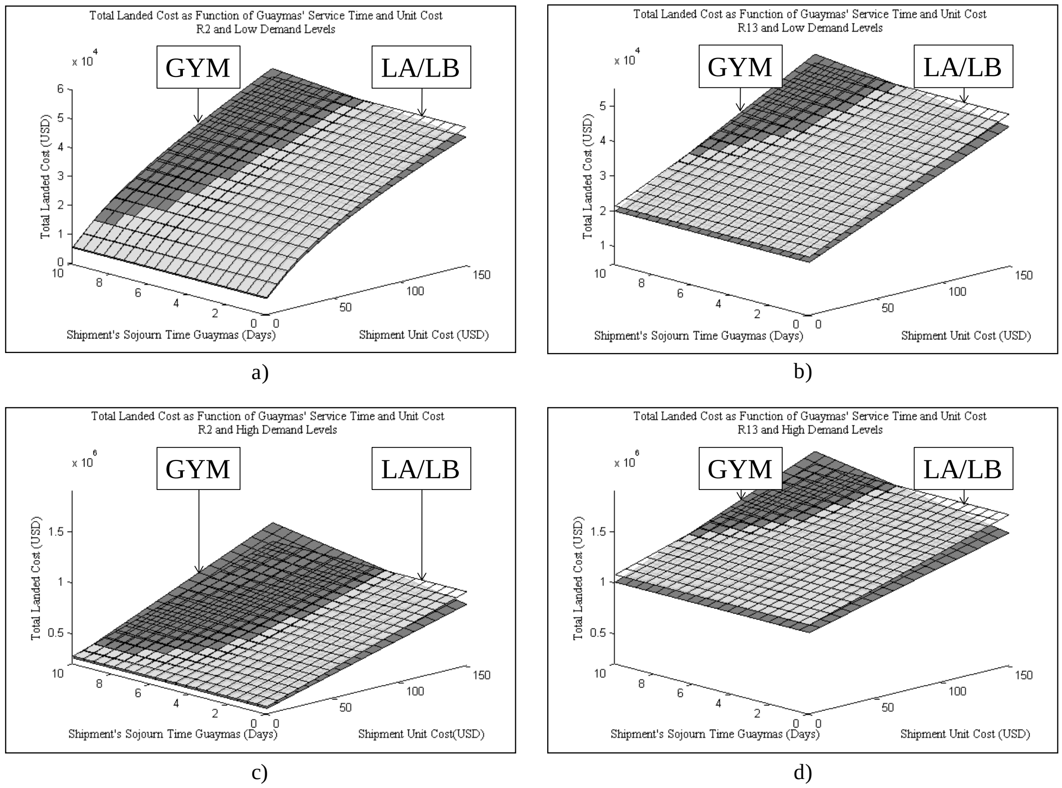


Figure 4.9 - Annual TLC as Function of Service Time and Shipment Cost

The graphics shown in the figure above emphasize the effect of lead time variability at the port of Guaymas. The shipment's unit cost is changed along the x-axis; the average sojourn time of Guaymas is changed along the y-axis, while the observed sojourn time in the Port of Los Angeles is fixed. As it can be observed in the set of graphics, the plane showing the TLC for Guaymas increases as its average sojourn times are increased. Figure 4.9 a) and b) show the behavior at low demand levels while c) and d) show the high demand levels.

From this visual representation of the total landed cost behavior, it is concluded that lead time variability can be an important parameter for the Port of Guaymas to be competitive. It can also be observed how the difference between the costs associated with each Port change as function of this lead time and the shipment unit cost. This last difference is to be explored in the following step of the results interpretation and is what provides the competitive parameters for the Port of Guaymas case study.

4.4.2 Ports Parameter

This section of the results interpretation is based on the Port *savings* computed with the **Iterative Process B** described in section 3.6.2. The specific objective of this part of the interpretation is the determination of the port's lead time frame where the Port of Guaymas is competitive. From these frames the parameters are then defined for the Port to consider.

In order to visually identify the windows of opportunity derived from the Port of Los Angeles/Long Beach lead time variability the savings computed in section 4.3.4.2 are shown in the same Matlab graphic module as used previously. These savings (Δ_Savings_Guaymas) ideally show the scenario where the Port of Guaymas is a better option over the competing Port. These are shown in the same fashion as in section 3.7.2.

First Figure 4.10 shows the *savings* for each of the changing scenarios described before. The plane on each graphic represents the behavior of those savings obtained in section 4.3.4.2. The *Z*-axis represents the savings as a function of Guaymas' assumed average shipment's sojourn time (*x*-axis) and the shipment's unit cost (*y*-axis).

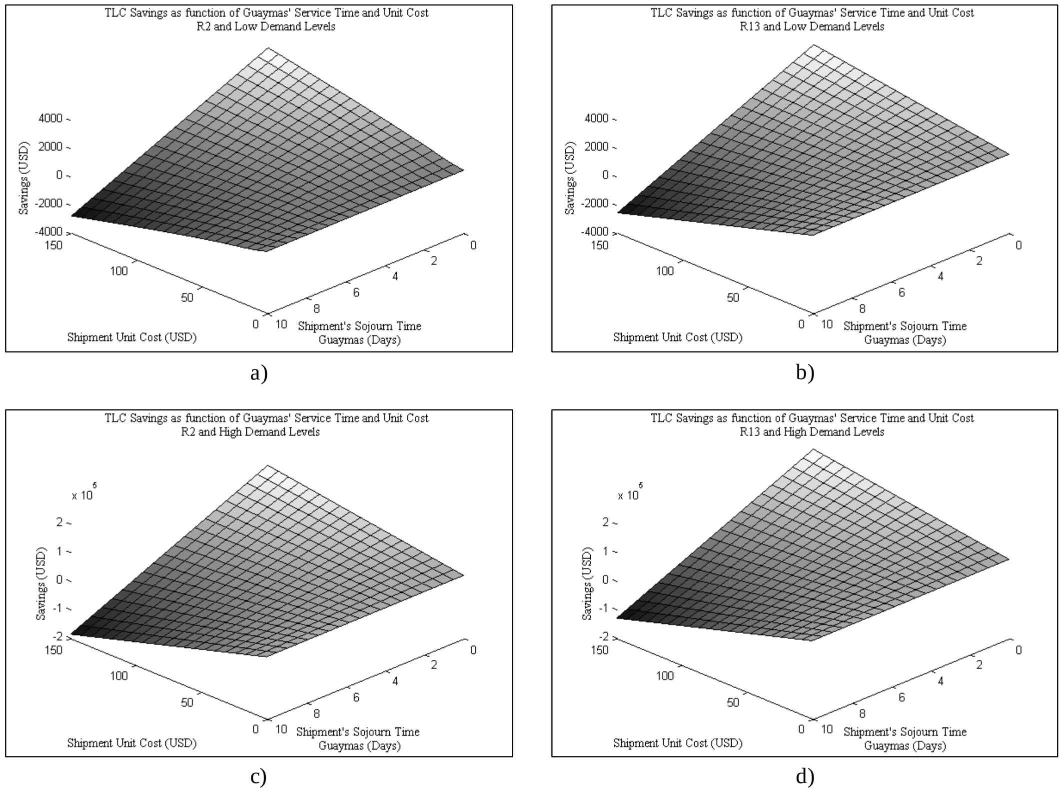
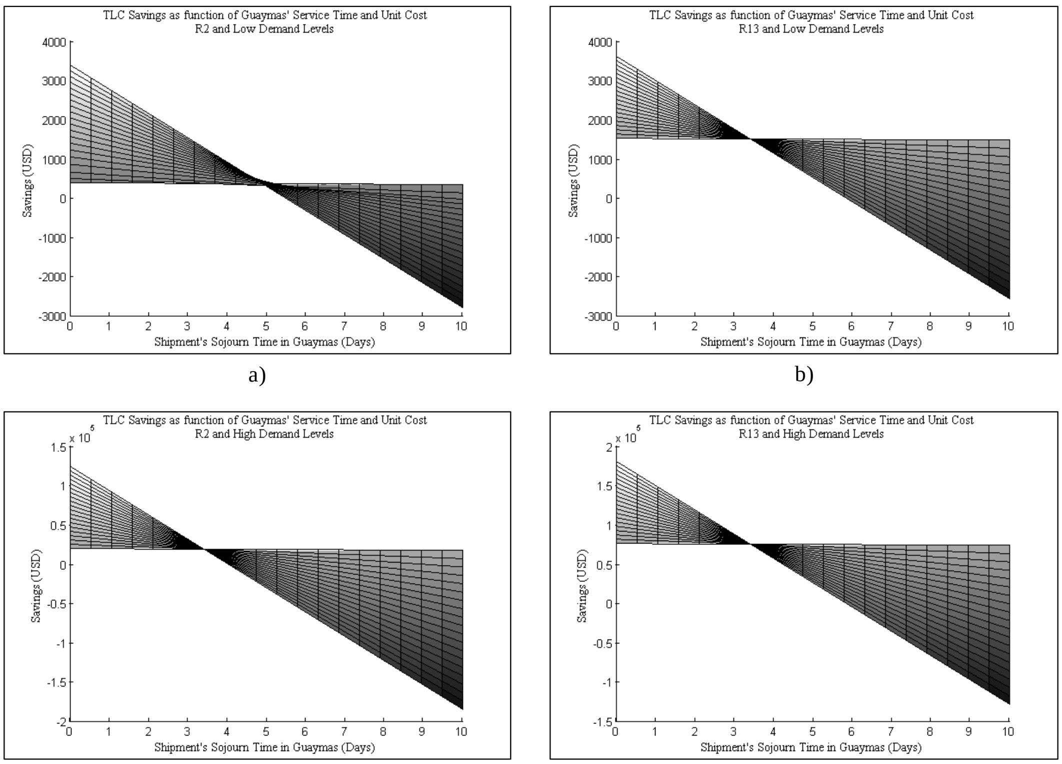


Figure 4.10 - Savings of Guaymas for each Changing Scenario

As it can be observed in the graphics above, the behavior of the savings are similar over the analyzed scenarios due the existing relationship between the total landed costs and the factors involved. As the savings move to the positive values, the gray scale pattern of the plane turns whiter, implying that the total cost of using the port of Guaymas with those specific parameter values is lower. On the other hand, as the gray scale pattern of the same plane turns black the savings are of a negative nature, which imply that the costs of using the port of Guaymas are higher. Of course the magnitudes differ significantly between the high and low-demand scenarios; still the port’s lead time threshold appear to be similar among all the graphics. Therefore, the window of opportunity for the Port of Guaymas to provide savings as compared to the competing port lie on the brightest part of the planes. The parameters providing these positive savings are of interest for the case study's conclusions.

In order to identify this parameters properly, the planes from the previous Figure 4.10 are modified to be shown in a different perspective, presented in Figure 4.11 below.



c) d)

Figure 4.11 - Graphic Analysis of Port Lead Time

In the graphics, the planes for each scenario are shown with the shipment unit cost axis removed from the perspective. This allows identifying the competitive frames easily as shown in section 3.7.2 example. Also it can be determined the scenarios where the savings vs. using the Port of Los Angeles/Long Beach are higher. For instance in Figure 4.11 a) it is observed that the positive savings starts when the Port of Guaymas offer a sojourn time for shipments lower than 4 days; still the highest saving is 3,000 USD yearly which is obviously not significant; on the other hand, Figure 4.11 d) shows than when this sojourn time is below the 3 days the savings become positive and if reduced to 1 or less the savings reach approximately 150,000 USD yearly.

This visualization provides the expected results from the methodology as implemented to the real case scenario. The graphics obtained from the proposed total landed costs comparison aid to define the parameters that the Port of Guaymas needs to offer in its container cargo service in order to be competitive within the region's supply chain.

4.5 Conclusions

After applying the proposed methodology to the case, Guaymas' competitive parameters are obtained. Additionally, the process provides an overview on which shipments scenarios are more prone to be attracted by a competitive service in the Port of Guaymas. Table 4.14 shows the results of the comparison for each of the proposed scenarios.

Table 4.14 - Findings of Port of Guaymas vs. Port of Long Beach

Scenario	*Conclusion vs. the Port of Los Angeles*
1	No Significant Savings
2	Low Savings by using Guaymas
3	No Significant Savings
4	No Significant Savings
5	Low Savings by using Guaymas
6	High Savings by using Guaymas
7	Low Savings by using Guaymas
8	High Savings by using Guaymas

It is important to note that these competitive parameters come from benchmarking the ports competing for the supply chain of the region. In this case study it was assumed that the Port of Los Angeles/Long Beach was the port presenting the highest competition. Then its observed lead time variability was benchmarked and modeled for the logistic cost comparison.

The methodology then helps to conclude that a commercial container operation in the Port of Guaymas needs to offer a service time no larger than 3 days. This means that in order to be competitive versus the commercial port of Los Angeles/Long Beach, its operations need to be fast and effective. This suggest that the transit time from the origin to the port, and to the port to the destination may be longer; but if the port service time is confined in the identified threshold the Port of Guaymas can still be competitive. This is concluded from the scenarios with the highest savings obtained by using the Port of Guaymas -those where the shipment's sojourn time was between 0.5 and the 3.0 days-. Based on this economic impact on the total landed costs, it is also suggested to the port of Guaymas that the profiles where it could provide higher savings are those from scenario 6 and 8. Therefore, it is concluded that the Port should focus on those specific shipment profiles for competitiveness. In this case, the shipment profiles which relate to a regional container service for goods with high year demands and high volume/weight (Rate = R_{13}). Another conclusion driven from this case study was that the unit cost is not that relevant on the profile selection criteria.

These observations show that the port of Guaymas can be competitive for the supply chain of the region's companies. Even though the Port of Los Angeles/Long Beach provides service at higher scale, there are specific situations where the Port of Guaymas can be competitive if an effective, constant service is provided.

5. METHODOLOGY VALIDATION

5.1 Introduction

The methodology developed during the present study emphasizes the impact of service time variability of a commercial port on the logistic costs of its customers. The underlying objective is to determine service time parameters for this impact to be reduced by a competitive port. Section 3 and 4 discussed the methodology that was developed and its implementation to a specific case study. The last issue addressed in this thesis is related to the validation of the methodology. The reason behind this is to support the hypothesis that lower port's service time variability yields lower total logistic costs and that it can be a decisive factor for port competitiveness.

In order to validate the methodology used for competitive service time estimation the plan is to integrate this variability cost into a Mixed Integer Program model. The costs derived from this change in behavior are to be added to the model's objective function as a cost component. These will be based on the set of port parameters identified for each of the competing ports. The expected result is to see the port using the competitive parameters -defined from the methodology- to attract more user demand. In this section of the document, the validation of these parameters as a competitive baseline is presented. This section overview the process followed to create the necessary validation.

5.1.1 Approach for Validation

The initial step is to define a mathematic approach for this validation. As it was already mentioned, the selected tool for this was Linear Programming. Following the validation purposes, and once the costs of the alternatives have been determined, the decision of implementing these stochastic cost parameters into a Mixed Integer Programming problem (such as the Assignment Problem) was taken. The purpose of this integration is the validation of the proposed methodology.

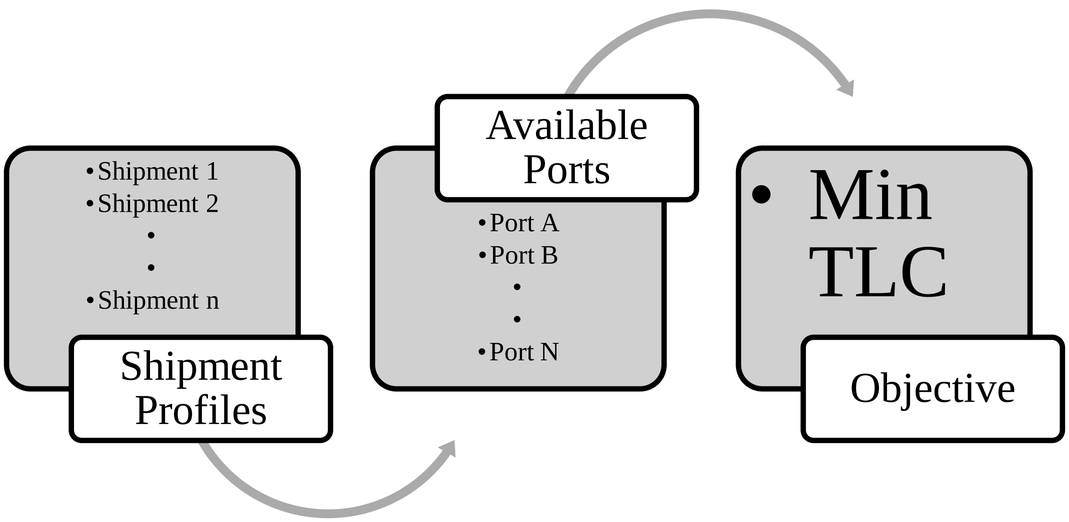


Figure 5.1 - Alternative Shipments/Port flow for Objective Function

Figure 5.1 shows an alternative flow on how a logistic network can be analyzed with the proposed framework. Given a set of shipment profiles and a set of transportation channels (ports), the decision variable can be set as the proper shipment/port mix to use subject to each profiles and ports' attributes. This is a flow problem that can be solved as an "Assignment Problem"

5.2 Suggested Model for Validation

The suggested model used to validate the methodology of the present research is a Mixed Integer Programming model; specifically known as the Assignment Problem. Given a set of goods to be shipped through different transportation channels (or ports) available, the Assignment Problem selects the proper combination of shipment/port that yields the lowest total landed cost for the entire set. This assignment problem is also closely related to transportation problem. The assignment problem used is defined as:

Minimize Aggregated TLC =

$$\sum_{i=1}^{n}\sum_{j=1}^{m} LC_{ij}x_{ij}$$ (1) Aggregated Logistic Cost

s.t.:

$$\sum_{i\epsilon I} x_{ij}=1 \; ; \forall j\epsilon J$$ (2) Shipment assigned to one port only

$$x_{ij}\in\{0,1\} \; ;\forall i\epsilon I, \forall j\epsilon J$$ (3) All values for decision variables must be binary

Where:

x_{ij}	Binary Decision Variable: Assign port *j* for shipment *i*

Parameters:

i	Index: set shipment profile
j	Index: set available commercial ports in the network
LC_{ij}	Logistic Cost of using port *j* for shipment *i*

For the MIP model above several terms need to be addressed in order to elaborate its characteristics. The objective function (1) refers to the aggregated logistic costs. This constitutes the total landed cost of each shipment i as it's moved through port j which is multiplied times the assignment decision variable. These variables (3) are binary and represent a "yes or no" decision, which equals 1 if the shipment i is done through port j and 0 otherwise. The summation of these cost terms for all n shipments over the total m available ports represents the aggregated logistic cost which is set to be minimized. Furthermore restriction marked as (2) in the model is the mathematical constraint that forces the model to assign one port per shipment only to avoid duplicates. The MIP model is coded in the mathematical software MPL for execution. The code is shown in Appendix D.

Using this MIP approach the model will allocate the shipments to the available ports in a way that the aggregated logistic cost of all the shipments is minimized. Again, this will be a function of the shipment's characteristics and of the available ports' costs and operation times. In the next section the procedure followed for validation are presented and then the results are discussed.

5.3 Model Implementation and Results

Once the validation model is defined, the next step is to check how the assignments of random shipments are done to different ports. Additionally, it is of particular interest to check whether the port lead time variability can be an impact factor on the total landed costs. For this purpose, two indicators are to be observed from the validation test results. These are (1) the quantity of parts assigned to each port and, (2) the changes in the aggregated logistic costs. Both as a function of the observed shipment's sojourn time in each port.

The steps followed to confirm this hypothesis are described in this section. First, the general problem presented in Chapter 3 is considered again. At this point some attributes are assigned to the network's links and nodes; some random shipments are created for testing the model as well. Next, the validation process is described. The process focuses on testing the assignment model with shipment's sojourn time in port as a changing parameter. Finally, the results are shown and discussed within the context of validation.

5.3.1 Testing Problem Description

For the validation model implementation the general problem described in section 3.1.1 is retaken. Figure 5.2 shows the simplified directed network diagram as depicted in the general problem.

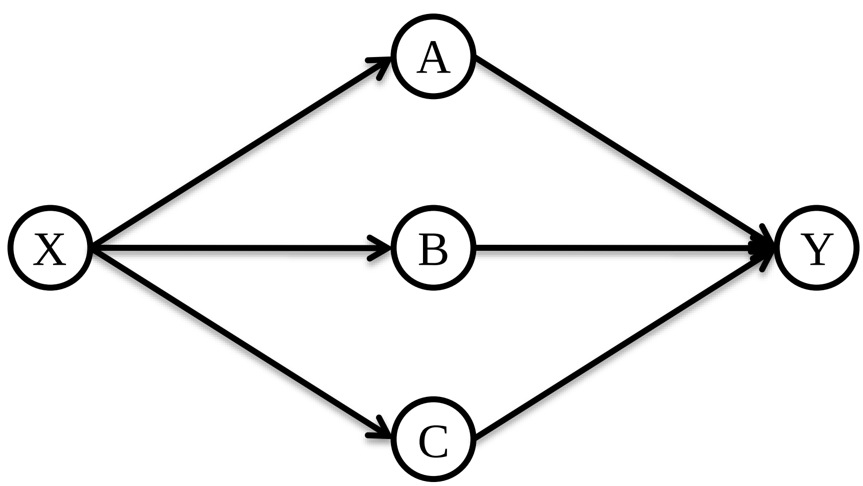


Figure 5.2 - Simplified Network for General Problem

In the general problem, the primary objective of Port A is to position itself as a competitive port within the network. Therefore service time of Port A is of interest. For the validation purposes it is assumed that shipments are done from point X to point Y. The available ports are shown as nodes A, B and C. The characteristics that define the port's and links parameters of the network are defined randomly; but they are required to capture certain differences of interest. The first assumption done is related to the segments. In this network $\overrightarrow{XA}$, $\overrightarrow{XB}$, $\overrightarrow{XC}$, $\overrightarrow{AY}$, $\overrightarrow{BY}$ and $\overrightarrow{CY}$ are all different in terms of distances, costs, time in transit, and most importantly shipment's sojourn times in each port. The quantities assumed in the model evaluation for these parameters are shown in Table 5.1.

Table 5.1 - Logistic Network Parameters for Validation

Parameter	*Port A*	*Port B*	*Port C*
Service Level	95	95	95
R_2	\$360	\$400	\$440
R_{13}	\$1350	\$1500	\$1650
Sea Transit Time	17	14	15
Land Transit Time	0.25	1	1.25
Sojourn Days	Changing % of Average(B,C)	3.296	0.532

As it was mentioned, in this validation process the service time parameter of Port A is of particular interest. This service time is to be modified on the following step of the process to check validation objective.

The next step after retaking the general problem is related to the shipments to test for the overall validation. To create these shipments a 100 random set of values of each of the factors shown in Section 3.5 are generated. The factors considered for shipment are shown in Figure 5.3.

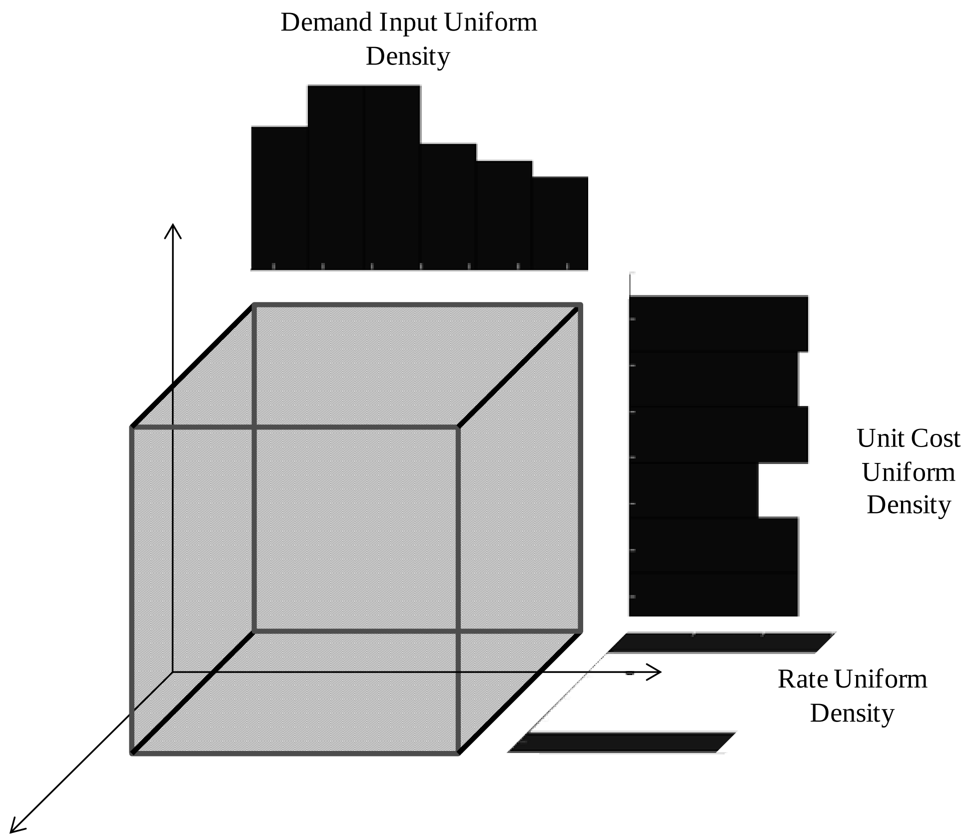


Figure 5.3 - Uniform Sampling from Factor for Shipments

For the technique shown in Figure 5.3, it is assumed that the probability of each factor when considered a random variable is randomly distributed. This means it follows a uniform density probability function. This is assumed for each of analysis and uniformly testing the factors involved. Additionally, the values for each shipment's factors are confined within the limits shown before.

5.3.2 Validation Methodology

Once the values for the ports (network nodes and arcs) and the random shipments are created these are set into the mathematical model shown in Chapter 3. This is used to obtain parameter LC_{ij} in MIP equation (3). At this point of the process the next step is to execute the validation model iteratively:

(1) Shipment's sojourn time in each *j* ports (A,B,C) is fixed as per specific service level (Port A service time is initialized to 0.0 days).

(2) The assignment model is executed for all *i* shipments at the specific service level.

(3) Assignment model results and aggregated cost are logged.

(4) Shipment's sojourn time in Port A is increased as a % of the other port's average service times.

(5) Model is executed again (return to step 2).

(6) Steps 2 through 5 are done iteratively until the aggregated logistic cost stabilizes.

These steps are defined from the process in section 3.7.1 in order to stay within the context of the thesis methodology. The assignment model iterations are expected to corroborate the impact of port's added lead time to the shipments costs.

5.3.3 Results

The next step on the validation is to visualize and interpret the results within the context of the logistic analysis. The results logged from the previous iterations are shown in Table 5.2 and a visualization of these is presented in Figure 5.4.

Table 5.2 - Results from Validation Iterative Process

Sojourn Time Port A (% of B and C Av. Service Time)	*Aggregated Logistic Cost*	*Shipments Port A*	*Shipments Port B*	*Shipments Port C*
10 %	7,356,513.37	100	0	0
25 %	7,415,680.08	91	0	9
50 %	7,485,482.37	71	0	29
75 %	7,529,121.52	53	0	47
90 %	7,545,910.68	45	0	55
110 %	7,562,297.71	37	0	63
125 %	7,570,968.57	31	0	69
150 %	7,581,625.92	22	0	78
175 %	7,586,485.66	12	6	82
190 %	7,587,230.38	10	8	82

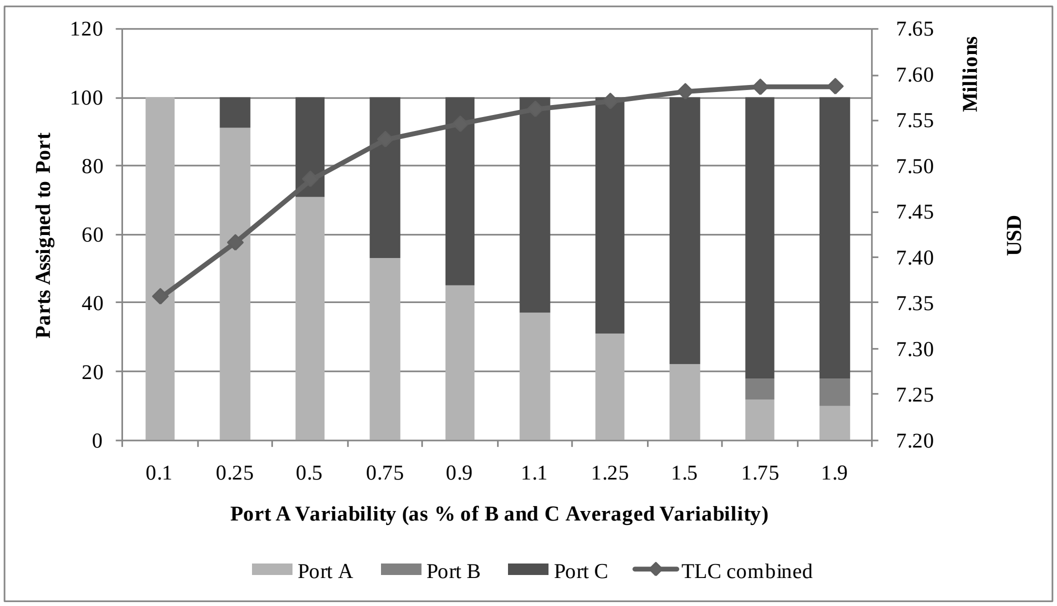


Figure 5.4 - Logistic Cost and Shipment Assignement by Port

In Figure 5.4 the shipments assigned to each port are depicted as the bar plots as percentiles and are shown in the primary axis. The aggregated logistic cost is shown in the plot line for the secondary axis. Both are presented as function of the shipments' sojourn time in Port A as percentage of the other ports' service times. As it can be deducted from these results' visualization, it is clear that as the marginal service time variability increases in port A it ceases of having shipments assigned. Additionally, the costs are lower as the shipments are assigned to the port presenting the lower sojourn times.

5.4 Conclusions

The proposed integration of the assignment model and the TLC model can be helpful when trying to find the proper shipment-port combination for a very large shipment population scenario. In other words, the approach can provide a good solution for any quantity of shipments as they are tested among different ports. In spite of this not being the primary objective of this chapter, the usefulness of the integration is worth mentioning.

Moving on with the validation, the results discussed in the latter part of this chapter are consistent with the underlying objective. The assignment model has obviously selected the port-shipment combination that yields the lowest aggregated logistic cost. The suggested validation procedure confirms two key concepts. First, it confirms that the lower the marginal service time the port offers, the safety stocks required by its users are reduced. Being this a significant part of the considered logistics costs, these are reduced at the same rate. The second concept addressed by the validation's results is how the port can define the service time based on the shipments assigned to it. The assignment model provides the amount of shipments that the port could attract from the hinterland's demand as its sojourn time changes. This is done through the sensitivity analysis of the assignment model by changing the shipments' sojourn time in Port A parameter in every iteration.

At the end the assignment model, using the proposed logistic costs as parameters shows that the as the Port's marginal service time variability is reduced the port can capture more shipments. Thus, being more competitive for the hinterland's supply chains and providing the validation to the proposed thesis methodology.

6. CONCLUSIONS AND FUTURE RESEARCH

6.1 Introduction

This chapter provides the author's final comments regarding the relevance of the thesis for the problem at hand. The final chapter of the presented document is related to the conclusions derived from the studies and research done through the development of this thesis. The main ideas obtained throughout the research are discussed in such a way that the objective is justified properly. First, the thesis justification is discussed followed by the summary and conclusion. The thesis contributions and the future research recommendations defined from the issues in the studies are discussed at the end.

6.2 Thesis Summary and Conclusions

The development of this thesis originates from a commercial port's necessity to offer higher competitive services to its hinterland. Since the port's role is crucial in globalized supply chains, it was determined that a competitive port has a positive impact on the economic development of its users. Therefore, the underlying objective of the research was to identify how a port can define operations parameters to offer higher, competitive service levels, either to increase its competitiveness or to trigger a competitive service.

The research was focused on the determination of those parameters that make a port more competitive in order to attract the containerized freight of its hinterland. After reviewing the available literature for port selection and competitiveness, it was concluded that there was an opportunity on assessing the port’s service time variability as a potential area of improvement. Specifically, the vessel sojourn time in a port was to be considered as the most variable component of the total transportation lead time. The reason behind this is that very little research was identified in the open literature that analyzes this factor on the port’s user costs. Therefore, the thesis statement is that the reduction of service time variability in commercial ports reduces the impact on their users’ logistics costs; thus enabling the port to improve its service and become more competitive with respect to other ports.

Overall, the thesis proposed a methodology that can help a port administrator to define these marginal service time variability parameters in the context of shipments’ sojourn time in port. The methodology focuses on (1) determining the impact of transportation lead time variability on supply chains, and (2) defining the proper service times that make the port competitive, by benchmarking on other ports already serving the same region. The methodology establishes a relationship between port’s lead time variability and total landed costs. This association is based on the economic impact of inventory derived from the service time variability. It allows for interpretation of the transportation lead time variability in relation to the port’s availability and their time-based operations in terms of the users’ logistic metrics.

The methodology relies on several tools already used in supply chain modeling, logistics, statistics and probability analyses, as well as in the operations research area. The methodology uses a specific port as the starting point. The objective of this port is to become competitive over a defined hinterland or to begin offering an efficient service to its users. The outlined steps for that purpose are basically to benchmark on the port (or ports) already competing in the hinterland. The objective of this benchmark is to identify what is the service level offered by commercial ports to the companies in the region.

In the proposed methodology, a total landed cost model is suggested to be used as a base for service time comparisons. In order to identify the components needed to make these comparisons, the process first defines the logistic network characteristics to analyze (which are the origins, the transportation channels available and the destinations of interest). Next, it identifies the relevant information needed to be gathered from the network and its users. Once the network and users attributes are analyzed through the suggested model, a sensitivity analysis is done over the shipment’s sojourn times in the port of interest. As it is compared to the other ports’ service, the sensitivity analysis provides the port of interest the limits (in days) to which its service time is confined in order to be competitive. The methodology also identifies which shipments are more attractive to the port of interest. This is which shipments will provide greater savings to the port users if these competitive parameters are considered.

The methodology was also applied to a case study during the development of the thesis. In the depicted scenario, the port of interest is the regional city-port of Guaymas, Sonora in Mexico. The port is currently looking for ways to offer an efficient container service for the region. The necessity of such service was triggered by the issue that companies located in the region are currently serviced by the heavy congested ports of Los Angeles and Long Beach, California in the United States. As the port of Guaymas seeks to offer a service for containerized merchandise that can benefit the region and act as a relief for the congested ports, the methodology is used to identify its potential competitive advantages. The methodology results for the port of Guaymas showed that in order to be competitive it requires offering a container release time no greater than 3 days. Additionally, it suggests for the port to focus on those shipments which has high consumption rates and a high volume or weight profile. That means that as long as the service times of the port of Guaymas stays within this limit, the port represents a proper service option for the Port of Los Angeles/Long Beach; therefore the port would achieve a competitive positioning in the region's supply chains. The presented case study shows that the methodology proposed in this thesis helps identify the impact of port's service time variability and determine the competitive parameters related to this metric.

The last part of the research proposes a procedure to validate the methodology. This process uses operations research models to support the thesis statement. The procedure consisted in creating random shipments to be sent from a specific origin to a specific destination. At the same time, different ports (transportation channels) with different characteristics were available for these shipments. The approach used for the validation was an *assignment problem* model . This approach used the methodology's total landed cost of the shipments to decide through which of the available ports was the destination going to be reached. The presented validation model shows that independently from the amount of shipments, the port with lower service times would receive more assignments. Furthermore, it shows that using ports with lower, regular service times yields an aggregated lower logistic cost for the entire set of shipments. This validates the proposal that using the service time parameters determined from the methodology would provide a competitive positioning for a low-variability port.

Overall the methodology developed in this thesis helps to conclude that a commercial port can take proactive steps to become more competitive and an integral part of the region's supply chains by properly defining its service levels. Additionally, a commercial port can have an advantage if it provides a cargo service time significantly less variable than its competitors. This is concluded from the fact that inventory and penalty costs derived from lead time variability can exceed those derived from other factors –like longer transit time.

The next part of the conclusion discusses the contribution of the present research and at what levels of study the presented thesis can be beneficial.

6.3 Thesis Contribution

The contribution and benefits of the present thesis can be segmented as follows. First, given the situation where a port is not able to influence the clients' ordering policies -such as order quantities and frequencies-, the methodology helps a port determine under which conditions it can provide an efficient service to their clients. This means it can help the port establish operation guidelines and references that yields a competitive positioning within the supply chains of the hinterland. This guidance and parameters are determined towards the port's lead time variability. In other words, how does the port align its operations and what decisions has to be taken as part of the logistic strategy, such as long term investments (such as expedited custom operations) which could potentially reduce service time for all shipments.

Second, this thesis shows that identifying the proper competitive parameters for a port is economically beneficial for the potential port users. If the logistic costs of the port's clients are reduced by an effective service, the users can also reduce their operational costs. Being the port users linked directly to the economic development of the region, it is believed that an efficient, low-variable port service can trigger the economic development of the region. If applied accordingly, the thesis methodology would yield eventually lower logistic costs for the companies within the port's influence region; which at the end would be beneficial for the economic development of the region.

Other contributions are related to application of the methodology in common strategic planning. The methodology can be used as a powerful benchmark tool for port competitiveness. In the same way, the cost model used throughout can be implemented in an operations research model (as shown in the validation section) and be used as an aid on any given company's logistic decisions. The setup and computational part of the methodology is shown as an iterative process which can be easily interpreted as a set of instructions/pseudo-code. In this way, it could be integrated as a user-friendly computer application that would allow port administrators to identify competitive service time parameters.

It is relevant to emphasize on the development of methodologies that support nowadays ever-evolving logistics. This was one of the main motivators for the study in question; it is intended to be a practical tool for real port-logistic strategies and supply chain decisions.

6.4 Recommendations for Future Research

Some of the assumptions done through the presented research provide topics of further discussion. In the same fashion, other concepts and ideas were identified through the research processes that require a more deep analysis. These are somehow related to underlying objective of the thesis and are considered as opportunity areas for future research.

6.4.1 Service Time Variability Information

One of the most common obstacles identified through the development of the presented case study was related to the service time information. The lack of service time data available and/or structuring slowed the analyses significantly. This is mostly due the relevance or potential benefit of this is sometimes overseen by port administration. Specifically for the methodology developed in the present study the service time data is a key factor used to identify competitive operation parameters, as well as a critical part of the supply chain costs.

This service time data can be recorded among different perspectives like the client's or the internal port's perspectives. During the research, it was observed that most Port Administrations keep record of their internal performance in terms of service time; unfortunately, this data is not processed accordingly to define their service times. On the other hand, the companies that rely on the port for their commercial operations rarely consider port's lead time variability on their metrics, mostly because they outsource freight forwarders or Third Party Logistic (3PL) companies for their merchandize transportation.

It is then considered that a valuable contribution to the supply chain research is related to the development of service time variability record. This can be related to the ports used in the chain (or in other logistic network nodes). This should be developed in such a way that it can aid other performance metrics; and also could be customized for its usage on commercial ports and their clients.

6.4.2 The Shipping Companies Perspectives

The thesis was focus on how the commercial port could be competitive with regard to its client's logistic costs and service levels. Complementary to this are the shipping companies themselves, which are another key player on the supply chain. During the development of the thesis and the case study, it was assumed that a regular service was going to be available for the port of interest. It is believed that in order to be competitive the port needs to offer to the companies not only an ascertainable market, but is also required to offer a competitive service for the shipping companies.

This is why that research related to the shipping companies' perspective is suggested. Some of the reviewed literature considers the role of these companies as a key component in the supply chain, but still it is suggested to study this thoroughly. Some of the suggested research related to the shipping companies as a integral part of the port competitiveness are:

- Determine which metrics are used by the shipping companies to define routes or a call in the port of interest.
- Determine the optimal specifications and vessel service designs that align to the shipper's metrics and strategies.

The suggested research complements the underlying objective of the present thesis and should be considered as part of the port competitive positioning strategies.

6.4.3 Alignment of the Internal Port Operations

One of the main opportunity areas suggested for further research for port competitiveness is related to the internal port operations. This is an area that has been widely studied by material handling experts. The suggested research however is related to the findings that can be derived from the methodology.

It is believed that the internal operations of the port need to be aligned to the shipment's sojourn time limits. This means that once these bounds are defined, the specific objectives need to consider this variability constraint in order to achieve the competitive advantage. Examples of these specific objectives can be (but are not limited to):

- Maximize Port Revenue
- Minimize Operations Time Variability

The decision variables can range from the logistic procedures to the infrastructure design and specifics. These operations research models need to be setup in such a way the provided service time is considered. Additionally, they should be able to assist in the internal port planning and investments validation, among other strategies.

6.4.4 The Shipments Characteristics

One of the research opportunities identified is the shipments' characteristics and its impact on the port's competitiveness. In chapters 3 and 5, the assumptions done to create the shipment profiles considered their attributes as uniformly distributed among the main factors. These factors were the transportation rate based on dimensional weight, and the unit cost and demand. The scenarios under which the methodology was tested were created considering high/low levels of the aforementioned factors. For validation purposes, random shipments were created which were considered as uniformly distributed as well.

The suggested research is more related to the behavior of the proposed cost models under scenarios, in which the shipment attributes follow other probability distributions. This research could focus on identifying the competitive parameters for ports that seek to provide a service for these non-uniform shipments. The methodology is expected to identify these competitive parameters as well but they may present a different challenge to the analyst, in such way that these present a higher (or lesser) opportunity for the port.

6.4.5 Port Efficiency Measuring from Proposed Methodology

Lastly, when working with the proposed validation model another research extension was identified. The idea behind this research suggestion is based on working the model backwards to estimate efficiency of a specific port as used by its clients. Assuming that service time for a specific port is unknown but logistic costs of several shipments made through this port are known, the port's lead time variability cost component can be solved from the model.

Solving this component for several shipments can lead to the identification of the port's efficiency. This metric can be defined from the changes in logistic costs derived from the port's service time variability; thus, the metric can be simply the *observed release days* per *container* (or *shipment*) as solved from the port costs component. These observations can then be compared versus the expected service time from the port in order to have an approximation of its efficiency. This can be done from the user perspective and regardless of any privileges or available information from the port.

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APPENDIX A

MATLAB CODE FOR TLC COMPARISON

```
% The following file uses an example to create the graphical interpretation
% of the lead time variability impact shown in Section 3.7.1.

%% Results Matrices
double Q(20,20);
double QW(20,20);
double NQ(20,20);
double TCY(20,20);
double AI(20,20);
double SS(20,20);
double IT(20,20);
double ICY(20,20);
double TLC(20,20);

%% Unit Variables
p = 5; % Weight in Kg
d = 50000; % Demand in Units
c = linspace(1,150,20); % Variable Unit Cost in USD
i = 0.15; % Percentage for Cost of Opportunity

%% Transportation Variables
v = linspace(0,10,20); % Port A Variability

% The values in the following arrays correspond to [Port B, Port A]
VAR = [5.41 0]; % Service time variability @ 99 percent SL in days
TRANS = [14 16]; % Transit time in days
TRANSSEA = [2000 1600]; % Transportation Cost per Container Unit (sea)
TRANSLAND = [900 500]; % Transportation Cost per Container Unit (land)
TRANSTOT = TRANSSEA+TRANSLAND; % Total Transportation
[C,V] = meshgrid (c,v); % Surface Graph Setup

%% File Loop
for l = 1 : 2 % 1 to 2 compares Port B vs Port A

   %% Variables
   VL = VAR(l);
   TTL = TRANS(l);
   mt = TRANSSEA(l);
   lt = TRANSLAND(l);

   %% Transportation and Order Costs:
   %% EOQ
   for j = 1 : 20
      for k = 1 : 20
```

```
        Q(j,k) = sqrt((2*d*0.1*c)/((i*C(j,k)+(2*400))));
    end
end
clear j k;

%% Order Count
for j = 1 : 20
    for k = 1 : 20
        QC(j,k) = (d)/Q(j,k);
    end
end
clear j k;

%% Order Transportation Cost
for j = 1 : 20
    for k = 1 : 20
        OT(j,k) = Q(j,k)*400;
    end
end
clear j k;

%% Order Cost
for j = 1 : 20
    for k = 1 : 20
        OC(j,k) = QC(j,k)*0.1*c;
    end
end
clear j k;

%% Total Transportation Cost (Annual)
for j = 1 : 20
    for k = 1 : 20
        TCY(j,k) = OT(j,k)+OC(j,k);
    end
end
clear j k;

%% Inventory Costs:
%% Average Inventory Cost
for j = 1 : 20
    for k = 1 : 20
        AI(j,k) = (Q(j,k)/2)*(i*C(j,k)); % average inventory cost *(orders)
    end
end
```

```
   clear j k;

   %% Safety Stock Inventory Cost
   if  l == 2 % l = 2 is Port A
      for j = 1 : 20
      for k = 1 : 20
         SS(j,k) = (d/365)*(i*C(j,k))*V(j,k);% Demand/365 * holding cost * Port
A Variability in Days
      end
      end
      clear j k;
   else % Port B
      for j = 1 : 20
      for k = 1 : 20
         SS(j,k) = (d/365)*(i*C(j,k))*VL;% Demand/365 * holding cost * Port B
Variability in Days
      end
      end
      clear j k;
   end

   %% In-Transit Inventory Cost
   for j = 1 : 20
      for k = 1 : 20
         IT(j,k) = (d*i*C(j,k)*TTL)/365; % (Demand * transit time * holding
cost)/365
      end
   end
   clear j k;

   %% Total Inventory Cost (Annual)
   ICY = AI+SS+IT;

   %% Total Landed Cost (Annual)
   TLC = ICY+TCY;

   %% Surface TLC
   title('Total Landed Cost as function of Port A Variability and Unit Cost');
   xlabel('Costo Unitario (USD)');
   ylabel('Port A Service Time Variability (Days)');
   zlabel('Total Landed Cost (USD)');
   surface(C,V,TLC);
   hold on;
end
```

APPENDIX B

ESTIMATION OF PORT OF LOS ANGELES / LONG BEACH SERVICE

TIME VARIABILTY - DATA SUMMARY

Random Data Information		
	Asian Port:	Shanghai CN
	US Port:	Long Beach/Los Angeles
	Weight:	>500 kg
	Inalnd Destination:	Guaymas Hinterland (Nogales/El Paso)
	Year:	2007

Entry	*Week Date*	*Weight (Kg)*	*Real Ship Date*	*Release Date*	*LT (Days)*
1	12/31/2006	13712	12/16/2006	1/2/2007	17
2	1/7/2007	6496	12/23/2006	1/7/2007	15
3	1/14/2007	8439	1/4/2007	1/18/2007	14
4	1/21/2007	17285	1/12/2007	1/25/2007	13
5	1/28/2007	17825	1/18/2007	2/2/2007	15
6	2/4/2007	19344	1/20/2007	2/4/2007	15
7	2/11/2007	4491	1/30/2007	2/12/2007	13
8	2/18/2007	5336	2/6/2007	2/19/2007	13
9	2/25/2007	14007	2/10/2007	2/26/2007	16
10	3/4/2007	10433	2/22/2007	3/10/2007	16
11	3/11/2007	11176	3/1/2007	3/17/2007	16
12	3/18/2007	12608	3/10/2007	3/24/2007	14
13	3/25/2007	24964	3/14/2007	3/29/2007	15
14	4/1/2007	4154	3/22/2007	4/3/2007	12
15	4/8/2007	4388	3/29/2007	4/12/2007	14
16	4/15/2007	1464	4/5/2007	4/17/2007	12
17	4/22/2007	3455	4/12/2007	4/24/2007	12
18	4/29/2007	8468	4/19/2007	5/2/2007	13
19	5/6/2007	3496	4/26/2007	5/10/2007	14
20	5/13/2007	3489	5/3/2007	5/16/2007	13
21	5/20/2007	2173	5/5/2007	5/20/2007	15
22	5/27/2007	1640	5/17/2007	5/30/2007	13
23	6/3/2007	16000	5/18/2007	6/5/2007	18
24	6/10/2007	3960	5/31/2007	6/12/2007	12
25	6/17/2007	1640	6/7/2007	6/19/2007	12
26	6/24/2007	9734	6/14/2007	6/27/2007	13
27	7/1/2007	11176	6/21/2007	7/4/2007	13
28	7/8/2007	11659	6/24/2007	7/8/2007	14
29	7/15/2007	12320	7/5/2007	7/17/2007	12
30	7/22/2007	1080	7/12/2007	7/28/2007	16
31	7/29/2007	3080	7/19/2007	7/31/2007	12
32	8/5/2007	10604	7/26/2007	8/8/2007	13

33	8/12/2007	13221	7/30/2007	8/14/2007	15
34	8/19/2007	2302	8/9/2007	8/22/2007	13
35	8/26/2007	12863	8/12/2007	8/28/2007	16
36	9/2/2007	1507	8/23/2007	9/6/2007	14
37	9/9/2007	21497	8/30/2007	9/11/2007	12
38	9/16/2007	7060	9/6/2007	9/19/2007	13
39	9/23/2007	12848	9/13/2007	9/26/2007	13
40	9/30/2007	14216	9/23/2007	10/5/2007	12
41	10/7/2007	5284	9/20/2007	10/8/2007	18
42	10/14/2007	13423	9/30/2007	10/17/2007	17
43	10/21/2007	20516	10/11/2007	10/25/2007	14
44	10/28/2007	15563	10/18/2007	10/31/2007	13
45	11/4/2007	11592	10/21/2007	11/5/2007	15
46	11/11/2007	24138	11/1/2007	11/15/2007	14
47	11/18/2007	9034	11/4/2007	11/16/2007	12
48	11/25/2007	16678	11/8/2007	11/25/2007	17
49	12/2/2007	12597	11/22/2007	12/6/2007	14
50	12/9/2007	21460	12/2/2007	12/15/2007	13
51	12/16/2007	20489	12/6/2007	12/19/2007	13
52	12/23/2007	19012	12/9/2007	12/24/2007	15

APPENDIX C

ESTIMATION OF PORT OF LOS ANGELES / LONG BEACH SERVICE TIME VARIABILTY - GOODNESS OF FIT

Goodness of fit - Port of Los Angeles/Long Beach Service Time	
Data Points	52
Estimates	Maximum Likelihood Estimates
Accuracy of fit	0.0003
Level of Significance	0.05
Distribution:	Erlang
Parameters	
Minimum	11 days
M	3
B	0.999981
Media	14 days
Test:	Kolmogorov-Smirnov
Data Points	52
K-S stat	0.157
Alpha	5.00E-02
K-S (52,5.e-002)	0.185
P-value	0.136
Result	DO NOT REJECT
Test:	Anderson-Darling
Data Points	52
A-D stat	1.23
Alpha	5.00E-02
A-D (52,5.e-002)	2.49
P-value	0.258
Result	DO NOT REJECT

APPENDIX D

VALIDATION ASSIGNMENT MODEL - MPL CODE

```
TITLE
	Ship_Port_Assgn;

INDEX
	i = (A, B, C); !Ports available
	j = 1..100; !Number of Shipments to Assign

DATA
	cost[i,j] := datafile(costs_VAR.dat); !Different data files are used for
different Variability levels of Port A ("_VAR").

BINARY VARIABLE
	x[i,j]; !Select to use port i for shipment j

MODEL
	Min TLC = SUM(i,j:x*cost);

SUBJECT TO
	OnePortOnly[j]		:		SUM(i:x) = 1;

END
```