Eindhoven University of Technology

MASTER

Measurement and improvement of delivery performance of third party logistics in SABIC Europe

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Award date:
2010

Link to publication

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Eindhoven, August 2010

Measurement and Improvement of Delivery Performance of Third Party Logistics in SABIC Europe

by

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BSc Industrial Engineering — Middle East Technical University 2008

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in partial fulfilment of the requirements for the degree of

Master of Science

in Operations Management and Logistics

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Series Master Theses Operations Management and Logistics

Subject headings: logistics, game theory, contract.

ABSTRACT

This master thesis investigates the reasons of low delivery performances of sea shipping and inland barging third party logistics service providers, and tries to develop a Performance-Based Logistics Contracting model with the help of Non-Cooperative Game Theory in order to motivate the providers to perform better for an increased delivery performance. In addition, it tries to define key performance indicators for sea shipping in order to reflect customer satisfaction more successfully.

PREFACE

This Master Thesis report is the result of my graduation project for the progam Operations Management & Logistics at Eindhoven University of Technology. This project took place for seven months from January 2010 to August 2010, at SABIC Europe under the Sourcing & Contracting department of Chemicals Business Unit.

For his contribution to this project, first of all, I would like to thank my first supervisor at TU/e, Marco Slikker. With the help of his constructive feedbacks, guiding suggestions, assisting ideas and professional support, I have been able to create and finalize a sound project with non-trivial conclusions out of several vague problem symptoms. Our discussions during the meetings have been challenging, but constructive and significantly contributing to the progress of the project. I also want to thank my second supervisor, Tom van Woensel, for his feedbacks and opinions.

Furthermore I would like to thank my supervisor from SABIC Europe, Michel Wintraecken. His encouraging feedback, extensive knowledge and close interest on the project have helped my project to have useful and effective results with meaningful insights. I would also like to thank Jacob Beck and Wien Ubachs for their time and input to this project.

Recep M. Gungor

August 2010

MANAGEMENT SUMMARY

Focus on the operations of Third Party Logistics is gaining importance in highly competitive markets, where customer satisfaction is driven by on-time deliveries. The chemicals division of SABIC Europe also gains revenues by market-driven prices, thus customer service has a great responsibility to deliver products on-time in full and in the perfect condition. However, SABIC wants to increase the customer satisfaction more, besides a better relationship management with the Logistics Service Providers (LSPs). Their problems were stated as: *SABIC Europe does not have robust delivery performance measures for some transportation modalities, especially the performance for shipping is not well-measured to successfully reflect customer satisfaction. More importantly, uncontrollable uncertainties like weather, port availability, congestion etc. are not taken into account while contracting and delivery scheduling. Moreover, to prevent low delivery performances, third party LSPs' performances are not regulated by any means.*

In order to find a remedy to the problems stated above, the aim of this research is designated as to find answers to the questions of: how delivery performance can be measured better for the transportation provided by third party logistics providers, what the causes of late deliveries are, and how the performance of LSPs can be improved through contracts.

Better on-time delivery performance measurement was a necessity for shipping, because of the nature of the shipping industry. The contracts with LSPs and customers were done to agree on a loading time window, instead of a delivery date or a delivery time window. Although reports indicated high performances for being on-time for loading, customer complaints indicated otherwise. Customers were not satisfied with the logistical operations, in terms of deliveries which arrived later than expected. Solution to this problem was possible by developing new key performance indicators (KPIs) which reflect customer satisfaction better. A realistic measure was determined to be the one which estimates when the delivery should be done the latest, like it is contracted for other transportation modalities. In other words, an *expected delivery date* is being estimated from the loading time window agreed, expected loading time and the expected transit time. This measure reflects customer expectations about when the ships should be at the customer site for discharging.

Reasons of the delays during the processes of shipping and barging were analyzed in detail, using monthly reports and individual shipment files. Results indicated that the biggest responsibility on late deliveries belonged to LSPs, with *late arrivals for loading* and *long voyages*. Other delay reasons such as product availability, weather conditions, scheduling, etc. were also present but were found to be relatively of lower impact. The underlying reasons behing these two causes were investigated. Late

arrivals for loading stems from the previous shipment of the concerned ship, which faced a delay that affects SABIC's shipment. Although LSPs schedule the movements of their ships as reasonable as they assume, they want to keep the utilization of their ships as high as possible to maximize their profits. Thus, for that reason, they do not reject shipments despite the probability that the schedule will be too tight to accomodate uncertainties. Also, the root cause behind the long voyages was that, besides an effective proportion of weather conditions, ships tend to travel at their economic speed when they are not in a hurry for their next shipments. In other words, when they have no following shipment, they go at economic speed not caring about when to arrive to the customer.

These root causes were defined as opportunistic behaviors of the LSPs caused by the asymmetric information which SABIC does not possess. According to the literature this could be remedied by performance-based contracting with LSPs, which employ incentives and penalties to reward or punish on-time delivery performances of LSPs. For that purpose, a contracting model was constructed using Non-Cooperative Game Theory. The model was approached by a game which shows sequential decisions of SABIC and the LSP, and it was built such that *principal offers a contract with parameters which maximizes his profit, and the agent responds to this offer choosing an effort level which will result in a performance outcome*. Depending on the outcome, LSP is either penalized for not being on-time or rewarded for being on-time at the customer site. Besides the decisions of SABIC and LSP, uncertainties and delays which were discovered during the previous analyses were also included in the model.

The model aimed to motivate two types of efforts of the LSP, which the previous analyses concluded: scheduling effort to be on-time for loading, and speed effort to shorten the transit times. A contract is offered to the LSP such that they will obtain an expected profit which will prevent them from rejecting the contract, and that they will choose their profit-maximizing option as well. Focusing on a single shipment, specific conditions exist which motivates distinct levels of effort. After these conditions are determined, optimization problem of SABIC can be solved to maximize its expected payoff in order to find the optimal values of three contract parameters: initial payment, penalty and reward.

The model was solved for an example case, and the results indicated the following insights:

- The optimal solution for SABIC has an expected delivery performance of 97,34%, which is high with respect to the current score 91,93%.
- Both efforts are profitable for the LSP at the optimal solution, and the optimal scheme results in expected additional profits for SABIC despite higher expected payments to the LSP.

- Choices of the LSP depend on only “Reward and Penalty” offered, and is independent from the initial payment.
- Received reward for being on-time should be at least the expected cost of LSP’s efforts, so that increasing the effort will be advantageous for the LSP.
- A highly deterrent penalty factor is necessary to force the LSP to perform as desired.
- The game structure fits the barging process and problems, however for other modalities it needs to be reconstructed considering the prominent delays and possible efforts.

Despite some deficiencies of the model stemming from the underlying assumptions, it provides an understanding about how the performance-based incentive contracts could be constructed. It also provides the infrastructure to be adapted to other modalities, and produces insights about what to consider when building such a contract.

The contract model also contributes to the Third Party Logistics Outsourcing area in terms of being able to obtain a solution of a real-life case study. This fact indicates the possibility to implement such models to contracting decisions and also supports the appropriateness of *Non-Cooperative Game Theory* to approach such a problem.

To conclude, it is recommended that an extensive analysis about delay reasons should be conducted in order to detect the improvement opportunities, and a game-theoretical model can be a useful tool if the solution involves LSPs.

Table of Contents

CHAPTER 1: INTRODUCTION

This research was conducted as a project at SABIC Europe, and it investigates the factors affecting the delivery performance of third party logistics service providers (LSPs), definition of key performance indicators and improvement opportunities. Aim of this research is to answer the questions: how can delivery performance be measured better for the transportation provided by third party logistics (3PL) providers, what are the causes of late deliveries, and how can the performance of LSPs be improved through contracts. Prior to the project, an extensive literature review was conducted about the abovementioned subjects.

The research is at a balance point between rigor and relevance, i.e. it does not contain highly formal models which are too far from practicality, also does not aim for the solutions for specific cases which are far from literature.

1.1. Organization of the Report

In the later sections of this chapter, SABIC Europe is introduced and the research area is specified. In *Chapter 2*, design of the project is explained, starting from the current situation until the development of the project methodology.

In *Chapter 3*, at first process flows are drawn and explained. Using these process flows, process and delay analysis are conducted, including interviews and statistical analyses, and consequently the findings are stated.

Chapter 4 is devoted to the definition of potential key performance indicators (KPIs), and further elaboration of critical delay reasons. In this chapter, selection criteria of KPIs and deficiencies in the current KPI reporting system and their improvements are explained. Using the defined KPIs, critical delays are detected and the most important factors hindering the on-time delivery performance are revealed. Finally in this chapter, possible improvement opportunities about these factors are shortly explained, and it was decided that the most applicable improvement is through performance-based contracting.

In *Chapter 5*, a performance-based logistics outsourcing contract model is developed using Non-Cooperative Game Theory, an example solution and resulting findings are represented, and scenario analyses are conducted.

Finally, in *Chapter 6*, some conclusions are drawn about the complexities about the implementation of the contracting model, and future research directions are advised.

For a better understanding of this report, it is advised for the reader to first examine the List of Abbreviations in Appendix I and the “Terms and Definitions” in Appendix II.

1.2. Company Description

Company information, products, organization and supply chain structure of SABIC Europe are explained in this section.

1.2.1. SABIC Europe

SABIC (Saudi Basic Industries Corporation), established in 1976, is one of the world's top 10 petrochemical companies. Headquartered in Riyadh (Kingdom of Saudi Arabia), SABIC is the largest non-oil company in the Middle East. It has the number one global position at the production of granular urea, mono-ethylene glycol, MTBE and engineering plastics. SABIC's total assets measure over $72 billion and annual revenue exceeds $40 billion. 33,000 employees work for SABIC worldwide and SABIC operates in more than 100 countries.

In Europe, SABIC employs approximately 6,300 people. Main European office for the strategic business units Plastics and Chemicals is based in Sittard (The Netherlands). Sales of plastics and chemicals are managed via an extensive network of local sales offices throughout Europe, while main Manufacturing and Research facilities are based at several locations in the Netherlands, Germany, UK, Italy, Austria and Spain.

The mission of SABIC is "to responsibly provide quality products and services through innovation, learning and operational excellence while sustaining maximum value of the stakeholders". And their vision is "to be the preferred world leader in chemicals" (SABIC, 2008).

1.2.2 Products and Organization

There are more than 60 final products that are being produced and sold by SABIC. However in Europe, SABIC is a major producer of plastics, chemicals and innovative plastics. Main products and their manufacturing plants in Europe are given in the table below:

<table>
<tr><td rowspan="5">Chemicals & Intermediates</td><td>Olefins</td><td rowspan="7">Geleen (The Netherlands),
Teesside (United Kingdom)
Gelsenkirchen (Germany)</td></tr>
<tr><td>Aromatics and gasoline products</td></tr>
<tr><td>Fibre intermediates</td></tr>
<tr><td>Industrial gases</td></tr>
<tr><td>Linear alpha olefins</td></tr>
<tr><td rowspan="2">Plastics</td><td>Polyolefins</td></tr>
<tr><td>PVC, Polyester and PS</td></tr>
<tr><td rowspan="3">Innovative Plastics</td><td>Resins & LNP Compounds</td><td rowspan="3">Bergen Op Zoom, Enkhuizen and Raamsdonksveer (Netherlands), Grangemouth and Thornaby (UK), Fosses (France), Pontirolo and Olgiate Olona (Italy), Cartagena (Spain) and Wiener Neustadt (Austria)</td></tr>
<tr><td>Specialty Film & Sheet</td></tr>
<tr><td>Polymershapes</td></tr>
</table>

Table 1.1: Products and Manufacturing Facilities of SABIC

Only chemicals and intermediates from the table above are taken into account in this project, and other products are excluded, because the project will be carried out within the Supply Chain Sourcing and Contracting sub department under Chemicals Strategic Business Unit. The full organization chart and the position of the department are given in Appendix III.

1.2.3. Supply Chain Structure

Chemicals and intermediates are produced in the manufacturing facilities of SABIC which operate steam crackers. The production process produces outputs in a stochastic yield (i.e. Output of the cracking process depends on different factors and results in different product output rates.). Feedstocks of the crackers are LPG, naphtha and gasoil; which are produced by refining oil. A clear representation of the production flow that chemicals follow is given in the Figure 1.1.

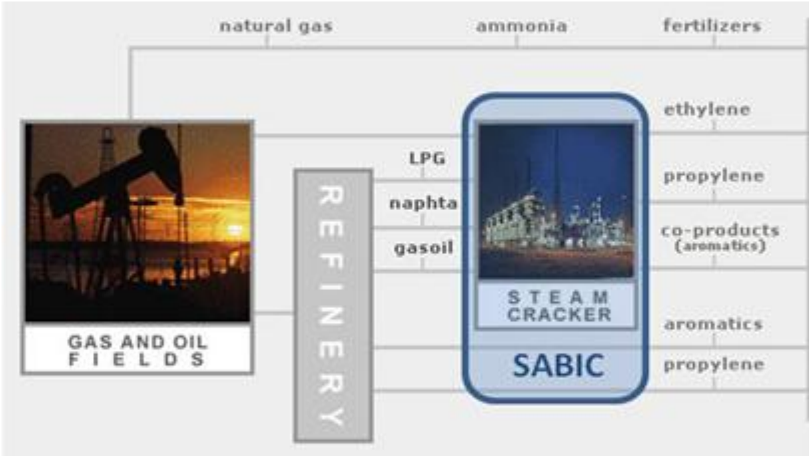

Figure 1.1: Production Flow of Chemicals and Plastics

SABIC also operates 10 logistical hubs (storage points) in the Netherlands, the United Kingdom, Belgium, Italy, Spain, Sweden, Poland, and Malta. "These serve to optimize the supply chain and secure an uninterrupted flow of products produced in Saudi Arabia and marketed in Europe" (SABIC, 2008). Also, there are storage tanks at the end of the production lines, inside the chemical plants.

The supply chain structure of SABIC for chemicals, related only with the sales in Europe is given in the figure below:

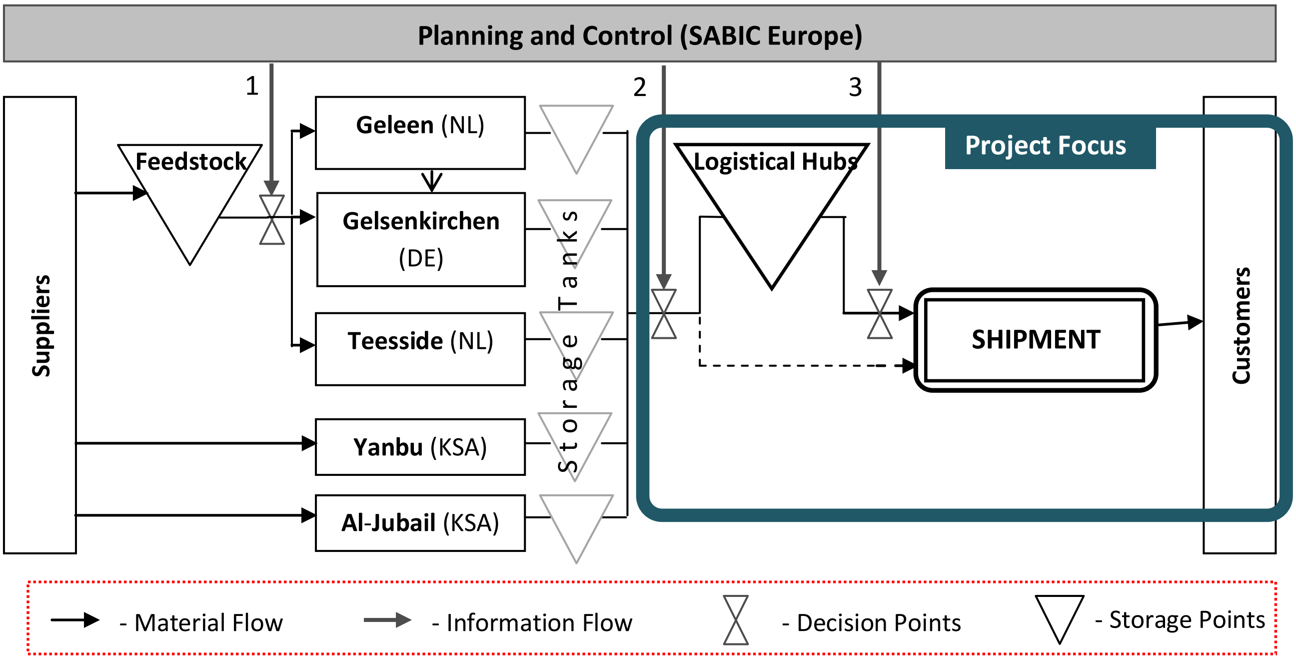

Figure 1.2: SABIC's Supply Chain Structure

As shown in the figure above, raw materials of the manufacturing facilities in Europe are supplied and stored in the Feedstock, at the Port of Antwerp and Rotterdam. Feedstock is then sent to the facilities for production and resulting end-products are at first stores in the storage tanks, and some are sent to the logistical hubs. From the two production sites in Saudi Arabia, additional chemicals are procured in order to satisfy the demand. When there is a customer demand, shipment is done from the logistical hubs, or directly from the storage tanks in the manufacturing plants.

Figure 1.2 depicts three decision points: the first one (Decision point 1) is for the procurement of raw materials (such as naphtha) into the manufacturing facilities from the feedstock. The second (Decision point 2) is for the transportation of end products to either directly to the customer or to the logistical hubs. Third decision point (Decision point 3) represents the shipment made to the customer from the logistical hubs.

Another important point to mention about SABIC's supply chain structure is that some chemical products are used as an input for the production of plastics, generally on the same production site. However there is an exception, as can be seen in Figure 1.2, ethylene is sent from Geleen to Gelsenkirchen via pipelines to feed plastics production.

This project focuses on the delivery process of chemicals and intermediates within Europe, therefore does not take into account the former elements of the supply chain. Manufacturing is not under concern, and product availability in logistical hubs is not the primary focus. Also, all logistics activities are outsourced to logistics service providers, thus SABIC cannot control all parts of the supply chain processes. Therefore this research involves third party logistics and the contractual relation of the outsourcer with them.

1.3. Research Area

Outsourcing of logistical services has grown dramatically in recent years almost at an exponential rate (Briggs et al., 2009). In 2007, the global logistics market had a size of $804.6 billion and by 2012 it is estimated to increase 29.3% to a size of $1040.6 billion (Walsh,2009). In Europe, third party logistics industry generated $139 billion revenue during 2006 (Transport, 2007). As the industry grows, solutions provided by these companies and relationships with the outsourcers become more complicated (Selviaridis and Spring, 2007).

In parallel to this, the recent highly competitive markets require cost reductions and continuously satisfying customers, therefore productivity in operations. With the employment of just-in-time operations to cope with the competitive market, lead times are being shortened. This objective of shortening lead times is also crucial for the companies without just-in-time operations, for the necessity of minimizing stock-out probability and the objective of decreasing working capital with lower stock levels. Besides satisfying the customer's required lead time, shutting down the continuous manufacturing flows (e.g. in chemical industry) because of the delays in procurement of raw materials comes with a great cost.

Combining the abovementioned advancements in the markets, it is possible to say that efficiency and success of outsourced logistics operations are critical for the customer satisfaction. In order to reach the desired customer service levels, relationships with third party logistics service providers should be managed and controlled and their operations should be monitored and intervened if necessary.

Also, in a highly competitive market like the chemicals market, where market sets the prices, service quality gains a greater importance, which is the trigger of customer satisfaction. As explained before, the service quality, in our case delivery performance, should be improved to remain in the competition.

This research contributes to this area in terms of monitoring and improvement of LSP's performance, to increase customer satisfaction, from a relationship management perspective.

CHAPTER 2: PROJECT DESIGN

This chapter explains the design of this research in detail, with a small introduction to the problem setting, initial problem signals, how a problem definition is constructed based on these signals, what the research questions are, and with what kind of a methodology we could approach the problem.

2.1. Problem Setting

Chemical industry differs from other industries in terms of security concerns and regulations for the transportation process. Transportation is managed through a fair number of quality and security checks of materials and transportation vehicles; and chemicals can be transported via all transportation modes (Truck, train, ship, barge, air and pipes), however air transportation is not preferred by SABIC because of economical and environmental reasons. Besides, since vehicles should be specially designed to be able to fit the requirements to transport hazardous chemical products, vehicle arrangements require large investment. Because of the mentioned reasons; specialized third party logistics providers undertake the chemical transportation, i.e. most chemical companies outsource their transportation.

Transportation modes differ in many aspects, especially in costs. A modified version of the comparison of different modes done by Christiansen et al., (2004) is given in Table 2.1. Cost characteristic (as a row), barge and pipeline modes (as columns) are added to the initial table; information are obtained by interviews.

		Mode				
		Truck	**Train**	**Ship (Vessel)**	**Barge**	**Pipeline**
Characteristics	**Cost**	Highest	High	Low	Moderate	Lowest
	Fleet variety	Small	Small	Large	Large	N/A
	Trip length	Hours/Days	Days	Days/weeks	Days	Hours
	Schedule (time) preciseness	High	Very low	Low	Low	High
	Operational uncertainty	Smaller	Small	Larger	Large	Smallest

Table 2.1: Comparison of Transportation Means

The table above helps to explain the reasons for the preference of a modality over the other and general causes of problems. Cost row represents the cost of transportation per unit volume; trip length is the average expected time during which the transportation takes place; fleet variety means the number of types of different vehicles for a modality; schedule preciseness is the ability to conform to committed dates; and operational uncertainty is the occurrence frequency of unexpected events hampering the transportation.

In SABIC, when a customer is to be contracted, the choice of transportation mode is given depending on transportation cost and reachability. Since most of the deliveries are done to customers with long-term (at least 1-year) contracts, shipment schedules can be arranged to respond to long transportation lead times. In shipping and barging, LSPs are contracted by the help of brokers mediating this relationship. It is also worthy to note that SABIC rarely uses intermodal transportation in exceptional conditions, *all shipments are planned to be done via a single type of modality*.

2.2. Initial Problem Signals

At first when SABIC was contacted, the complaints were stated as:

- On-time delivery performances of 3PL service providers are lower than desired.
- Especially for sea and rail transportation, the delivery lead times are very variable and uncertain, planned loading times and transportation durations have a possibility of being changed.
- Customer's flexibility in terms of delivery time is not always applicable for the compensation of occurring uncertainty, thus customer dissatisfaction is inevitable for late deliveries.
- The definition of delivery performance is sometimes confusing and may not ensure customer satisfaction.
- For some LSPs, delivery performance cannot be measured.

The problem signals given above are broad statements of raw perceptions which need to be analyzed in depth. In other words, the problems need to be delineated to determine the scope of this project.

2.3. Problem Delineation and Project Scope

In order to capture the problems correctly, by the help of interviews within SABIC and with some LSPs, material and information flows for each modality were examined separately at a high level. Besides the flows, delivery performance definitions for each modality and current performance levels according to the measures being used were obtained.

The revealed problems and current performance measures for different modalities are as given below:

Transportation Mode	*Current Performance Measure*	*Problems*
Truck	= # of orders delivered to customer before committed delivery date /Total # of orders	No significant problems yielding low delivery performance
Ship	= # orders loaded within the committed loading laycan / Total # of orders	- Perception confusion about delivery performance definition (Laycan conformity vs. Customer satisfaction) - Long voyages with unpredictable times because of uncertainties - Late (or at the very end of the laycan) arrival of the ship to the port - Probability of not leaving the port (because of weather conditions or congestion)
Barge	= # of orders delivered to customer before committed delivery date / Total # of orders	- Late arrival of barges to the loading location - Demurrage (Barges waiting at the customer site for the tank to be emptied)
Train	= # of orders delivered to customer before the committed date of delivery / Total # of orders	- Not receiving the delivery information from neither the LSPs nor the customers. - Unreliability of monthly delivery reports taken from LSPs
Pipeline	= # of orders released to the pipe on agreed date / Total # of orders	- Pressure inside the pipes may not allow the release of the required amount of gas.

Table 2.2: Delivery Performance Measures and Problems of Different Modalities

To summarize the utilized performance measures given in Table 2.2; it can be said that a successful on-time delivery condition is satisfied when the vehicle(s) arrives on the agreed day, for truck, barge and train. However for ships (words "ship" and "vessel" will be used interchangeably throughout the report), the delivery is on-time when loading is finished within the finally agreed laycan. Note that laycan indicates a (mostly 3-day) time interval within which the ship should arrive at the port and get loaded.

In addition to the above problems; one of the most important matters was that the perceived delivery performances (especially for ship and rail) were much lower than calculated, supported by the negative customer feedbacks received in the form of customer complaints. As a matter of course, this was not visible in the material and information flows; rather, it was discovered by the interviews.

Although there are significant problems for ships, barges and trains, it is not possible to focus on all of them because of the time constraint of the project. For that reason, to narrow down the project scope, yearly aggregate volumes that are transported by each mean, and the cost that are paid to LSPs for each of them are examined to see which modalities are more critical in the whole planned deliveries. Pipeline transportation is excluded from this analysis because the role of the LSP is negligible, on-time delivery is directly dependent on product availability, and the data were not available.

Percentage of volumes and costs are represented in the following charts:

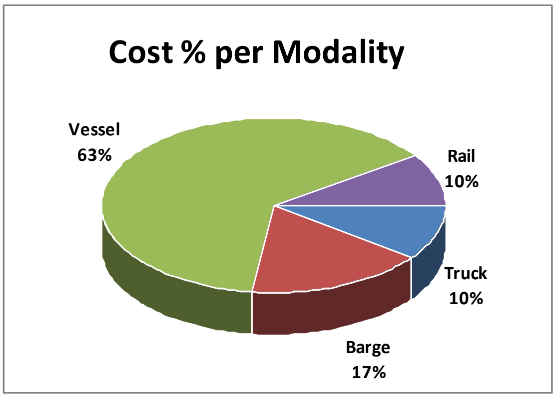

Figure 2.1: 2009 Cost % for Modalities

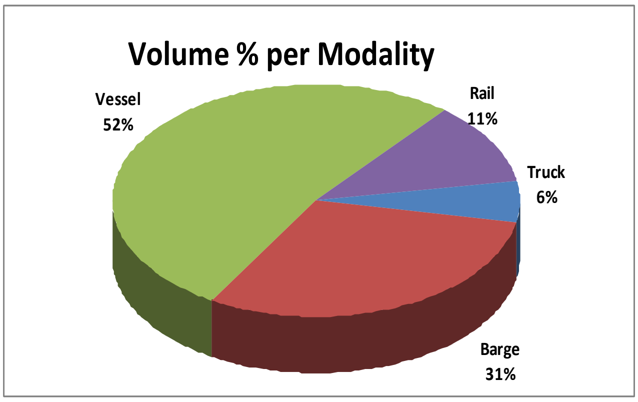

Figure 2.2: 2009 Volume % for Modalities

Although rail has the lowest performance, most of the transportation is done by ships and barges, and they constitute a considerable amount of all yearly transportation costs. To make a final decision, a Pareto analysis is conducted with a new parameter which is defined for each modality as: *(1 - Delivery performance) * (Volume Carried).* Although it was stated that there are problems in delivery performance measurement for some modes, at this point they are assumed to be credible representatives of the current situation.

This parameter represents the percentage of late delivered total volume for each modality, as an approximation to the delivery performance in terms of volume, instead of orders, which was assumed previously. Also, it helps to see the combined effect of modalities' low delivery performance and their importance for the company. The resulting graph is given as a Pareto Chart in Figure 2.3.

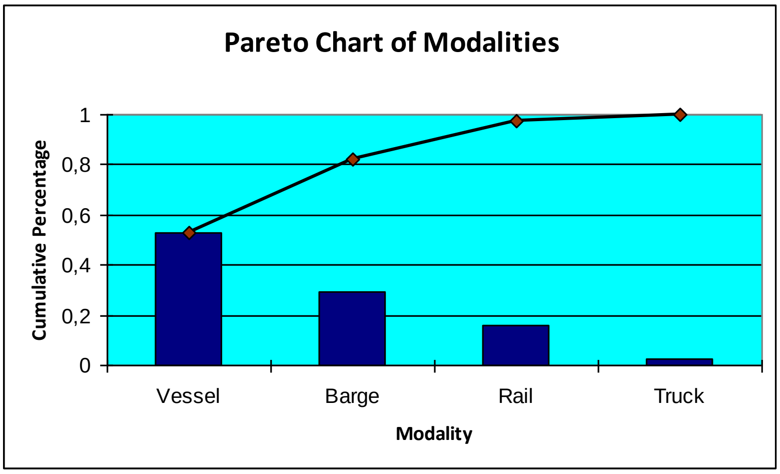

Figure 2.3: Pareto Chart

From the chart, it can be seen that 82% of the total volume delivered late is faced within ship and barge transportation. These two modalities rule out the other two, by the 80-20 rule of Pareto analysis. Although current delivery performances were not accurate, and shipping performance should be lower than the given value; it still constitutes the major part of the low delivery performance. Therefore, the findings do not violate the assumption.

As a result, it is decided to focus only on shipping and barging.

2.4. Problem Definition

Now that the scope of research is narrowed down to ships and barges, important problems about these modalities can be stated in detail as follows:

- There is confusion about delivery performance when the agreement includes a laycan time window. For SABIC, after the loading laycan is satisfied, delivery is assumed to be successful in terms of contracted conditions. This is a regular application regarding the nature of the shipping industry. However, because of the weather conditions and other reasons, the ship can arrive later than expected and customer may not be satisfied according to their expectations about the delivery. Therefore, performance indicators do not reflect both LSP's total work and satisfaction of the customer.
- Operational uncertainties (such as loading problems, device breakdowns, late arrival of ships, tank cleaning and surveying, long-lasting voyages) and uncontrollable uncertainties (such as weather conditions, berth occupancy, frozen waters, waiting in the queue at the ports and canals) are not taken into account when agreeing with a customer for a ship delivery, because LSP is only obliged to be on-time for loading. When either of these uncertainties happens, the risk of late arrival to the customer increases.
- Ships of LSPs' arrival at the ports can be late within the agreed laycan, or even after the laycan. The promised loading laycans are requested by the customer, only the customer has an expected time interval for the delivery of its order. Lateness of the ship to the loading port significantly increases the risk of late arrival to the customer, considering the operational and uncontrollable uncertainties.
- Barges have the same problem of late arrival like the ships. However, the difference is that there are no laycans, barges have to arrive within smaller time intervals (i.e. a day). When a barge

arrives to the loading location, by adding the loading and travel time, an ETA is indicated to the customer. Although customers generally agree with updated times, it results in an undesired situation for the customer.

- Like the weather conditions that apply for shipping, barges have the same uncontrollable uncertainties such as congestions at the canal locks, frozen canals and low water levels at rivers. Canal locks can operate for one barge only; and since no scheduling of ships is done at the locks, barges may have to wait for their turn. In addition to that; in winter when canals are frozen, the barges can be stuck to wait for the ice breakers so that they can continue their trips. More importantly, water levels in the rivers can be low depending on the climate, which does not allow barges to travel.

The abovementioned problems are depicted in a cause-and-effect diagram. The diagram gathers the problems in three categories: low LSP performance, poor performance measurement and uncontrollable uncertainties; which result in low perceived delivery performance. The cause-and-effect diagram representing the problem situation for decided modalities is given in the figure below:

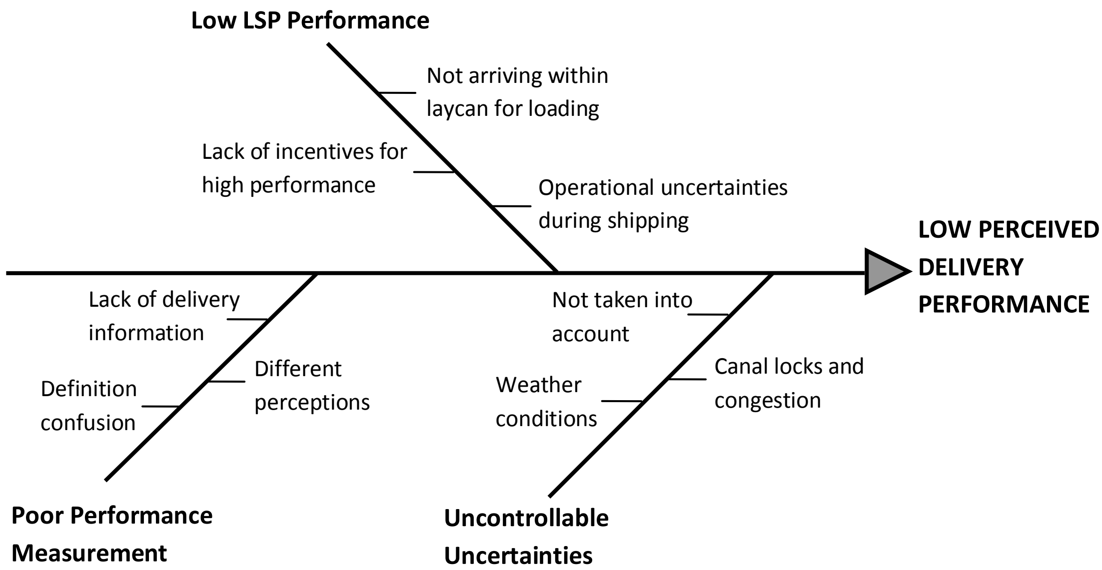

Figure 2.4: Cause & Effect Diagram

Summarizing the abovementioned issues, the problem can be stated as follows:

SABIC does not have robust delivery performance measures for some modalities, especially the performance of shipping is not well-measured to successfully reflect customer satisfaction. More importantly, uncontrollable uncertainties like weather, port availability, congestion etc. are not taken into account while contracting and delivery scheduling. Moreover, to prevent low delivery performances, third party LSPs' performances are not regulated by any means.

2.5. Research Questions

From the problem statement specified, the following research questions are generated:

1) How can delivery performance be measured better for the transportation provided by 3PL?
   a) What is the difference between perceptions of different parties (customer, supplier and LSP) involved in terms of delivery performance?
   b) How good are the current delivery performances for the modalities?
   c) Which other metrics reflect the delivery performance better?
2) What are the reasons that hinder on-time deliveries? How do they affect the delivery process?
   a) Where are the performance inhibitors within the delivery process? Where do the bottlenecks exist?
   b) What are the criticalities of detected performance inhibitors?
   c) What are the contributions of parties to the low performance?
3) What is the role of contracting in the performance of the delivery process?
   a) What are the stimulative factors of performance in LSP contracts?
   b) What are the opportunities in these contracts that yield higher delivery performance?

2.6. Project Methodology

As the research questions indicate, this project is in three directions; the first one is about the measurement and identification of the performance measures; the second one is about discovering delays and their importance, and the third is about discovering improvement opportunities and role of contracts in improvement.

The literature has important indications about these issues. There are useful methods for performance indicator identification and performance measurement. In addition to these, for the purpose of improvement, contents of the contracts are shown to be effective for regulating the behavior of the contracted parties. Especially, having performance levels, incentives and penalties in the contracts are found to be essential.

For the methodology of project approach, some steps of the reflective and regulative cycles of Van Aken (2007) and Van Strien (1997) for research design will be followed. The cycles are represented in the figure below:

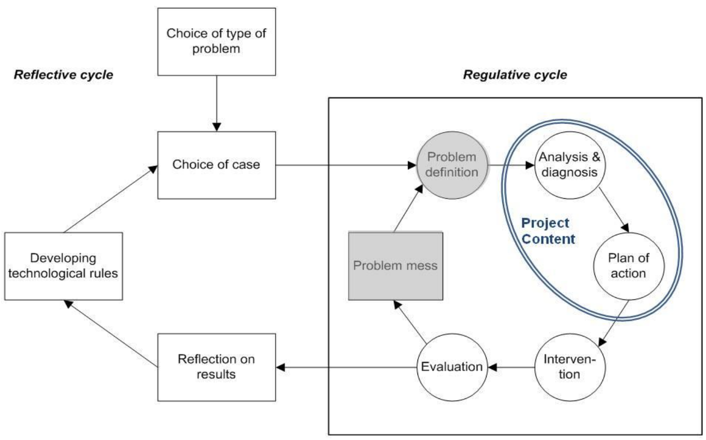

Figure 2.5: Research Design Cycle

The part of the Reflective cycle which is excluded from the Regulative cycle is under the control of the company alone, but Regulative cycle covers the regulation of the problem within a project. Regulative cycle commences with a *problem definition* derived out of the *problem mess*. The *analysis and diagnosis* step is the part of the project in which quantitative and qualitative research methods will be used. *Plan of action* step represents the design of solutions for the problem. The *intervention* phase is the implementation of the developed design, and *evaluation* is done to check the effectiveness of solutions.

A problem definition is already extracted from the problem mess by the preparation phase and until this point (Thus, they are indicated in grey). The remaining steps to apply for whole project are analysis and diagnostics of the problem situation, then plan of action to suggest improvements. Intervention and evaluation of the planned improvements will not be applied because of the time constraint of the project.

The methodology of the project was built in such a way that it reflects the findings in the literature, and tries to capture the research questions posed.

For the design of the better performance measures, a part of the framework provided by Bourne et al. (2000) is utilized. The steps of this framework which are taken during this project are:

- identifying key objectives
- designing measures
- initial data collection and measurement
- reflection

At first, interviews were conducted with employees in SABIC and some LSPs, in order to obtain performance-related expectations and priorities of these parties. These elements are considered not only under time dimension; but also under financial, informative and flexibility dimensions as proposed by Rafele (2004). In parallel, process maps will be drawn and critical processes will be discovered with the help of customer complaints, KPI (Key Performance Indicator) reports and shipment files. The findings about delays and the process flows reflects on the measures to be defined. Then, potential key performance indicators are defined, selected and measured and insights will be developed.

Besides their contribution to the KPI development process, delay analysis is also useful to detect improvement points, opportunities and low-hanging fruits, if there are any.

For the contracting scheme; initially, company policies and objectives were confirmed to be suitable for regulation through contracts. After confirmation, problematic processes and their occurrence frequencies (which are revealed before) help deciding on regulatable behaviors of LSPs. Finally, stemming from the behaviors of the LSPs which can be regulated, a contracting game with an incentive scheme is introduced. This game utilizes a performance-based logistics contracting model, which takes into account the profit-maximizing behavior of both parties.

The complete methodology of the project is represented in Appendix IV.

CHAPTER 3: PROCESS AND DELAY ANALYSIS

In this chapter, data sources are presented, shipment ordering and shipment processes for ships and barges are explained, and discovered delay reasons are introduced. Process flows were drawn to elicit the shipping process timeline, to spot the places of problems (problematic processes), and to see the interactions between parties. Delay analysis is done using the available and obtained data. Important findings of the delay analysis for shipping and barging are indicated separately.

This chapter is organized as follows: In the first section, data sources are presented; then in the later sections, process flows are explained and delay frequencies and patterns are represented separately for shipping and barging.

3.1. Data Collection

In order to analyze further the shipping and barging processes and the delays throughout these processes, data and information were needed. Qualitative information about current delays, frequently occurring problems, data availability and planning considerations were gained via interviews with LSPs and relevant people in SABIC. Interviews within SABIC were low structured, and did not have standardized questions. However, interviews with LSPs needed to be standardized, in order to get answers in the same dimensions.

Two interviews were conducted in total with LSPs for vessel shipments. One of them was with Naviglobe (ship owner), and the other was with Broere Essberger (ship owner) and Braemar Seascope (ship broker) together. In a general sense, the questions aimed to obtain information about:

- Information registry and sharing,
- Frequent causes of the delays,
- Scheduling method and behavior.

Complete results of these interviews are given in Appendix V; however, the findings will be mentioned throughout the report.

Interviews within SABIC and with LSPs helped to depict the whole shipment processes for ships and barges.

Most importantly, it was found that detailed data exists for every shipment which provides sufficient input for the analysis. Ship masters are obliged to keep a document called “Statement of Facts” for every shipment, which serves as a log file of the loading process. This document contains temporal data (what was done when), all delays and technical reports about the loaded material. Reported delay information and states of the ship throughout the timeline were recorded using these documents.

Ship brokers deliver selected information in these documents as a summary, in KPI reports given on a monthly basis. These KPI reports are kept for COA contracts, not for Spot shipments or Time Charters (See Appendix II for the differences between these types of contracts). The main aims of these reports are:

- keeping monthly track of delivery performance for each ship owner
- seeing demurrage and other costs payable to the ship owners
- keeping record of Contracted vs. Actual loading figures
- keeping other records of the shipments to serve analytical purposes as historical data
- observing problems which occurred during the shipment process

However, these reports do not provide a full-scale vision of every shipment, including delay information. Besides, temporal data are not recorded by most of the brokers. Because of that reason, in order to observe and track the states of all shipments, and to calculate the frequencies of occurring delays; individual Statements of Facts needed to be analyzed. For ships on time charter, all relevant data were obtained also from the statements of facts.

The analysis for shipping was restricted to the shipments of 2009 only, because of the time constraint of the project. In total, 433 shipments were included.

For barging, no interviews were conducted with LSPs, because of the operational similarities. Unfortunately; any detailed document such as statement of facts was not available or reachable; therefore only data source was the monthly KPI reports prepared for barging. Those KPI reports are very similar to shipping KPI reports in terms of content, but there are extra information such as the requested vs. actual loading and discharging dates, which were helpful in the analyses.

Barging shipment data of 2008, 2009 and the first quarter of 2010 were included in the analysis together. In total, 1222 shipments were used.

3.2. Shipping Process Flow

The whole shipment consists of two distinct processes: shipment ordering process (before the order is confirmed) and shipping process (after the order is confirmed). The first part was deemed important because the laycans are frequently changed or updated for a single shipment according to the availability of the ship's schedule, product availability at SABIC and previous position of the ship. These kinds of frequent changes results in *customer dissatisfaction*, because of the resulting extra effort of the customer on the modification of production, material and inventory planning.

The second part, shipping process, is also very crucial to analyze in order to detect problematic processes and responsible parties of those problematic processes.

3.2.1. Shipment Ordering Process Flow

Ordering of the shipment from the LSP according to the laycan requested by the customer is done as follows:

- Customer requests a laycan for loading, to be loaded from and discharged to specified ports, 2-5 weeks in advance of the requested loading dates.
- SABIC checks inventory levels for product availability at the loading hub at the requested laycan; and if the product will be available, SABIC contacts LSP for the availability of its schedule.
- An alternative laycan is offered to the customer, if the requested laycan is not appropriate for either of the parties.

– If an alternative laycan is offered, customer checks inventory levels and sees if the offered laycan is applicable.
– If not, with an ongoing communication cycle, a final laycan is agreed on by all parties.
– If any delays occur during the previous voyages of the related ship after the laycan agreement is done, an update of the laycan may be requested by the LSP. In that case, SABIC and customer reacts on the applicability of the update, and the laycan is modified according to the new conditions.

The processes explained above are depicted with a process flow diagram, given in Appendix VI.

3.2.2. Shipment Process Flow

Shipping process starts after the order confirmation and ends with the delivery of products to the customer. The process in-between is as follows:

– Previous shipments of the agreed ship are monitored until the laycan.
– If any delay or problem occurs which will result in a late arrival for the concerned shipment, a change in the laycan is requested by the LSP. The requested laycan should then be agreed by all parties.
– When it is the shipment time, the ship arrives to the port and gets instructions from the shore (SABIC, port authorities and other tank operators) about when and where to berth.
– If the berth is available, the ship berths and the surveyor starts to survey the ship.
– If the ship is approved by the surveyor and is ready to be loaded, the loading starts.
– After loading is completed, ship master receives the bill of lading and leaves the port.
– If there are any delays during the above stated processes which will result in a significant lateness, LSP informs SABIC about the delays and this information is then transferred to the customer.
– During the voyage, LSP is obliged to send estimated time of arrival (ETA) information periodically.
– When the ship arrives to the unloading site; if the customer's berth is available, she berths and discharges the products.
– Once the discharging is finished, LSP sends delivery information to SABIC.

The process is depicted as given in Appendix VII.

Derived from the process flow and by the help of interviews; the shipping process timeline is drawn and responsibilities of the parties for the process lengths are shown as given in the figure below:

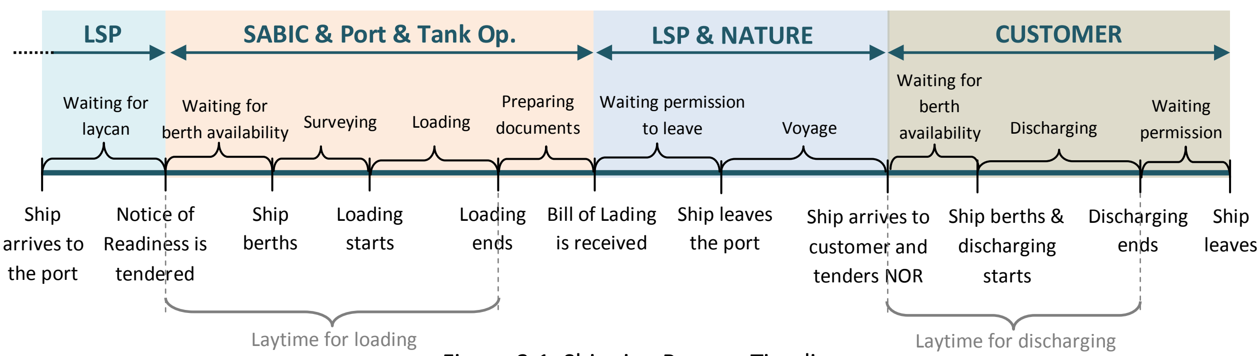

Figure 3.1: Shipping Process Timeline

As can be seen in Figure 3.1, LSP is responsible for the ship's arrival time to the loading port with respect to the laycan, and the voyage length as a result of ship's speed. SABIC is responsible for the loading processes, because it controls the shore operations. Customer is responsible for all discharging processes; however they do not affect the satisfaction from the delivery process. Also nature plays an important role in the timeliness of the shipment, by affecting weather conditions.

3.3. Shipping Delay Frequencies and Patterns

In order to conduct a comprehensive analysis of the vessel shipments of 2009, available information were categorized and cross-tabulated. The Excel file, into which the information was recorded, included around 50 columns under the categories:

- General Information
- Temporal Information about Loading, Voyage and Discharging
- Performance Measures and Analysis
- Delay Information

The cross-tabulation of columns helped consider important relationships which might indicate a correlation, and not skip anything. In total, 73 combinations were selected according to their coherence with this project's objectives and SABIC's requirements, and they were analyzed.

Not all analyses brought an interesting finding; thus, only prominent ones will be explained here.

Laycan Changes:

The fact that frequent laycan changes result in customer dissatisfaction raised the question: "How frequently do the laycans change?" In KPI reports and shipment correspondence, those changes can be observed, and this way they were recorded. The data showed that 16.7% of the shipments in 2009 faced at least one change in their laycans. Shipments of some logistics providers tend to face this change more frequently.

Laycan changes are highly dependent on the product availability at the shipment day, berth scheduling, LSP's ship scheduling and the delays occurring early during ship's previous voyages.

Ships' Arrival Behavior for Loading:

Ships have the right to arrive to the port for loading at any time within a three-day laycan. Arrival day of a ship (In first, second or third day of laycan) becomes more important considering that later arrivals increase the chance of late delivery. The pattern of arrivals, for all shipments and without time charters, is depicted in the Figure 3.2.

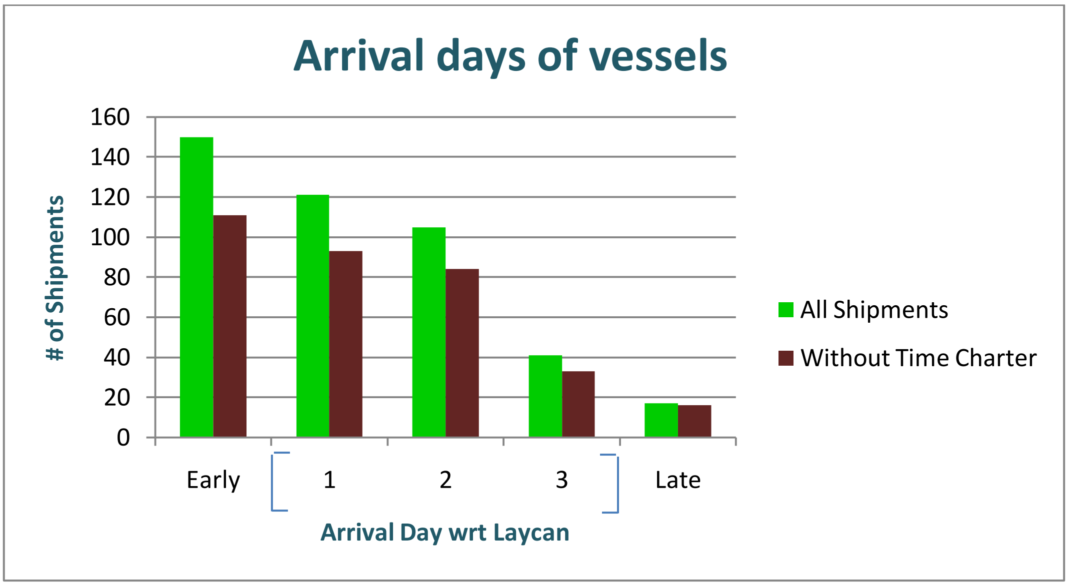

Figure 3.2: Arrival Days with respect to Laycans

The figure above shows that the accumulation is at earlier days, and this is a good indication of arrival behavior of the ships. However; it can also be observed that exclusion of time charters causes a significant drop in early arrivals. The reason behind this is that SABIC is more successful in scheduling time charters than the LSPs, i.e. ships on time charter are more controllable and thus flexible; because SABIC focuses on being on-time rather than maximizing the utilization of the ships.

Still, arrivals on 3rd day and late arrivals are not negligible. Analyses in latter sections will prove the fact that these shipments are the problematic ones.

Voyage Length:

Expected voyage lengths (transit times) are present at all three parties, as the same values, received from the same source. The expected transit time of a particular shipment directly affects the delivery expectations of the customer. Since the processes after arrival for loading are not contracted by the logistics provider, SABIC has no control over the traveling behavior of the ships, as well as the uncontrollable uncertainties such as weather conditions.

To analyze this problem; expected transit times were extracted from SAP, and actual transit times were recorded from the statements of facts. Of the shipments for which this information was available, (actual transit time)/(expected transit time) statistic was calculated for the sake of standardizing all shipments which have different transit times. This statistic was obtained for all LSPs and lanes. When all shipments are taken into account, the data fitted normal distribution which confirms that *expected transit times are good estimates*. However for some lanes, voyages were found to last longer more frequently. The reason of this might simply be that the expected transit times are not realistic. But more probably, there is a repeating problem about the ship's voyages.

Time Spent for Loading Processes:

Starting from the tendering of Notice of Readiness, and ending with the ship starting her voyage; the processes of loading were gathered under three time portions, named: "NOR to Berth", "Berth to Loading End" and "Loading end to Sail". This distinction was helpful because the effects of different delays change in magnitude. These times were averaged for all shipments, and also excluding early arrivals. Resulting shape is depicted in Figure 3.3.

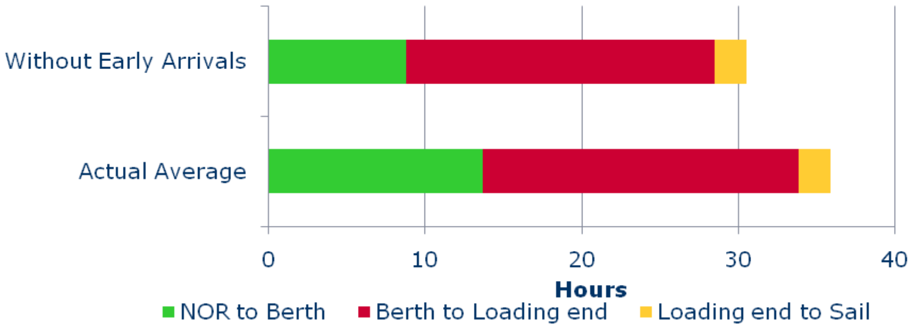

Figure 3.3: Loading Process Time Distinction

38% of the total time spent at the loading port is before the start of loading. This percent corresponds to more than 13 hours, and it is unnecessarily long considering that one hour is enough for a ship to start loading. The reasons for this will be explained later.

"Loading end to Sail" time interval is the least problematic one; because after loading is finished, delays occur rarely and time is relatively shorter.

Another good implication of the above figure is that the exclusion of early arrivals resulted in a 4-hour decrease in "NOR to Berth" time. This is because the shore or berth is not ready to commence loading when the ship arrives early, i.e. early arriving only causes longer waiting times.

In addition to these, waiting times were calculated for different load ports. For some busy ports or busy berths inside ports such as Malta and Rotterdam, this time is found to be much greater.

<u>*Delays:*</u>

As stated before, ship masters have to keep a log file for loading, called "statement of facts". These documents not only have the temporal status data, but also delays and their durations are recorded during the shipment. Delay information was obtained from those files and also late arrival of ships was added as a pre-occurred delay. The most frequent delay reasons are found to be:

- *Awaiting instructions*: Waiting for SABIC's or other tank operators' shore operatives to give instructions about where and when to berth.
- *Bad weather*: Waiting for weather conditions to be suitable for loading or travelling. (Information about weather delays during voyage were not available, thus they are included in Long Voyage).
- *Berth unavailability*: Waiting for berth to be available, i.e. waiting for the previous vessel, which is being loaded at that time, to leave the berth.
- *Congestion*: Waiting for the permission of port authorities to berth, when the port is congested.
- *Late arrival*: Waiting for the ship to arrive, the ones arriving later than the end of laycan.
- *Loading problem*: Waiting for a remedy to resume loading, which is halted by a problem such as pump breakdowns or other technical faults caused by the loading equipment.
- *Long voyage*: Transit times from load port to discharge port which are longer than the expected transit time.

- *Product unavailability*: Waiting for the product to be present in the tank.
- *Shore unreadiness*: Waiting for the shore to be ready to commence loading.
- *Waiting surveyor*: Waiting for the surveyor, who will survey the tanks before the product is loaded, to arrive at the loading berth.
- *Other*: Waiting for other delays which occurred only once in 2009. These delays mostly occur during loading and mostly LSP's are responsible for them.

The statistics revealed that **53.12%** of all shipments of 2009 face at least one delay. Some shipments face more than one, therefore the frequencies of these delays are collected as their number of occurrences. Their frequencies are given in Figure 3.4.

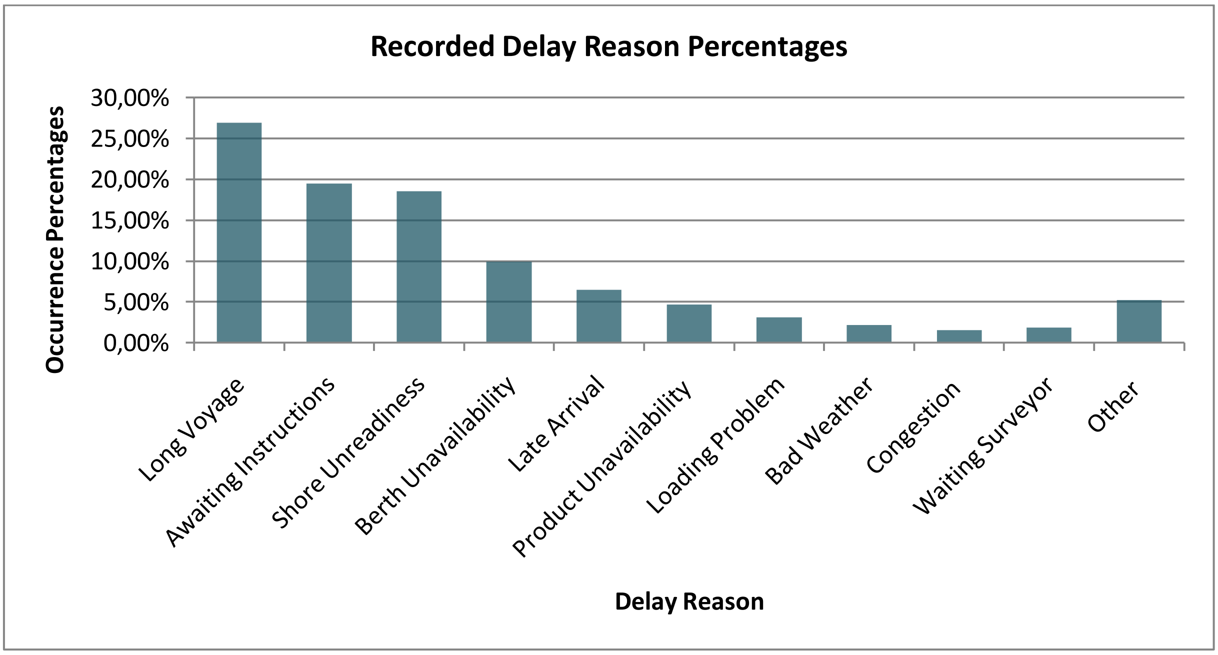

Figure 3.4: Shipping Delay Reason Percentages

As seen in the above figure; the three most frequent delays are "Long Voyage", "Awaiting Instructions" and "Shore Unreadiness".

Occurrence positions of the delays are given in Appendix IX. Percentages of the delays given in Figure 3.5 were positioned on the timeline according to their occurrence places as follows:

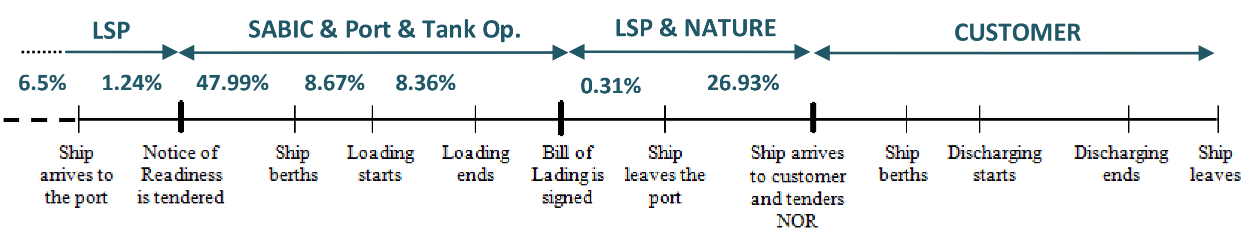

Figure 3.5: Shipping Delay Reason Positions

This figure shows that, most (47.99%) of the delays are caused by SABIC, port authorities and other tank operators which performs the loading in the name of SABIC, after tendering of Notice of Readiness until the ship berths. Delaying effects of LSPs and natural uncertainties are relatively lower with 26.93% during the voyage of the ship. Although the responsibilities of the parties are distinguished as given in Figure 3.5, there were exceptional situations in the examined data where Nature causes delays during loading (in the interval of SABIC, Port and Tank operators). When these exceptional situations are separated and the responsibilities of Nature and LSP during voyage are split up, nominal responsibility percentages of different parties were obtained. Figure 3.6 below shows the distribution of responsibilities to the parties.

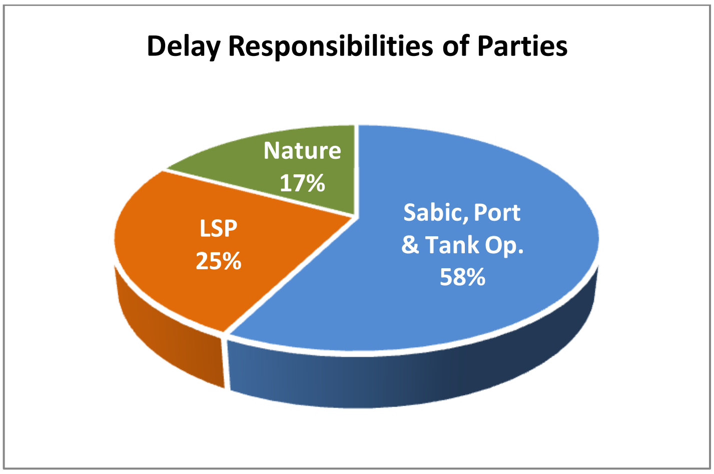

Figure 3.6: Shipping Delay Responsibilities

Although the analysis shows that most of the delays are caused by SABIC, port or tank operators, their effects were unknown. Analysis revealed that not all of the delays cause late arrival to the customer site, such as “Awaiting Instructions”. That is because 57.14% of “Awaiting Instructions” and 50% of “Shore Unreadiness” are faced when the ship arrives early, or in the 1st day of the laycan. Thus, it means that not all delays result in late deliveries, some of them are more critical than the others. To detect these critical delays, late delivered cases needed to be investigated separately. However, since the contracts with LSPs and customers include only the agreement on the loading time, there is no measure to detect late deliveries. For that purpose, new performance measures are required to be defined. Identification of new performance measures and further delay analysis is done in Chapter 4.

Other Findings:

Besides the abovementioned important findings, there were also other relatively less important points that needed attention. These findings were:

- Majority of product unavailability had occurred for two products (Ethylene and Cyclohexane). However, this is caused either by early arrivals of the ships (when there is no product) or by probability. Even if the probability of a product of not being available is small, large number of shipments makes it visible. Indeed, these are the main products which together constitute 46.5% of all sea shipments.
- Even though freezing products and sea passages were deemed important by the logistics providers as the affect of weather conditions, there was no seasonality on performances. All metrics showed a random pattern, which were not significantly lower in winter period.
- Performance metrics were measured for the shipments which arrived for loading in different days of the laycan. It was seen that long voyage percentages drop as the arrival day

increases. Explanation of this is that ships tend to travel faster when they are late for loading. If they arrive early and set off for the customer earlier than expected, they tend to travel slower.

3.4. Barging Process Flow

Shipment ordering process of barging is almost the same as the ships'; the only difference is that instead of laycans for loading, parties agree on specified delivery dates to the customer. Although shipment process of barges is also almost the same as shipping, it differs in some aspects because that the loading and/or discharging may not be done at ports. In that case; there are jetties arranged for loading alongside the canals instead of berths. Another important difference is that; besides the agreed delivery date, there is also a requested loading date which is scheduled an expected-amount-of days before the delivery date. The complete process is given in Appendix VIII.

From the given process flow and with the help of interviews, the timeline and division of responsibilities are derived as given in the figure below:

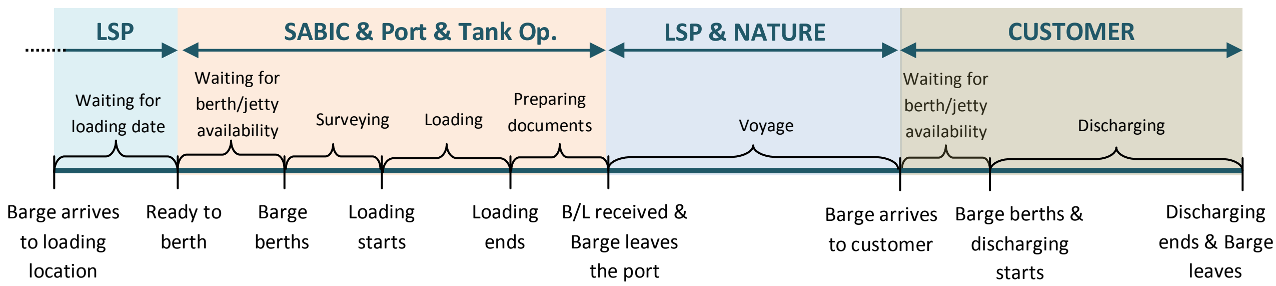

Figure 3.7: Barging Process Timeline

As can be seen in Figure 3.7, the process timeline is slightly different from and responsibilities are exactly the same as the ships' flow. Only difference is that when loading and/or discharging of the products is not done at a port, no permission is needed to leave the jetty.

3.5. Barging Delay Frequencies and Patterns

As stated before, shipment documents were not available for barges. Also, no interview was conducted with a LSP. Therefore the only data sources were the KPI reports which were analyzed thoroughly via Excel. Data were collected into an extensive Excel file, which included data in the following categories:

- General information
- Delay information
- Performance variables and measures

Imported findings are explained in detail.

On-time Performance:

For barging, two on-time performance measures are applicable for loading and discharging. On-time delivery performance is 86.1% according to the calculations and 92.23% according to the LSPs, which are both lower than the target of 2010, 95%.

On the other hand, on-time loading in the requested loading time is 79.6%. This statistics is very low; however it does not predict late deliveries alone.

Delays:

Not all LSPs report the reasons of delays for late deliveries in the KPI reports, but still the delay information in complete KPI reports are suitable for analysis. However, the numbers are not a perfect representative of reality because of two reasons: hidden delay information which is not reported may result in biased ratios, and the lack of temporal data which makes it hard to point out the magnitude of lateness.

The current data indicates the following delay reason percentages:

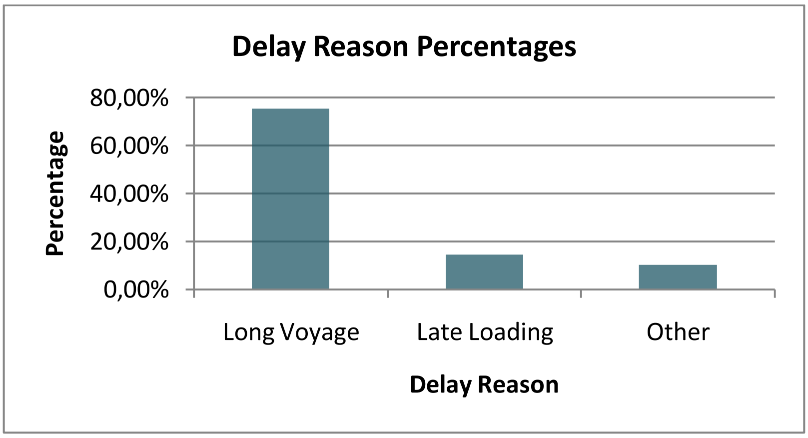

Figure 3.8: Barging Delay Reason Percentages

Other reasons include closed locks, weather problems, shore unreadiness, waiting for discharge, waiting for loading, product unavailability, long loading duration, previous SABIC voyage, shore problems and being redirected by SABIC during the voyage.

Although it was stated before that there may be odd ratios of occurrence between delays, the most frequent delay reasons are long voyages and late loading as given in Figure 3.8.

Other Findings:

Besides the abovementioned findings, there are other important points which are worthy to mention:

- Delivery performance for the shipments with long voyage is 78.13%, whereas it is 94.15% for the shipments with voyages shorter than the expected transit time. This finding indicates the fact that long voyages have a significant effect on the resulting delivery performance.
- Similar to the previous statistic; delivery performance for the shipments that were loaded late is 55.21%, whereas it is 91.69% for the shipments that were loaded on the requested loading date. It shows the high criticality of the late loadings on the resulting delivery performance.
- Long voyage percentage is 52.05% on average; however the long voyage probability changes depending on the timing of loading. For the shipments loaded on-time it is 54.01% and for the late loaded shipments it is 44.4%. A similar finding was also discovered for ships, which

was explained by speeding up during the voyage to be on-time at the discharge location, when loading finished later than expected.

- In winter period, delivery performance is lower; and this is visible in the data. The score drops to an average of 76.9% during the months November, December and January. This might be explained by the effect of weather conditions.

To sum up the analysis done in this chapter, it can be said that there are significant and influential delays which occur during different phases of the shipment process. Besides, there are patterns which provide clues for SABIC that are needed to be investigated further. In the analysis for both shipping and barging, it was concluded that not all reported delays certainly contribute to late deliveries, thus the late deliveries should be examined separately. However for shipping, there is no delivery deadline agreed between the parties, which make it difficult to detect late deliveries. In the next chapter, the approach to this problem will be explained and the analysis on late deliveries will be presented.

CHAPTER 4: KPI IDENTIFICATION AND PROMINENT DELAYS

As concluded in the previous chapter, late arrivals should be analyzed separately to detect critical delay reasons and reveal improvement opportunities. For that purpose, new KPIs are required for shipping, whereas for barging late deliveries are known.

This chapter starts with KPI identification, and briefly mentions about KPI reporting deficiencies and improvements. Then, late deliveries are analyzed for both shipping and barging and critical delays are pointed out. After that, all reported and discovered delay reasons and their root factors are analyzed by an extensive cause and effect diagram, and prominent delay reasons are determined via detailed discussions over each reason. Finally, improvement opportunities are presented and discussed briefly.

4.1. KPI Identification

Inside the current contracts signed with LSPs; delivery terms, conditions and KPIs are defined. Although there are custom-tailored clauses in the contracts depending on the parties and the outsourced service, most clauses are chosen as the universally accepted contract terms which are used for similar logistics outsourcing relationships.

On-time criteria are also included in these universally accepted clauses, and it is different from the criteria of other transportation means. In sea shipping, because of uncertainties, timing of the ships is far from being precise. These natural and stochastic uncertainties were stated before, and shipping agreements are done such that the consignee is aware of the variability in transportation durations and neither of the parties is kept responsible for these uncertainties. Satisfying these conditions; first, parties agree on the time of loading instead of a time for delivery because of the uncertainties that may occur during the voyage. Secondly, loading time is accepted as a time interval (in our case it is a 3-day laycan for loading) because of the uncertainty in the port operations.

Thus; instead of a delivery date or time, parties agree on a laycan within which the ship is obliged to arrive to the port for loading. Given as one of the problems in Chapter 3; this obligation does not reflect the perceived delivery performance, in other words, customer may not be satisfied with the delivery although it is loaded within the laycan. For that reason, new KPIs need to be identified to better reflect customer satisfaction.

This kind of a problem does not exist for barges; the KPI definitions are clear and non-problematic. Contracts with barge logistics providers include the delivery performance in terms of delivery date to the customer, a pre-determined day for discharging. Since this measure represents the whole shipment process until arrival to the customer, it is assumed to reflect customer satisfaction well. Therefore, this chapter focuses only on shipping.

4.1.1. Delays and Responsibilities

As explained in Chapter 3, parties' responsibilities for the shipment processes vary throughout the shipment timeline. Responsibilities over the processes also bring the responsibilities of the delays that occur during these processes, which were also explained in Chapter 3.

Until the tendering of Notice of Readiness for loading, only responsibility belongs to the LSP. Therefore, the current agreement on laycan for loading only covers the LSPs' success. However, other parties and uncertainties also alter the performance outcome; which is sometimes a negative result (late delivery) according to the customer's expectations although LSP conforms to the contracted on-time condition.

After the ship arrives to the port within the laycan; SABIC's, port authority's and tank operator's responsibilities are to make the berth, shore, product and surveyor available to commence loading. After the ship is loaded, during the voyage; not only the natural delays the process by difficult weather conditions, but also LSP has control over the voyage length in terms of ship's speed and route.

Therefore better KPIs should be defined to cover the whole process, since the current performance measure does not cover the whole process and responsibilities.

4.1.2. KPI Identification and Selection

Although the facts that were explained about the drawbacks of the current KPI are important; changing the contracts to agree on a delivery date, like for other transportation means, may not be acceptable for the LSPs.

Unfortunately, no measure is available to evaluate vessels' performance for arrival to customer site. However, measures can be derived using existing parameters.

The basis idea for developing the performance indicators is to check the status of the shipment at further states of the whole process. In other words, the idea is to see if the process is where it should be at a given state. This is done by the projection of the laycan dates for loading to latter states of the shipment. To remind again, aim is to shift the understanding of delivery performance from realization contracted responsibilities at load port to reflect customer satisfaction.

For the further states of the shipment process over the timeline, there should be norms which serve as measures of these milestones. Since the only agreed time norm is laycan time window; further milestones can be derived using other available data, such as pumping rates, allowed laytime, customer expectations, expected transit times and historical data.

The timeline, states and distinguished time intervals to be estimated are given in the figure below:

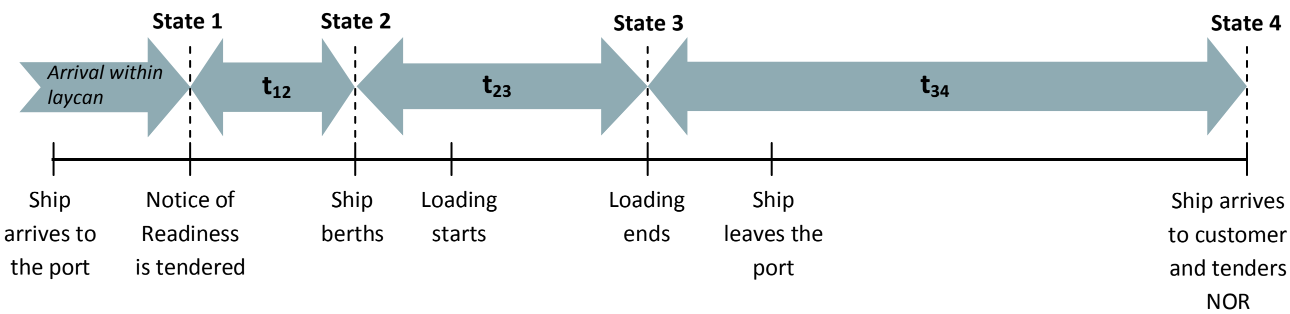

Figure 4.1: States and Time Intervals on the Shipment Timeline

Derived KPIs for given states by estimating the expected lengths of distinguished time intervals are described as follows:

State 1:

The performance measure which is currently accepted and being used in SABIC is "% of shipments tendered NOR before end of laycan" (***Measure 1***). A similar kind of measure can also be represented in a weighted fashion, using the quantities as weights. It might be reasonable to observe a weighted measurement because loaded amount is proportional to the sales figure, i.e. it reflects the satisfaction by prioritizing bigger customers. Therefore, to reflect this situation, a performance measure can be named as “% of volume belonging to the shipments whose ships tendered NOR before the end of laycan” (***Measure 2***). Although this measure would provide a weighted estimate from different point of view, SABIC prefers to utilize order shipment-based measures instead.

As explained before, changes in laycan are not confronted positively by the customers (excluding the changes which were requested by the customer). In order to reflect the effect of this dissatisfaction, initial laycan can be used and the measure can be formulated as: “% of shipments tendered NOR before end of the initially agreed laycan” (***Measure 3***). However, the disadvantage of this shipment is that it lacks to reflect important delays when there are big changes in the laycan. For example; if the laycan is moved forward by 2 days, a huge voyage delay lasting up to 2 days is not captured as a problem.

State 2:

The nominal period length t_{12} is supposed to last about an hour, however it is also dependent on the loading port (Busy ports may inevitably increase the required time to berth). Since it is a negligible time fraction in terms of days, projection is not necessary and the measure can be stated as: “% of shipments berthed before end of laycan” (***Measure 4***).

State 3:

t_{23} changes depending on the quantity to be loaded and the type of the product. The total loading time includes a constant pump setup time (s) and the loading time, which is a product of quantity (q) and pumping rate (r_i , where i is the product type). Thus, the total loading time can be estimated as: $t_{23} = s + q*r_i$. Note that this expected time is an estimation of the ideal loading situation without a problem or delay. More simply, expected loading time can also be taken as 1 day, which is the average loading time without a delay. It can be reasonable to take the expected time as 1 day because the customer does not estimate the loading time in terms of hours.

As a result, the performance measure can be stated as “% of shipments finished loading before the end of laycan + estimated loading time” (***Measure 5***). Also, to eliminate the risk of estimating a variable, another measure can be stated simply as “% of shipments loaded before end of laycan” (***Measure 6***). However; this last measure does not take into account the fact that loading larger quantities takes longer time, and this longer loading time is expected by the customer. Also, ships arriving on the last day of laycan have almost no chance to finish their loading before the end of laycan.

State 4:

Furthest projection is done at state 4, where customer receives the shipment. Instead of the start of discharging, NOR tendering time is taken as the milestone; because it shows that the ship arrived and is ready to discharge, and further delays are under the responsibility of the customer. Customer cannot produce additional dissatisfaction after this point, in terms of delivery, towards SABIC or the LSP.

Estimating t_{34} is easier because expected transit times of ships are recorded in SAP. They are given in terms of days, and are common in the databases of both SABIC and the customer. Therefore, the performance measure can be formulated as: "% of shipments tendered NOR for discharge before the end of laycan + estimated loading time + expected transit time" (***Measure 7***).

Note that obtaining weighted measures and/or using initial laycan can also be done for states 2, 3 and 4. However, the non-preferredness of these methods make it unnecessary to repeat obtaining undesired measures.

The calculated measures are given in Table 4.1.

State	Measure #	Performance Measure	Score
1	1	% of shipments tendered NOR before end of laycan	96,27%
	2	% of volume belonging to the shipments whose ships tendered NOR before the end of laycan	92,31%
	3	% of shipments tendered NOR before end of the initial	90,44%
2	4	% of shipments berthed before end of laycan	93,24%
3	5	% of shipments finished loading before the end of laycan + estimated loading time	92,43%
	6	% of shipments loaded before end of laycan	82,05%
4	7	% of shipments tendered NOR for discharge before the end of laycan + estimated loading time + expected transit time	91,93%

Table 4.1: Performance Measures and Their Scores

Stemming from the discussed deficiencies and biases of Measures 2, 3 and 6; their scores are relatively lower and therefore deemed as not realistic. Scores of Measures 4, 5 and 7 are parallel; which are estimated in the same sense. These three measures indicate a lower performance with respect to Measure 1; which was initially assumed to lack in reflecting customer satisfaction.

Here, there is a distinction of decisions concerning the KPI selection: what should be measured and what should be used in the contracts. Although it was discovered that Measures 4, 5 and 7 are more realistic than Measure 1; because of delay responsibility concerns and unknown amount of flexibility that estimated durations contain, their inclusion in the contracts might not still be fair to the shipping LSP. Thus, they are advised for the use of measurement and analysis only.

4.1.3. Current Reporting Deficiencies

During the analysis plenty of KPI reports were examined, which were prepared separately by each broker; therefore their shapes and contents were different. There is a 3% difference between the reported and calculated delivery performances for shipping, and a 6% difference for barging, and it stems from the erroneous completion of those reports.

Besides the necessity of better filling in of the data, a more reliable reporting system results in a clearer and more appropriate base for performance measurement. Currently in SABIC, a web portal is being prepared for this purpose which will take time to be put into use completely.

The following deficiencies in the analyzed KPI reports stand out:

- Some of the important columns are not filled-in for all shipments. Especially "Comments" column which is supposed to contain delay information is mostly kept empty and thus delay information is not available.

- It is not possible to see if the laycan of a shipment has been changed or not.
- Names of some columns are perceived differently and therefore different types of data are filled in.
- Some LSPs (intentionally or not) entered on-time information erroneously.
- It is difficult to verify the performances reported by the LSPs using the data in the reports, because the on-time data is entered by hand by the LSPs.
- Putting all KPI reports together for the use of a comparative analysis is very difficult for SABIC.

The abovementioned deficiencies were needed to be eliminated.

4.1.4. KPI Reporting Improvements

As an improvement to deal with the deficiencies, a standardized KPI report template was constructed. Fortunately, standardization had already been a subject of discussion in previous departmental meetings. As explained before, all data is available at LSPs as statements of facts and therefore additional information can be obtained easily.

The report template was aimed to be in an understandable form, not too complex or too lacking. The following features were added to a chosen pre-existing report template:

- Laycan date is separated into two columns; initially agreed laycan and finally agreed laycan. This way SABIC can keep the track of laycan changes and their frequencies.
- The information of the ship tendering Notice of Readiness within laycan is calculated automatically to prevent erroneous data entering.
- Notice of Readiness tendering date and time information were requested. When entered, it can be used: to monitor the arrival behaviors of LSPs, to verify the timing that was claimed, and to feed the formula of on-time arrival statistic.
- Automatic calculations are added for cost and payment columns again to prevent erroneous entering of these data.
- Explanations were added to some misunderstood columns, stating what kind of information is required.

The resulting template was tested and sent to the brokers, who fill in these KPI reports. An example of the template can be seen in Appendix X.

4.2. Critical Delays

As mentioned before, this section explains the critical delays which are most significantly influencing the shipment process to result in late deliveries. The analysis for shipping employs the newly defined KPIs.

4.2.1. Critical Delays of Shipping

In order to detect the delays which critically cause late deliveries to the customers, late delivered shipments were examined, using the new delivery performance measure, which shows the shipments which arrived to customer later than the “Laycan end + Estimated Loading Time + Expected Transit Time”.

All late delivered cases were explained by a delay reason, or a combination of multiple reasons. The frequencies of those reasons are as given in the Figure 4.2.

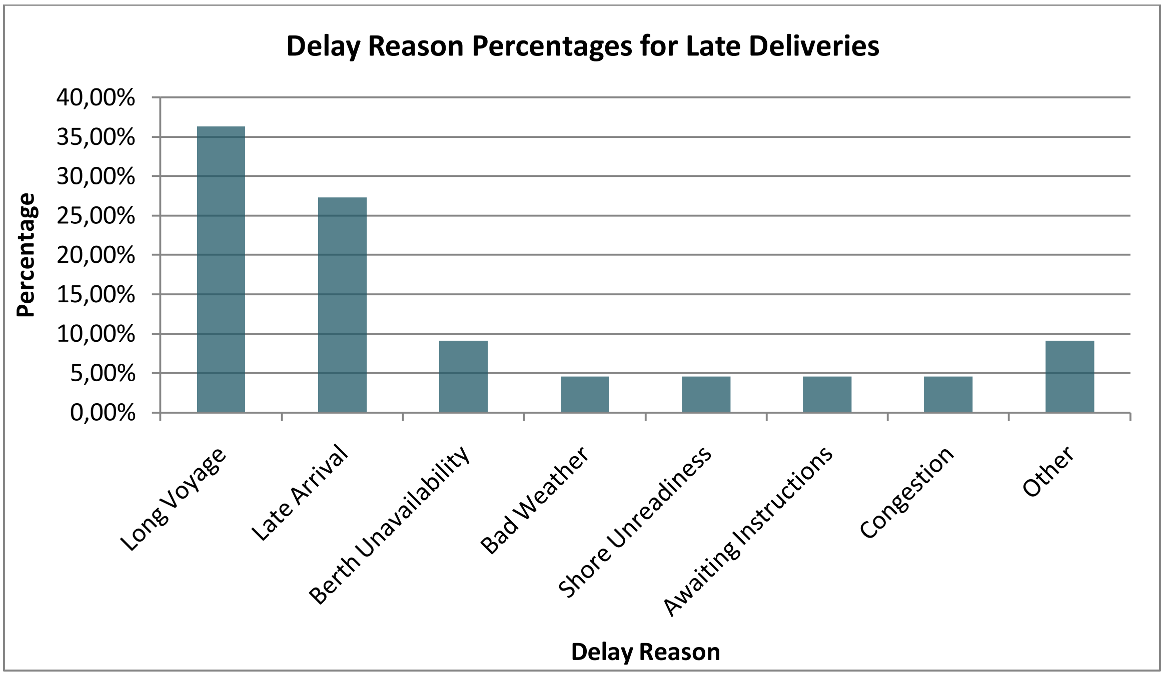

Figure 4.2: Shipping Delay Reason Percentages for Late Deliveries

Note that some shipments face more than one delay, and the percentages in Figure 4.2 indicate their occurrence frequency percentages. As can be seen in that figure, most influential delay factors which result in late deliveries are "Long voyage", "Late Arrival" and "Berth Availability". These factors' contribution to lateness on the time scale is as given below.

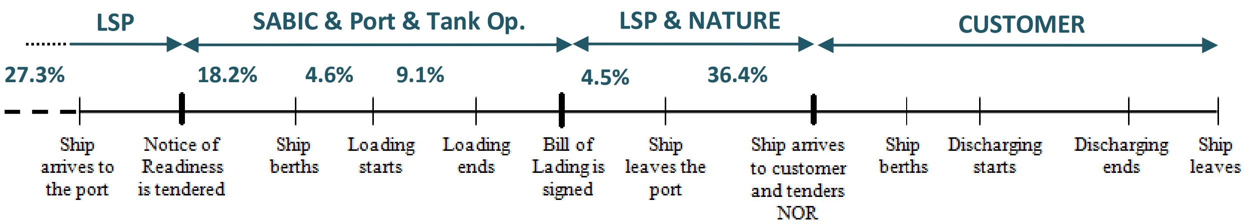

Figure 4.3: Shipping Delay Reason Positions for Late Deliveries

Figure 4.3 shows that the majority of the delays –that cause late deliveries- occur in three intervals: before arrival for loading (27.3%), between NOR tendering time and berthing time (18.2%), and during voyage (36.4%). Other delays added together, Figure 4.4 shows the responsibility distinction of critical delay factors, derived in the similar sense as it was done previously.

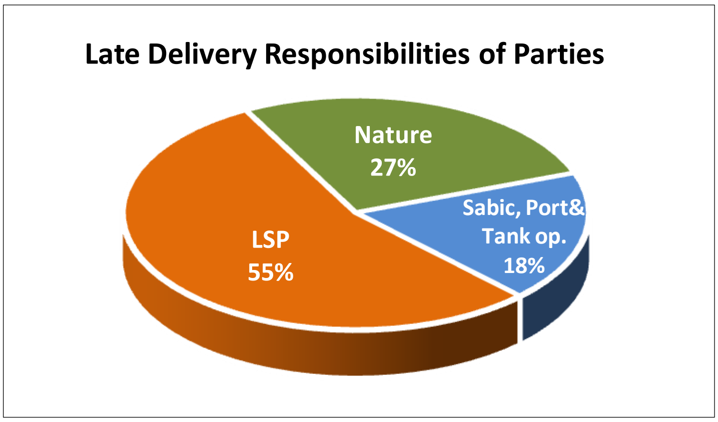

Figure 4.4: Shipping Delay Responsibilities for Late Deliveries

There is a significant difference in parties' responsibility percentages, between the analyses of recorded delays and the delays that result in late deliveries. The influences of LSPs on the resulting delivery performance are in fact much bigger and the influence of SABIC is much lower, because some delays occur in special conditions or last shorter compared to the others.

Thus, the biggest responsibility on late deliveries belongs to the LSPs, and the second important contribution is done by the Nature. Since natural influences cannot be manipulated or prevented, the way to improvement seems to be via configurations of LSPs.

4.2.2. Statistical Analysis on Shipping

In order to support the findings which were obtained from the analysis in Excel, correlations were examined between the delay occurrences, late arrivals and discharges, and other variables. This analysis included the data including all shipments of 2009. According to the correlation matrices are given in Appendix XI, the resulting correlations are represented as given in the structural model in Figure 4.5. Although a correlation indicates a bilateral relationship, one-sided arrows in Figure 4.5 represent the temporal sequence of events.

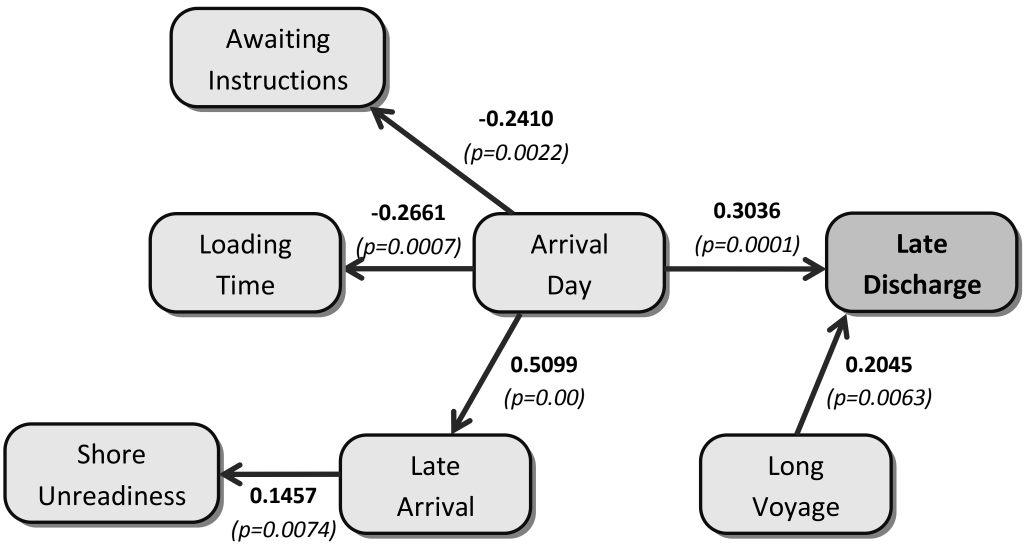

Figure 4.5: Structural Model of Delays

In Figure 4.5, bold numbers on the arcs represent the correlation coefficients which indicate the magnitude of change in the target variable with a unit change in the origin variable. Also, p-values show that these relationships are significant, since they are all below 0.05 significance level. Qualitatively, findings were as follows:

- Lateness of arrival to the customer site for discharge is significantly affected by two variables: long voyages and arrival day for loading. This is in line with the previous findings. Among these two variables, arrival day has a higher affect on lateness.
- "Awaiting Instructions" are negatively correlated to the "Arrival Day" for loading. Also, "Shore Unreadiness" is indirectly negatively correlated to "Arrival Day". These correlations also correspond to the finding which stated that mostly early arrivals face these delays.
- Total time for loading is negatively correlated to the pumping rate as expected. And pumping rate is positively correlated to the arrival day. This might be explained by: that pumping rate is increased intentionally, or that ships who will load smaller amounts arrive later knowing that their loading will last shorter.

4.2.3. Critical Delays of Barging

Similarly for barging, late delivered cases were examined separately. Resulting delay frequency percentages are found to be as given in the figure below:

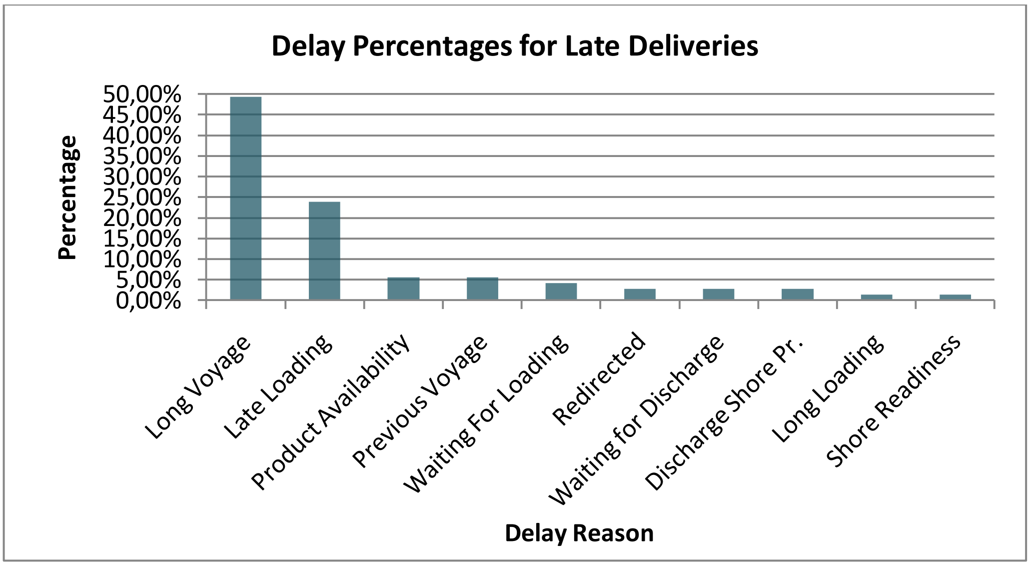

Figure 4.6: Barging Delay Reason Percentages for Late Deliveries

Figure 4.6 indicates that the most critical delays are long voyages (49.3%) and late loading (23.94%), in line with the general delay statistics. Moreover, the criticality of *other* (than the first two) delay reasons are greater because 19 out of 34, in other words 55.9% of recorded delays resulted in late deliveries. This statistics is 14% (35/250) for long voyage and 12% (17/141) for late loading. This difference might be explained by the fact that late loading and long voyages may be compensable, or do occur using the flexibility of the expected transit time.

Voyage is longer than expected for the 68.63% of all late delivered cases, whereas it was 52% for all shipments. The above delay analysis results in the following responsibility distinguishment as given in Figure 4.7.

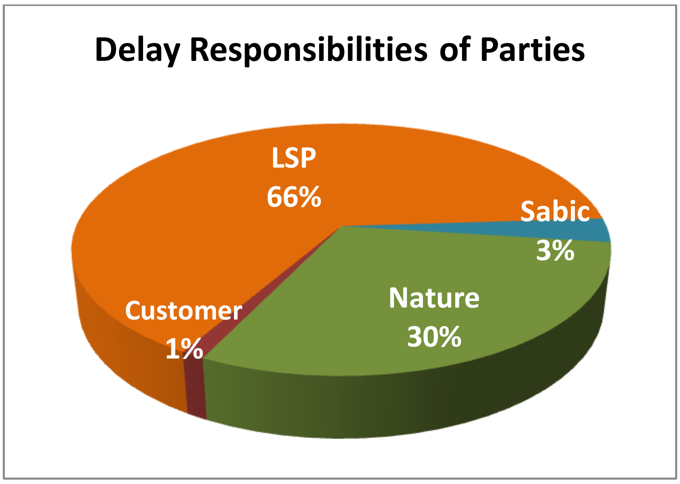

Figure 4.7: Barging Delay Responsibilities

Like it was found in the delay analysis for shipping; also for barging, the party with the biggest responsibility in terms of late deliveries is the LSP (with a contribution of 66%). Nature also has an important contribution to late deliveries.

4.3. Prominent Delays and Potential Improvements for Shipping

This section aims to list every stated and discovered delay reasons that increase the duration of the shipment under consideration which were detected in previous analyses and interviews, and states root causes and factors which influence the delay reasons; for shipping. Then, their actual effects on the resulting delivery performance are discussed, and a final cause & effect diagram is produced as a result to see the improvement opportunities. Finally, an overview of pointed improvement opportunities is given.

This analysis was only done for shipping and not for barging, because the *delays for barging are clearer,* only two reasons were found to be significant and far more critical than the others. Also, improvement opportunities for barging are also visible, which will be discussed at the end of this section. Thus, this analysis only elaborates shipping delays.

4.3.1. Evaluation of Delay Reasons

An extensive cause and effect diagram is formulated in order to question the root causes and factors which affect result in delays during a shipment. By the help of this analysis, it is aimed to achieve two objectives:

1. Obtaining a final cause & effect diagram which shows significant causes of delivery performance.

2. Revealing the most reasonable directions to focus in order to improve delivery performance.

Primary delay factors that might affect the delivery performance are given in the cause and effect diagram in Appendix XII. These factors consist of delays, and other variables which have direct effects on delays. The diagram was constructed via the delay analyses done in Chapter 3, and interviews with done with LSP's and relevant people at SABIC. It serves as a big picture to see all the discovered and stated (by interviews) delay reasons and the variables which causes them. Figure 4.8 is a simplified representation of this diagram.

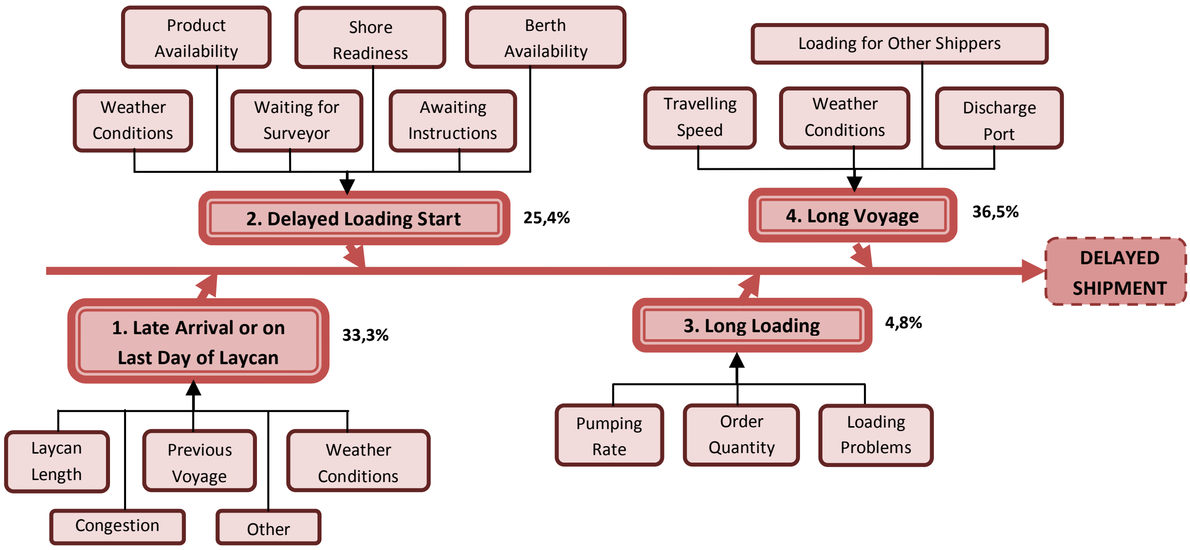

Figure 4.8: Simplified Cause & Effect Diagram for Delayed Shipment

The primary factors are numbered according to their occurrence order throughout the delivery timeline. There are four primary factors which are: late arrival (or arrival on last day of laycan), delayed loading start, long loading and long voyage. Secondary factors, as seen in Figure 4.8, are the causes and variables which are directly related to the resulting primary delay. Tertiary factors are given in Appendix XII, and represent the root variables and causes of the secondary factors.

The tendencies of main factors to cause a decrease in the delivery performance are presented as the percentages of occurrence frequencies. The frequencies are taken from late deliveries according to the performance measure which was identified as Measure #7 as defined in Section 4.1.

Since only primary and secondary factors are depicted in this diagram, the branches are extended to indicate tertiary factors and explained separately below.

Elaboration of Late Arrival or Arrival on Last Day of Laycan

The diagram in Appendix XII indicates the root factors and reasons which can result in a change in the outcome when altered. As depicted, there are five main factors which explain late or near-end arrivals of the ships to the loading port.

a) ***Laycan Length:*** Laycan length is mostly agreed as a 3-day period, but can be customized according to exceptional situations and according to customer's request. It is stated in the contract with the customer, and also indicated in the contract with the LSP which is responsible for handling deliveries to this particular customer. Laycan length reflects customer's flexibility to some extent. However; this length is standard for more than 95% of SABIC's shipments, and is *not* preferred to be changed.

b) ***Congestion:*** Some ports are congested more frequently than the others, such as the ports of Amsterdam, Antwerp and Malta. The decision of which load port to use is made by SABIC, depending on the agreements with LSP, product availability and other minor reasons. However, congestion rarely causes a late delivery with respect to other major delay reasons.

c) ***Previous Voyage:*** The most binding reason of late arrivals is the effect of previous voyage of the ship. Previous voyage can be delayed by any kind of problem, as now being explained for the current shipment. In addition, discharge operations can also delay the ship. LSP's prepare and modify their dynamic schedules with a flexibility, but also trying to maximize the utilization of their ships. Also; they receive demurrage costs when the delay is because of loading or discharging, to cover their probable lost time and utilization. However, generally they do not lose the next shipment, as long as they can extend the next laycan or they believe that the vessel will still be on-time at the next load port within the laycan. In this situation; either they arrive just before the end of laycan or they arrive late, increasing the odds of a late delivery to the customer. For some situations LSP's might not consider late arrival as a problem because delivery performances are not stated as minimum service levels in their contracts.

At this point, improvement opportunities lie within the scheduling of the LSPs, by increasing the flexibility of the time spared to complete a shipment. Interviews revealed that LSP's utilize informal customer prioritization (i.e. they do not want to lose their major customers) and sometimes they force some shipments (which they do not want to reject) to fit in between two other shipments, using a part of their flexibility.

d) ***Other LSP-related Delays:*** LSP's are supposed to make the tanks of the ship ready to load before the next loading, according to the specifications stated in their contract. However, there are situations when the ships arrive on-time, but the ship is not ready to load. There will be extra processes to make it ready such as cleaning tanks, which causes an additional delay. However, these kinds of delays are not very frequent and ship masters are asked to tender a new Notice of Readiness after it is ready.

e) ***Weather Conditions:*** Voyage of the ship to the loading port can be delayed by weather-related events such as storms. Although this occurs frequently, it cannot be prevented or controlled. It cannot be easily predicted as well, as the analysis indicated that its occurrence does not follow a seasonal pattern. It may be predicted a couple of days beforehand, but it is relatively a shorter period considering that the shipment is fixed from at least one week before. When it is predicted by LSP, the laycan may be updated.

<u>*Elaboration of Delayed Loading Start*</u>

The six factors which explain delayed loading start can be seen in the diagram in Appendix XII, and are explained below:

a) ***Weather Conditions:*** Waves or wind sometimes causes instability of the ship, which prevents and delays loading; because hazardous chemicals are sensitive for this kind of actions while loading and also pumps may be harmed. However, like explained before, it cannot be prevented.

b) ***Product Availability:*** In general, product becomes unavailable when there is a problem with the production (such as cracker breakdown); but the reported delays are because of smaller problems. The reason is that, when there is a big problem which will take a long time to fix, shipments are cancelled or products are supplied from other companies to fill the gap. The situations when the logistical hubs are out of stock occur because of unsuccessful production or inventory planning. Safety stock calculations or shipment planning may be examined to find cause of this problem, but product availability is a non-frequent problem.

c) ***Waiting for Surveyor:*** Besides this being a minor delay (happened 6 times in 2009), also its reasons are variable (such as surveyor being stuck in car traffic). Therefore this problem is not an important one to focus on and easy to correct by ending the contract with the problematic surveyor.

d) ***Shore Readiness:*** Setup times may be necessary between two loadings, including equipment change at the shore. Also; if any problem occurs with the loading equipments or storage, ship has to wait until shore is ready to commence loading. The time spent waiting for shore readiness can be eliminated by a better shore planning, however it requires a larger problem solving approach. Besides, this is a relatively less frequent delay.

e) ***Awaiting Instructions:*** After the ship arrives to the port and tenders Notice of Readiness, the ship master has to receive berthing instructions from the shore to start loading. Sometimes these instructions are not given, mostly at times when the ship arrives earlier than the start of laycan. It was proven by the analysis that the majority of this delay does not cause late deliveries because of the effect of early arrivals; but there are still some other reasons, such as waiting for the allowance of port authorities, delay caused by the previous loading or other *unknown*. A delay in previous loading should result in berth unavailability or shore unreadiness, but sometimes shore personnel (SABIC or other tank operator) prefers not to give instructions. As a conclusion; since the reasons behind this delay are variable and therefore require a greater attention, it does not imply an improvement opportunity.

f) ***Berth Availability:*** Berth availability is an issue of berth scheduling, which is done by SABIC. Some berths at some ports tend to be used more frequently, which increases the chance to be affected by the delays of previous loading. Considering the uncertain nature of sea transportation, sparing a certain time for each loading is not possible. Therefore schedules are being frequently updated, according to the statuses of other shipments. When the berth is known to be not available, berths of other companies are used for loading.

At this point, another improvement opportunity may be present. Although berth scheduling is very dynamic and uncertain, it may be improved by adding additional flexibility for SABIC's shipment via customer prioritization or other means.

Elaboration of Long Loading

Although loading delays cause only 4.8% of all delays and thus any improvement opportunity under that category will not result in a significant increase in the resulting delivery performance; still, factors explaining the long loading time are explained below:

a) ***Pumping Rate:*** Pumping rate of the product is specified in most of the contracts. Some products may be sensitive to loading with high pressure. However, when the loading is planned to be done from another berth which does not belong to SABIC, product is loaded at a pumping rate as contracted with the terminal owners. Besides; some products are loaded with the help of gravity, for sensitivity reasons and economical considerations, because power is not needed when the ship is to be loaded with gravity.

b) ***Order Quantity:*** Order quantity is proportional to the loading time as expected by both SABIC and customers. Therefore expected loading time estimation of customer is done taking into account the quantities. It does not cause a delay.

c) ***Loading Problems:*** Loading can be halted because of reasons such as pump breakdown, leakage and other technical problems from the shore-side. Most prominent one of those reasons is pump breakdowns, which requires the pump to be replaced and a spare pump has a possibility of not being present on board. In this situation, supply of a new pump takes time. This problem is tried to be prevented using special maintenance regimes, which minimizes the risk of breakdowns. However, it still does not eliminate the probability.

Elaboration of Long Voyage

The four secondary factors which explain the voyages which last longer than desired are explained in detail as follows:

a) ***Travelling Speed:*** Speed of a ship changes according to its specifications. Some ships travel slower, because they have smaller engines; and although a discussion about this element is a part of the negotiation process, it is not specified in the contracts. The ships undergo a vetting process, to approve the current specifications of the vessel, but speed is not one of those specifications. More importantly, there is an economic speed by which the ship consumes the smallest amount of fuel possible. Since LSP's agree with SABIC to be on-time for only loading, the processes after that affect nothing but the ship's own schedule. If the ship's schedule is not too tight; ship master prefers to go with the economic speed, regardless of the previous delays which will result in a late delivery.

At this point, another improvement opportunity draws attention. Speed adjustments of the ships are possible and can be stimulated by SABIC through the contracts.

b) ***Weather Conditions:*** Reasons are the same as described earlier for late arrivals.

c) ***Discharge Port:*** The role of discharge port in long voyages is simply determining the distance to travel. The bigger is the distance, the larger is the transit time. As a part of planning, the transit times are taken into account for determining the laycan for loading. Discharge port is requested by the customer and specified in the contracts.

d) ***Loading Other Tanks for Other Shippers:*** Most of the ships have multiple separated tank compartments which can handle different products and different orders. If the order of SABIC utilizes only some of those tanks, remaining may be used by other customers of the same LSP. In that case, loading is done from a different berth (or even different port). This adds a significant time to the voyage, which spends a part of the expected transit time. Moreover, the same concern is also valid for discharging, i.e. the ship may visit other ports on their way to discharge some of their tanks. However, in some of the major contracts with LSP's, SABIC agrees to be the only or the last customer to be served, so that transit time is only used for the voyage. This way, expectations of the customers about arrival times can be satisfied.

CAUSE & EFFECT DIAGRAM FOR LOW DELIVERY PERFORMANCE

As a conclusion for the discussion done about delay reasons in this section, the most important reasons which result in low delivery performance are selected and are shown in Figure 4.9. This cause & effect diagram is a reduced version of the initial diagram, which only explained delays. This diagram only shows the major problems that result in late deliveries. In addition, the factors which are open to improvement are given in bold.

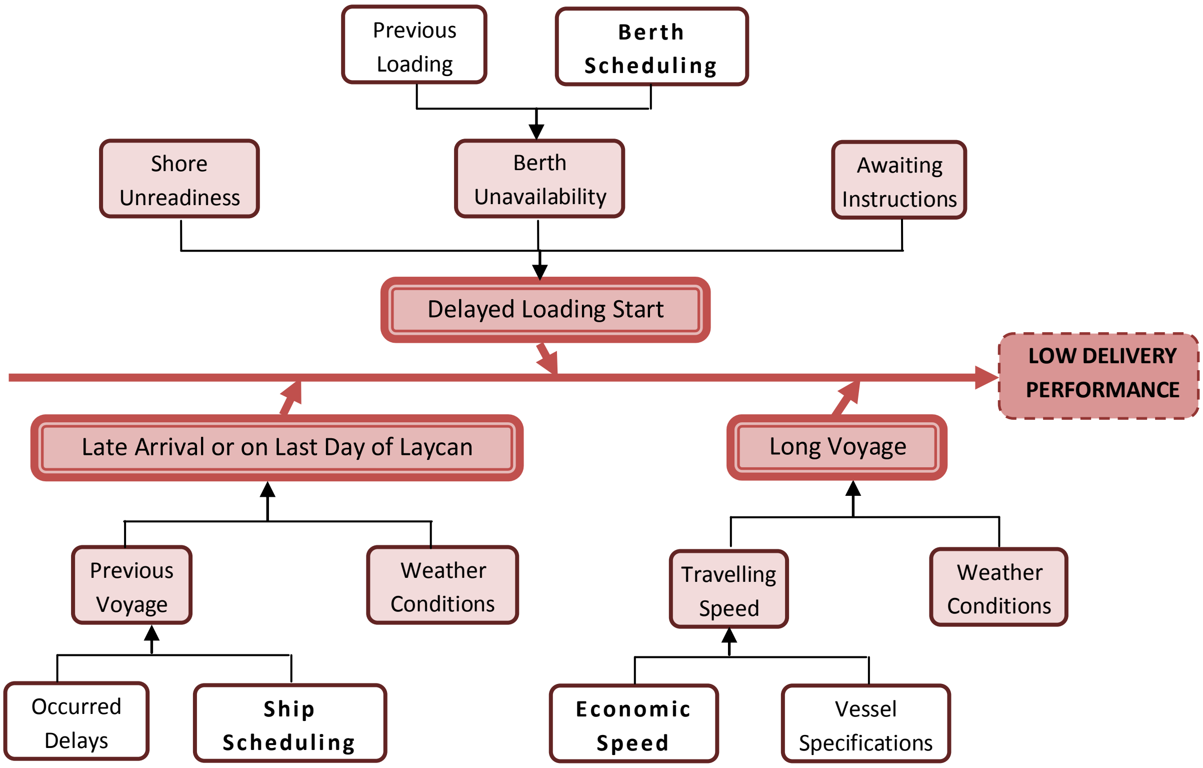

Figure 4.9: Cause & Effect Diagram for Low Delivery Performance

Improvement opportunities, which are emphasized in Figure 4.9, are discussed in the following section.

4.3.2. Overview of Potential Improvements

In this section, an overview to the improvement opportunities for shipping is given and their applicability is discussed.

Berth Scheduling:

People, who are responsible for the berth planning, do this according to the following logic:

Berth scheduling is done monthly at the end of the previous month. Shipments to be loaded from a specific berth have specified loading laycans, determined before that planning period. These laycans are inserted over the timeline, without overlapping. A scheduled month looks like as follows:

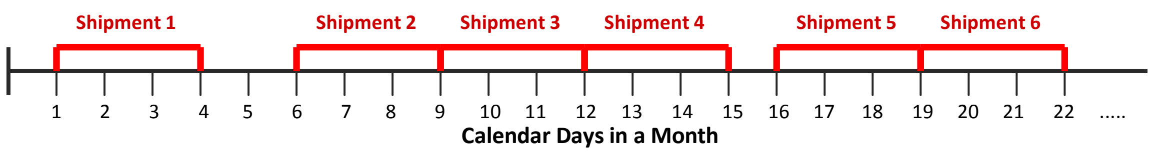

Figure 4.10: Berth Scheduling

The problem about this logic is the contracted loading terms. It is contracted with the logistics provider that the ship should arrive to the port for loading within the laycan. This means that the ship has the right to arrive at the last minute of the last day of her laycan. Considering the fact that loading lasts for almost one day (22.21 hours) on average, she will occupy the berth for one more day if no problem occurs during loading.

Assume that the schedule for the current month is done like in Figure 4.10. All laycans are 3-day periods, and there are 6 shipments in total which will be loaded from that berth. If Shipment 3 arrives at noon of the last day of the laycan, the loading will finish at noon of the next day. In case that the vessel of Shipment 4 is present at the port in the beginning of her laycan, she will have to wait at least 12 hours for “Berth Availability” to start loading. More importantly, if any problem occurs during the loading of that previous shipment, she will have to wait for a longer time.

In a nutshell; the problem of scheduling is about the working logic, with not taking into account the fact that loading time and late arrival of the previous shipment will cause a delay to start loading. A possible remedy can be adding buffer time before every shipment, to serve as a flexibility to absorb delays caused by the previous shipment. It can function successfully for non-busy ports when also flexibility can be added without a loss. This way, planners can try to make the schedule not so tight.

Also, a more detailed and strong approach as a solution to this problem can be via a better scheduling. Authors such as Lim (1998), Kim and Moon (2003) and Lee and Chen (2008) focus on the berth scheduling problem and tries to optimize the berthing sequence and costs. However, this scheduling problem is by itself a complicated task to solve, and also its impact to final delivery performance is relatively smaller. Thus, it will not be included in the content of this project.

Economic Speed:

The origin of that problem is related to the loading terms in the contract with the logistics provider. As explained before, LSP’s are contracted just to be on-time for loading. Loading process and the voyage are not under their concern, unless they will utilize the ship in a later voyage. However; when the schedule of that particular ship is relaxed, the LSP will simply behave to minimize its costs. During the voyage, decreasing the fuel consumption by setting the speed of the ship to her economic speed provides an opportunity to cut costs.

This fact is not reflected inside the contracts; and more importantly, the speed behavior of the LSPs is not observed by SABIC. If such an opportunistic behavior occurs, the customer receives the order later than expected and thus it triggers the dissatisfaction.

There are a number of possible remedies to this problem. First is the addition of a clause to the contract, stating either minimum average speeds for different ships, or pre-determined expected transit times. Second solution can be to reject a ship which does not satisfy the required speed conditions from the beginning, by the vetting process. Third and the most applicable solution can be the use of incentive contracting to prevent opportunistic behaviors. This solution also forces the LSPs to make an additional effort only when necessary.

Ship Scheduling:

Relevant information, about ship scheduling, has been obtained as a result of the interviews with logistics providers. Three important points were obtained as a result of these interviews. The most important point is that *LSPs try to keep the utilization of their* ship*s as high as possible*. Second one is that ship*s' schedules are highly dynamic, updated daily by their final status*. Third important point is that *LSPs use customer prioritization when necessary*. As explained before, LSPs are responsible of informing SABIC whenever there is a delay about the previous voyage of the ship. As explained by the process flows in Chapter 3; when SABIC receives the information about the status of the ship, stating that she will not be able to arrive within the laycan; a new shipment schedule will have to be arranged again satisfying product and berth availability for SABIC, and sufficient inventory level at the customer, and enough flexibility in the ship's schedule.

When the related ship has a tight schedule, and a voyage is delayed for some reason, either the next shipment will be cancelled (or transferred to another ship) or reserved days for the next shipment will have to be shifted forward. Shifting the reserved days will affect the shipment after that, and maybe the shipment after that. This chain of shifting effect will result in less flexibility, and the shipments will be more vulnerable to delays.

The underlying reason of this problem is the fact that LSPs do not want to lose sales or reject shipping orders, in order to keep the utilization of their ships as high as possible. The order information is at the LSP side; and SABIC has no idea about how much flexibility the ship has, and how much increase of late delivery probability is put by this lack of flexibility.

Since the LSP's behavior about scheduling might be damaging for SABIC; the opportunity that arises from LSPs' customer prioritization stands out as an improvement opportunity. In the literature, asymmetric information about ship's schedule and this kind of opportunistic behavior of the LSP is referred to as "overstating capability". By overstating their capabilities, LSP's behave as they have enough flexibility in their schedule, however more than half of the shipments face delays. This can be improved by developing performance-based logistics contract model, which include incentive schemes to induce truth-telling.

To sum up; in this chapter most important problems about shipping were found to be late arrivals for loading, long voyages and berth unavailability. For barging, most important two reasons are late arrivals and long voyages as well. As mentioned, improvement opportunity over berth scheduling will not be focused on, but *economic speed* and *ship scheduling* opportunities require a special attention. An incentive contract model can be designed to improve the delivery performance of the logistics service providers through these two improvement opportunities. Similarly, these opportunities also are applicable to barging, as confirmed by the relevant people in SABIC, since the problems are in the same direction. Thus the improvement of the delivery performances of both modalities is possible through the same approach.

CHAPTER 5: PERFORMANCE-BASED LOGISTICS CONTRACTING

As concluded in the previous chapters, the most important problems of both shipping and barging are parallel and originate from opportunistic behaviors of the LSPs. However, specific behaviors of LSPs depend on occurrences of uncertainties (delays). Discussions in SABIC about this problem revealed that performance-based contracting might be a solution this problem. It was mentioned before that currently there are no regulations or reflections of low delivery performances inside the contracts.

When LSPs' performance is not controlled or regulated through contracts, asymmetric information at LSPs' side can be problematic. If cost and capability information of the LSP is not present on the outsourcer's side, LSPs can misinform the outsourcer about their capabilities. Therefore it might result in the following:

- ☐ Opportunistic behavior: Main objective of LSPs is to maximize their profits, even if it requires them to behave in opportunistic ways in unobserved areas.
- ☐ Not meeting targets: Outsourcer cannot meet its performance targets if it is not negotiated with the LSPs. In this direction; LSPs may not be aware of the targets and moreover, they may not have an incentive of performing better.

The present situation of the contractual relation between SABIC and its LSPs seems problematic and may be open to face difficulties about the abovementioned facts.

As explained before, ship scheduling behavior of the LSPs contain opportunistic behavior and optimistic planning. LSPs try to maximize the utilization of their ships, so that they achieve a better Return on Investment. Therefore they do not want to lose sales, i.e. do not want to reject shipment orders, and try to accept as many shipments as possible that fit their schedules. This order-accepting of LSPs results in a tighter schedule and less flexibility for each shipment. Less flexibility makes the shipments more vulnerable to delays, increasing the chance of late arrivals for loading. Another opportunistic behavior of the LSP occurs during the shipment. If the concerned ship does not have a tight schedule, ship master prefers to go at economic speed; not caring about arrival time to the customer. This behavior stems from the agreement, which only obliges the LSP to be on-time for loading.

What LSPs do when they accept a shipment order is to "overstate their capabilities". Using the advantage of asymmetric information at SABIC's side, they have the opportunity to overstate their capacity. Even if the LSP is aware that the ship will be able to arrive on later days of the laycan, not to reject the shipment, it will claim to be on-time. Also, traveling at low speeds can be labeled as an opportunistic behavior.

According to Sols et al. (2007), these opportunistic behaviors and asymmetric information can be remedied by incentive contracting.

This chapter is organized as follows: at first the contract model and its construction will be explained, and a solution will be provided. Then, scenario analysis will be conducted and practical insights will be reached. Finally, the model's monthly implications will be presented and possible extensions will be discussed.

5.1. Contract Model

An incentive contracting model was built, which aims to manipulate LSP's behavior via the parameters given in the contract. This is referred to as "Performance-based logistics contracting" in the literature, and it contains schemes to reward or penalize the LSP depending on its performance. The base question of this kind of contracting problem is: "How should the incentive schemes be structured to ensure reliable vendor performance?" (Bryson and Ngwenyama, 2000).

In the literature, incentive contracting problems are considered in a Principal-Agent (Agency Theory) problem setting. In this setting, *principal* defines the rules, and the *agent* chooses an action in response. According to Logan (2000); this setting is suitable when the two parties involved have different and conflicting goals, and when it is difficult for the principal to measure or predict agent's actions. Therefore this setting is applicable to our situation. In our logistics outsourcing contracting case, it is clear that the principal is the outsourcer (SABIC), the agent is the service provider, the rules are contracts and the responding action of the agent is its choice of action.

The main idea of the approach is that*; the principal offers a contract with parameters which maximizes his profit by anticipating agent's behavior, and the agent responds to this offer choosing actions which maximizes their profits and it will result in a performance outcome*. The agent is expected to shrink as much as it can to cut costs. Since the setup of the problem analyzes sequential decisions, the model is expressed as a non-cooperative game. Also, individual objective of SABIC is expressed as an optimization model.

Scope of the Model:

For the ease of calculation and analysis, a single shipment is chosen as the scope of this model. This scope choice makes it easier to analyze LSPs' decisions given for each shipment, rather than for multiple shipments. Thus, incentives or penalties are applied per shipment, depending on the shipments being on-time or not.

Incentives could also have been applied to an aggregated performance, i.e. monthly; however considerations about the decisions given for multiple shipments would cause complexities. Monthly schemes can also be obtained by extending a single shipment model to obtain aggregate implications.

5.1.1. Contracting Game

As explained before; consecutively, SABIC defines contract parameters and LSP responds to these parameters by choosing an effort level which maximizes its profit. Thus, the first move belongs to SABIC (Player 1) and second move belongs to the LSP (Player 2); the game in extensive form is as described simply in the figure below:

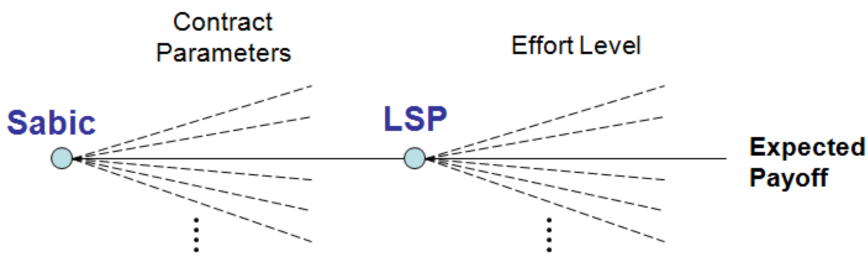

Figure 5.1: Contracting Game

SABIC is the first player who defines the contract parameters: initial payment, incentive and penalty. When it is LSP's turn, it chooses one of the effort level possibilities, with the highest payoff. By backward induction, it is possible to define contract parameters such that LSP's highest payoff will be provided by the desired effort level. However, the game does not only consist of two consecutive moves, the decisions of the LSP depend on different situations. These different situations will be reflected as the occurrences of distinct uncertainties in the model, as chance moves.

There is a distinction about the problem approach depending on information symmetry. If the costs of LSP's efforts are visible by SABIC, then the Nash equilibrium can be easily found. However; if this information does not exist at SABIC's side, "beliefs" about different states of the world (costs of LSP) come into the equation (Kraus, 1996). In this case, SABIC will have to consider an expected outcome, which is the weighted average of the outcomes corresponding to different beliefs about LSP's costs.

However, *estimating intangible variables like beliefs is more difficult than predicting LSPs' costs*. Since the cost information can be approximated, the option with asymmetric information is eliminated and symmetric information is assumed. LSP's costs are estimated as given in Appendix XIII, however these parameters will be elaborated later.

5.1.2. Preliminary Assumptions

Some assumptions needed to be made in order to build the model in a simpler form. Those assumptions are stated as:

- ☐ A higher delivery performance should result in better gains for SABIC. It is assumed that after a service level quality threshold (delivery performance), the market segment of SABIC changes and this is expected to result in 2% price increase.
- ☐ SABIC has symmetric information about the costs of LSP's effort levels, as explained before.
- ☐ An effort level of LSP does not result in a deterministic outcome, because it is affected by external causes such as weather conditions. Therefore, performance outcome of a LSP in a period is dependent on both the effort levels, occurring uncertainties (delays) and the external conditions which makes the on-time delivery probability (α_i) a function of LSP's effort level, delays and the random factors.
- ☐ The optimization problem of both SABIC and LSP is to maximize profits. Although there are long-term concerns in terms of relationship governance, it is assumed to have negligible effect over the short-term objectives.
- ☐ Although chemical companies and LSPs are highly dependent on each other in the market; in the relationship between SABIC and LSP, the powerful party is SABIC because the dependence of LSPs is much higher.

5.1.3. Mathematical Model

As the analysis on previous chapters indicated, there are delays and uncertainties at different points over the timeline, which affect the delivery performances. Also, the discussion on improvement opportunities concluded that improvements are possible at two points. Taking these findings as the starting point, the contract model is built considering the sequence of events and decisions over the timeline. This sequence is given in the timeline and explained below:

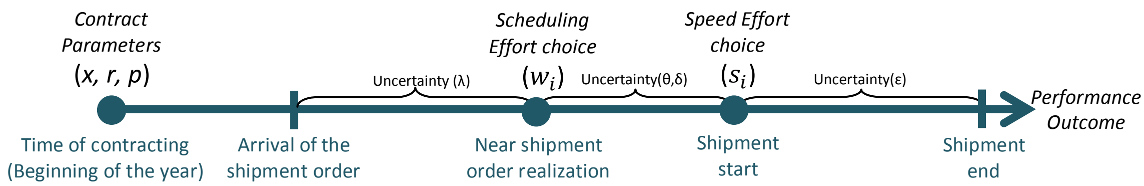

Figure 5.2: Sequence of Events

On-time delivery (Performance Outcome) probability of a shipment involves internal and external variables. Internal variables which alter the outcome are: scheduling behavior and speed adjustments of the LSPs.

<u>Decision Variables of LSP:</u>

$$\boldsymbol{s_i} = Speed\ effort\ for\ shipment\ i \quad = \begin{cases} 1 & if\ ship\ travels\ at\ top\ speed \\ 0 & if\ ship\ travels\ at\ economic\ speed \end{cases}$$

$$\boldsymbol{w_i} = Scheduling\ effort\ for\ shipment\ i \ = \begin{cases} 1 & if\ previous\ order\ is\ rejected \\ 0 & if\ previous\ order\ is\ not\ rejected \end{cases}$$

$$\boldsymbol{e_i} = (\boldsymbol{s_i}, \boldsymbol{w_i}) = LSP's\ effort\ level\ per\ shipment$$

Since findings suggested that two most important causes of delay are late arrival and voyage length; LSP's effort level is reduced down to 2 decision variables, namely: speed effort (s_i) and scheduling effort (w_i). For the ease of calculation, these effort levels are limited to be either done or not, as binary variables. Speed effort could be represented as the average speed for one shipment; but since it is impossible to estimate speeds for every voyage, the speed adjustments for each shipment can be categorized as travelling "at full speed" (s_i = 1) or "at economic speed" (s_i = 0) using averaged values. For the scheduling effort; since only the previous shipment can cause a delay affecting its subsequent shipment, order rejection effort can be represented as $w_i = 1$ if a the previous shipment order is rejected.

External variables are the delays caused by nature and other parties involved which were introduced as uncertainties in the system. These variables are; arrival of a shipment order to the LSP which might restrict SABIC's shipment, delays caused during the previous shipment before SABIC's shipment, possible delays at the loading port, and random factors during the voyage. In order to have a simple and analyzable model, uncertainties λ , θ and δ are included in the model as binary variables, representing the situations when the delays occur or not. Their occurrence probabilities and the magnitudes of the delays are explained below:

<u>External Variables:</u>

$$\boldsymbol{\lambda} = Arrival\ of\ a\ restricting\ shipment\ order \ = \begin{cases} 1 & if\ an\ order\ arrives \\ 0 & otherwise \end{cases}$$

$$\boldsymbol{\theta} = Delay\ caused\ by\ the\ previous\ shipment \ = \begin{cases} 1 & if\ delay\ occurs \\ 0 & if\ delay\ does\ not\ occur \end{cases}$$

$$\boldsymbol{\delta} = Delay\ at\ the\ loading\ port \quad = \begin{cases} 1 & if\ delay\ occurs \\ 0 & if\ delay\ does\ not\ occur \end{cases}$$

$\boldsymbol{\varepsilon} = Random\ factors\ affecting\ a\ voyage\ following\ a\ Uniform\ Distribution\ inside\ (0, L)$

Parameters Related to the External Variables:

$\boldsymbol{P_\lambda} = Probability\ that\ a\ restricting\ shipment\ order\ will\ arrive$

$\boldsymbol{P_\theta} = Probability\ that\ a\ delay\ will\ be\ caused\ by\ the\ previous\ shipment$

$\boldsymbol{P_\delta} = Probability\ that\ a\ delay\ will\ occur\ at\ the\ loading\ port$

$\boldsymbol{D_\theta} = Expected\ magnitude\ of\ delay\ \theta$

$\boldsymbol{D_\delta} = Expected\ magnitude\ of\ delay\ \delta$

The contract period starts at the beginning of the year, when the prices and payment parameters are defined. When a shipment order arrives to SABIC, it is forwarded to the LSP. A shipment of SABIC that was accepted by the LSP has a possibility of being restricted by the previous shipment whose order arrives to the LSP with some probability (P_λ). This might be rejected by the LSP, which is a proactive effort of the LSP (w_i), anticipating a possible delay in SABIC's shipment. After that point in time until the ship sets sail to the customer, the ship goes to the loading port when it is the shipment time (laycan for ships or requested loading date for barges) and gets loaded. In this time interval, the shipment can be delayed by the previous voyage with a probability (P_θ) unless it was already rejected (w_i=1) or if no other shipment order was received by the LSP (λ=0). Also, delays might occur at the loading port (δ) such as berth unavailability, loading problems, etc. Finally, at the start of its voyage to the discharge port, ship might speed up (s_i) to compensate the lost time and to be on-time. This is a reactive effort of the LSP, which shortens the expected travel time by traveling at top-speed. Finally, during the voyage, random factors such as weather conditions can cause delays (ε).

Assumptions of the Model:

- Adverse effects, which hinder the on-time probability, either occur or not, except ε, with probabilities obtained from historical shipment data.
- If a shipment order does not arrive to the LSP which will restrict SABIC's shipment (λ=0), there is no previous shipment to reject and therefore scheduling effort will not be relevant (w_i=0). On the other hand, if it arrives, scheduling effort can be either high or low according to the choice of the LSP. This can be represented as:

$$w_i \in \{0,1\} \quad when\ \lambda = 1$$

$$w_i \in \{0\} \qquad when\ \lambda = 0$$

- Similarly, if no restricting shipment order arrives (λ=0) or if an order arrives and the scheduling effort is high (λ=1, w_i=1), the effect of the previous shipment (θ) will be irrelevant.
- Satisfying the two above conditions, it can be said that a decrease in the on-time delivery probability occurs only when there is a previous shipment (either it never occurred or it was rejected), and there is a delay in that shipment which affects SABIC's shipment. This can be represented together to represent an expected decrease when:

$$\min\{\theta, \lambda - w_i\} = 1$$

- A reward or penalty should be implemented according to a measure defined clearly and reasonably accepted by both parties (Charron, 2006). Since it is necessary to observe the delays after loading, i.e. effect of speed effort, the fully projected measure which provides a deadline for the ship to be at the discharge port (Measure #7 as derived in Chapter 4) is adopted.
- An example situation is adopted to obtain solutions, which is a contract agreed for the shipment of a specified product between specified ports at a determined price.
- Uniform distribution was assumed for the random variable ε, for the ease of calculations.

Other decision variables and parameters are explained below:

Decision Variables of SABIC:

$\boldsymbol{r} = Reward\ given\ per\ shipment\ if\ it\ is\ on - time$

$\boldsymbol{p} = Penalty\ given\ per\ shipment\ if\ it\ is\ not\ on - time$

$\boldsymbol{x} = Initial\ payment\ per\ shipment$

Parameters:

$\boldsymbol{R} = Revenue\ of\ the\ outsourcer\ received\ for\ an\ on\ time\ shipment$

$\boldsymbol{u_0} = Reservation\ utility\ of\ the\ LSP$

$\boldsymbol{o} = Fixed\ payment\ per\ shipment\ according\ to\ the\ old\ contract$

$\boldsymbol{\gamma} = Expected\ time\ gained\ by\ speed\ effort\ s_i$

$\boldsymbol{c_s} = Cost\ of\ LSP's\ speed\ effort\ per\ shipment$

$\boldsymbol{c_r} = Cost\ of\ LSP's\ scheduling\ effort\ (rejection)\ per\ shipment$

$\boldsymbol{A} = Allowed\ total\ time\ to\ complete\ a\ shipment$

$\boldsymbol{T} = Nominal\ time\ required\ for\ loading\ and\ voyage$

Output Variables:

$\boldsymbol{\pi_L} = Logistics\ Service\ Provider's\ payoff\ per\ shipment$

$\boldsymbol{\pi_O} = Outsourcer's\ payoff\ per\ shipment$

$\boldsymbol{\alpha_i} = On\ time\ delivery\ probability\ of\ shipment\ i$

$\boldsymbol{c(e_i)} = Occuring\ cost\ to\ LSP\ depending\ on\ the\ effort\ level\ of\ voyage\ i$

$\overline{\boldsymbol{T}} = Total\ time\ for\ loading\ and\ voyage\ without\ \varepsilon$

$\overline{\boldsymbol{T^{\varepsilon}}} = Actual\ total\ time\ for\ loading\ and\ voyage$

Taking into account the dependencies of efforts and delay probabilities on each other; the game in extensive form is constructed. Figure 5.3 represents possible actions of the parties, chance moves, all possible outcomes and the corresponding expected on-time delivery probabilities which will determine the expected payoffs.

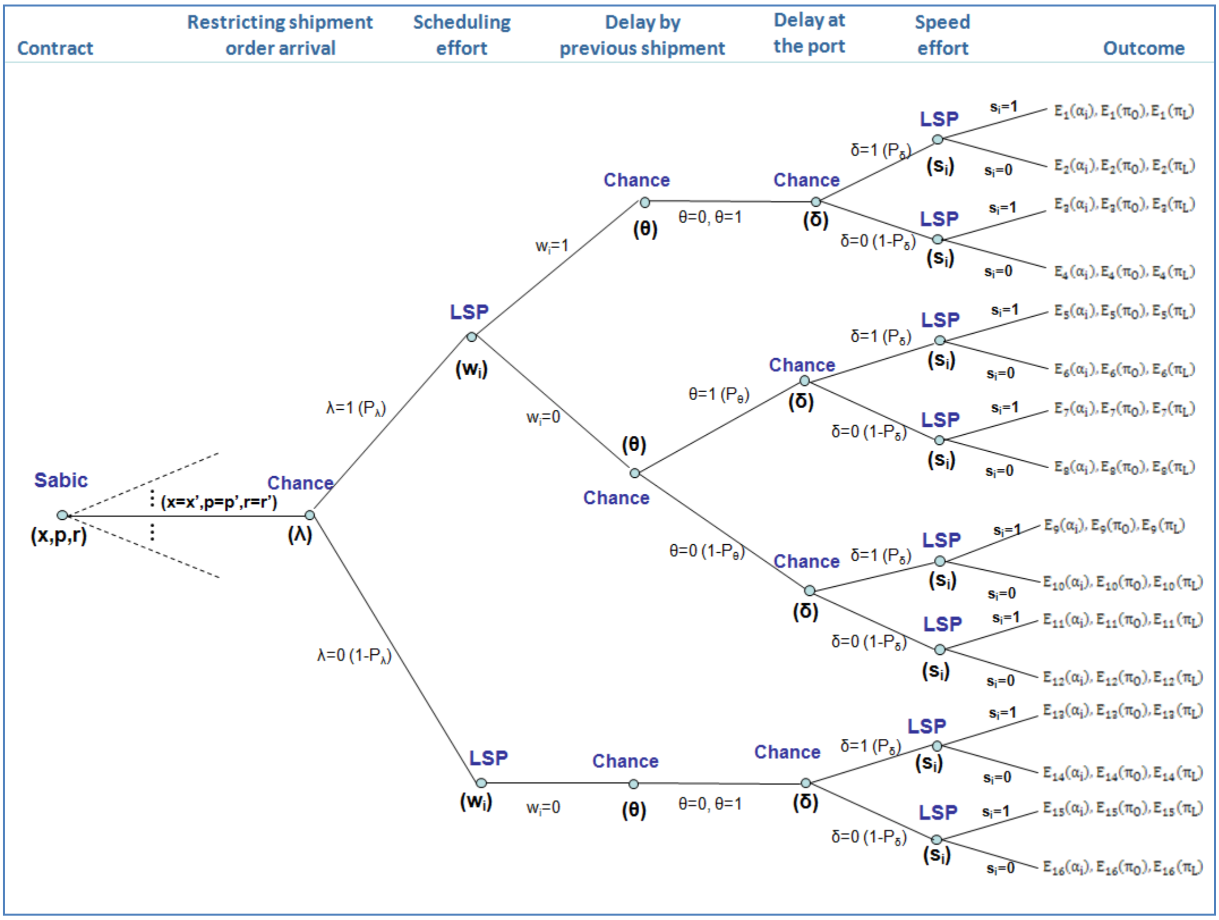

Figure 5.3: Game in Extensive Form

Different performance levels occur with different probabilities and have different expected payoffs for both SABIC and LSP. The contracting model aims to maximize the expected payoff of SABIC taking into account all uncertainties. Note that the performance outcomes are parallel when $min\,\{\theta, \lambda - w_i\} = 0$. This brings a simplification to the model in terms of speed effort choices, i.e. the speed effort choice tradeoffs are the same between $\mathrm{E_1(\pi_L)}$ and $\mathrm{E_2(\pi_L)}$, $\mathrm{E_9(\pi_L)}$ and $\mathrm{E_{10}(\pi_L)}$, and also $\mathrm{E_{13}(\pi_L)}$ and $\mathrm{E_{14}(\pi_L)}$. Similarly the condition of choosing $\mathrm{E_3(\pi_L)}$ over $\mathrm{E_4(\pi_L)}$ will be the same as choosing $\mathrm{E_{11}(\pi_L)}$ over $\mathrm{E_{12}(\pi_L)}$ and $\mathrm{E_{15}(\pi_L)}$ over $\mathrm{E_{16}(\pi_L)}$.

Payoff functions of SABIC and LSP are:

$$\pi_O = R * \alpha_i - x - r * \alpha_i + p * (1 - \alpha_i)$$

$$\pi_L = x + r * \alpha_i - p * (1 - \alpha_i) - c(e_i)$$

where

$$c(e_i) = c_r * w_i + c_s * s_i$$

According to the performance measure identified in Chapter 4 for sea shipping, the latest point in time for the ship to arrive to customer site for discharge was assumed to be "Laycan End + Estimated Loading Time + Expected Transit Time". Assuming that a shipment process is supposed to start when laycan starts, the defined parameters can be represented over the timeline as follows:

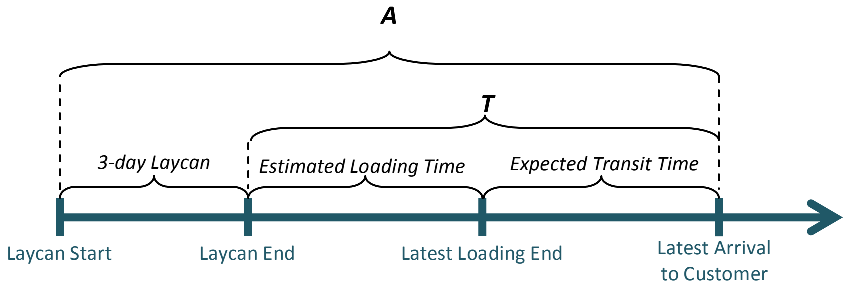

Figure 5.4: Nominal and Allowed Times over The Timeline

Figure 5.4 indicates the customer's expectations and the flexibility which results from the laycan time window. Customer expects for the ship to arrive the latest at the indicated point. Allowed time (*A*) represents a large time window in which the shipment is required to be started and completed. Thus, LSP has a 3-day flexibility to accommodate delays.

Actual total time spent for voyage can be represented as:

$$\overline{T^{\varepsilon}} = T + \min\{\theta, \lambda - w_i\} * D_\theta + \delta * D_\delta - s_i * \gamma + \varepsilon$$

and

$$\bar{T} = T + \min\{\theta, \lambda - w_i\} * D_\theta + \delta * D_\delta - s_i * \gamma$$

where $T = Estimated\ Loading\ Time + Expected\ Transit\ Time$ serves as the nominal time length to complete a shipment. Delays occurring throughout this timeline increase this nominal length.

The following figure depicts the calculation logic of the on-time delivery probability.

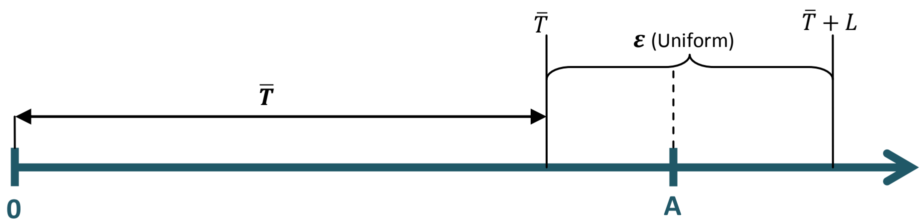

Figure 5.5: Derivation of On-Time Delivery Probability

Nominal loading time, previous shipment and port delays and speed effort together indicate the earliest time to complete the shipment (represented as $\bar{T}$ in Figure 5.5 above). Random factors can delay the shipment at most until the time $\bar{T} + L$, because ε follows a uniform distribution. If the actual shipment time ($\overline{T^{\varepsilon}}$) is less than or equal to *A*, the shipment is assumed to be on-time. Thus, on-time delivery probability can be shown as:

$$\alpha_i = P(\overline{T^{\varepsilon}} \leq A)$$

Expected on-time delivery probabilities are derived considering the probability distribution of ε. Since the random factors were assumed to follow a uniform distribution, the probability distribution function is:

$$f(x) = \begin{cases} 1/L & if \quad 0 \le x \le L \\ 0 & otherwise \end{cases}$$

As a result, expected on-time delivery probability function can be represented as:

$$E(\alpha_i) = \min\left\{1, \max\left\{0, \frac{A - \bar{T}}{L}\right\}\right\}$$

$$E(\alpha_i) = \min\left\{1, \max\left\{0, \frac{A - T - \min\{\theta, \lambda - w_i\} * D_\theta - \delta * D_\delta + s_i * \gamma}{L}\right\}\right\}$$

Expected payoffs of SABIC and LSP can be stated as:

$$E(\pi_O) = p - x + (R - r - p) * E(\alpha_i)$$

$$E(\pi_L) = x - p + (p + r) * E(\alpha_i) - w_i * c_r - s_i * c_s$$

Since the expected payoffs depend on expected on-time delivery probabilities and the effort choices of the LSP, a solution to the presented game can be found by firstly determining the expected probabilities for all possible outcomes. Then the expected payoffs of LSP and SABIC at the root of the game can be found in terms of contract parameters. The expected payoff of SABIC can then be maximized using an optimization problem.

In the literature; authors such as Lim (2000), Liu et al. (2007), Wu and Liu (2009) approach this optimization problem in a similar sense. The aim is to derive the optimal contract parameters (initial payment, penalty, reward) using the principal's optimization problem. Principal tries to maximize its expected payoff, subject to two constraints: Individual Rationality (IR) and Incentive Compatibility (IC). The model, which adopts a similar approach, is described as follows:

Maximize $\boldsymbol{E(\pi_O)}$

s.t. $E(\pi_L) \geq u_0$ (IR)

$e_i(s_i, w_i) \in argmax\, E(\pi_L)$ (IC)

p, r, x, ≥ 0, w_i, s_i binary

The Individual Rationality (IR) constraint requires that the expected payoff of the agent is at least as much as its reservation utility. This constraint is important to ensure that the agent will not reject the contract, and switch clients. Incentive Compatibility (IC) constraint is necessary for the assumption that the agent will choose the move with the highest (expected) outcome, at LSP's decision nodes. This constraint serves as a representative of agent's payoff function inside the principal's maximization problem. Thus, this constraint considers that LSP will chose the best action when the turn is its.

The solution steps of the problem are as follows:

1. Estimate and/or obtain the required parameters.
2. Calculate expected on-time delivery probabilities for each possible outcome.
3. Determine the best moves of the LSP for different conditions via backward induction.

4. Obtain expected payoffs of the LSP and SABIC at the root of the game depending on the decision variables: *p*, *r* and *x*.
5. Maximize SABIC's expected payoff over these variables, also taking into account the individual rationality constraint.

5.2. Solution of the Model

A solution to this problem can be found using an example case, namely an example contract which is agreed to transport a specified product from a specified port to another specified port via specified ships. Explanation of parameter estimations are given in Appendix XIII. As stated before, this problem can be solved via backward induction. Now that the parameters are known, Speed Effort Choice part of the game with expected on-time delivery probabilities and expected payoffs of the LSP for each outcome can be depicted as follows:

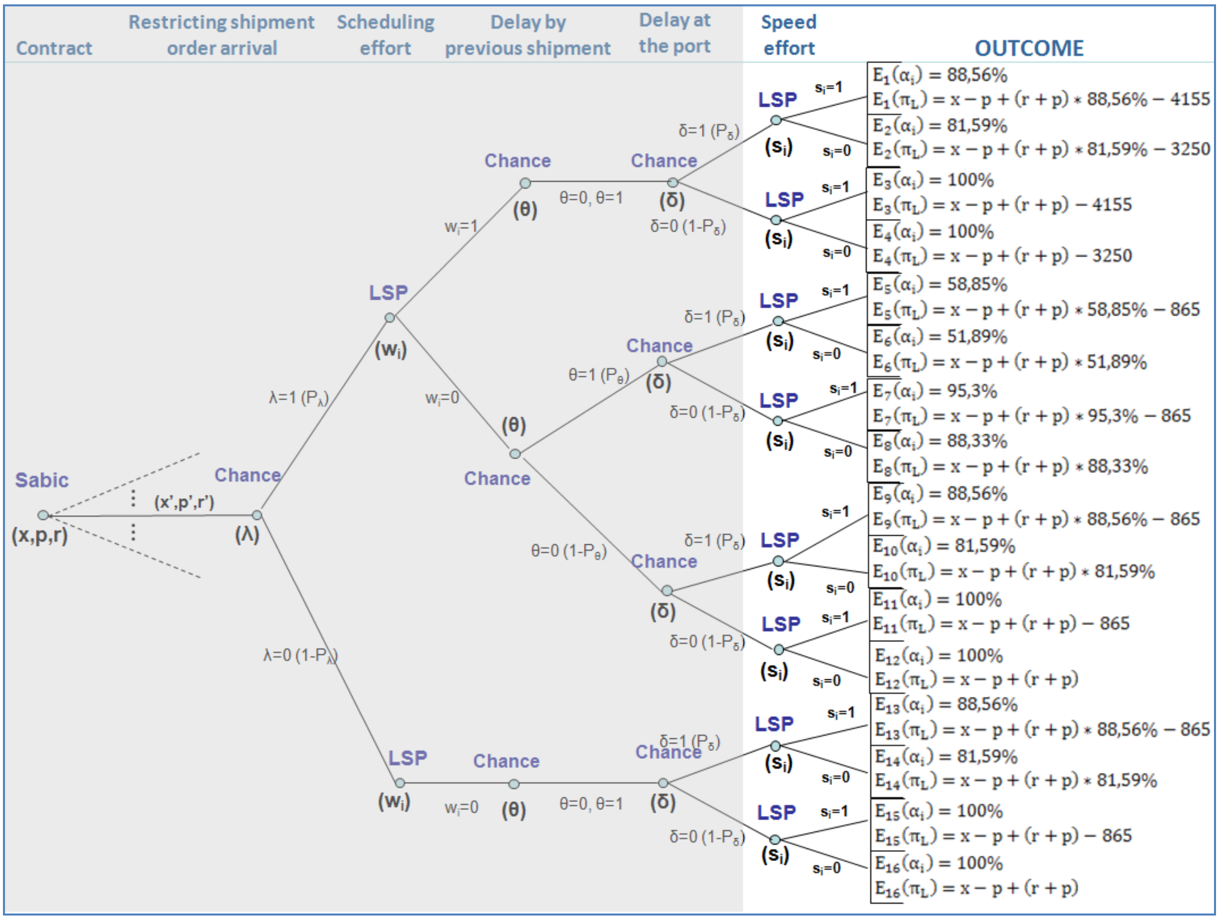

Figure 5.6: Game Solution – Speed Effort Choice

At some nodes, choice of the LSP is predictable independent from the contract parameters. This means that there is no tradeoff between a high effort level and a low effort level, LSP will choose the low options with lower costs. These nodes are: $E_4(\pi_L)$, $E_{12}(\pi_L)$, and $E_{16}(\pi_L)$. For the other decision nodes, LSP will choose the s_i=1 when the payoff with that choice is higher, which requires the same condition to hold for all five nodes. The condition can be represented in general form as:

$$(r + p) * (E_1(\alpha_i) - E_2(\alpha_i)) \geq c_s$$

When parameters are used, the condition becomes:

$$(r + p) * 6{,}97\% \geq 865$$

$$(r + p) \geq 12415{,}29 \quad (1)$$

Thus, $E_1(\pi_L)$, $E_5(\pi_L)$, $E_7(\pi_L)$, $E_9(\pi_L)$, and $E_{13}(\pi_L)$ will be higher when the above condition is satisfied. And the other options, $E_2(\pi_L)$, $E_6(\pi_L)$, $E_8(\pi_L)$, $E_{10}(\pi_L)$, and $E_{14}(\pi_L)$ will be more profitable when:

$$(r + p) \leq 12415{,}29 \quad (2)$$

Employing probabilities at the chance nodes, the game at the Scheduling Effort decision point is reduced as:

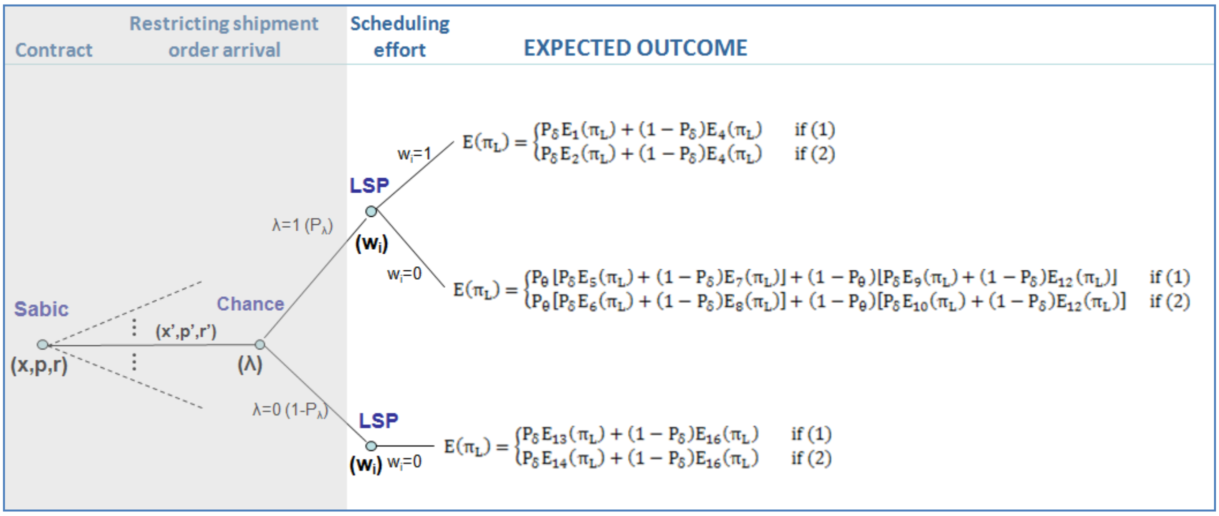

Figure 5.7: Game Solution – Scheduling Effort Choice

At the scheduling effort decision point, the decision conditions can be found for two previously derived conditions, (1) and (2).

If $(r + p) \geq 12415{,}29$, w_i=1 is more profitable when:

$$P_\delta E_1(\pi_L) + (1 - P_\delta)E_4(\pi_L) \geq P_\theta[P_\delta E_5(\pi_L) + (1 - P_\delta)E_7(\pi_L)] + (1 - P_\theta)[P_\delta E_9(\pi_L) + (1 - P_\delta)E_{12}(\pi_L)]$$

When parameters are entered, this inequality becomes:

$$(r + p) * 4{,}15\% \geq 1092{,}2$$

$$(r + p) \geq 26297{,}77$$

The inverse of that inequality makes w_i=0 more profitable. Note that the inverse is limited by the preliminary condition (1).

On the other hand, if $(r + p) \leq 12415{,}29$, w_i=1 is more profitable when:

$$P_\delta E_2(\pi_L) + (1 - P_\delta)E_4(\pi_L) \geq P_\theta[P_\delta E_6(\pi_L) + (1 - P_\delta)E_8(\pi_L)] + (1 - P_\theta)[P_\delta E_{10}(\pi_L) + (1 - P_\delta)E_{12}(\pi_L)]$$

With the parameters, the condition becomes:

$$(r + p) * 6{,}263\% \geq 1354{,}17$$

$$(r + p) \geq 21620{,}86$$

However, this condition results in an empty set since the preliminary condition was $(r + p) \leq 7567{,}804$. The inverse of this inequality becomes bounded by the preliminary condition itself, since when $\{r, p: (r + p) \leq 21620{,}86\} \cap \{r, p: (r + p) \leq 12415{,}29\} = \{r, p: (r + p) \leq 12415{,}29\}$.

Finally, when the remaining uncertainty is incorporated with the found conditions, the expected payoff function of SABIC at the root node become:

$$E(\pi_O) = \begin{cases} P_\lambda[P_\delta E_1(\pi_O) + (1 - P_\delta)E_4(\pi_O)] \\ +(1 - P_\lambda)[P_\delta E_{13}(\pi_O) + (1 - P_\delta)E_{16}(\pi_O)] & \textbf{if } (\mathbf{r} + \mathbf{p}) \geq \mathbf{26297,77} \\ P_\lambda\left[P_\theta\left(P_\delta E_5(\pi_O) + (1 - P_\delta)E_7(\pi_O)\right) + (1 - P_\theta)\left(P_\delta E_9(\pi_O) + (1 - P_\delta)E_{12}(\pi_O)\right)\right] \\ +(1 - P_\lambda)[P_\delta E_{13}(\pi_O) + (1 - P_\delta)E_{16}(\pi_O)] & \textbf{if } \mathbf{26297,77} \geq (\mathbf{r} + \mathbf{p}) \geq \mathbf{12415,29} \\ P_\lambda\left[P_\theta\left(P_\delta E_6(\pi_O) + (1 - P_\delta)E_8(\pi_O)\right) + (1 - P_\theta)\left(P_\delta E_{10}(\pi_O) + (1 - P_\delta)E_{12}(\pi_O)\right)\right] \\ +(1 - P_\lambda)[P_\delta E_{14}(\pi_O) + (1 - P_\delta)E_{16}(\pi_O)] & \textbf{if } (\mathbf{r} + \mathbf{p}) \leq \mathbf{12415,29} \end{cases}$$

The expected payoff function given above indicates the expected payoffs for three intervals of (r+p), representing preferred moves of the LSP, which was represented by the IC constraint of the optimization problem. As the next step is finding the maximum of that function, only IR constraint should be considered.

The optimal solution was found via Excel Solver, for each interval of (*r+p*), with the conditions used as constraints. As the objective function ($E(\pi_O)$) takes its shape depending on (*r+p*), the optimal solution should be independent from the *initial payment* "*x*". This was supported by solving the model for different *x* values; the optimal payoff of SABIC was found to remain constant. Thus in further analysis, this parameter is set to current payment (*x=o, i.e. initial payment is the current payment*), for the ease of understanding.

The table below summarizes the optimal solutions for each interval of (*r+p*):

Interval	(r+p)< 12415,29	12415,29 ≤(r+p)< 26297,77	26297,77≤(r+p)
x	€ 40.625,00	€ 40.625,00	€ 40.625,00
r	0	1040,73	1787,68
p	0	11374,56	24510,09
r+p	0	12415,29	26297,77
$E(\alpha_i)$	91,62%	94,20%	97,34%
$E(\pi_L)$	€ 40.625,00	€ 40.625,00	€ 40.625,00
$E(\pi_O)$	-€ 8.317,97	-€ 7.632,06	-€ 7.388,40
Payoff Increment	-	€ 685,91	€ 243,66
Payment to LSP	€ 40.625	€ 40.946	€ 41.712

Table 5.1: Optimal Solution and Variables

In Table 5.1, the first interval corresponds to the current situation at SABIC, when no incentives or penalties are applied and therefore there is *no extra effort* of the LSPs. The expected delivery performance score also validates the accurateness of the parameter estimations, since the current delivery performance according to the new measure was found to be 91,92%.

Simply, minimum bounds of the given intervals indicate the minimum amount to set for (*r+p*), which maximizes the expected payoff of SABIC. This is a reasonable finding considering that for slightly higher (*r+p*) values the expected delivery performances are the same.

Implementation of the optimal reward and penalty values in the second interval results in an expected increase from 91,62% to 94,20% in terms of delivery performance. This motivates the *speed effort* of the LSP, with € 221 of expected additional payment which will return an expected net profit of € 685,91 per shipment.

Similarly, the highest effort when *speed and scheduling efforts* more profitable is observed by setting *r* and *p* according to the optimal solution in the third interval. With respect to the previous option, this scheme requires an expected additional payment of € 766 to the LSP which brings an additional € 243,66 of profit in return. At this interval, the solution is optimal for SABIC and the expected delivery performance becomes 97,34%.

It can also be observed from Table 5.1 that the IR constraint is always binding at the optimal solution. This was also stated by Lim (2000).

Another important point which can be observed from Table 5.1 is the large values of the penalties. Since the optimization problem tries to maximize SABIC's expected payoff, which increases as penalty increases and reward decreases, the penalty is kept as high and reward is kept as low as possible as long as the expected payoff of the LSP is at its reservation utility. A small decrease in the optimal penalty value will increase the reward (because of the lower limit of r+p) and therefore result in a suboptimal solution.

5.3. Scenario Analysis

Because of the structure of the expected on-time delivery probability function, changes in the parameters might require resolving of the model from scratch. Since the probability is bounded between 0 and 1, tradeoff conditions for the speed effort decision which were found to be the same for all decision nodes as $(r+p)*(E_1(\alpha_i)-E_2(\alpha_i)) \geq c_s$ in the example solution, does not always be the same when $E_1(\alpha_i)=1$ for instance. In this situation, the probability differences become different for distinct decision nodes. As a result, derived piecewise function of SABIC's expected payoff will have more than three intervals which result in different expected payoffs. Thus, at situations like these, model needs to be resolved and scenario analysis for extensive number of scenarios will be highly time-consuming.

For that reason, some parameters were only changed ±50% to observe the behavior of the optimal solution. Solutions for other parameters whose changes do not result in such a problem were obtained for some values in a determined range. Scenario analyses for important variables are explained in detail in Appendix XIV. In summary, the analyses resulted in the following findings:

- With every 50% increment in the revenue that is assumed to be obtained for an on-time shipment (*R*), optimal expected payoff of SABIC increases by $R*50\%*E(\alpha_i)$.
- The lower limit of making the speed effort more profitable increases as the cost of speed effort increases, and the lower limit of making both efforts more profitable decreases as this cost increases.

- Expected payoff of SABIC decreases as the reservation utility increases, and more importantly, (r+p) becomes constant after a threshold as it is bounded by the lower limit of the highest effort level ($r+p \geq 26297,77$).
- Expected on-time delivery probabilities decrease as the magnitudes of delays increase, except that changes in the magnitudes of the delays caused by the previous shipment (D_θ) do not affect the expected on-time delivery probability when scheduling effort is more profitable.

5.4. Practical Insights

To translate the findings of the model into practical insights, the following points should be emphasized:

- When the whole month is considered, calculating the outcomes of the effort levels will be too complex for the LSP to come to decisions. Every decision will be dependent on the prior decisions and latter uncertainties (potential problems). Besides, relaxing their efforts for the last shipments might not be the preferred choice because of the unknown importance of these shipments. That is to say; the current incentive scheme provides an environment where the outcomes of the adjustment of their effort levels will be visible, decision making will be simpler, and theoretically LSP's will set efforts to aim 100% on-time delivery performance.
- For every case, because of the IR constraint, payment to the LSP should be at least the sum of its reservation utility and the expected costs for its efforts.
- Choices of the LSP depend on only "Reward and Penalty" offered, and is independent from the initial payment. Thus for a given initial payment, optimal reward and penalty values can be derived which results in the same optimal expected payoff for SABIC.
- Since providing rewards is considered for a "profit-sharing" purpose, SABIC cannot grant LSP a reward for an on-time delivery which is greater than its gain as extra revenue for that on-time shipment.
- Received reward for being on-time should be at least the expected cost of LSP's efforts, so that increasing the effort will be advantageous for the LSP. In other words, rewards and penalties become effective in terms of effort choice only when the expected additional gain of the LSP for an on-time shipment is high enough to compensate their expected costs for that effort.
- Since the penalty value is found to be very large when the highest effort is desired; it can be concluded that a highly deterrent penalty factor is necessary to force the LSP to perform as desired.
- The reward and penalty values are highly sensitive to the costs of the LSP, thus the estimation of the costs should be done carefully.

5.5. Monthly Incentive Scheme

The model constructed before focused on a single shipment, and introduced a scheme which applies for separate shipments. Monthly implication of the applied model per shipment can be observed when the shipments for one month are aggregated. For that purpose, following parameters can be defined:

$\boldsymbol{n} = \ \# \ of \ monthly \ shipments$

$\boldsymbol{N} = (i = 1,2, \dots, n) = \ Set \ of \ shipments$

$\boldsymbol{\alpha} = \frac{\sum_{\forall i \in N} \alpha_i}{n} = Resulting \ monthly \ delivery \ performance$

For every shipment, the paid amount differs depending on ship's being on-time or not. Following the initial payment x, either a reward (r) or a penalty (p) is issued.

Thus, the payment per shipment is equal to = $\begin{cases} x + r & if \ \alpha_i = 1 \\ x - p & if \ \alpha_i = 0 \end{cases}$

Then the monthly total payment to the LSP becomes:

$x * n + r * \sum \alpha_i - p * (n - \sum \alpha_i) = x * n + r * \alpha * n - p * n * (1 - \alpha) = (x - p) * n + \alpha * n * (r + p)$

Monthly payment to the LSP is a linear function of α, with the constant of $[(x - p) * n]$ and the slope of $n * (r + p)$. Depending on the decision variables x, r and p; resulting incentive scheme is as given in the figure below:

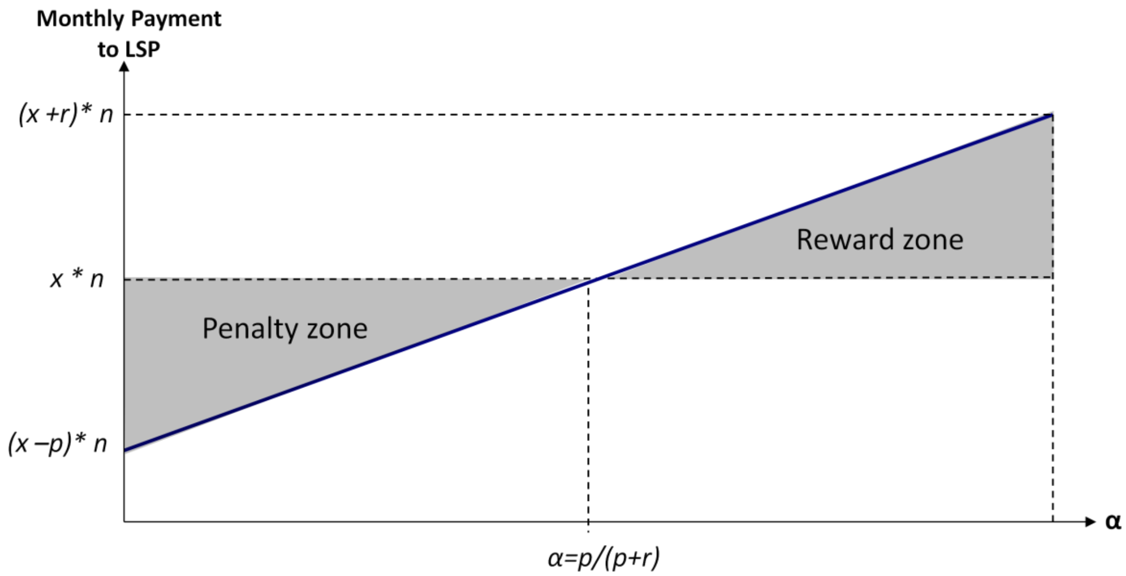

Figure 5.8: Monthly Incentive Scheme

The resulting monthly incentive scheme is a linearly increasing function of monthly delivery performance, where LSP gets neither any reward nor penalty when its monthly performance is $p/(p + r)$. The maximum payment is obtained when the performance is equal to 1, which is the desired outcome.

5.6. Possible Extensions

In order to make the model simple and analyzable, and because of restrictions such as data availability and difficult estimation of parameters; the model had assumptions and simplified decision variables. It is difficult but possible to extend the current model for the aim of obtaining better results.

First of all, the effort decision variables of the LSP can be made continuous instead of binary variables. Especially speed effort would be clearer, if the data about fuel consumption at each speed level was available. This extension would make the model more realistic because the current model makes the LSP pay the cost of traveling at the ship's top speed, independent of how much increase in speed is sufficient to be on-time.

Similarly, binary uncertainty variables can also be made continuous, adding more stochasticity to the model. Although the model will be much more difficult to solve, it can yield more realistic results.

Another extension would be the incorporation of different monthly incentive schemes. Current scheme of single shipment scope results in a standard monthly incentive scheme, which was indicated earlier. One option would be to extend the model to a monthly scope, and the second option would be to convert monthly payments to a single shipment. However in the first option, the behavior of the LSP would be more difficult to analyze when it is supposed to give monthly effort decisions. The drawback of the second option is that every shipment would be depending on other shipments, which makes the model dynamic to its core.

There is incomplete information about the state of the world at the time of contracting. The random variables such as weather conditions become available just before the shipment takes place. However; the effect of this variable (ε) is assumed follow a uniform distribution, which might not be realistic. As it directly influences the calculation of expected on-time delivery probabilities, the influence of this random variable is significant and important; thus, an accurate estimation of this random variable's ingredients and its distribution would make the model more realistic.

A last extension opportunity would be the addition of exceptional conditions into the model as constraints. For instance; since the LSPs would not want to be kept responsible for the influence of external variables, contract parameters would be conditioned such that LSPs are not penalized for certain late deliveries because of external variables.

5.7. Concluding Remarks

The model described in this chapter builds an understanding about how the performance-based logistics contracts should be constructed, and what should the considerations include. Despite the simplicity and strict assumptions, calculations and analyses are successful to capture the main understanding of incentive contracts.

As the delay analyses indicated, the most important problems of shipping and barging are both in the same direction: on-time arrival for loading and voyage length. Thus, incentive-based logistics contracting is also an improvement opportunity for the barges. Although the model was built considering shipping, it can also be used for barging because of the similarity of the shipment process and problematic delays. For that purpose, the model does not require any structural modification, only the parameters should be re-calculated.

Moreover; it might also be applied to other modalities of transportation, assuming that delay problems lie within the same two causes. If there are additional delay causes which can be remedied by a higher LSP effort, a preliminary analysis needs to be done and the model can be extended to include these additional causes.

CHAPTER 6: CONCLUSION

This study aimed to depict problematic shipment processes which decreased the delivery performance of third party logistics service providers, to define key performance indicators which reflect customer satisfaction more correctly, and to build improvements of their performances through performance-based logistics contracts. For shipping and barging; process flows were drawn to distinguish between the responsibilities of different parties involved, and a process timeline was constructed. Then from collected shipment data, problematic processes and their frequencies were observed and inserted over the timeline. This helped to observe the contribution of the parties to late deliveries. Also, KPI identification for on-time deliveries was done via the estimation of process lengths over the same timeline. Seven KPIs which had different advantages and disadvantages were identified, and some of them were suggested for measurement and also used in the further thesis work.

Delay analysis concluded that most influential delays under the responsibility of LSPs are: late arrivals for loading and long voyages for both shipping and barging. Remedy of these delays required a higher effort from the LSPs, which needed to be motivated via the contracts. Thus, a performance-based logistics contracting model was built for that purpose. The model included LSPs' efforts for on-time arrival for loading and for faster voyages, which were stimulated using the contract parameters such as penalties and rewards. A contracting game was defined, where the latter action of the LSP to set its efforts could be controlled by the contract parameters. In other words, contract parameters can be defined such that the desired effort level of the LSPs is stimulated, and is the most profitable option for the LSPs. Conditions which depend on the cost and performance outcome of the efforts were defined, and they point out different effort levels. Lastly, optimization problems for all possible effort levels were deducted. The model was solved for a sample situation, and the findings indicated that highest effort levels of LSPs can be motivated via optimal rewards and penalties, which anticipates an increase of 5,72% in the delivery performance and results in a better payoff for SABIC compared to the current situation.

6.1. Complexities and Deficiencies

Considering the delay analysis, it should be pointed out again that the delay frequencies do not perfectly reflect reality, since the perfect delay information were not obtained from the LSPs. This is a drawback of relying on historical data, which may not be kept in the best way. Especially for barging, the analysis results might be biased, and in the future, better bookkeeping is required for a better measurement process. However, the analysis still succeeded in pinpointing crucial problems and the results are valid.

During KPI identification, there were deficiencies about the time-interval estimations. Although the expected transit times were available, expected time for loading is difficult to estimate and dependent on the volume. Thus, it requires extra work to come up with a better estimation equation which is more realistic than the regression model. Also, there is a difficulty about utilizing the identified measures inside the contracts with customers and LSPs, because of the unusualness of the measure with respect to the rest of the market. However, this might be a starting point to provide an understanding of the distinction between what kind of measure should be put inside the contracts and what kind of measure to use for performance measurement aiming to reflect customer satisfaction.

As explained in Chapter 5, the constructed contracting model is kept simple using simplistic distributions and binary variables in order to be analyzable and to provide understandable implications for SABIC. For that, assumptions and simplifications were made which also resulted in deficiencies which were explained in section 5.6. Despite the model being simple, there are also complexities about finding a solution, since some of the parameters are difficult to estimate. Parameters such as the costs of the LSP, expected future revenue increase as a result of an on-time delivery, and the probabilities of the defined uncertainties were approximated in this study, however, it is very difficult to perfectly estimate these parameters in order to the perfect solution.

6.2. Implementation at SABIC

It has been previously noted that the contracting model can be adapted to barging with small modifications, however implementation to other modalities require a preliminary analysis. Although the structure of the game will be the same, parameters should be estimated using historical data even for barging. Currently in SABIC, KPI reporting about barging has important deficiencies, which will require some time to collect healthy and useful information for the estimation of required parameters. For other modalities, prominent delays and improvement opportunities may be different which may require a very different game to be built.

Solution steps for shipping were stated in 5.1.3, which required estimating the parameters in the beginning, calculating on-time delivery probabilities and obtaining expected payoffs, then deriving SABIC's maximization problem and solving it to obtain optimal contract parameters. This should be done for each concerned contract, because changes in the parameters might result in significant differences although the structure of the game does not differ according to other contracts.

This requirement stems from the nature of the "Expected on-time delivery probability" function, the resulting formulas are not universal and are higly dependent on the contract (expected transit time, loading time and ship specifications). Thus, this complexity makes it necessary to resolve the game and afterwards the optimization problem by hand. Also, magnitude of the delays can also change according to the contract because every contract concern a specified load port and a route. Delays at different ports and on different routes may vary significantly, therefore these parameters can also be reestimated according to the concerned load port and route.

If the derived formulas for the example situation are utilized for different contracts, suboptimal and even trivial results might be obtained.

Thus, it can be said that an easy software implementation is not possible, all calculation steps should be integrated for the model to function for all possible parameter ranges. Therefore, as desired by SABIC, an implementation of the model in Excel would be highly time consuming. Because of that, as it was also previously stated in Chapter 2, intervention step of the research design cycle of Van Aken (2007) and Van Strien (1997) is not applied under the extent of this project.

6.3. Future Research Directions

In the literature, the studies about performance-based logistics contracting are limited. Plenty of articles such as Platz and Temponi (2007) and Sols et al. (2007) limit their discussions to verbal implications and suggestions. Research with derived mathematical models are all analyzed under agency theory, and are limited to the studies of Lim (2000), Bryson and Ngwenyama (2000), Liu et al. (2007), Wu and Liu (2009), which are very similar in reasoning and content. Other studies elaborating incentive contracting are either irrelevant or inapplicable to the 3PL setting. The present studies lack solutions for example cases and numerical analysis, thus they only include theoretical mathematical representations. Furthermore, there are also no extensions or contractions to represent different scopes and schemes.

This study contributes to the relevant research area by its different scope, the business case implementation and resulting practical implications. It showed that with careful assumptions and estimations, a contracting model can be used in real life contracting applications. It also pointed out the reasoning for determining the penalty and reward variables, e.g. paying for LSP's efforts' costs by the reward, necessary conditions which should be satisfied per effort to obtain the maximum possible payoff.

Future research should be conducted to fill the abovementioned gaps. Most importantly, real-life applications or case problem solutions should be added to the literature. Another contribution would be to quantify different payment schemes, since current studies only consider two possible payment options: penalized or rewarded. Also, stochasticity extensions can be applied to the existing models in terms of asymmetric and incomplete information such as external variables which are not apparent at the time of contracting.

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APPENDICES

APPENDIX I: LIST OF ABBREVIATIONS

3PL	Third Party Logistics
LSP	(Third Party) Logistics Service Provider
KPI	Key Performance Indicator
NOR	Notice of Readiness
B/L	Bill of Lading
COA	Contract of Affreightment
ETA	Estimated Time of Arrival
ELT	Estimated Loading Time
ETT	Expected Transit Time
IR	Individual Rationality
IC	Incentive Compatibility

APPENDIX II: TERMS AND DEFINITIONS

Laycan: A (generally 3-day) time window within which a ship is required to arrive at the loading port at a ready-to-load condition. A laycan for loading is agreed on contract with both the customer and the ship owner. For shipping, there is no agreement about discharge date.

Vetting: is the process of checking the ship's specifications if she satisfies the requirements to be used for the shipment. SABIC has its own conditions, and customers may require additional conditions.

Vessel Nomination: SABIC includes a nomination procedure in contracts with ship owners (LSPs). The procedure implies informing ship owners about a wider laycan two weeks beforehand. The next step is that within a couple of days, ship owners send the name of the ship which is most likely to be available to be used according to their schedule, so that SABIC can vet the vessel.

Berth: Inside the ports, berth is the place beside the storage tanks, where ships are loaded. It is also used as a verb "berthing", which means to connect ship to that place completely.

Jetty: Jetties are equivalent to the berths which are in ports, but they have a broader meaning. Jetties can exist in canals, rivers and other waterways and are used to accommodate ships or barges.

NOR (Notice of Readiness): The ship captains tender the NOR (which is a document) when they arrive at the port and the ship is ready to be loaded. After NOR is tendered, it is SABIC's responsibility to prepare the berth and load the tanks.

Laytime and Demurrage: Laytime is the total time allowed for loading + unloading of the ship. When they last longer than the allowed laytime in the contract, an amount is paid to LSP called 'demurrage'. If the time is long because of loading problems, SABIC pays the demurrage. If it is caused by a discharging problem, demurrage is paid by the customer. If the total time is shorter than allowed, it is recorded to the laytime bank to be used in next shipments.

Bill of Lading: is the document which represents the transfer of ownership from one party to the other. When the material is fully loaded to a tank, a bill of lading is signed by the ship master (captain). From that time on, customer owns the material and customer's payment can be transferred to SABIC. This document also prevents a possible confusion of delivering materials to the wrong consignee. The working logic of bill of lading is represented in the figure below:

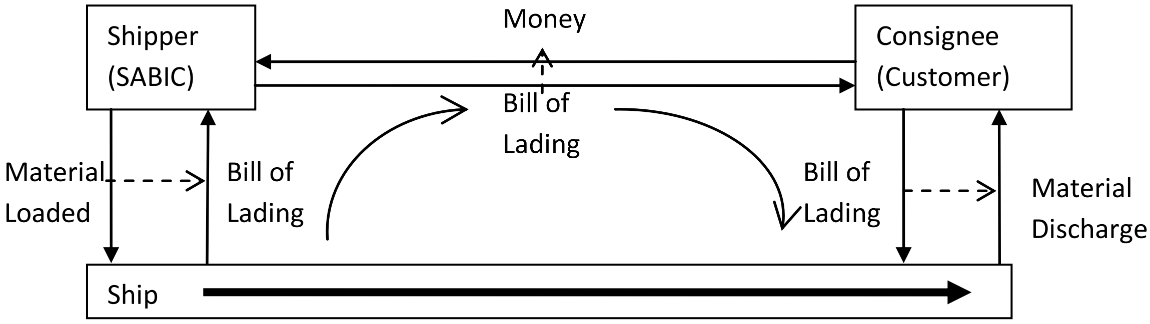


Figure II.1: Bill of Lading

Contract types with LSPs:

- ☐ *COA (Contract of affreightment):* is the contract signed with the ship owner, which includes: the material to be shipped, the approximate frequency and volume of shipments, the specified ships and costs involved. In this type of contract, LSP has to make the ship available at the port within laycan.
- ☐ *Time Charter:* is the contract signed with the ship owner, which includes the usage of the ship throughout a period (one or two years). Like renting, SABIC has the rights over the ship, and schedules itself. No other company is served with the same ship unless it is sublet by SABIC (in the times when there are no shipments).
- ☐ *Spot:* is the one-time contract signed with a LSP with available ship. LSP are found through brokers.

APPENDIX III: ORGANIZATION CHART OF SABIC

SABIC has six Strategic Business Units (SBU) which differ according to the product groups and are directed by a vice president in Riyadh. These SBUs have their own supply chain management functions, which control all supply chain management operations throughout the world. Supply Chain Execution Europe is divided into four sub-departments, as depicted below.

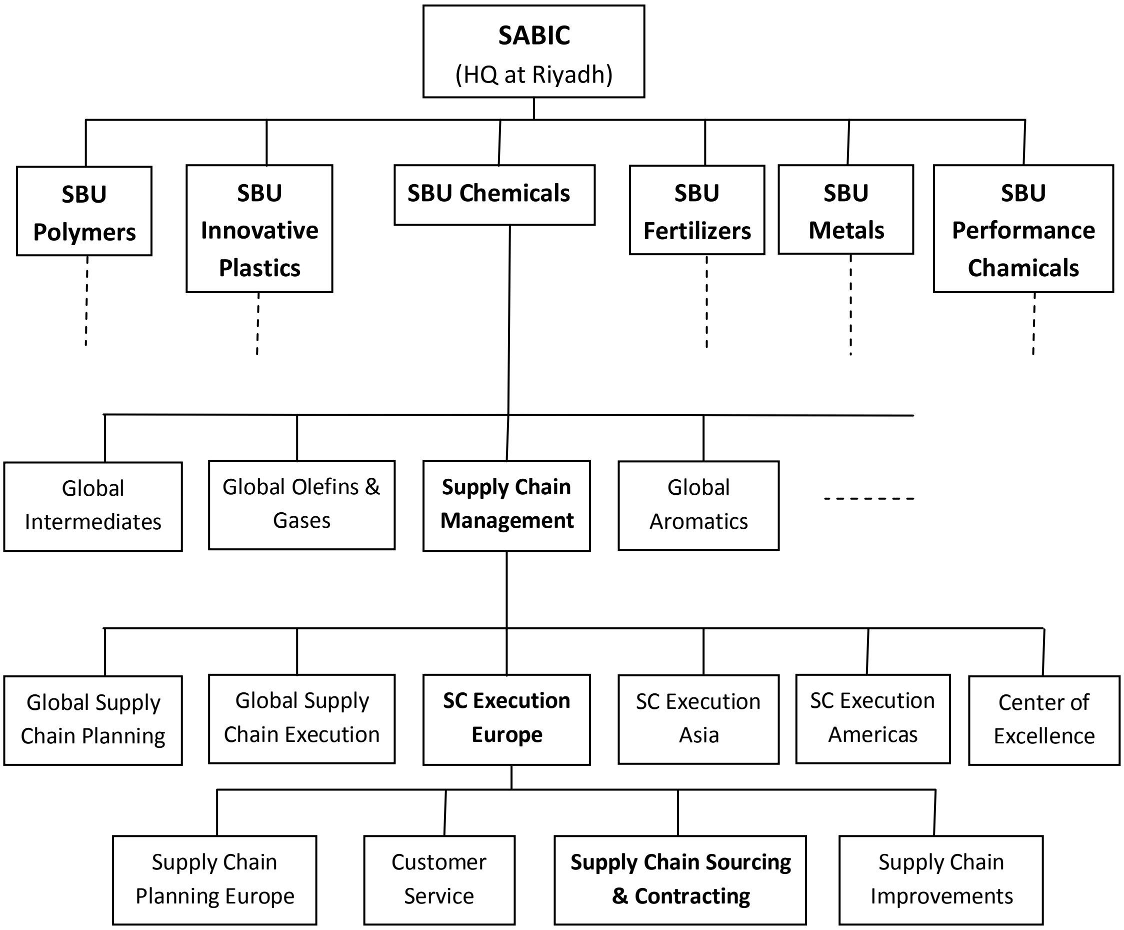
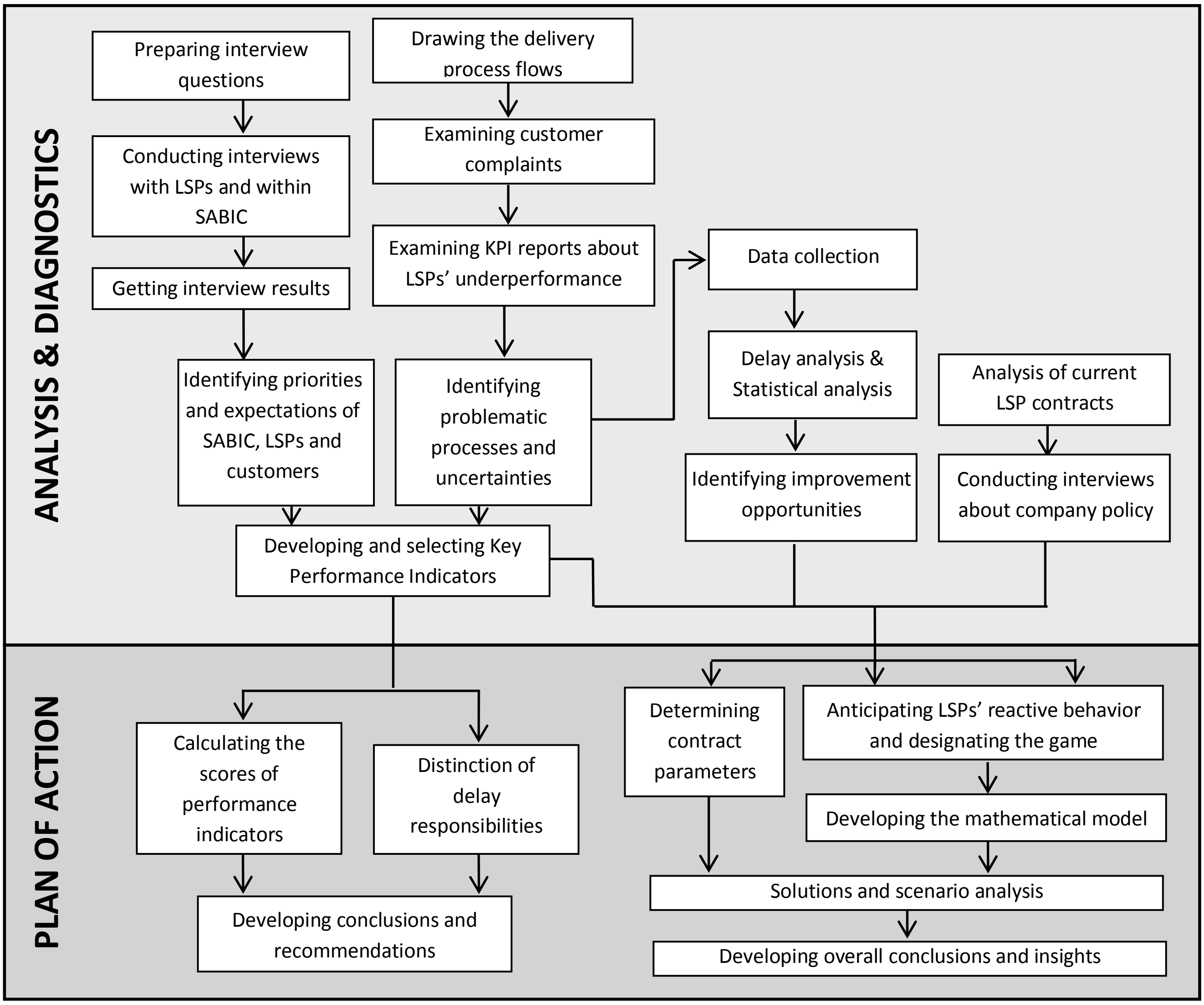


Figure III.1: Organization Chart

APPENDIX IV: PROJECT METHODOLOGY



APPENDIX V: INTERVIEWS WITH LSPs

BRAEMAR SEASCOPE AND BROERE ESSBERGER

0. General Information

- Essberger operates 24 ships with high utilization levels. There are 6-10 shipments commencing in one day.
- Based in London, Braemar Seascope is one of the largest ship broking companies in the world.

1. Information registry

- All information about the shipments is available minute-to-minute in the documents called “Statement of Fact”. But only the demanded information is sent to SABIC via KPI reports because the shipment files are very large and some information is unnecessary.

2. Frequent causes of delays

- Certain ports have more frequently occurring congestions and other problems, therefore delays are inevitable.
- Most important factor is weather, especially in the northern seas of Europe where the weather is harsh.
- Second important delay factor is berth congestion. Some berths tend to cause problems more frequently.
- In Baltic Sea, sometimes ice breakers should be awaited in winter.
- Products may be frozen because of the cold. If there is no heating because cold weather was not anticipated before, ship has to wait for the temperature to go up.
- Third important problem is the malfunctioning pumps.
- Surveyors are sometimes late.
- Surveying may be delayed because of the cleanness of the tank.
- Some products such as Glycols require cleaner conditions; therefore extra time will be spent on cleaning.

3. Scheduling

- When there is a change in the laycans, they bend the schedule and adapt it.
- If the change is several days (up to one week for Essberger)
- There is a discharge-load connection in same or close ports so that when loads are discharged in one port, it will be again loaded for the next customer in the same port.
- There are separate chartering desks in Hamburg and Dordrecht. They modify the same schedule containing all ships. Everyday they print the final form of the schedule and control the positions of ships operating that day.
- Generally FCFS is adopted for operations, SABIC generally gives orders a couple of weeks in advance. However, when there is a spot shipment or a change short before the shipment, it is harder to cope with.
- Essberger tries to keep 75% of their shipments as contract shipments and the remaining 25% for spots and other. Contracted customers such as SABIC have priority over the spot.

4. **Other important information**

- Longer trips have higher uncertainty.
- As number of customers whose products are loaded into the same ship increases, loading time increases as well.
- Loading lay time is reported for the customer's products only. Any delay is broken down to be distributed over the loading times.
- ETAs are generally measured by the optimal performance.
- Success of ETAs depends on the past experience of the ship owner.
- Sometimes, loads of different customers are loaded from different berths.
- Small ships are more sensitive to weather conditions.
- Pumps are operated by ships and ports.
- Ships have their own maintenance regimes however pump breakdowns cannot be fully controlled. Sometimes there are signals and they can prevent breakdowns but it is a stochastic case.

NAVIGLOBE

0. **General Information**

- Naviglobe operates the time charter in the UK - ARA lane.
- Has a smaller number of ships, compared to the previous companies. 3 ships are contracted with SABIC.

1. **Information registry**

- Naviglobe keeps information about the ship such as speed, pitch, fuel consumption, loading and discharge speed, etc. in order to evaluate the ships.
- Ship evaluations are used for measuring vessel experience performance, which points out the weaknesses of ships about operations.

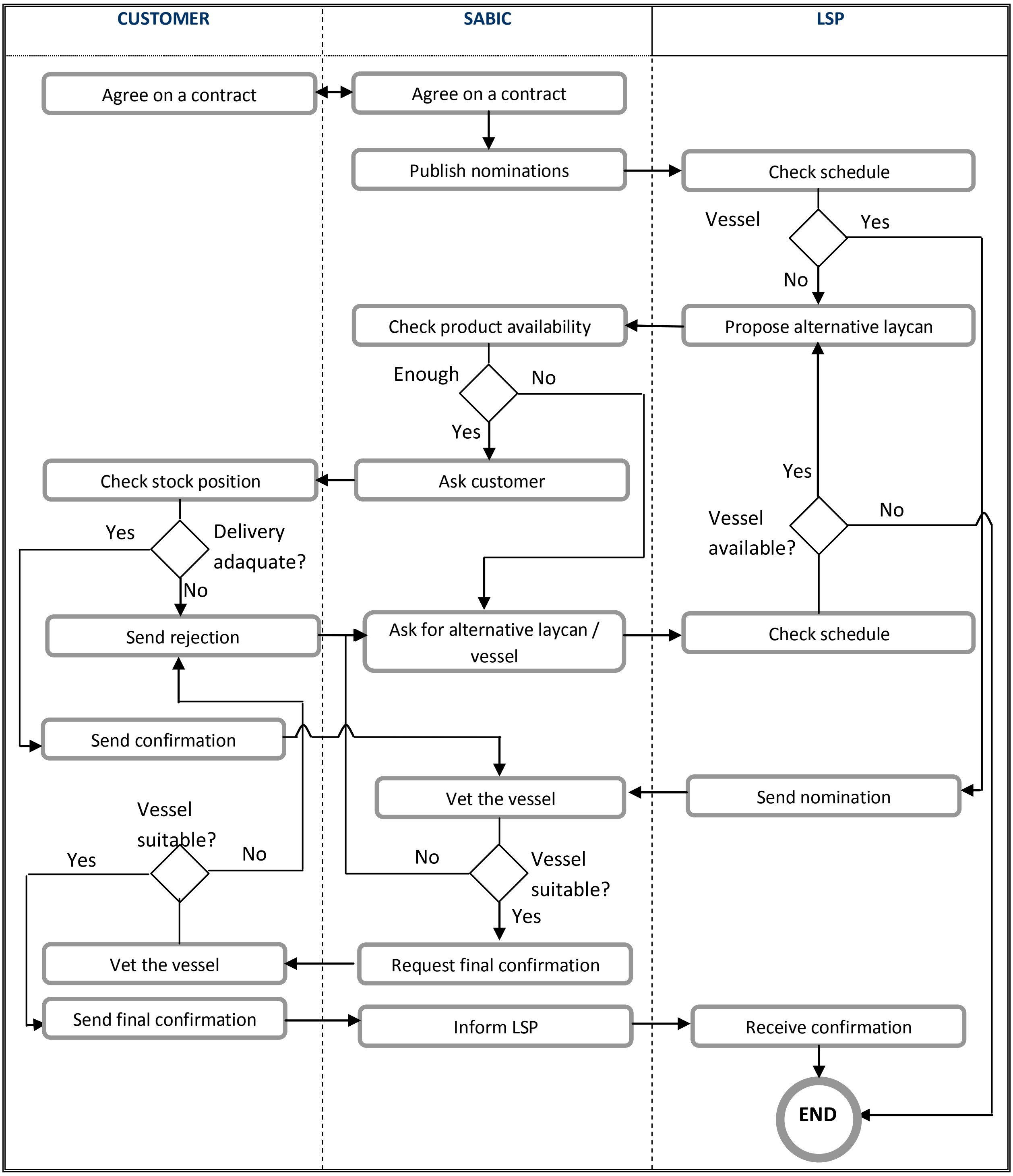
2. **Frequent causes of delays**

- Naviglobe finds weather conditions as one of the major reasons of delay. Another important delay is the jetty occupancy (berth availability) especially in English ports.
- Other important causes of delay are: lateness of surveyors, breakdown at production site (therefore product availability), mechanical problems about the ship, some pilot issues and French strikes.

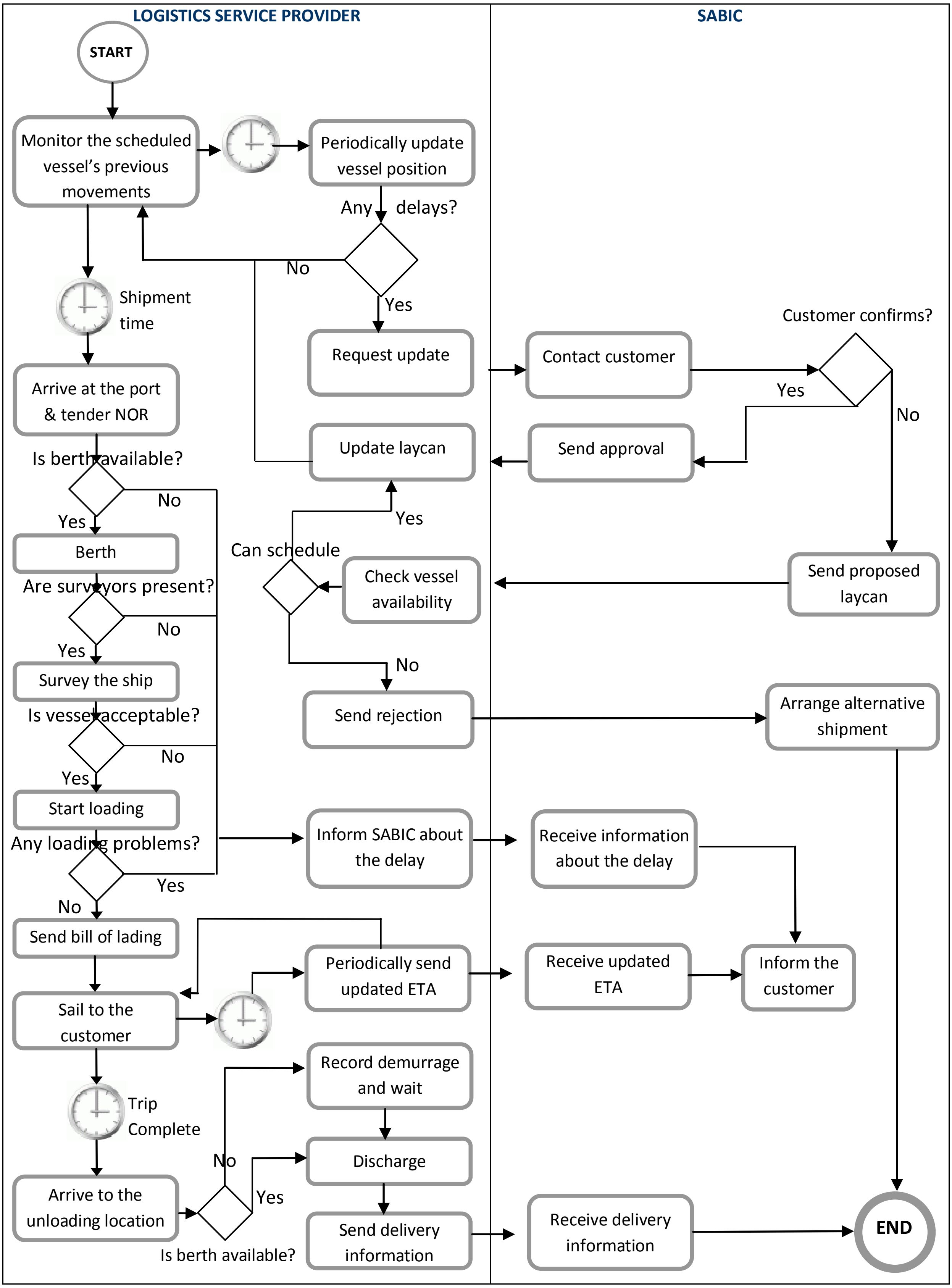
3. **Scheduling**

- Customer prioritization is done for the customers with long-term contracts and ships with constant laycans.

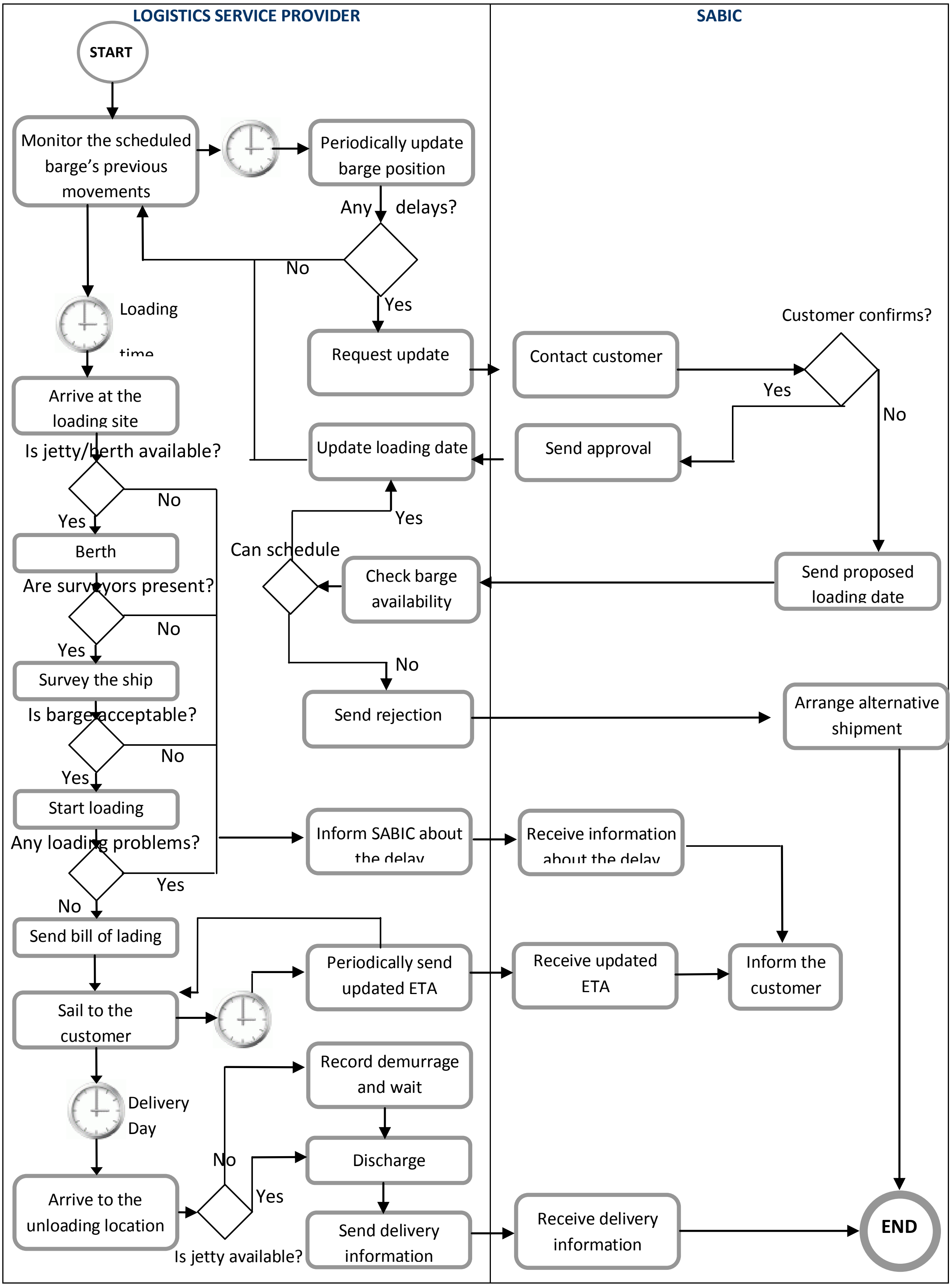
APPENDIX VI: SHIPMENT ORDERING PROCESS FLOW



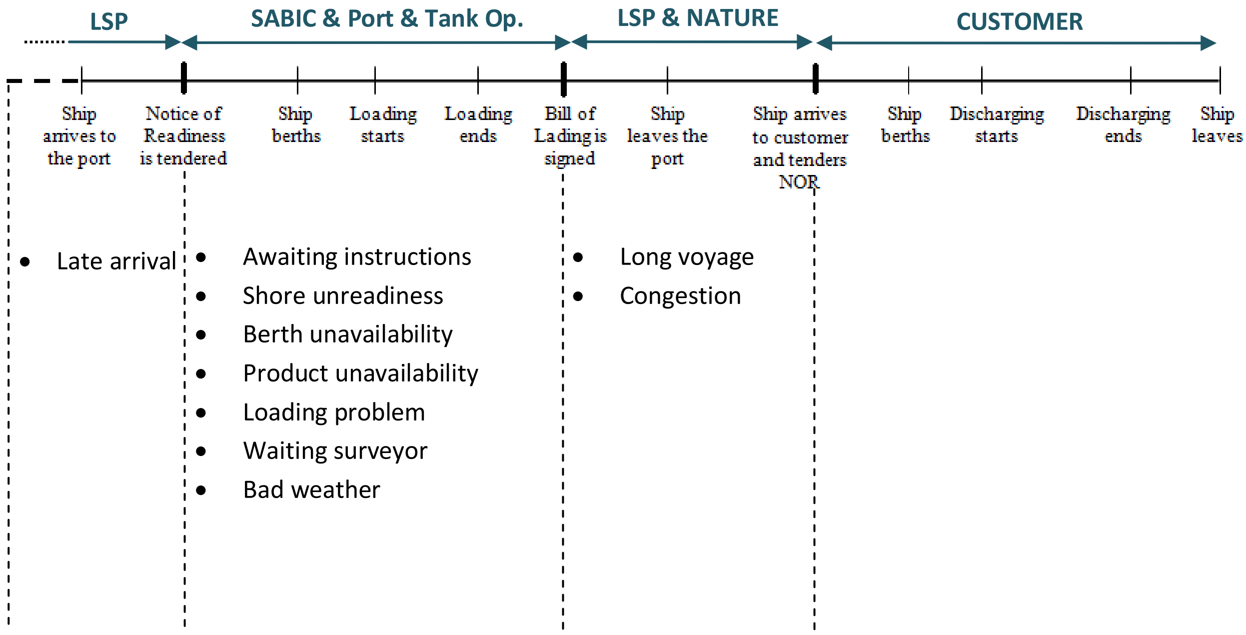
APPENDIX VII: SHIPMENT PROCESS FLOW



APPENDIX VIII: BARGING SHIPMENT PROCESS FLOW



APPENDIX IX: SHIPPING DELAY POSITIONING



APPENDIX X: KPI REPORTING TEMPLATE

Sabic Shipment	COA VOY NO.	Voyage reference Owner	B/L DATE	VSL NAME	Initially agreed LAYCAN (dd-dd	Finally agreed LAYCAN (dd-dd mmm)	Reason for change	NOR Date |	Time	NOM QTY	B/L FIGURE	LOADPORT	DISPORT 1	DISPORT 2
NOR B4/WITHIN LAYDAYS? Y/N	VOY W/O INCIDENT? Y/N	FREIGHT RATE (EUR)	TOTAL LAYTIME ALLOWED (hrs)	BUNKER SURCHARGE	TOTAL FREIGHT INC BUNKER SURCHARGE	OVERALL RATE PMT	DEM RATE (EUR)	Demurrage (EUR)	Loadport Laytime (hrs)	Disport Laytime (Hrs)	Other costs	Comments about -Incident, -Delay, -Others		

APPENDIX XI: CORRELATION ANALYSIS

Because of the differences in the data sets (different shipment sets are utilized because of the data availability) which were used for correlation calculations, correlation tables were obtained seperately.

	Arrival Day	Long Voyage	Late Discharge	Shore Unreadiness	Awaiting Instructions	Berth Unavailability	Total Loading Time
Arrival Day		-0,1326	0,3036	-0,0129	-0,2410	0,0825	-0,2661
		(159)	(159)	(159)	(159)	(159)	(159)
		0,0955	0,0001	0,8721	0,0022	0,3010	0,0007
Long Voyage	-0,1326		0,0558	-0,0177	0,1066	-0,1857	0,0146
	(159)		(159)	(159)	(159)	(159)	(159)
	0,0955		0,4850	0,8251	0,1812	0,3191	0,8552
Late Discharge	0,3036	0,0558		-0,0531	0,0966	0,0091	0,3239
	(159)	(159)		(159)	(159)	(159)	(159)
	0,0001	0,4850		0,5062	0,2256	0,9093	0,0000
Shore Unreadiness	-0,0129	-0,0177	-0,0531		0,1102	-0,0375	0,0543
	(159)	(159)	(159)		(159)	(159)	(159)
	0,8721	0,8251	0,5062		0,1666	0,6391	0,4969
Awaiting Instructions	-0,2410	0,1066	0,0966	0,1102		0,0174	-0,3564
	(159)	(159)	(159)	(159)		(159)	(159)
	0,0022	0,1812	0,2256	0,1666		0,8278	0,0643
Berth Unavailability	0,0825	-0,1857	0,0091	-0,0375	0,0174		0,0948
	(159)	(159)	(159)	(159)	(159)		(159)
	0,3010	0,1191	0,9093	0,6391	0,8278		0,2348
Total Loading Time	-0,2661	0,0146	0,3239	0,0543	-0,3564	0,0948	
	(159)	(159)	(159)	(159)	(159)	(159)	
	0,0007	0,8552	0,0000	0,4969	0,0643	0,2348	

Table XI.1: Correlation Table 1

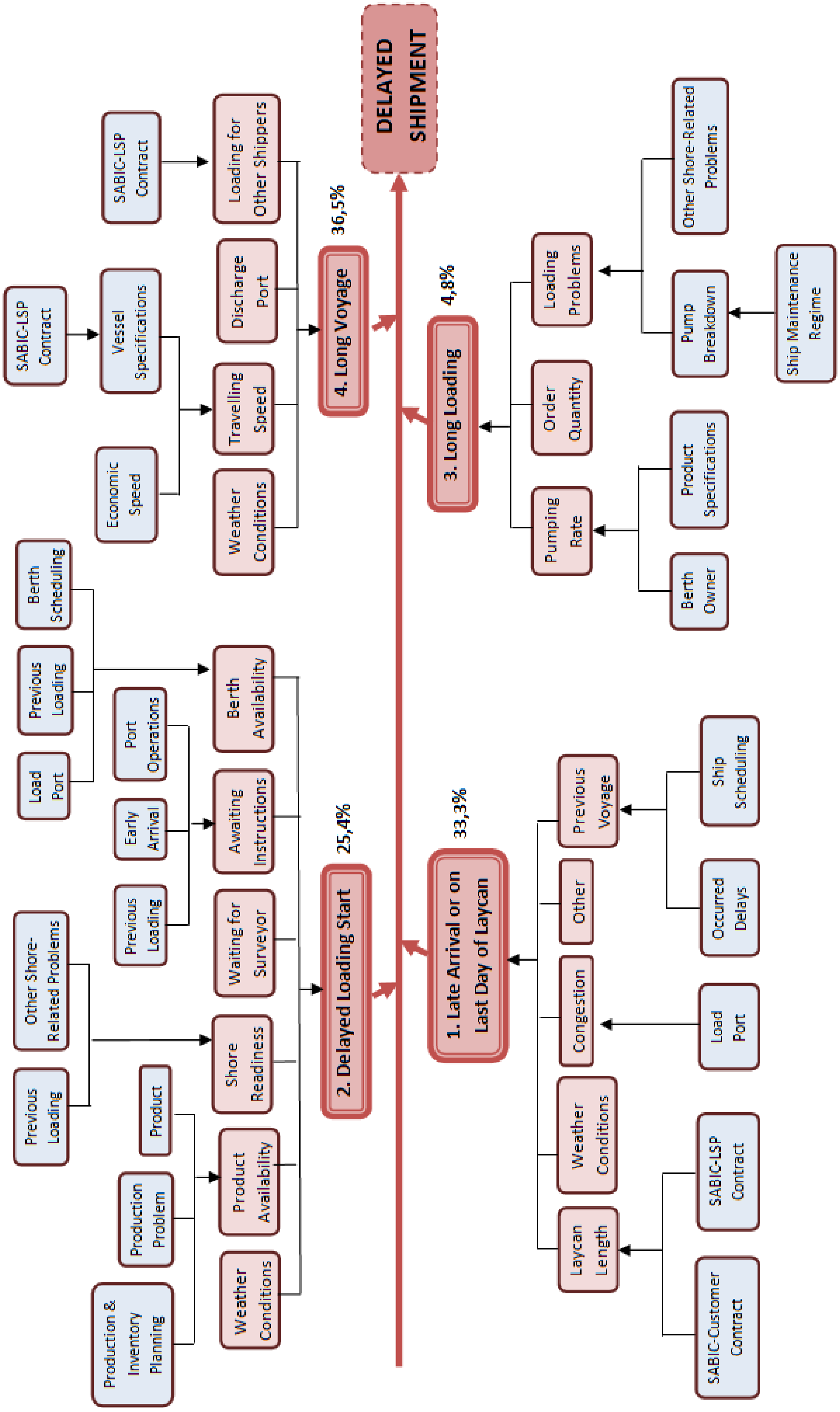
	Long Voyage	Late Discharge
Long Voyage		0,2045
		(177)
		0,0063
Late Discharge	0,2045	
	(177)	
	0,0063	

Table XI.2: Correlation Table 2

	Shore Unreadiness	Late Arrival	Arrival Day
Shore Unreadiness		0,1457	0,0639
		(337)	(337)
		0,0074	0,2417
Late Arrival	0,1457		0,5099
	(337)		(337)
	0,0074		0,0000
Arrival Day	0,0639	0,5099	
	(337)	(337)	
	0,2417	0,0000	

Table XI.3: Correlation Table 3

APPENDIX XII: COMPLETE CAUSE & EFFECT DIAGRAM FOR SHIPPING



APPENDIX XIII: ESTIMATION OF PARAMETERS OF THE MODEL

Estimations of the parameters are explained in this Appendix.

SABIC's Revenue (R):

On-time deliveries to the customer affect revenue by changing the following:

- *Customer complaint handling costs*: Increased customer satisfaction will result in a decrease in the number of customer complaints. Consequently, this will also increase the time and resources devoted to handle the complaints. However, it is negligible considering it has relatively much lower costs.
- *Increased profits by customer satisfaction*: Satisfaction of the customer results in a better trade relationship and increases the sales, therefore the revenue. However, this kind of an effect can only be measured in the long term. In this sense, it is similar to "backorder costs" used in production decision models. It should reflect the intangible adverse effect of the future loss of customer goodwill (Liberopoulos et al., 2010). Besides the fact that it is almost impossible to estimate the future sales, other means of monetizing customer satisfaction are very difficult to utilize. Only feasible approximation is possible by the involvement of two variables: increase in the production output and increase in the price. Price values are available for different market segments, by which the companies are classified according to their service qualities. However, currently SABIC's production plants are working in their maximum capacities, and therefore production output cannot be increased.

Thus, only positive effect of an on-time delivery is the increase in price. This increase is expected to be around 2%. Since the price of Cyclohexane per ton is $858, the increase in profits for a shipment of 2500 tons will be around €35,263 per shipment.

Payment in the old contract (o):

Currently, only fixed payments are used in contracts. Considering the example done for the transportation of Cyclohexane between Tees and Antwerp, a shipment of 2500 tons on average costs SABIC exactly € 40.625.

Expected time gain by speed effort (γ):

An investigation on shipment specifications revealed the economic and full speeds of a ship which is very similar to the one inside the contract taken as the example. The economic speed was found to have an average of 10,7 nautical miles per hour, and full speed can be up to 13 nautical miles per hour. Thus, considering an expected transit time of 24 hours between Tees and Antwerp, an increase in speed will bring 4,25 hours.

LSP's Cost ($c(e_i), c_s, c_r$):

Estimation of the cost of varying speeds is simple and manageable when a single voyage is considered. Cost of providing sufficient speed levels (c_s) was estimated using ships' specifications such as economic speed, maximum speed and fuel consumption; and also fuel prices. Thus, in formulas:

$$c_s = \begin{pmatrix} fuel\ cons. per\ day\ at\ Max. speed * voyage\ duration\ at\ Max. speed - \\ fuel\ cons. per\ day\ at\ Econ. speed * voyage\ duration\ at\ Econ. speed \end{pmatrix} * fuel\ price$$
$$= € \, 865$$

On the other hand, cost of increasing scheduling flexibility for LSP is harder to estimate. It only contains the opportunity cost of rejection of previous (in schedule) shipment orders (c_r), which will change for each ship and each period. Under assumptions such as fixing the payment and route for the same ship, cost of rejecting an order can be represented simply as the cost of a shipment (o). However, not all shipments have the necessity of being rejected, they can be simply shifted to other days or can be transferred to other available ships. Since there is no historical information about the schedules of LSPs and the number of owned ships can vary for different LSPs, it is almost impossible to estimate the probability of being have to reject the shipment. Thus considering only one ship, superficially, it is assumed that LSP cannot provide any flexibility for SABIC's shipment by arranging other shipments only when its monthly schedule is full. Decision to focus on a month can be supported by the fact that LSPs' schedule for a month is determined at the end of the previous month, i.e. shipments are not expected to be transferred to previous or next months. Again, superficially, it is assumed that the probability of having a specific number of reserved days in a month is the same for every possible number. Therefore, probability of having a full schedule is taken as 1/30.

$$c_r = o * \frac{1}{30} = € \, 1.354{,}17$$

Probability of a restricting shipment order arrival (P_λ):

Assuming that only the shipments which arrived early to the loading port did not have previous shipments, the existence probability of a previous shipment before SABIC's is assumed to be the percentage of the shipments which did not arrive early. This approximation gives an estimate of 65,44%.

Probability that a previous shipment will delay SABIC's shipment (P_θ):

Assuming that arrivals after the first day are delayed by the previous shipment, excluding time charters, the percentage of the shipments which arrived after the first day are taken as a percentage of 39,47%.

Magnitude of Delay $\boldsymbol{\theta}$ (D_θ):

For the shipments which arrived after the first day, lateness of the shipments had an average of 18,12 hours.

Probability that a delay will occur at the load port (P_δ):

The percentage of shipments which faced at least one delay at the load port were found to be 23,27%. This statistic did not include early arrivals because the analysis showed that the majority of delays such as *awaiting instructions* which occur on early-arrived shipments do not result in lateness in terms of delivery to the customer.

Magnitude of Delay δ (D_δ):

For the shipments which faced a delay at the loading port (excluding the ones which arrived early), this magnitude is calculated as the average of "total loading time - estimated loading time". This magnitude was found as 22,23 hours.

Random factor ε and its distribution Uniform (0,L):

Distribution of the random variable ε was assumed to be uniform, which took a value between 0 and L. Lower limit is zero because the amount of delay cannot be negative. Upper limit L was calculated from the historical data as the "2*(average time lost during the voyage)" when outliers are eliminated, because the mean of the uniform distribution is expected to be L/2.

Reservation Utility (u_0):

Reservation utility of a LSP is necessary to ensure LSP does not reject the contract. Although it is difficult to know to what extent they will still want to sustain their contractual relationship, it can be assumed that the current pricing is determined after firm negotiations and they settle for the minimum profit they are willing to obtain. Therefore the reservation utility of a LSP for a single shipment can be assumed to be the expected payment they will obtain using the old contract pricing (*o*).

APPENDIX XIV: SCENARIO ANALYSIS

Because of the explained complexities and the time constraint, scenario analysis was conducted only to see the effects of changes in parameters R, c_s and u_o on the optimal solution. These parameters were chosen as the most important factors because they highly affect the resulting optimal solution. Besides, changes in the expected delivery performances for the intervals of possible effort levels (three intervals of SABIC's expected payoff as found in the solution) were observed with respect to changes in delay magnitudes. The analysis is explained below.

Optimal Solution with respect to R

Optimal solutions were obtained for the situations where R was increased by 50% and decreased by 50%. Findings indicated that with every 50% increment in the revenue, optimal expected payoff of SABIC increased by $R * 50\% * E(\alpha_i)$. This finding makes sense since the multiplier of *R* in the expected payoff function of SABIC is $E(\alpha_i)$.

Optimal Solution with respect to c_s

Similarly, solutions for 50% increase and 50% decrease in the cost of speed effort were obtained. As expected, the optimal payoffs decreases as the cost increased. However, the most important effect of this change is on the intervals, the lower limit of making the higher speed effort more profitable increases as the cost increases. On the contrary, the lower limit of making the both efforts more profitable decreases as the cost of speed effort increases. This last finding can be explained by the fact that when speed effort cost is increased, the expected on-time probability stays the same as the difference between the costs of showing only speed effort and two efforts decreases.

Optimal Solution with respect to u_o

Changes in the optimal solution were observed with respect to changes in the reservation utility of the LSP. The solutions were obtained for 5 cases, ranging from 80% to 120% of *o*.

Expected payoff of SABIC has decreased as the reservation utility increased but more importantly, changes in reward and penalty values were worthy to note. Following figure gives the change in (*r+p*) with respect to the increase in the reservation utility.

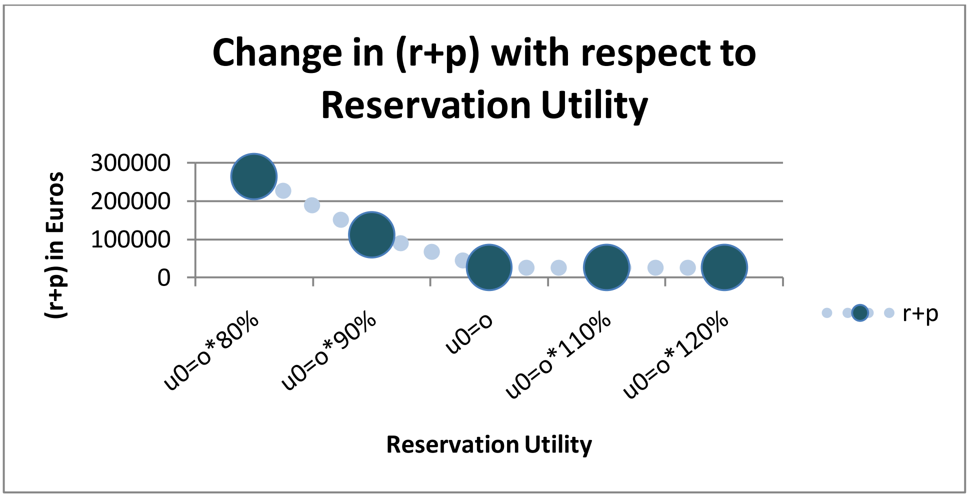


Figure XIV.1: Change in (r+p) wrt Reservation Utility

At lower reservation utilities, to maximize the payoff of SABIC, the model makes the reward as small and the penalty as large as the IR constraint allows. However, after a threshold, constraint on (r+p) that represents the condition which makes the efforts profitable becomes binding, and thus (r+p) becomes constant. After that threshold, reward increases and penalty decreases in order to balance the expected payoff of the LSP, to make it equal to the reservation utility.

Expected On-Time Delivery Probabilities with respect to D_ϑ

Changes in delivery performances in all three effort level possibilities were obtained for different values of the delay caused by the previous shipment. The following figure was obtained:

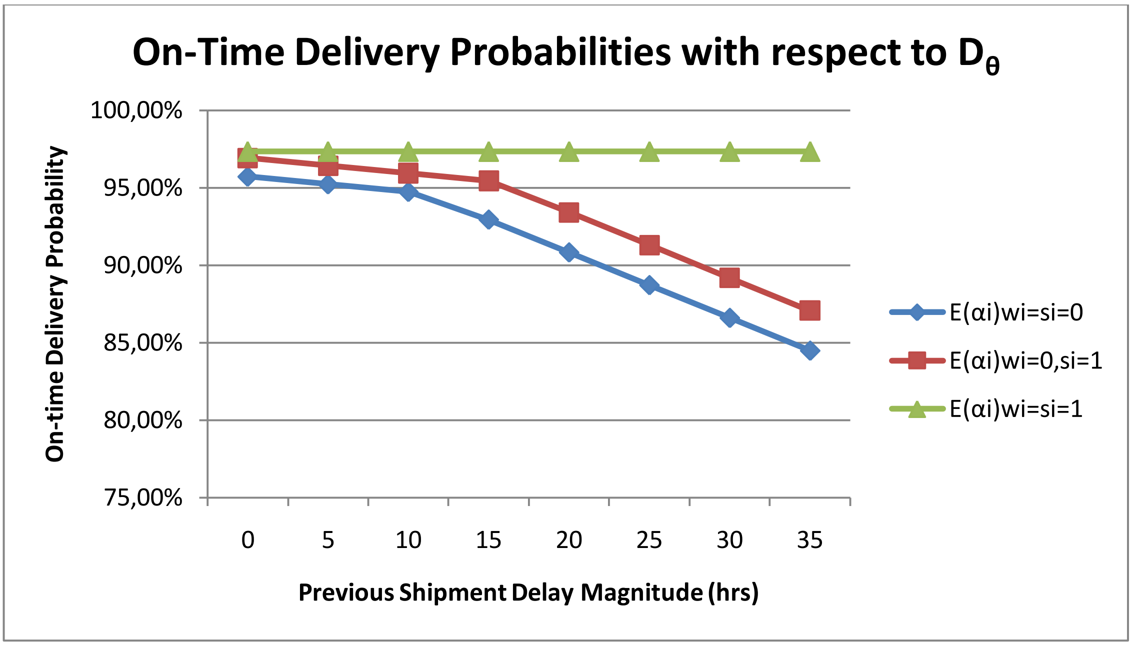


Figure XIV.2: Change in On-Time Delivery Probability wrt Previous Shipment Delay

Stable value of the performance at full effort level is explained by the elimination of possibility of this delay by the scheduling effort. Also, the changes in the slopes of other effort levels are a result of the bounded expected on-time delivery probability function. When the magnitude is under some level, the expected on-time probabilities stay at 100% for some possible outcomes whereas it drops for other outcomes. After that level, the performances decrease together.

Expected On-Time Delivery Probabilities with respect to D_δ

Similarly, changes in expected on-time delivery probabilities were observed with respect to changes in the magnitude of delay at the load port. The following figure was obtained:

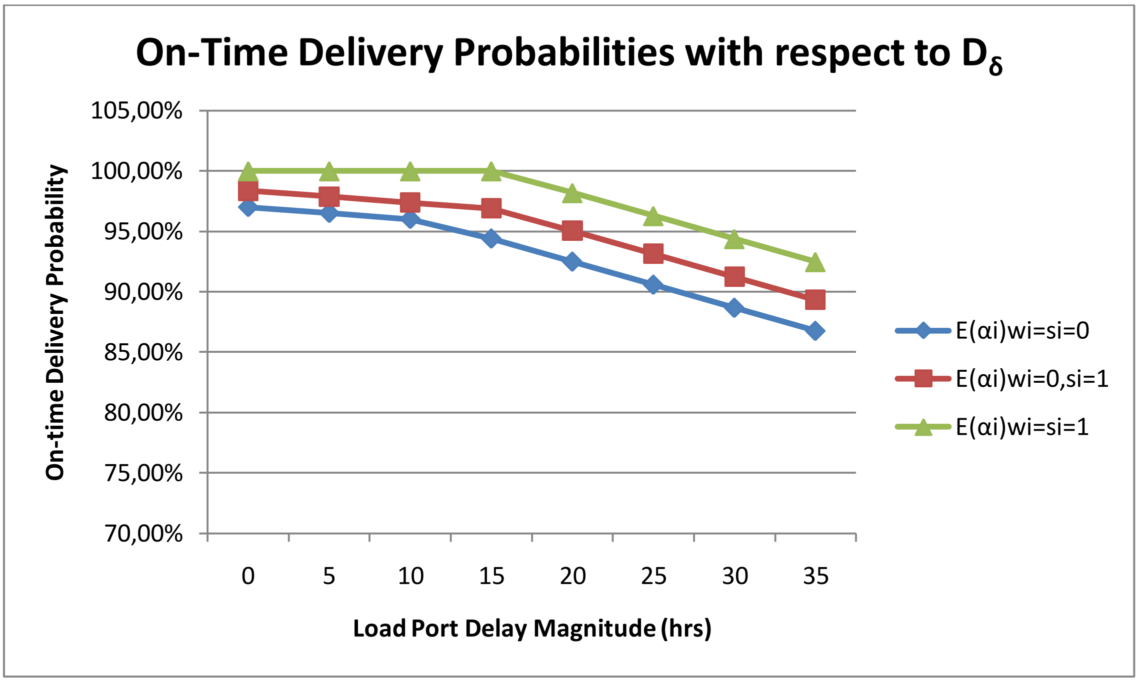


Figure XIV.3: Change in On-Time Delivery Probability wrt Load Port Delay

As explained for the previous scenario analysis on the other delay's magnitude, changes in the slopes of expected probabilities are explained by the structure of the function. In addition to that, the reason for the breaking points to occur at different magnitude levels can be explained by the fact that the threshold which results in the dropping of probabilities below 100% for some outcomes is different for distinct effort levels. For the lower efforts, expected probabilities are smaller and therefore this threshold occurs earlier.

APPENDIX XV: POSTER