





Total Cost Analysis of Logistics Purchasing:

A study of alternative logistics services, time slot delivery, personnel contact quality, and the evaluation of CO_2 emissions for the sea transportation

Master's thesis in Supply Chain Management

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Abstract

The automotive manufacturing industry today is mainly relying on third-party logistics (3PL) to manage their inbound, outbound and aftermarket flows. Generally, logistics costs account for a high percentage of companies' total operation cost. Therefore, from a total cost perspective, it is important to analyse the critical factors of decision making in logistics purchasing, such as evaluating carriers' service types, service performances, and environmental impacts.

The purpose of this master thesis is to investigate the contributions that Volvo Logistics purchasing can make to reduce the total cost for the Volvo Group. To fulfil this aim, two plants in the Volvo Group are selected as case plants, which have provided both qualitative and quantitative data. Interviews, surveys, observations and organizational documents are the major sources of data collection. Besides, based on the theoretical framework, the cost differences between LTL service and parcel service of light-weight shipments were compared; a calculation tool for the waiting time cost was created for data analysis, and the interrelations between the time slot delivery and waiting time cost were deeply analysed. The thesis also includes the estimation and discussion of the cost of personnel contact quality in the goods reception. In addition, a CO_2 evaluation model was introduced in order to estimate the CO_2 emission from the sea transportation.

The findings presented in this thesis can contribute to a better understanding of selecting different logistics services for a specified weight range; estimating waiting time cost and managing time slot delivery. Furthermore, this research highlights the critical parameters of CO_2 emissions evaluation of sea shipments, which could be implicated by Logistics Purchasing in future sourcing projects.

Key words: Total cost, Logistics Purchasing, 3PL selection, Freight Rate, Time slot management, Waiting time cost, Language Barrier, CO₂ emission evaluation, EEOI

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List of Abbreviations

3PL - Third Part Logistics

ABC method - Activity based costing method

- CFS Container freight station
- CV Coefficient of variation
- DDT Door to Door Transport
- EFTA The European Free Trade Association
- EMSA European Maritime Safety Agency
- FTL Full-truck-load
- IAT Internal arrival time
- IMO the International Maritime Organization
- LCL Less-than-container load
- LP Volvo Group Logistics Purchasing
- LSQ Logistics Service Quality
- LTL Less-than-truck load
- MCT Main Carriage Transport
- MEPC Marine Environment Protection Committee
- MRV Monitoring, Reporting, and Verification Regulation
- OCT On Carriage Transport
- PCT Pre-carriage Transport
- Ro-Ro Roll-on/roll-off
- SOP Standard operating procedures
- TCO Total Cost of Ownership
- TDABC Time driven activity-based costing
- TEU Twenty-feet equivalent units
- THU transport handling unit
- TISSM Total Impact Supplier Selection Model
- VBA Visual Basic for Application
- VGLS Volvo Group Logistics Services

1 Introduction

In this chapter, a general background and problem description are presented, followed by the purpose and research questions. Lastly, the study limitations and report outline are described and then given.

1.1 Background

In past decades, logistics and supply chain management as a discipline has changed considerably in many companies, especially in the manufacturing and retail sectors. Costs, tied-up capital, as well as customer experience, are all affected by logistics. An effective and efficient logistics system plays an important role in companies' high performance and competitiveness to profitability (Jonsson, 2008).

To put resources in the core business, save on capital investment and avoid financial risk, most companies choose to outsource some or all of logistics activities to third-party logistics (3PL) suppliers. Increasingly companies have drawn attention to logistics purchasing or third-party logistics (3PL) selection, to release tied-up capital and satisfy customers.

At the same time, several 3PL selection methods have been developed by researchers, such as analytic hierarchy process (AHP), fuzzy AHP, a technique for order preference by similarity to ideal solution (TOPSIS), the total cost of ownership (TCO), and so on (Tezuka, 2011). Since 3PL selection contains both quantitative and qualitative factors, it was researched as a multi-criteria decision-making (MCDM) problem that contains both qualitative and qualitative factors. These criteria may include 3PL's price, expertise, reputation, financial stability, service flexibility, and service reliability (Sharma and Kumar, 2015). Though these techniques are good enough to deal with a number of qualitative and quantitative factors, these factors may be conflicting in nature also. In practice 3PL selection depends more on business requirements, guided by business strategy.

1.2 Volvo Group

The Volvo Group is a Swedish multinational company and a global leader in manufacturing trucks, buses, construction equipment and marine and industrial engines. Aside from sales and services, it also offers complete financial service and solutions in many markets. The Volvo Group is headquartered in Gothenburg, with approximately 95,000 employees over the world. It has production facilities in 18 countries and customers in 190 markets. (Volvo Group, 2016)

The Volvo Group comprise ten business areas in total: Volvo Trucks, UD Trucks, Renault Trucks, Mack Trucks, Group Trucks Asia & JV:s, Volvo Construction Equipment, Volvo Buses, Volvo Penta, Governmental Sales and Volvo Financial Services (Volvo Group, 2016).

Figure 1-1 illustrates the organization structure of the Volvo Group. The orange box, Logistics Purchasing, is the division mostly concerned in this thesis.



Figure 1-1. Organizational chart of Volvo Group (Volvo, 2016)

1.2.1 Volvo Group Logistics Services

Volvo Group Logistics Services (VGLS) is the division designing, managing and optimising logistics service for the Volvo Group. VGLS cooperates with more than 1500 logistics suppliers over the world, purchases nearly 10 billion SEK logistics service per year, handles around 15000 distribution points (to dealers or body builders) and 10500 pick-up points. Its responsibility can be divided into following four parts:

- 1) Global manufacturing logistics: transport material to all Volvo Group plants and deliver all finished Volvo Group products to customers.
- 2) Global aftermarket supply chain: supply material to spare parts warehouses, optimize inventory of spare parts, handle orders and deliver spare parts to dealers.
- 3) Packaging: globally manage Volvo packaging pool, manage and design special packaging.
- 4) Customs compliance and trade governance: ensure global customs compliance and strategic optimization

1.2.2 Volvo Group LogisticsPurchasing

Volvo Group Logistics Purchasing (LP) is the department responsible for the sourcing of transportation globally for the Volvo Group. It selects the transport suppliers to be contacted in a certain region or on a certain route. For the past years, LP has done dedicated work to enhance transport networks through sourcing projects, and it is continuously exploring how to take a further leap in optimizing the logistics cost for the Volvo Group.

LP is organized into three commodity teams, Road, Sea & Rail and Air. All commodity areas have a global responsibility to optimize the purchase of their commodity. The regional organization has the responsibility to optimize the purchase from a regional basis. Within the VGLS Purchasing, there is also a development team focusing on analysis and development of the processes and tools, and a business control team that follow up and analyse the purchase performance and perform measurements of suppliers.

1.2.3 Current cost evaluation model - TISSM

Total Impact Supplier Selection Model (TISSM) is designed and implemented by purchasing development team, in order to select the carrier from a total cost perspective in sourcing projects. Figure 1-2 shows the six parameters that are currently included in the TISSM, in sourcing project different parameters can be conducted to calculate the total cost.



Figure 1-2. Total Impact Supplier Selection Model (VGLS, 2016)

The focus of the model lies in quantifying differences in costs between quotations more than just the rate. Parameters that will incur the same costs for all suppliers are therefore not of interest, since it does not provide any input to what supplier quotation to select. The idea of the model is that it, when completed, shall be used as a framework to quantify all possible quantifiable parameters. The model is to be placed between the "initial requirements for suppliers" and the "soft parameters" and what (Ellram, 1995b) refers to as "gut feeling" that come into the final judgment. Currently, the model is to consist only of "hard values", such as rate, delivery precision, lead time and cost of change. These four parameters are quantified to monetary units in total cost view.

1.3 Purpose and ResearchQuestions

The **purpose** of this thesis is to investigate the contributions that LP can make to reduce the total cost for the Volvo Group. The purpose was divided into two parts: identifying non-value added activities in existing logistics process, and analysing how LP can reduce the cost of these non-value added activities.

- 1. Should LP purchase Parcel Service as a standard service for light-weight shipments? In Volvo's inbound flow, some light-weight shipments are transported in the LTL (Lessthan-Truck-Load) service. In some cases, the chargeable weight of the shipment can be much heavier than the actual weight of the goods, which means the freight of delivering light-weight shipments is wasted in the transport package material. This research question aims to find an alternative logistics service to supplement the existing service in the perspective of reducing the total cost.
- 2. What is the cost of the uncoordinated delivery time slot, and should LP consider the time slot delivery as one of service performance in the future inbound sourcing projects?

In this research, authors found that not all Volvo Plants have time slot management in the goods reception activities. This research question aims to find out the waiting time cost due to uncoordinated delivery time slots and give a solution to reduce this potential cost.

3. What is the cost of personnel contact quality in goods reception, and what LP can do to enforce carriers to improve personnel contact quality?

According to the initial investigation of our study, communication issues due to truck drivers' language skills were complained often from the side of Volvo plants. This research question aims to find out the cost of the language barrier between trucks drivers and the Volvo plants in the process of goods reception, and to provide solutions to these issues and standardize the carrier's performance.

4. How to evaluate CO2 emission for sea transport carriers?

Volvo has a goal to reduce 20% of CO2 emission by 2020 comparing the emission level in 2012. In order to achieve this goal, LS has developed a model to estimate CO2 emissions for different transport segments in Volvo. Currently, the CO2 emission evaluation has developed for the road transportation and FCL transportation. However, the CO2 evaluation calculation for the LCL (Less-than-Container-Load) transportation and Ro-Ro transportation in sea segment is not developed. This research question aims to find out potential methods to evaluate CO2 emission for sea transport carriers.

1.4 Scope

This thesis focuses on the transportation operations for goods reception. According to the data from Volvo, its internal logistics accounts for a large proportion of the total logistics cost. Therefore, the task of data analysis aims at finding out non-value-added activities in goods reception and direction for cost reduction of these wastes. Since the two case plants in this thesis are both located in Sweden and share similar carriers, the study is based on the scenario of the EU area. The Volvo Logistics Service already have a CO₂ calculation model to evaluate the carriers' CO₂ emission performance. However, the CO₂ evaluation for Roll-on/roll-off (Ro-

Ro) shipments and Less-than-container load (LCL) shipments still had not be developed. Based on the existing model, the method for evaluating CO_2 emission of Ro-Ro shipments and LCL shipments are created in this thesis.

This thesis was performed at the Purchasing Development department at the Volvo Group Logistics Purchasing division. We hope this paper can contribute to the Purchasing Development department in future sourcing projects. Therefore, this thesis aims at improving the efficiency of logistics from the sourcing perspective.

1.5 Outline of Report

The overall framework of this thesis takes the form of six chapters. The first chapter mainly presents the background of the thesis and an initial description of the Volvo Group. It also introduces the purpose, research questions and the scope of the thesis. The second chapter concerns with the relevant theoretical background which includes in logistics, 3PL selection, the total cost of ownership. A few essential logistics concepts are introduced, as well as sourcing logistics service from a sustainable perspective. In Chapter 3, the research process and the methods employed for this study are presented. Thereafter, the requirements from internal customers for the 3PL service are described in Chapter 4. The data collected from literature review, interviews, organizational documents, and survey are presented in this chapter as well. Chapter 5 explains the limitations of this project, states the key results from the study, and makes some suggestions for further research. The last chapter presents the contribution of the thesis by answering the research questions separately, and other relevant findings gained from the whole project are also included.

2 Theoretical Framework

2.1 Logistics

Over the past two decades, logistics industry has developed dramatically from simple transports and storage to an important role of company's competitive strategy. The definition of logistics is the efficient flow of materials from raw material to end user, and also the reversed flow of material such as defected products and recycling. (Jonsson, 2008; Christopher, 2005). The modern logistics is an important factor when it comes to creating competitiveness and profitability for many companies. Logistics aims to fulfill four basic requirements: the customer is being satisfied with the delivered specified product provided in the agreed quantity, the order must be delivered to the right location and at the right time, the order must be provided in good condition, and the financial cost of the order should be reasonable and competitive. Logistics covers forecasting, planning, implementing, and controlling the result. (Oskarsson, et al 2006)

To manage and control the logistics process, one perspective is to use Oskarsson's six delivery service elements which were defined in 2006. And another important part is to understand the total cost including transportation, handling, inventory, carrying, administrative costs and other costs. These cost analyses are critical factors in decision making, for example, when company to implement a change in a process, or outsource some part of logistic activities. The detailed analysis of these costs will be described further in this report.

2.1.1 Automotive Logistics

The automotive industry is one of the world's largest manufactory sectors. Automotive logistics is an essential part of the automotive company. The characteristics of the automotive logistics are capital intensive, technology intensive and knowledge intensive (Suthikarnnarunai, 2008). With the development of the automotive industry and the growing complexity of global logistics, the automotive company faces obvious cost pressure in its logistics. According to the statement of (Sabadka, 2015), in the automotive industry, logistics costs account for 6% of total revenue and are still on the rise.

The automotive logistics process includes inbound logistics, outbound logistics, in-plant logistics and other logistics like reverse logistics.

- **Inbound logistics:** Inbound logistics refers to the transport, storage, and delivery of raw materials coming into a business (Jonsson, 2008).
- **Outbound logistics:** Outbound logistics refers to the process of transport and related information flow from the production line to the end customers (Jonsson, 2008).
- In-plant logistics: In-plant logistics covers movements of raw materials, components, and sub-assemblies in the manufacturing plant, as well as transportation to or from stocking points or line-sides, and moves out finished products to the factory gate (Baudin, 2005).
- **Reverse logistics:** Reverse logistics is the process of moving goods from the end destination for proper disposal. Generally, the transportation of products to be remanufactured are included in the reverse logistics (Srivastava, 2008).

2.2 Third Party Logistics

A common way for companies to outsource logistics activities is to purchase Third Party Logistics (3PL) services. Using 3PL means to use external companies to manage the logistics functions which are traditionally handled inside the firm (Fairchild, 2016). And in most cases, companies like to purchase multiple logistic services instead of individual logistics activities from 3PL. On the other hand, companies can also decide if the entire logistics process needs to be outsourced or only part of activities within the process.

The 3PL industry can provide multiple benefits to their partners and has been widely used in different areas. Compared to traditional in-house logistics, 3PL suppliers have a lot of core competencies which made them more effectively and efficiently in managing logistic activities. Therefore, by outsourcing logistics activities, companies can reduce their logistics cost, focus on their core business, improve service quality, and reduce capital investments in logistics facilities and equipment (Somuyiwa Adebambo et al.). For example, the distribution centres, cross docks, transport vehicles and information systems can generate an enormous cost to the company and generate financial risk at the same time. After outsourcing the logistics activities to 3PL, lots of capital investment can be saved and spread risks to logistics subcontractors.

From the perspective of economies of scale and economies of scope, another advantage of using 3PL for the firms is to increase their net value by reducing costs. And based on the different types of 3PL, the economies effects can be different. An 'asset-type' provider owns related assets such as truck fleets, warehouses, etc. 'Non-asset type' providers, such as generalized trading firms and consulting firms, do not own assets for logistic activities.

However, how to select a 3PL supplier is highly complex in the decision-making process. The company needs to consider multiple factors such as lead time, accuracy, price, etc. Competent 3PL suppliers can efficiently manage the logistics flow, provide good coordination and have strong ability to source reliable partners and sub-contractors.

2.3 Logistics Service Quality

Logistics service quality (LSQ) refers to the customer satisfaction of logistics service (John, 2001). From a customer perspective, LSQ not only relates to the company's operation cost, turnover rate, and inventory levels; but affects corporate performance, customer satisfaction and also market competitiveness. LSQ has become a key source of competitive advantage for logistics service users (Mentzer et al., 2001).

The notion of LSQ has been studied from different perspectives: objective and subjective quality (Irene et al, 2008), service components (Harding, F.E ,1998), internal measures and external measures (Stock, G.N, 1998), marketing customer service and physical distribution service (Mentzer et al., 2001). Among them, John's research identifies nine concepts in LSQ concerned by customer segment:

- Timeliness
- Order release quantities
- Order procedures
- Order accuracy

- Order quality
- Order condition
- Order discrepancy handling
- Information quality
- Personal contact quality

There are other components as well. In line with traditional service quality research in marketing, logistics services involve people who often take orders and deliver products and procedures for placing orders and handling discrepancies. According to Mentzer et al. (2001), the interactions that customers have with these people and procedures should affect their perceptions of overall logistics services. In this thesis work, on the basis of VGLS needs, we followed four categories of performance in our framework.

Timeliness

Timeliness refers to the ability to deliver the order to the consignee within an agreed upon time (Hult 1998; Hult et al. 2000). This delivery time can be affected by transportation time, as well as the cut-off time when products are unavailable, and the orders will be deferred in the next or particular delivery wave for the vehicle time slot problem (John, 2001; Karin and Anna, 2015). Timeliness is related to transport lead time. When it comes to the estimation of transport lead time, it usually indicates the length of time between the action of pick-up and delivery. However, considering the criteria of the earlier cut-off time caused pick-up delay, the actual lead time of that order will, therefore, be increased by one day.

On the other hand, the actual delivery time will also affect timeliness even within a "same" lead time. In reality, since the transit network and transport capability are different between logistics service suppliers, the actual delivery time for the same address can vary from 8:00am to 4:00pm on the same day, which could affect urgent orders.

Order Release Quantities

One important concept behind order release quantities is product availability. It has been seen as a major factor of logistics excellence. Customers are fully satisfied when they can get all the quantities they want. To achieve that, the organization needs to find out what is the need behind volume requests of customers. In most cases, stock outages can have a big impact on customer satisfaction and even loyalty, and it is hard to quantify the actual financial loss (Mentzer et al., 2001).

Order Condition

Order condition refers to the lack of damage to orders. If customers cannot use the products due to the damage during shipping or production, they should start correction procedures with either shippers or suppliers. (Mentzer et al., 2001)

Order Procedures

Order procedures are about how efficient and how effective the procedures can be followed by the users. It was important to make order placement procedures both effective and easy to operate (Mentzer et al., 2001).

Order Accuracy

Order accuracy refers to how closely shipments match customers' orders upon arrival. This includes having the right items in the order, the correct number of items, and no substitutions for items ordered (Mentzer et al., 2001).

Order Quality

Order quality refers to how well products work. This includes how well they conform to product specifications and customers' needs. Whereas order accuracy addresses the complete set of products in the order and order condition addresses damage levels of those items due to handling, order quality addresses manufacturing of products (Mentzer et al., 2001).

Order Discrepancy Handling

Order discrepancy handling refers to how well logistics service providers' address any discrepancies in orders after the orders arrive. If customers receive orders that are not accurate, in poor condition, or of poor quality, they seek corrections from LSP. How well LSP handles these issues contributes to customers' perceptions of the quality of their services (Mentzer et al., 2001).

Information Quality

Information quality refers to the perceptions of the customer and the information provided by the logistics supplier regarding products from which customers may choose (John, 2001). With the wide use of EDI, the order transport status can be grasped by the logistics service users transport system automatically. The timeliness and accuracy of information could affect the customer's logistics management deeply. If the information is available and has adequate quality, customers should be able to use the information to make decisions (Mentzer et al., 2001).

Personnel Contact Quality

Personnel contact quality refers to the customer orientation of the supplier's logistics contact people, for example, account manager, customer service, etc. Specifically, customers care about whether customer service personnel are professional, empathize with their situation, and help them resolve their problems (Mentzer et al., 2001).

2.4 Logistics Cost

Logistics costs are the associated costs generated by logistics activities. In different companies, logistics costs can have different forms. It can be regarded as the cost of the supply chain, the expenditure of the logistics department, or refer to the cost of an individual process. Usually, it is used as an important indicator of Supply Chain Performance of the company. According to (Jonsson, 2008), the logistics costs can be divided into the following eight categories. These eight categories have impacts on each other, and some coverage overlaps.

Transportation and Handling Costs

Transportation and handling cost means the cost of transporting goods from origin to destination, which generally includes transport, handling, and damages to goods during

handling. According to the transportation range of goods, it also can be divided into external cases and internal cases (Jonsson, 2008).

External transportation and handling cost refers to the cost of transporting goods from an external site to the company plant, or from the plant to an external destination. It mainly contains the costs of loading, moving, reloading and unloading. Choosing a third-party logistics company to handle external transportation is a common practice of many companies, and the corresponding cost will be reflected in freight. However, sometimes this freight is included in the total price of the goods, then the cost will be difficult to break down for external transportation activities (Jonsson, 2008).

Internal transportation and handling cost refers to the cost of transporting goods within the company plants, mainly including picking, internal movements, and packaging, and sometimes includes inventory carrying and storage costs (Jonsson, 2008).

Packaging Costs

Packaging costs include packing, marking, labeling goods and the cost of the corresponding packaging materials. If reusable packages have been chosen, then it can generate related costs like administration storage, return transport and reconditioning of packages accordingly. In many cases, these costs may also be attributed to other categories of logistics costs (Jonsson, 2008).

Inventory-carrying Costs

Inventory-carrying costs refer to the cost of holding goods inventory, which is mainly determined by the quantity of goods stored. It also includes the risk and financial costs caused by inventory and keeping goods (Jonsson, 2008).

Administrative Costs

Administrative costs are the costs of operative management of material flows and long-term planning, such as the administrative personnel cost for order processing, planning stock reports, and the costs of communication and operation systems for logistics activities (Jonsson, 2008).

Ordering costs

Ordering costs refer to the costs of performing the ordering process for procurement. In many cases, ordering costs can be categorized as other specific logistics costs, for example, the labor costs of placing an order can also be classified as administrative costs, and the corresponding costs of transportation and handling activities can be classified as transportation and handling costs (Jonsson, 2008).

Capacity-related Costs

The capacity costs in a logistics system consist of costs for capital invested in vehicles, machines, cross-docking, warehouse, etc. Capacity costs are often affected by the utilization of equipment. In general, the higher the utilization of equipment, the lower the cost to each unit (Jonsson, 2008).

Shortage and delay Costs

Storage and delay costs are closely related to delay in goods delivery and a shortage of goods. This cost may also be incurred by the absence of sales, loss of goodwill, cargo damage and extra transportation (Jonsson, 2008).

Shortage and delay costs are often difficult to predict. If the consignees are end customers, in a better case scenario a single or multiple transactions could be affected due to the delays in delivery. Conversely, in a worse case, customers may lose confidence and seek other companies, resulting in loss of customers. If the consignee is a plant, delay and shortage of materials or parts can lead to production line downtime, waste of machine and worker hours, and impacts to the production plan in the worst case (Jonsson, 2008).

Environmental Costs

The environmental costs are related to the logistics activities which impact on environmental quality, such as increased costs to reduce CO2 emissions or the usage of recyclable packaging materials. The manifestations of these effects can be direct or indirect, short or long term, monetary or non-monetary, so it is often difficult to estimate them in the actual situation. (Keitel et al., 2011, Jonsson, 2008)

2.5 Total Cost of Ownership

The concept and philosophy of the Total Cost of Ownership (TCO) are not new; it has been referenced in many kinds of literature and the theory of it has been adopted by many companies gradually. Ellram and Siferd (1993) point out that, in the practice of TCO, rather than the purchase price, other cost parameters such as acquisition, use, and maintenance expense should be considered in the evaluation of the purchasing process. In the research of Ellram and Siferd (1993), by using the theory of the TCO, "true cost" of any activities should be allocated, the company is required to find out the "incur costs" of each process and detect the value-added activities. The company should also consider the internal costs and external activities impact on the price of purchasing goods or service.

Ellram (1995a) listed several reasons for applying TCO in purchasing. Primarily, TCO can assist the decision making of supplier selection, the performance evaluation of suppliers and process changes. Other secondary reasons for a company adopting TCO is that it can provide support on the recognition, foreseeing, comparing, improving the performance of suppliers. In addition, TCO can give suggestions on the negotiations, strategic alliances, reduction of the supply base, forecasting the performance of new products and source focusing.

Dollar based approach and value based approach are the two major approaches applied in the TCO model. In the study of Ellram (1995a), comparison of the two approaches is illustrated. For the dollar based approach, actual cost data from each cost parameters of the TCO model are collected. Even though, the process of data gathering is complicated, the result and illustration of the dollar based approach are straightforward. In order to collect the accurate data of cost parameters in the TCO model, considerations are made. One of these is the principle of activities based costing, also known as ABC which assists in quantifying the "true cost" of each activity. For the data which is not easy to monetize, for example, some performance data, the value based approach is introduced to transform these qualitative data into quantitative data. The process of data transforming is complex and time-consuming and

lengthy explanations are required in each cost parameter. Unlike the dollar based TCO model, the value based model does not trace the money spent directly. In the value based model, the performance of suppliers is scored in each cost parameter, and the collected points of these parameters can help the buying company understand the discrepancies among different suppliers. In general, the dollar based and value based approaches are both time-consuming. Consider the complexity of the value based approach, a small number of cost parameters are recommended to be focused on in the value based TCO model. On the other hand, both approaches can contribute to the selection of suppliers and process improvement. While the direct result from dollar based model can be used in the evaluation of existing supplier and the decision for reducing supply base.

When preparing the implementation of the TCO analysis in the purchasing, the cost impacted the purchased goods or service should be understood. The company should look at all costs incurring in the purchasing from a specific supplier when using TCO approach. Creating a diagram of the entire acquisition process is the best way to find out the cost parameters for building a true TCO. Rather than the direct cost, the purchasing price, some hidden cost parameters should be collected and considered. According to the research of Ellram and Siferd (1993), some hidden costs are summarized, they include quality associated costs, delivery associated costs, communication costs, and service associated costs and some management costs.

After identifying the potential cost parameters, some questions should be considered and solved in the process of cost analysis. According to the suggestion of Ellram and Siferd (1993), the questions are:

- Which activities consume the most time?
- What are the costs of these activities?
- What drives the level of these costs?

It should be noted that all TCO models are based on the available historical data, and that the predetermined information does not contribute to the TCO analysis.

The benefits of adopting TCO approach are obvious. First of all, the TCO approach is logical and easy to understand. Secondly, it brings the total costs of a good or service into perspective, so that can help in the decision making of supplier selection. Data involved in the TCO model can provide essential information for negotiating ad reducing the total cost in the purchasing process (Ellram and Siferd, 1993). According to the report from Degraeve et al. (2004), 19.5% saving of the expense on the logistics service purchasing of Alcatel Bell was reached by using TCO approach.

From the study of Ellram (1995a), some limitations exist in the adoption of TCO approach. Since the complexity of TCO, much accounting and costing data should be put in at the beginning, and it becomes the major barrier to many companies. But the situation that is lacking data readily can be improved as the implementation of activity based costing in many organizations. In addition, as mentioned above, the process of TCO is time-consuming, therefore, the expense of operating TCO should be considered in practice.

2.5.1 Costing Management System

According to the (Horngren and dawsonera, 2014), several terms are defined in this section.

- 1. **Cost object**: the object is the item which the cost is compiled, for example, the production, the customer, activities, etc.
- 2. Cost pool: a set of individual costs which are allocated to the costobject.

In order to understand the costs and profitability in the business, the **costing management system** is the concern of the decision maker. A set of tools and techniques, which forms the costing management system, is designed to help decision makers find out the information of costs, for example, the operational control, management strategy, measurement of inventory level, cost of goods, etc. (Horngren and dawsonera, 2014).

In the 1990s, almost all American companies accepted the traditional costing system, which just uses a single cost pool for all overhead costs of production (Horngren and dawsonera, 2014). It worked well in some simple production processes because of the directed costs, including materials and labors, make up a high percentage of the total cost. The accuracy of the overhead costs of the production does not have an essential impact on the measurement of the total cost (Cooper and Kaplan, 1988).

However, when a company grows, the operation of business becomes more complex. The traditional costing system cannot help the decision maker understand the actual cost of the business. Activity based costing (ABC) method is developed and assists the decision maker in understanding how much the product consumes in different activities and assign more overhead costs in the accounting than the traditional costing system (Turney, 1992). The basic idea of ABC is to identify different activities in the business and map operations of the business with resources in these activities.

2.6 Queuing Theory

"Queuing theory is the mathematical study of waiting lines or queues. A queuing model is constructed so that queue lengths and waiting time can be predicted." (Sundarapandian, 2009)

Queuing theory has a high value on practical implication of making business decisions about the resources needed to provide a service. It was invented by Agner Krarup Erlang when he simulated the number of phone calls arriving at an exchange by a Poisson process. This theory has since seen applications in many fields, such as telecommunication, traffic engineering, computers, etc. (Menasce et al., 2004). It also has been widely used in the design of banks, hospitals, factories, shops, as well as in project management (Mayhew and Smith, 2006).

In queuing theory, a model is constructed to estimate the length and waiting time of queues. Queuing model contains operating system as well as resource requirements. In order to describe a queuing system, several essential elements of the system should be defined.

Calling population

The calling population also named as population or source, one of its primary characteristics is it can be categorized as finite or infinite. In a finite calling population, the number of customers (vehicles, passengers, etc.) in the system affects the arrival rate (Allen, 2014).

Composition of arrivals and/or departures

The arriving of customers can be scheduled or at a random time.

Service time Distribution

The service time of each customer can be regular or of some random duration.

System Capacity

System capacity refers to the limit amount of customers that the queuing model can handle at any time (Möller and Schroer, 2014).

Number of Servers

Queuing system can be divided into two types by the number of servers: single-server system and multi-server system (Allen, 2014).

Queue Discipline

This is the principle for selecting the next customer to be served. One of the most common queue disciplines is "First in first out", which abbreviated as FIFO. It refers to "customers are served one at a time and that the customer that has been waiting the longest is served first" (Möller and Schroer, 2014). Besides, "Last in, first out" (LIFO), "Processor sharing", "Priority", are all some common queue disciplines practical implication.

2.7 Sustainable Logistics

Traditionally, logistics performance measures only oriented to cost, lead time and precision, however, nowadays sustainability has also been considered as one of the measures by increasing companies. Sustainable logistics means ensuring logistics activities are environmentally friendly and no waste, especial focusing on reducing greenhouse gas emissions. The largest source of carbon emissions in entire logistics activities is freight transport. According to the World Economic Forum (2009), three parties have the collaborative responsibility of sustainable logistics: logistics and transport service providers, shippers and buyers as recipients of such services, and both government and non-government policy makers.

As suppliers, logistics and transport companies should improve their energy efficiency and optimize their transport network, invest low fuel consumption technology or equipment, and look to switch to more environmentally friendly modes within their networks. As purchasers, shippers and buyers should evaluate environmental performance during their logistics sourcing process, work with consumers to let them better understand the carbon footprints of their products, and label properly to make recycling easier. Policy makers should promote further regulations to limit pollution across logistics process, and give concessions to those companies have lower energy consumption or use clean energy. In recent decades, carbon emissions and energy efficiency have been the subject of much works in logistics, particularly freight transport. Many environmental laws and EU legislation have issued on transport

industry due to the concern on increased climate change problem (Grant, Trautrims et al. 2015).

2.7.1 CO₂ emission of sea transport

90% of the global cargo is transported through the sea, according to the statics from International Maritime Organization (IMO), the shipping industry consumed 2 billion barrels of bunkers, and the amounts of CO_2 emissions are over 1.2 billion tones, accounted 3% of total global amounts. According to the statement of IMO, if no action or control measure is taken, greenhouse gas emission from shipping industry would increase by 75% in 2020.

In 2016, The 70th Marine Environment Protection Committee (MEPC 70) developed a roadmap and timeline for reducing ships' greenhouse emissions. In this roadmap, data monitoring, data analysis, and decision making are the three key milestones. According to the report of MEPC 70, before 2020, the emission data from merchant ships should be collated and monitored and in 2020 (MEPC 76) the second phase-data analysis should be started. The decision should be made in the MEPC 78 (IMO, 2016).

Although IMO has not yet issued any clear and detailed rules on guiding the shipping industry to reduce CO_2 emissions, IMO has developed Energy Efficiency Operational Indicator (EEOI) guidelines for the ships' operation. The EEOI has been introduced as an energy efficiency indicator reflecting the actual operating conditions of the ship and the amount of carbon dioxide emitted from the unit transportation. Even EEOI is not obliged all operators to accept; the guidance still plays an essential role in monitoring the fuel consumption and operation management of a ship.

3 Research Method

3.1 Research Design

The purpose of the study was to investigate the contributions that LP can do to reduce the total cost for the Volvo Group. Based on this purpose, the research process was designed as Figure 3-1, which consists of three phases: data collection, analysis, and conclusion. A detailed explanation is provided below.

Data Collection

After defining the purpose at the beginning of the study, the first step is to create general research questions. The starting point of the research is to focus on how third-party logistics services, purchased by LP, impact the Volvo Group, especially the Volvo plants' operation. During this period, several interviews are conducted from LP to study research questions. In addition, both academic literature and company documentation are to be reviewed in parallel, to avoid replicating studies previously composed by LP and limit the scope of this thesis.

Step 2 is selecting relevant divisions. VGLS as the division most concerned in this thesis, was interviewed in this step, in order to clarify the responsibilities of LP and the process of sourcing projects. In addition, two Volvo plants were chosen as study case plants. Plant A was chosen because it works aligned in different plants all over the world, and it is more organized than other divisions in Volvo.

Step 3 is collecting relevant data. Numerous semi-structured interviews are conducted from departments in VGLS and case plants, and some internal statistics are also collected from interviewees. Additionally, to understand the viewpoint from logistics service suppliers, surveys were sent out and collected to the carriers who have bid for the Volvo Group Less-than-truck load (LTL) services.

Analysis

Two data analysis methods are applied in this thesis, the qualitative data analysis method, and quantitative data analysis method.

For the qualitative data, the analysis process is conducted as three steps. Firstly, data classification should be done. The qualitative data from the interview, case plant and survey are sorted based on the event, activities, research area, etc. Secondly, identify the relationship between the research purpose and sorted data. In this step, analytical and critical thinking play an essential role in the research. Since the findings of qualitative analysis depend on the individual judgment of the researcher, the qualitative study cannot be repeated to achieve the same result. The last step is summarizing the data. In this step, all findings are needed to connect with the research aim and related research question.

For the quantitative data analysis, raw numerical data is expected to turn into the meaningful information through rational and critical thinking. The same figure with a set of data can be interpreted in different ways. Therefore scientific analysis and fair judgment are important in the quantitative analysis. In this thesis, the excel spreadsheet is used to assist with analyzing the quantitative data.



Figure 3-1 Research Design Process (Bryman and Bell, 2015)

3.2 Data Collection

Two types of data, the primary and secondary, data are collected in the process of data collection. The primary data, including measurements and quantifications, are collected through observations, interviews, and surveys. The secondary data is the information which has been collected for other purpose but can be applied to the current study (Bryman and Bell, 2015). Data collection methods, such as the literature review, interview, and organization document study, are employed in this thesis.

3.2.1 Literature Review

In the field of social sciences, literature review usually has been organized in two parts: summary of key information and synthesis within specific conceptual categories (Bryman and Bell, 2015). Summary of information means a recap of the important data information from different sources. In the stage of synthesis, information is re-organized and analyzed for the further investigation of a research problem. A literature review is an important step for the researchers to study the research problem and understand the contribution from others. It can help to describe the relationship of similar or different opinions, identify new methods or ways of thinking of this research, and find gaps in the existing literature. In addition, a literature review is also aimed to prevent duplication of effort and identify areas of scholarship (Levy and Ellis, 2006).

The relevant literature such as books, scientific articles have been searched through Google Scholar and the Chalmers Library database. Some of the information has been found in the reference lists and course guides of related research areas. Main key words for finding appropriate literature are: total cost of ownership, 3PL provider selection, logistics, time slot, CO_2 calculation, Energy Efficiency Operational Indicator (EEOI), language barrier.

3.2.2 Case Study

In order to illustrate a thesis or principle, case study method is used to closely study a particular person, group or situation. Usually, a case study focuses on a small geographical area with a limited number of individuals and a limited time period. It can be considered as a robust research method to investigate the real-life phenomenon by detailed analysis of several events and their relationships when a holistic and deep investigation is needed. As Yin (1984) said, "as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clear; and in which multiple sources of evidence are used."

Most times, a case study is about learning and analyzing complex real life issues in the past reports or studies. Through case studies, researchers can conclude the quantitative statistical results and pre-conditions of different outcomes. After that these results and information can help to explain the social and behavioral problems in the question or a similar case in current study. According to Tellis (1997), by including both quantitative and qualitative data, case studies help to explain both the process and outcome of a phenomenon through complete observation, reconstruction, and analysis of the cases under investigation.

Two plants in the Volvo Group were chosen for the case study; both plants are located in Sweden, which has similar goods reception processes and shares similar inbound logistics suppliers (carriers). The case plants were interviewed about what logistics services affect their

internal logistics costs and efficiency. Some statistics related to goods reception, delivery time slot, delivery precision, etc. were collected separately from two plants.

Plant A

Volvo Plant A manufactures diesel engines and engine components for most business areas within the Volvo Group. The production in Plant A can be divided into 3 processes: casting, machining, and assembly. Besides these, it has some other support functions such as maintenance and logistics.

Plant B

Volvo Plant B manufactures and assembles cabs, complete trucks, and kits for the Volvo Group. Nowadays, it employs 1524 people and is designed to be capable of producing 12200 trucks per year.

3.2.3 Interview

The purpose of the interview is to collect primary data for research. The interview consists of two parties, the interviewer, and the respondent. A formal meeting is designed between these two parties through specific communication methods, such as e-mail, phone contact or face-to-face communication. As a qualitative approach, questions are designed to help the interviewer have a deep understanding of the aim and objective of the research. In order to yield more information about the study phenomenon, the interview question should be kept neutral and open-ended (Bryman and Bell, 2015). In addition, the understandable questions and sensitive questions are helpful to achieve accurate qualitative data (Bryman and Bell, 2015).

There are three types of interview: Structured Interviews, Semi-Structured Interviews, and the Unstructured Interviews (Bryman and Bell, 2015).

Structured Interview

In the structured interview, a set of questions to the respondent is predesigned. In addition, the information and the order of these questions are fixed for each participant. The rating scale can help evaluate the answers of interview questions. Telephone and personal contacts are the common interview methods in the structured interview.

The process of the structured interview is strictly controlled, and respondents have limited freedom to talk. However, the structured interview can ensure participants understand all the questions and give the equal opportunity of each respondent to show their skill.

Semi-structured Interview

In the semi-structured interview, some questions are prepared, but the sequence of them is flexible for different respondents. During the process of the interview, some questions can be canceled, and new questions can be added.

The process of semi-structured interview is flexible, as well as the interviewer can influence the topic when unexpected issues occur. The different core list of questions for different respondents and unfixed sequence of questions make the flow and sharing of views more natural. However, before the interview, the interviewer should understand the background of each participant and the question design is time-consuming. The bias of the interviewer is also a substantial barrier to the process of research.

Unstructured Interview

The unstructured interview is designed as an open and free discussion between the interviewer and the respondent. The discussion is under predefined topics, but there are not standardized forms and directive questions and answers in the process. The aim of the unstructured interview is to understand in depth the prepared topic.

The unstructured interview can produce rich data and can provide a general understanding of the issue when little is known in a starting stage. However, there are obvious weaknesses with the unstructured interview. The process of the interview is time-consuming, and there is a lack of control. Therefore, the interviewer should be a good leader in the interview. As a good listener, the interviewer should keep nonjudgmental and allow different views. In addition, silence should be tolerated, and respondents can have enough thinking time. In addition to the time and control issues in the unstructured interview, little factual information may be provided in the rich data. The interviewer should have a correct understanding of the statement of respondents.

3.2.4 Interview method for the thesis

The objectives of the interview in this thesis work are finding out the overhead cost of good reception in the case company and how logistics service impact on the in-plant logistics performance. Before the interview, a list of interviewees was provided by the Volvo Group Logistics Purchasing. The interviewees of the initial list are the management of the logistics purchasing department and two case plants of Volvo group. A semi-structured interview is conducted at this phase and interview topics are around the general information of the logistics operation in case plants, current challenges in the process and potential interviewees for the further step. Different interview guides are prepared according to different topics and the function of the department.

In order to collect more information related to the research theme, semi-structured interviews were conducted in the data collection process. An initial list of interviewees was provided by the Logistics Purchasing department in Volvo. Managers and employees from Logistics Purchasing department and two case plants are on this list. At the initial stage of the interview process, the focus was primarily on what logistics purchasing can do better in the sourcing project. Some general questions related to the current challenges in logistics services were organized in the initial interviews. Since the interviews were designed semi-structurally, several requirements from internal customers (i.e., two case plants) about third-party logistics services were discovered and discussed at the beginning of the research. The four research questions, which have been described in Chapter 2, were confirmed after the discussion with the thesis supervisor. The interviews are designed to solve these specific research questions.

3.2.5 Survey

The survey is one of the most common ways to collect statistical data and has been widely used by governments, private and public organizations, researchers and private individuals (Kothari, 2004). Usually, a survey is associated with a list of questions and a group of chosen people. The questions can be answered independently by each participant, or through a face-

to-face meeting with researchers. In the latter case, the researchers ask the questions and fill out the questionnaire based on the answer and response of interviewer. In this case, the researcher can explain potential ambiguities and reduce the misunderstanding from different individuals (Anderson, 2006).

This study chose web survey as a method to collect data, for the chosen respondents are geographically widely spread and time efficiency. The main benefits of web survey are timesaving and fast spread speed. Questions and answers can be collected quickly by automatically downloading into a pre-defined database, which is convenient to both researchers and people answering the question (Bryman and Bell, 2011). The survey was conducted using Google Forms which is a valuable web survey tool for facilitating data collection and analysis. The whole questionnaire is shown in Appendix B.

According to Czaja and Blair (2015), unit nonresponse is the principal source of no sampling error in web surveys, and its response rate is usually lower than traditional survey methods, like interviewer-administered population surveys and surveys for special populations. One important factor to increase the acceptable response rates is the follow-up contacts in mail or web surveys. In other words, the problem of nonresponse can be reduced if surveys are targeted to a particular group, such as members of one organization or employees in industry. Besides, if the instrument is relatively short and appears easy to complete, respondents might be more likely to participate. To encourage more participants to reply to the survey, in total, only 10 questions were included in the questionnaire. The respondents were asked to answer the capabilities of offering specified time slot delivery services and drivers' English language skills.

The standardization of the survey was high since the questions were the same for the different actors (Trost, 2012). However, semi-structured interview questions were also used in this survey, based on the choice for some answers, different question sets will be applied in the survey. For some of the questions, an alternative option called "other" is provided, and the respondents could write their opinions in a more customized way.

Additionally, Trost (2012) has suggested sending an accompanying letter together with the survey questionnaire. Thus, the responders can better understand the purpose of the survey and get more motivation to answer the questions. It might be more helpful if the researchers could even explain the importance of their research and the potential achievement from this survey.

30 participants from 24 logistics companies were involved in this survey. These 24 logistics companies are existing or potential road transport suppliers for the Volvo Group. Both the company list and contact information were provided by the Purchasing Development team. The survey was designed to be confidential, since LP will be informed of the results of the survey, and the responders might exaggerate their companies' service performance if their employers are disclosed. In order to get more reliable data and reduce the risks of misunderstandings, it is important for researchers to provide a confidential and strict questionnaire. Therefore, the questions have been reviewed by the supervisor and the mentor of this thesis who works in LP. With their help, many mistakes and unclear terms were modified or explained in a clearer way with less ambiguity. The purpose of this survey is also

explained with the deep interpretation of the communication, to further encourage respondents to provide an effective and reliable answer.

3.2.6 Organization Document

Organizational documentation data is an essential data resource for this thesis project. In the process of data collection, some secondary data are extracted from the company's internal documents, such as standard operating procedure (SOP), contracts, presentations, internal statistics, etc.

Some examples of the mentioned documents are internal presentations, instructions, standard operation processes, logistics service contracts. Volvo IT intranet, named Violin, is the main database for this thesis which allows access to internal documents, moreover, other internal data was supplied by different interviewees during the data collection phase.

3.3 Data Analysis Method

3.3.1 Method of Comparing Logistics Service

The freight rate is the cost of transporting goods. The freight rate charged by the shipper is determined by many factors. The main factors in the calculation of the freight rate include transport mode, cargo weight, size, distance and pickup and delivery area.

Comparing the existing LTL service in Volvo Group and the parcel service provided by the third party, the pricing of these two services is quite different. In order to compare the different charges of the two services, the existing LCL transport service, and potential parcel service, are set up. For the two services, the same type of cargo is delivered from material suppliers to the case plant, and all material suppliers selected for this thesis are located in Sweden.

3.3.1.1 Freight Calculation of LTL service

In this scenario, all cargo is packaged in the carton box EMB 100, and these carton boxes are delivered in the wood pallet K1.

For one EMB 100 carton box, the size is 17.6 cm*14.4 cm*8.6 cm; the weight is 0.08 kg. Since the volumetric weight is calculated as $1m^3=250$ kg in the parcel service, the volumetric weight of EMB 100 is 0.55kg per carton box.

The size of a K1 pallet is 33 cm*61.5 cm*82 cm. The weight of K1 is 17.53kg. Since the volumetric weight calculated as $1m^3=250kg$ in LTL service, the volumetric weight of K1 is 41.6 kg per pallet.

Based on the certain parameters including origin, destination, weight, volume, and service level, three steps must be considered to determine the price.

1. Step 1- Calculate the chargeable weight: the chargeable depends on the density of cargo. The chargeable weight is the maximum value between the actual weight and volumetric weight.

The volumetric weight, also known as dimensional weight, is a pricing method in the calculation of freight rate. It equals to the volume of the transport package multiplied by a conversion factor.

- 2. Step 2- Determine the unit price: In order to ensure the transportation is profitable and the price is competitive in the market, the carrier will charge the customer different freight depending on the total amount of shipments. It means that for LTL service when the total transport weight is close to the full truck load, the unit price (e.g., price per 100 kg) will be lower.
- 3. Step 3: Determine the minimum charge:

The carrier usually set a minimum charge to ensure a certain profit margin, in the transport of less than a certain weight of the goods; the shipper needs to pay the minimum charge.

For different origin transportation area, the minimum charge is different.

According to the pricing contract of LTL service in VGLS, some data of minimum charge is not available. For some zip code areas, little weight LTL cargo is shipped from this territory since there is a cross dock, which consolidates LTL shipments into FTL shipments.

Based on the available data and considering the weight of the yearly amount of delivery packages from different material suppliers. The average minimum charge can be estimated as the following.

$$!"#\$!\%\#"O("*"+h!\$\%\# = \frac{\sum_{.})_{.}+/.}{\sum_{.})_{.}}$$

Equation 3-1

Where,

i = the area *i*, which is defined as the first two numbers of the zip code;

 n_i =the yearly amount of packages in area i;

c_{mi}= the minimum charge in area *i* (LTL service)

4. Step 4: Calculation the freight cost. The freight cost for the LTL service can be expressed as the following.

$$4_{565} = \begin{cases} \$ * \frac{\bullet}{100} ; ; h#) \bullet > 100 \frac{+/}{\$_{=}} \\ +/; ; ; h#) \bullet < 100 \frac{-/}{\$_{=}} \\ Equation 3-2 \end{cases}$$

Where,

r = r is the freight rate, for the LTL service in Volvo, the freight rate varies with the chargeable weight;

 r_1 = the freight rate for the chargeable weight between 0 to 299kg;

m = the chargeable weight in the transportation;

 c_m = the minimum charge defined by the carrier.

3.3.1.2 Freight Calculation of Parcel Service

For the parcel service, the transport weight of the parcel is up to 100 kg. In this scenario, all cargoes are packaged in the carton boxes-EMB 100. In order to determine the freight rate of the parcel service, three steps need to be done.

- 1. Step 1: calculate the chargeable weight per parcel: the process is same with the LTL service; the chargeable weight is the maximum value between the actual weight and volumetric weight.
- 2. Step 2: Determine the transport price per parcel: the price per parcel depends on the weight range of the parcel. For different weight range, the carrier will provide a different price.
- 3. Calculate the total freight rate: the total freight rate is calculated by multiplying the cost per parcel by the amount of transported parcel.

3.3.1.3 Freight Comparisons of LTL and Parcel Service

The main difference in the two services is the freight rate. For delivering the same cargo from the same material supplier to the consignee, the Plant A, and the freight is charged differently. In order to compare the difference, only the freight cost of one pallet is considered in the LTL service. Assuming the number of inner packages, EMB 100, is n, the actual weight per inner loaded carton box is m, and the weight of the pallet is M.

For the LTL service,

 A#\%hB $!B#_{565} = '!C[**) + E, "GH*'#B$(+;#(\%hB]*Price per 100 kg.$

Equation 3-3

While for the parcel service,

 A#(\%hB $!B#_{NOPOR} =) * S$(+# S#$ S!$+#H$

Equation 3-4

The price per parcel is determined by the chargeable weight.

In addition, the operation costs of these two services are different. In the LTL service, the transportation and storage cost of the pallet should be considered. These differences will be discussed in Section 4.1.

3.3.2 Method of Simulating Queuing System

In order to estimate the waiting time and cost in the goods reception process at Volvo plant, a simulated queuing system is needed here to analyze either real collected data and random practical data. From the definition of Queuing Theory, the goods reception process is a single server model with multiple server points. For example, all trucks that arrive in a plant need to unload their goods, and 5 trucks can be processed at the same time, which means the system has one single server and 5 server points. The truck may have to wait before being served if all unloading docks are busy and the service priority is first-in-first-out (FIFO).

In this study, the Queuing System has been made in Excel with tables, VBA, and figures. A data analysis tool is also used to generate practical data. The system is valid with following assumptions:

- All trucks will be served in the order of their arrived time, FIFO.
- All trucks immediately stand in the queue after the registration.
- The unloading time is only affected by two factors: truck operating time and number of transport handling unit (THU).

We have found several exceptions in the collected data, which few trucks waited for a long time in the queue even when there is an empty unloading dock or the trucks behind it have been served first. These kinds of situations are not considered in this queuing system.

3.3.2.1 Input Parameters and Data

In this queuing system, five variables are used to simulate the real situation. The specific variables are given by the scope of the thesis. The variables are a number of unloading dock, operating time per truck, operating time per THU, cost of waiting time and service period. These variables are defined in the following sections.

Number of unloading dock

Unloading dock refers to the place for truck unloading cargo. Each unloading dock can only handle one truck at the same time. According to the two case plants data, each position has two workers to unload, scan and sort the received shipments. An available unloading dock should have the following conditions: an available site for trucks unloading goods, two workers (at least one in some cases), and available facilities for operating goods (e.g., forklifts). Physically, the number of unloading docks for a specific plant is fixed, while in the following calculation model the number of unloading docks should consider whether these conditions were available.

Operating time per truck

Operating time per truck refers to the time start from the truck arriving at unloading dock until it leaves.

Operating time per THU

Operating time per THU refers to the average time cost of unloading, scanning and sorting each THU. Practically, the way of estimating operating time per THU varies from different plants. The operating time per THU can be impacted by the process of unloading activities, network speed, the internal moving route, etc.

Cost of waiting time

In this study, the cost of waiting time was only included in the waiting time surcharged from carriers. According to related SOP, the transport rates are inclusive of one stop and a maximum of two hours for loading and unloading respectively (unless otherwise agreed in the Rate Sheet). Beyond the two-hour operating time, logistics companies are entitled to charge demurrage at a rate set out in the rate sheet for every commenced 30-minute period, however, the price per 30 minutes is different between trucks from foreign regions and domestics.

Service period

In this study, only the trucks which arrive within the working time and working days and given time period are included, which means if a truck arrives on Tuesday at 2:00 am or Saturday at 10:00 am, it would not be counted into the number of trucks on that day.

The input data of queue system should contain two parts: truck arrival time of each truck and number of THU of each truck.

Truck arrival time

Truck arrival time refers to the time that a truck registers its arrival at the plant's registration.

Number of transport handling unit (THU)

A number of transport handling unit refers to the number of handling units at the specific plant. Transport Handling Unit is a uniquely identifiable physical unit consisting of one or more packages (not necessarily containing the same articles) for enabling physical handling during the transport.

The real data is collected through the semi-structured interview of two case plants. And based on this, random practical data can also be generated through Excel for further analysis. In this study, discrete random data function has been used for practical data generation. For example, after analysis the time between arrivals in the real data, a simple distribution can be made like Table 3-1 below.

Time between arrivals (min)	Probability	
3	0.45	
6	0.22	
10	0.14	
30	0.12	
75	0.07	

Table 3-1. Probability of Time Between Trucks Arrival

Then the discrete random data generation function in the data analysis tool can take this table as arrive rate (λ) and generate random times between truck arrivals. The same method is also used to generate random data for the number of THU. Since the operating time per truck and operating time per THU are estimated as fixed values, the number of THU can determine the service rate (μ) in this situation.

3.3.2.2 Calculation Tables of Queuing System

Most of the calculation process of this queuing system is handled by two tables: Main Table and Unloading dock Table. The main Table contains all time-related data of each truck which can be used for queuing analysis and cost estimation. The column names and definition are shown below:

- Truck Info:
 - Truck No#: Number of arrival truck starts from 1
 - IAT: Internal arrival time (time between arrivals)
 - AT: arrival time of the truck

- Unloading dock Info:
 - Slot No#: unloading dock number
 - Start: unloading start time of the truck
 - ST: service time (truck operating time + unloading time of all THUs)
 - Finish: unloading finish time of the truck
- Cost Estimation:
 - WT: waiting time of the truck
 - TIS: time in system
 - Cost: waiting cost of the truck

Unloading dock Table is used to decide which unloading dock will be used for the arriving truck. The column number of this table is based on the number of unloading docks, and value of each position means the service time left in current position when a new truck arrived in the plant. After comparing, the left service time in all the positions, the new coming truck always goes to the position with minimum time left as the principle of FIFO.

Practical Example

A practical example here can be very helpful to illustrate how these two tables work. To avoid using real data in this thesis, the first 10 trucks in the generated random data will be used in this example as input data.

	Number of THU	Time between arrival	Truck Arrival time	Arrive time in min
Truck 1	150	20	06:20	380
Truck 2	1	20	06:40	400
Truck 3	65	10	06:50	410
Truck 4	65	10	07:00	420
Truck 5	30	0	07:00	420
Truck 6	100	15	07:15	435
Truck 7	100	5	07:20	440
Truck 8	15	10	07:30	450
Truck 9	15	5	07:35	455
Truck 10	30	10	07:45	465

Set input data and parameter:

Table 3-2 Example of Arriving Truck Record

According to the input parameters in Table 3-2, the start time of the queuing system is 06:00. Then the arrival time in column 3 can be calculated for each truck with given period between each arrival in column 2. In order to simplify the calculation process, time in minutes is used
in most places instead of normal time style. So, the arrival time 06:20 in the first row will be transformed to 380 minutes, which is calculated from 6(hours) * 60(minutes) + 20(minutes).

Unloading docks:	5
Service period:	06:00 - 23:00
Operating time per THU:	1 minute
Operating time per truck:	15 minutes
Cost of waiting time:	Р

Table 3-3 Example of Input Parameters

1. Fill in the first line:

By using above input data and parameters, the first line of the Main Table and Unloading Dock Table can be filled in as below.

Main Table									
Truck Info Unloading dock Info Cost Estimatic						ion			
Truck No#	IAT	AT	Slot No#	Slot No# Start ST Finish			WT	TIS	Cost
1	20	380	1	1 380 165 545					

Unloading Dock Table							
Time Left in each unloading dock							
Time	1	2 3 4 5			5		
380	0	0	0	0	0		

Table 3-4.Example of Main Table and Unloading Dock Table: Step 1 Fill in the first line

The first truck arrived in 380 minutes of the day (AT), and all unloading docks are equals to 0, which means free. Then it goes to the first free position slot number 1 (Slot No#). Since no waiting is needed, the truck starts to unload (Start) at the same time it has arrived in the plant. The number of THU of the first truck is 150, so the service time (ST) can be calculated as follows: Operating Time per Truck (15 minutes) + Number of THU (150) * Operating Time per THU (1 minute) = 15 + 150*1 = 165. After unloading everything, the truck left the first unloading dock (Finish) at 545 minutes of the day which is calculated by adding Service Start Time (380) + Service Time (165).

2. Fill up to 3 lines

Main Table								
Truck Info Unloading dock Info Cost Estimation					tion			
Truck No#	IAT	AT	Slot No. Start ST Finish			WT	TIS	Cost

1	20	380	1	380	165	545		
2	20	400	2	400	16	416		
3	10	410	3	410	80	490		

Unloading dock Table								
	Time Left in each unloading dock							
Time	1	1 2 3 4 5						
380	0	0	0	0	0			
400	145	0	0	0	0			
410	135	6	0	0	0			

Table 3-5.Example of Main Table and Unloading Dock Table: Step 2 Fill up to 3 line

When the second truck arrived in the plant, the first truck has already been served for 20 minutes. Since the Service Time of the first truck is 165 minutes, the Service Time Left in unloading dock 1 is 165 -20 = 145 minutes. In this situation, the second truck went to the unloading dock number 2 as it is the first slot with the minimum Service Time left. The same thing happened to the third truck which arrived 10 minutes later than the second one. Since both unloading dock 1 and 2 were still unloading the previous trucks, the third truck went into slot number 3.

	Main Table									
Tr	uck Info			Unloadin	g dock Info		Cost Estimation			
Truck No#	IAT	AT	Slot No#	Start	ST	Finish	WT	TIS	Cost	
1	20	380	1	380	165	545				
2	20	400	2	400	16	416				
3	10	410	3	410	80	490				
4	10	420	2	420	80	500				
5	0	420	4	420	45	465				
6	15	435	5	435	115	550				
7	5	440	4	465	115	580				
8	10	450	3	490	30	520				
9	5	455	2	500	30	530				
10	10	465	3	520	45	565				

3. Fill all 10 trucks

Unloading dock Table							
Time Left in each unloading dock							
Time	1	1 2 3 4 5					
380	0 0 0 0						

400	145	0	0	0	0
410	135	6	0	0	0
420	125	0	70	0	0
420	125	80	70	0	0
435	110	65	55	30	0
440	105	60	50	25	110
450	95	50	40	130	100
455	90	45	65	125	95
465	80	65	55	115	85

Table 3-6 Example of Main Table and Unloading Dock Table: Step 2 Fill all 10 trucks

For all the arrived trucks, by checking the Service Time left in each unloading docks, they always went into the position with minimum time left. One thing different from previously arrived trucks, the Start Time is later than the Arrive Time. Use truck number 8 as an example, when it arrived at the plant at 450, the unloading dock with minimum Service Time was position 3 which has 40 minutes left. So, truck number 8 needs to wait for 40 minutes before it can be served. Then the Start Time is calculated by Arrive Time (450) + 40 = Start Time (490).

	Main Table										
Tr	uck Info		ι	Jnloading (dock Info		Cos	Cost Estimation			
Truck No.	IAT	AT	Slot No.	Start	ST	Finish	WT	TIS	Cost		
1	20	380	1	380	165	545	0	165	0		
2	20	400	2	400	16	416	0	16	0		
3	10	410	3	410	80	490	0	80	0		
4	10	420	2	420	80	500	0	80	0		
5	0	420	4	420	45	465	0	45	0		
6	15	435	5	435	115	550	0	115	0		
7	5	440	4	465	115	580	25	140	0		
8	10	450	3	490	30	520	40	70	0		
9	5	455	2	500	30	530	45	75	0		
10	10	465	3	520	45	565	55	100	0		

4. Cost Estimation

Table 3-7 Example of Cost Estimation Result

After filling in all truck information and unloading dock information, the final cost of the day can be estimated based on the Waiting Time (WT) of each Truck. In this example, Trucks number 7 to 10 have some waiting time before they can start unloading. However, all the waiting time is less than 2 hours (120 minutes) which means no cost generated in this situation.

Besides the total cost, the Main Table can also be used to estimate Statistic values like Average Internal Arrival Time, Average Service Time, Average Time in the system and Average trucks in the system. These data might be used in later or future studies. From an efficiency point of view, the ideal scenario is that all unloading docks should be fully operational in the whole Service Period. In the Unloading Dock Table, 0 means the position is free, and it also indicates potential efficiency loss in this period.

3.3.2.3 Other functions of Queueing System

This Queueing system also includes several VBA (Visual Basic for Application) functions that can estimate waiting time, total cost and number of waiting trucks in each hour. These functions are not visualized as Calculation Tables, but they can process large amounts of data for several months or a year.

The major purpose of this queueing system is to simulate the Volvo goods reception scenario and provide data results for statistical analysis like bar charts, flow charts and regression function in data analysis tool. Therefore, the system is helpful for checking relevance between total cost and different variables like a number of the arrived truck in every hour and usage of each unloading dock. The detailed analysis result is discussed and shown in following chapters.

3.3.3 Time Driven Activity-based Costing (TDABC)

Activity based costing (ABC) method is developed and assists the decision maker in understanding how much the product consumes in different activities and assign more overhead costs in the accounting than the traditional costing system (Horngren and dawsonera, 2014). The basic idea of ABC is to identify different activities in the business and map operations of the business with resources in these activities (Stapleton et al., 2004).

According to the study of (Everaert et al., 2008), the company should identify overhead activities and map resource drivers to overhead costs in these activities. Then calculate the activity cost driver rate in each activity based on the function:

 $T+B("(BU + GVB W$("#$ $!B# = \frac{XGB!H + GVB GY Bh# !+B("(BU + GVB W$("#$))}{XGB!H "GH*"# !+B("(BU + GVB W$("#$))}$

Equation 3-5

The total cost can be derived by multiplying the activity driver rate by the number of cost objects.

The benefits of using activity based costing in an organization are obvious; it can help the company understand the actual costs in a business and find out where the cost arises as well as the non-value added activities in the business (Everaert et al., 2008).

(Kaplan and Anderson, 2003) claims that the more cost drivers are identified in the activities, the more accurate the result can be collected. However, it annoyed employees to spend much time identifying different cost drivers in the activity object. The units of each cost driver are different, some are transaction activities, and some are time based activities. The unity of the unit make the ABC-calculation model costly (Kaplan and Anderson, 2003).

Due to the difficulty of finding out the costs of each activity in ABC method, a better method called Time driven activity-based costing (TDABC) is developed (Everaert et al., 2008). In the implementation of TDABC, all resources and activities are based on time. It can improve the accuracy of the final result, and it is easy to update the model when additional cost drivers are considered in the activity.

The steps of applying the TDABC are described by (Kaplan and Anderson, 2003).

- 1. Calculate the cost per minute for capacity
 - a. Identify department or resource pool.
 - b. Identify overhead cost for the department/ resource pool.
 - c. Identify a number of people working in the department and working hours.
 - d. Estimate the practical capacity of the department.

 $4 \text{GVB S} \# \text{'} \text{O} * B \# \text{YG} \text{V} \text{SSHU} \text{O} \# +! \text{S}! + (BU = \frac{Z \# \text{S}! \$B^{\vee} \#)B^{[\text{V} \text{G}"} \# \$h \# ! W + \text{GVB}}{\sqrt{*^{\vee}} \# \$G\text{Y} \text{'} \text{O} * B \# \text{V} \ast \text{S}\$! + B(+! \mathbb{H} + ! \text{S}! + (BU))}$

Equation 3-6

- 2. Supplying derive unit times of activities
 - a. Identify activities within the department.
 - b. Identify the time drivers for the activities.
 - c. Identify the time for the time drivers in each activity.
 - d. Set up time equations for the activities.
- 3. Derive cost rate for the activity
 - a. Multiply the time equation by the cost per minute for supplying capacity.

3.3.4 CO₂ Evaluation

3.3.4.1 Energy Efficiency Operational Indicator (EEOI)

The Marine Environment Protection Committee (MEPC) has an approved Energy Efficiency Operational Indicator (EEOI) which was introduced by IMO, the International Maritime Organization, and was suggested for voluntary use in the guidelines (MEPC.1 - Circ.684) (Committee, 2009). By these guidelines, ships can choose to use EEOI and evaluate their performance regarding CO₂ emissions, which has been seen as an important indicator of consumption of bunker fuel oil. In addition, the EEOI also provides statistical data information and analysis results of a ship's performance related emissions and fuel efficiency. (Kotowska, 2015)

According to Andersson in 2016, the EEOI Guidelines present an expression of efficiency for a ship in operation with the format of CO₂ emitted per unit of transport work. It provides an evaluation approach of energy efficiency. For developing performance monitoring, the guidelines also recommend the ship owners, ship operators, and parties use an operational indicator either from these guidelines or other equivalent methods in their environmental control systems. (Kotowska, 2015)

According to (Committee, 2009), five steps are needed to establish the EEOI of an existing vessel. The main steps are:

- a. Define the period of the voyage
- b. Define the data sources
- c. Data collection
- d. Data conversion

e. EEOI calculation

Definition

In order to make it easier to extract the useful information, the required data such as traveling distance, the amount and type of fuels and all fuel information related to the CO_2 emission should be recorded. These data are defined as:

1. Fuel consumption

The fuel consumption is defined as all fuel consumed during the sailing process.

2. Fuel Type

The amount of CO_2 emission is directly related to the type of fuel. According to (Kołwzan and Narewski, 2012), Fuel mass to CO_2 mass convention factor (CF) is introduced to reflect the amount of CO_2 emission per unit specific type of fuel. The value of CF is as follows:

Type of Fuel	Carbon content	CF(CO2-t/Fuel-t))
Diesel/Gas Oil	0.875	3.206000
Light Fuel Oil (LFO)	0.86	3.151040
Heavy Fuel Oil (HFO)	0.85	3.114400
Liquefied Petroleum Gas (LPG)	0.819(Propane) 0.827(Butane)	3.000000 3.030000
Liquefied Natural Gas (LNG)	0.75	2.750000

Table 3-8. Convention Factor of Different Type of Fuel

3. Ships and cargo types

According to (Committee, 2009), the EEOI is applied to all existing ships, including dry cargo carriers, tankers, gas tankers, container ships, Ro-Ro cargo ships, general cargo ships and passenger ships which include Ro-Ro passenger ships.

There are no particular restrictions on the transported cargo. However the unit of EEOI corresponds to the expression of cargo mass carried or work done, the capacity transported. In general, metric tonnes (t) of the cargo carried is applied in the dry cargo carrier, tankers (liquid or gas), general cargo ships and Ro-Ro cargo ships. For other types of cargo, the expressions are different. The following form shows some particular cases.

Type of vessel	Type of cargo	Expression of cargo mass carried
Containership	Containers	TEUs (empty or full)
Container ship with other	Containers	1 loaded TEU=10 t
cargoes	&other types of cargoes	1 empty TEU= 2 t
Passangars shins	passongors	Numbers of passengers or
rassengers snips	passengers	gross tonnes of the ships
Car ferries and car carriers	Cars	Occupied lane meters

Railway/RO-RO vessels	Railways cars and freight vehicles	Occupied lane meters
-----------------------	---------------------------------------	----------------------

Table 3-9. Expression of Cargo Mass Carried for Different Types of Vessel

4. Voyage

The definition of the voyage in the EEOI calculation means a specific period begins at a department of one port and end at the department of the next port.

5. Sailing distance

The sailing distance is defined as the actual distance at sea in nautical miles for the voyage.

EEOI calculation

For a single voyage, the expression for EEOI is defined as:

Equation 3-7

Where,

j = the fuel type;

FC=mass of fuel consumed;

CF= non-dimensional conversion factor: fuel mass to CO2 mass;

• 00Pde = cargo carried (tonnes) or work done (number of TEU or passengers);

D= the nautical distance related to the cargo carried or work done.

When considering a period or a number id voyages, the average EEOI is defined as:

$$T'' # \$!\% # ^^` = \frac{\sum \sum A4_{.c} * 4_{bc}}{\sum (- 00Pde_{.c} * Z($$

Equation 3-8

Where,

i = the voyage number;

FC_{ij}=the mass of fuel j consumed at the voyage *i*.

3.3.4.2 Fuel consumption of the Propulsion system

According to the equation 3-7, the fuel consumption is an essential parameter which affects the EEOI numbers. The fuel consumption of a ship is a process of energy consumption, which exists in every aspect of the operation of the ship. The propulsion system, lighting, heating,

ventilation and air conditioning would consume the fuel in the ship; the major consumption is in the process of ship propulsion.

Propulsion fuel consumption

The diesel propulsion system is the most common propulsion system and it mainly used in almost all types of merchant ships. In the working process, it converts thermal force, which comes from the burning of fuels, to the mechanical energy or propulsion power to enable ships to maneuver themselves in the water (Song and Xu, 2012).

According to (Song and Xu, 2012), the fuel consumption of the main engine can be expressed as:

$$A4_{NPeNklm.en} = o_{NPeN}]VY +_{Rnd.nR}X$$

Equation 3-9

Where,

 o_{NPeN} = the Engine Power in the sailing;

 $]VY+_{Rnd.nR}$ = brake specific fuel consumption;

T = Distance/speed, the voyage time.

Vessel speed is the factor mostly influencing the performance of the engine, in general, the engine power is proportional to the third power of the actual sailing speed (Mansell, 2009).

$$o_{NPeN} = q''^r$$

Equation 3-10

Where,

K= constant;

v = the speed of the vessel.

When it comes to the diesel engine, their performance in terms of energy efficiency is commonly mentioned. In marine engines, brake specific fuel consumption (bsfc), also known as specific fuel oil consumption (sfoc) is often applied as the measure of the engine efficiency (Song and Xu, 2012). The bsfc measures the mass of fuel that is required to generate a certain amount of mechanical energy output from the engine.

 $]VY + = \frac{3.6 * 10^{6}}{y_{Rnd} * z\{|$

Equation 3-11

Where,

 y_{Rnd} = the energy efficiency of the engine;

LHV= lower heating value, it represents the specific energy content of the fuel, or in other words, the heat that is released by the full combustion of one kg of fuel.

Fuel Type	LHV(MJ/kg)
Methane	50,00
Diesel	43,4
Hydrogen	119,96

Table 3-10 LHV of Different Fuel Types

Considering the equation 3-7, the EEOI of the engine for a certain voyage can be expressed as:

$$\wedge \wedge \sum_{\text{Rnd}} = \frac{A4_{\text{NPeNklm.en}} * 4A_{\text{Rnd}}}{\underbrace{\bullet}_{00\text{Pde}} * Z}$$

Equation 3-12

Where,

A4_{NPeNklm.en} = fuel consumption due to the main engine;

 CF_{eng} = non-dimensional conversion factor: fuel mass (used in the main engine) to CO₂ mass;

• 00Pde = cargo carried (tonnes) or work done (number of TEU or passengers);

D = the nautical distance related to the cargo carried or work done;

Therefore, for a certain shipper, the CO₂ emission from the propulsion system is:

 $E!VV_{Qe} = '!VV_{QOPde} * Z * ^ _ Rnd$

Equation 3-13

Where,

mass_{cargo} = the cargo mass of a certain shipper.

D = sailing distance

*EEOI*_{eng} = the energy efficiency operational indicator for the main engine.

3.3.4.3 CO₂ Emission Calculation for LCL Shipments

For the LCL transportation, there are four types of cargo transport services: door-to-door service, door-to-CFS (container freight station) service, CFS-to-door service, and CFS-to-CFS service. The explanations of these four services are in the following:

- Door-to-Door: full container from the shipper's place to the consignee's place.
- Door-to-CFS: full container from the shipper's place to the carrier's CFS at the destination, consignee, arranges the collection of loose cargo.
- CFS-to-Door: loose cargo from the origin's CFS packed into the whole container and delivered to the consignee's place.
- CFS-to-CFS: loose cargo from the origin's CFS packed into the whole container and delivered the destination's CFS, consignee arranges the collection of loose cargo.

In this study, the evaluation of CO_2 emission only considers the operation at sea, which means the transportation on shore is excluded.

According to the interview of Logistics Purchasing department, the LCL project is outsourced to the third-party cargo forwarder. Considering the cargo service, Volvo Group Logistics Service has a limited impact on selecting sea transportation for the LCL cargo. Therefore, for LCL shipment, the emission factor based on trade lanes can be applied in the CO_2 emission evaluation. The emission factor comes from the Clean Cargo Working Group (CCWG), which is shown in Table 3-11.

Standardized trade lane	CCWG Average (g CO2/ TEUkm)
Asia – Africa	61,8
Asia – Mediterranean	54,9
Asia – Middle East/India	54,6
Asia – North America EC*	62,9
Asia – North America WC**	56,2
Asia – North Europe	43,8
Asia – Oceania	61,7
Asia – South America (EC/WC)	53,5
Europe (North& Med) – Africa	69,5
Europe (North& Med) – Middle East/ India	54,0
Europe (North& Med) – Oceania (via Suez/via Panama)	78,4

Europe (North& Med) – Latin America/ South America	63,7
Intra –Americas (Caribbean)	86,5
Intra – Asia	87,5
Intra – Europe	93,6
Mediterranean – North America EC (incl. Gulf)	70,3
Mediterranean – North America WC	60,8
North America EC – Middle East/ India	65,2
North America – Africa	84,0
North America – Oceania	74,7
North America –South America (EC/WC)	67,4
North Europe – North America EC (incl. Gulf)	75,0
North Europe – North America WC	69,4
South America (EC/WC) – Africa	58,8
Other	57,7

Table 3-11 CCWG Average for Standardized Trade Lane (EC=East Coast, WC=West Coast)

On the other hand, the unit of LCL shipments is kg or t, but the transported capacity of the carrier, mainly the container ship, is TEUs. In order to unify the units of parameters in the CO2 calculation, the weight of LCL shipments should be converted into TEU. According to the suggestion of IMO, one full loaded TEU equals 10 tonnes and one empty TEU equals 2 tonnes. Therefore, a certain weight of LCL shipments can be converted to a certain number of fully loaded TEUs as the following equation.

$$\int_{6\tilde{N}\tilde{O}} = \frac{5\tilde{U}5}{8}$$

Equation 3-14

Where,

 $"_{5\dot{U}5}$ = the weight of LCL shipments (t).

The CO_2 emission of LCL shipments in the sea segment can be expressed as:

 $\bullet_{\text{Qe}} = Z(\text{VB!}) + \# * \chi_{6\tilde{N}\ddot{O}} * 44\hat{a}\hat{a}_{O\ddot{a}RPOdR}$

Equation 3-15

4 Results

By using the selected research methods, this chapter presents the results analysed from the collected primary and secondary data. Freight cost of different logistics services, waiting time cost, language barrier impacts and CO₂ emission evaluation from sea transportation are also included in this chapter.

4.1 Alternative Logistics Solution

This section aims to describe what the logistics service types, under road transportation, can be considered in VGLS future sourcing projects.

4.1.1 Interview Result

In LP, commodity and sourcing department the road transport covers three service type: Fulltruck-load (FTL), Less-than-truck-load (LTL) and road express. FTL consist of Door to Door transportation, including dedicated services, and Dynamic milk run (MLK). The road express segment covers services by the road where the booking and pick-up are done the same day, and the required lead-time is shorter than the standard LTL and FTL lead-time. According to internal documents from VGLS, there are six types of transport legs in inbound road transportation:

- Pre-carriage Transport (PCT) refers to a transport leg that starts at the first consignor and ends at a cross dock.
- Door to Door Transport (DDT) refers to a transport let that starts at the first consignor and ends at the last consignee.
- Main Carriage Transport (MCT) refers to a transport leg that starts at one cross dock and ends at another cross dock.
- On Carriage Transport (OCT) refers to a transport leg that starts at a cross dock and ends at the last consignee.
- Milk Run 1st Leg (MLK 1) refers to a transport leg that starts at one or several "first" consignors and ends at one cross dock, and/or several "last" consignees.
- Milk Run 2nd Leg (MLK 2) refers to a transport leg that starts at one cross dock and ends at one cross dock in combination with one or several "last" consignees, or ends at one or several "last" consignees.

According to the interview and investigation from the case plant, some light weight parts are transported via LTL service from material suppliers to the plant. Generally, these light weight parts are packaged with small carton box, afterwards these fully loaded carton boxes are put into the wood pallet for transportation or storage. However, a number of delivery parts depends on the request from the plant. Sometimes, only one pallet is shipped to the plant, and the actual weight of the shipment is much less than the chargeable weight. In other words, a large proportion of the transport expense is the package martial rather than the cargo. Therefore, in the perspective of saving unnecessary expense of the transportation cost, Plant

A expect the Logistics Purchasing of Volvo Group can purchase alternative logistics service to solve this problem.

4.1.2 Computing Result

Based on Plant A's requirements, the focus is on the small parts which are transported in the K1 pallet. For these pallets, the inner package is the small carton box-EMB 100. According to the information from Plant A, the number of delivered packages, the fully loaded EMB 100, depends on the call off. Some small carton packages are delivered from the material suppliers to the Plant A in a small number. According to the statistics from Plant A, the material suppliers in Sweden who deliver the flexible amount of fully loaded EMB 100 are targets in this study. These material suppliers are located in different areas and provide different amounts of parts.

According to the statistics from Plant A, the average weight of these delivered packages is 3.2 kg.

Based on the statistics of arriving trucks in 2016, the number of THU of each transport is not stable. The distribution of the number of THU per transport in 2016 is shown in Figure 4-1.



Figure 4-1. Distribution of THU number

Figure 4-1, presents the frequency of delivered amount of THU in 2016. Based on the statistics, 13.64% of the arriving LTL trucks were loaded with less than 4 THUs per transport in 2016, and the percentage of trucks which carried only 1 THU delivery is 6.2%. According to the interview and feedback of Plant A, the cost of these 1 THU deliveries via LTL service will be analyzed. The alternative service, the parcel service, will be discussed to find out the possibility to change the existing LTL service.

Freight Cost in LTL Service

For the LTL transportation (K1 pallet) for the only one THU delivery, the freight rate depends on the chargeable weight and the minimum charge.

1. Calculate chargeable weight

Each K1 can take 30 EMB-100 inner packages at most, according to the interview from Plant A, the weight of fully loaded EMB 100 is up to 6 kg. The maximum actual weight for the one THU (i.e., K1+30*EMB100) is 201.5 kg, which includes the weight of the wood pallet.

Based on Plant A statistical data, the average weight of one fully loaded EMB 100 is 3.2 kg, which means the average weight of one THU (i.e., K1+30*EMB100) is 117.5 kg.

2. Calculate the freight

Assuming in area *i*, the minimum charge is c_{mi} , the price in the weight range 0 to 299 is c_1 per 100 kg. Therefore, when the chargeable weight is lower than $100^*c_i/c_1$ kg the freight would be charged at the minimum charge rate. The weight, $100^*c_i/c_1$ kg is defined as the minimum weight. The minimum weight is not a fixed number in different areas based on the signed contract between the carrier and VGLS.

Based on the LTL freight rate contract and the average weight of one THU shipment, for one THU delivery, the average weight is 117.5 KG which is lower than the minimum weight in Sweden. Therefore, the freight cost should be charged at the minimum charge.

Total cost on the delivery of one pallet in LTL service is decided by the yearly delivered amount of K1 pallets. Since the number of the EMB 100 for the delivery is dependent on the call off, the actual delivered number of EMB 100 packages is flexible from 1 to 30. In this research, assuming 6.2% of the light weight packages (Loaded EMB 100) transportation, which with the same distribution of all LTL transportation in Sweden, is considered to be delivered on one pallet. In Figure 4-2, it clearly shows that the average number of delivered packages in one pallet has an essential impact on the yearly delivered times. With the increase of an average number of EMB 100 per pallet, a number of delivered loaded K1 pallets goes down, and the freight cost decreases respectively.



Figure 4-2 Freight cost on delivery of the light weight cargo in one pallet(LTL service)

Parcel Service

1. Define the chargeable weight

The average weight for one fully loaded EMB 100 in the statistics of Plant A is 3.2kg. Therefore, the chargeable weight per EMB 100 is 3.2kg, which includes the weight of the carton box.

2. Define the price for different weight of parcel

For the parcel service, the price standard is unified in different areas of Sweden. For a different weight, the freight is charged at different prices, the maximum weight for each shipment is up to 100 kg.

Based on the price contract of parcel service and the chargeable weight, which is decided by the volume of the packaging and the weight limitation for the safety, of the fully loaded EMB 100, the weight distribution of different numbers of loaded EMB 100 is shown in Figure 4-3.



Figure 4-3. Weight distribution of different number of loaded EMB 100

3. Calculate the total cost of the parcel service

If the one THU is changed from LTL transportation to the parcel service, the total freight cost of the parcel is dependent on the average number of packages per delivery, which determines the freight cost in each delivery and the delivery time (i.e. the frequency of deliveries). In the calculation, the unit of the delivery times is deliveries per year.

$$A$#(\%hB + GVB) S!$+#H V#$"(+# = A$#(\%hB S#$ W#H("#$U * Z#H("#$U B('#V B('#V B)))))$$

Because any number more than 30 EMB 100 are required to be warehoused in K1 pallets, and a large amount of EMB 100 shipped by parcel service need to be repacked by the plant. It is infeasible to deliver all packages in the parcel service in reality due to this repacking. When it comes to the estimation of the yearly delivery time, 6.2% of the packages are assumed to be

delivered by the parcel service. 6.2% is the frequency of arrived trucks which only carried one THU in the LTL service in Sweden. Figure 4-4 shows that, for parcel service, delivery times depend on the number of average delivered EMB 100, the yearly delivery times go down with the increasing number of averaged delivered EMB 100. The total freight cost of parcel services for different delivery times is also shown in the Figure 4-4. For the same amount of packages, freight costs are reduced as the number of delivery times decreases.



Figure 4-4. The Relationship between Delivery Frequency and Fright Cost

Comparing the different services

In the comparison of LTL service and potential parcel service, the difference of freight cost is considered in this study. According to the freight calculation for these two different logistics services, the difference of freight is defined as that, for a certain number of delivered times, the freight of LTL service minus the freight of the parcel service. The result shows that the parcel service has the advantage in the freight cost when delivering small amounts of loaded EMB 100. The "small amount" means the delivered number of EMB 100 is lower than 30 per time. Since the delivery times depends on the average number of delivered EMB 100, the relationship between the freight savings of the parcel service (Freight of LTL service minus Freight of parcel service) and the average number of delivered EMB 100 per time is shown in Figure 4-4. In order to measure the advantage of the parcel service better, the saving percentage in different situations is shown in Figure 4-5. It presents that the advantage of parcel service would decrease when the average number of delivered EMB 100 per time goes up.



Figure 4-5 Freight Cost Saving (freight cost of LTL service – freight cost of parcel service)



Figure 4-6 Saving Percentage of Different EMB 100 Amount

4.2 Time Slot Delivery

In order to evaluate the possibility of booking time slot deliver service, this section illustrates and analyses the related data collected from interviews, surveys, and Volvo internal documents. Most data of goods reception process were collected from two case plants of the Volvo Group. One case plant's waiting time costs have been computed via the calculation tables of the queueing system which were mentioned in Section 3.3.2.2. Then, the interrelationship between the waiting time cost and the time slot delivery were analysed.

4.2.1 Interview and Survey Result

From the plant perspective, a time slot delivery makes it possible to schedule the goods reception reasonably, and improves the unloading efficiency, and reduces the cost of waiting time. From the logistics company's aspect, it can decrease the time of truck queuing and improve the efficiency of operation. Therefore, setting the delivery time slot is beneficial for both sides. However, in the practical operation, it would be very tough for logistics companies to ensure trucks reach the factory at a specified time slot.

For different logistics companies with different road transport services proceeding different routes, the difficulties setting the delivery time slot are completely different. For example, the transit time of a truck from Italy to Sweden is five working days, and it would be very difficult to require the truck driver to arrive at a specified time slot such as Friday 15:00-16:00. For a milk run delivery, since the truck pick up shipments from different places and deliver to different consignees stand by stand, the previous delay will affect the next delivery time.

According to survey results, all participants, who are based in the EU market, affirm that they can offer specified (pre-defined) time slot deliveries for FTL service; 80% of logistics companies among them can offer specified time slot deliveries for LTL and MLK services as well. 80% of carriers commit that the delivery precision of a time slot delivery is over 95%, and the surcharge for a specified time slot deliveries is offered case by case. Two participants have offered a reference rate for one specified time slot delivery; the range is between 20-50 EUR. The survey results present that 60% of participants think that route planning is the main challenge related to providing specified delivery time slots.

In addition to pre-set long-term delivery time slots, another way to specify the delivery time slot is to book a delivery time in advance; which is widely used in cross-docks goods reception. According to LP SOP, when delivering cargo to a VGLS or a 3rd party cross dock, the carrier should send a notification to the cross dock, by 15:00 at the latest on the previous working day before the delivery. Based on given information the cross dock will revert to the carrier with a confirmation of time of arrival and unloading time slot.

The statistics which is used in Section 4.2.2 was gathered for the selected two case plants Plant A and Plant B. The data acquired consisted of, part number, supplier name, pick-up point, pick-up country, estimated arrival time, received date, received time. The data was given separately for two studied cases in different formats.

Good Reception Process

Both Plant A and Plant B operate goods reception during two 8-hour shifts per day, 5 days per week. A regular goods reception at one dock for one truck takes 30-40 minutes in Plant A,

while in Plant B it usually takes around 1 hour. This is due to the average number of unloading THU per truck of Plant A is greater than Plant B. There are two unloading docks in Plant A, and five unloading docks in Plant B, each unloading dock has two workers per shift.

According to the interview with transport manager in Plant A, after the drivers arrive, firstly they go to registration and submit the shipping documents in order to get a proof of arrival, so called POA. The time of registration can vary from 8-15 minutes, depending on the quality of required shipping documents. Then the drivers wait in the dock queue area. The time spent waiting in the dock is dependent on the whether it is a peak or off-peak time and the queue. If the waiting time exceeds two hours, a surcharge will be invoiced by logistics suppliers. When the unloading dock is available, the truck will be moved to the unloading dock. The driver opens one side of the trailer and unfastens the cargo. After that, the shipping documents will be manually checked once again, and two workers start to unload the goods. Finally, the driver unfastens the cargo, closes the trailer, and drives out of the plant. The time spent on the unloading process can be estimated between 10-25 minutes, which mainly depends on whether the cargo has been loaded in a correct order and some other factors.

Two representatives from material handling in Plant B were also interviewed. After the cargo is unloaded from the trailer, workers need to scan and sort the shipments in order to store them in the correct and specific position in the plant. After all this cargo is moved into the plant, the unloading dock will be available for the next truck to unload. Therefore, the sorting and loading activities after unloading are important impact factors of good reception time in Plant B. The empirical data collected during the interviews in Plant B has enabled drawing the good reception process shown in Figure 4-7 below.



Figure 4-7. Plant B Goods Reception Process

Plant A

Plant A unloads an average of about 40 trailers per day, usually from 06:30 to 22:30, five days per week; but for some urgent goods, someone will be on duty for goods reception late at night or at the weekend.

The interviewee from logistics process management in Plant A, who has worked in the plant for 18 years, said that Plant A had set delivery time slots since 1995, by making oral

agreements with some logistics companies. In this thesis, this service named as *fixed time slot delivery*. Currently, these fixed time slot deliveries are offered by logistics companies with no surcharges, while if the truck cannot deliver in the specified time slot, as long as it arrives on the commitment day, it still counts as being delivered on time.

According to the statistics of Plant A goods receiving the record, there are total 20 logistics companies providing inbound logistics services to the plant. Among them, 13 logistics companies have made an oral agreement to deliver goods in a fixed time slot. In this case, logistics companies can set the time slots based on different departure territories. For example, Company F runs two routes to Plant A, it can be divided into two branch carriers as F1 and F2. Accordingly, these 13 logistics companies were divided into 32 carriers. It should be noted that some logistics companies only set delivery time slots for certain routes, which means not every departure territory has been covered under these 13 logistics companies.

The fixed arrival timetable of Plant A is from 7:00 to 22:00 on Monday to Thursday, and 7:00 to 20:00 on Friday. The width of each time slot is two hours, and each time slot can start on the hour during the working time. Logistics companies can select different time slots according to their route planning, and a specific departure territory may settle with two time slots. As shown in Table 4-3, nine carriers select two time slots during the same day (i.e., *C2, E1, E2, E3, I6, I10, I11, J*); and one carrier (i.e., *F1*) selects a four-hour consecutive time slot in the evening along with a two-hour time slot during the day. For example, logistics *Company E* delivers cargo from 4 departure countries to Plant A: Burgin (*Carrier E1*), the UK (*Carrier E2*), Germany (*Carrier E3*), and Poland (*Carrier E4*). It sets two time slots for trucks from the first three countries, and for the last departure countries, it selects only one time slot which is between 13:00-15:00 from Monday to Friday.

After this schedule has been set, it will be executed until logistics companies' contracts end. If one logistics company wants to adjust the delivery time slots due to the route planning or some other reasons, the company can contact Plant A to reset it.

Day Shift										Evening Shift						
07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	
	С	2	ŀ	Н		С	4		C2		С	6		Į.	4	
C	4	F	1	С	1		C	:3	A			L	2	11	10	
E	1	Ĺ	כ			E	1			F1				11	11	
	E	2	l	L		E	2		E3	3			J			
-	I	E	3			E	4			I	3					
1	6	0	9			11	0			I	5					
11	1		l	В			I	8		1	6					
	I.	1						9		11	2					
	I.	7														

 Table 4-1. Plant A delivery time slot schedule (Volvo, 2017)

Plant B

Two employees working in material handling in Plant B have been interviewed, one of them has worked at the plant for 29 years, and another for 12 years. According to their description, there are 5 unloading docks for trucks unloading, an estimated average unloading time for each trailer is around 1 hour, the working time for goods reception is from 6:45 to 23:45. The whole day of Monday, Tuesday, and the afternoon of Friday are peak times for goods reception in a week. In the worst situation, several trucks drivers have been waiting for 5-6 hours, parking area has been full of waiting trucks, and the queue has been too long causing a congestion of nearby highways.

Accordingly, the designed unloading capacity for Plant B is 80 trailers (5*16) per day. However, Plant B receives around 70 trailers per day, and it is already reached the limit of its unloading capability. In general, a lot of trucks arrive between 06:00-08:00 every day and cause congestion. Therefore, Plant B wants to set delivery time slots to receive 5 trucks per hour.

4.2.2 Evaluation of Time Slot Delivery's Impact on Goods Reception

Based on statistical results from transport system of Plant A, and manual writing record of Plant B, Figure 4-8 shows the total number of trucks arriving on each weekday in February 2017. Trucks which arrived between 23:00 to 6:00 or during the weekends are not included in this figure, and some missing data of Plant B recording were filled with projected data based on existing information. For Plant A, the total number of daily arrived trucks is between 150 and 200, and for Plant B, the number is between 250 and 400.



Figure 4-8. Total Number of Arriving Trucks in Weekdays (February 2017)

Figure 4-9 and 4-10 present the percentage of arriving trucks per hour from Monday to Friday in February 2017.



Figure 4-9. Percentage of Arriving Trucks per hour in Plant A



Figure 4-10. Percentage of Arriving Trucks per Hour in Plant B

Coefficient of Variation of Arrival Truck Number

Table 4-4, and 4-5 show the standard deviation and coefficient of variation (CV) of the number of truck arrivals per hour for the two plants. CV is a standardized measure of dispersion of a probability distribution or frequency distribution (BASU, 2016). The period for these statistical data was from 6:00 to 23:00, from Monday to Friday in February.

Comparing the CV between Plant A and Plant B, Plant A has a larger value than Plant B in four of the weekdays. The total average CV of Plant A is 0.53, which is also larger than the average value 0.45 in Plant B. Therefore, the comparison of CV shows that Plant B has a more even amount of truck arrivals than Plant A, during the whole week. However, the selected statistics ignored the fact that the actual working time for Plant A is longer than Plant B.

	Mon	Tue	Wed	Thu	Fri	Average
Plant A	1,51	1,03	0,98	1,39	1,62	1.31
Plant B	2,36	2,00	2,01	1.74	2,01	2.03

	Mon	Tue	Wed	Thu	Fri	Average
Plant A	0,52	0,42	0,43	0,54	0,74	0,53
Plant B	0,45	0,37	0,51	0,43	0,47	0,45

Table 4-2. Standard Deviation of Arrival Truck Number per Hour in February 2017

Table 4-3. Coefficient of Variation of Arrival Truck Number per Hour in February 2017

Even though both Plant A and Plant B start to receive goods from 6:30, Plant A set the first time slot delivery starting form 7:00, which causes much fewer trucks to arrive between 6:30 to 7:00 in Plant A than Plant B. On the other hand, Plant A stops goods receiving at 22:30 (Friday at 20:00), while Plant B stops at 23:30. Accordingly, the study reselects the period from 7:00 to 21:00 on Monday to Thursday, 7:00-20:00 on Friday, and compares the two plants' performance again. The results are shown in Table 4-6 and 4-7.

For Plant A, the total average of CV is 0.36, while for Plant B, the total average of CV is 0.41. The comparison of two plants' statistical data shows that during 7:00-21:00 (7:00-20:00 on Friday), Plant A has a more even amount of arriving trucks than Plant B during Monday to Wednesday, on Thursday the performance is quite similar, while on Friday Plant B is more even than Plant A.

	Mon	Tue	Wed	Thu	Fri	Average
PLANT A	1,03	0,77	0,65	1,11	1,52	1,02
В	2,19	1,90	1,98	1,57	2,02	1,93

Table 4-4. Standard Deviation of Arrival Truck Number per Hour in February 2017

	Mon	Tue	Wed	Thu	Fri	Average
PLANT A	0,39	0,29	0,25	0,39	0,50	0,36
В	0,42	0,34	0,47	0,39	0,45	0,41

Table 4-5. Coefficient of Variation of Arrival Truck Number per Hour in February 2017

Utilization rate of unloading capacity

From the perspective of the maximum capacity in each hour, the ideal scenario is to have each unloading dock fully operational in each time slot. Table 4-10 and 4-11 illustrate the exceeding and underused capacity per hour of Plant A and Plant B (i.e. (number of loading docks available - the number of trucks arriving)/number of loading docks). The red cells highlight the exceeding capacity over 100% which indicates all unloading docks are busy in that hour and one or more trucks were waiting in the queue.

2017 _Feb	06:30	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:30
Mon	13%	106%	81%	100%	119%	75%	75%	106%	113%	106%	106%	81%	69%	6%	31%	50%	13%
Tue	19%	94%	88%	100%	69%	50%	75%	81%	69%	50%	63%	81%	63%	44%	31%	56%	6%
Wed	6%	56%	75%	81%	63%	75%	94%	44%	56%	63%	81%	63%	75%	38%	50%	44%	6%
Thu	0%	100%	113%	88%	88%	81%	94%	88%	63%	63%	88%	88%	38%	44%	19%	31%	6%
Fri	6%	100%	50%	131%	63%	75%	44%	75%	100%	75%	100%	56%	13%	13%	25%	0%	0%

Table 4-6. Average Exceeding/underused Capacity per Hour, PLANT A, February 2017

As Table 4-10 shows, Monday is the busiest day for Plant A during all weekdays. There are 6 hours on Monday that the number of trucks arriving is greater than the number of loading docks available, especially concentrated in the afternoon. However, after 17:00, the utilization of capacity dropped quickly and kept decreasing until end of the day.

2017 _Feb	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00
Mon	181%	213%	138%	200%	81%	75%	106%	88%	106%	69%	125%	106%	31%	144%	6%	94%	17%
Tue	119%	169%	163%	75%	75%	113%	138%	100%	125%	242%	100%	106%	81%	119%	58%	75%	19%
Wed	63%	125%	69%	106%	106%	100%	88%	38%	163%	50%	169%	81%	44%	42%	0%	19%	0%
Thu	150%	156%	100%	94%	69%	38%	100%	69%	56%	83%	144%	56%	69%	69%	13%	25%	19%
Fri	50%	188%	81%	81%	94%	81%	200%	100%	100%	83%	75%	42%	13%	63%	25%	100%	25%

Table 4-7. Average Exceeding/underused Capacity per hour, B, February 2017

As Table 4-11 presents, the number of arriving trucks often exceeds the unloading capacity. On average, 9 out of 16 hours on both Monday and Tuesday, the unloading capacity is less than arriving truck numbers. Wednesday is little better, but still, one third of the working time is over capacity. The remaining two days of the week are much better than others. However, the exceeded percentage over 100 is still much larger than Monday in Plant A.

Overall, the total number of arriving trucks has already exceeded the maximum capacity of unloading docks, which means even in the ideal scenario some of the time slots are red. So the key to reduce waiting time for trucks is controlling the number of arriving trucks on Monday and Tuesday or increasing Plant B unloading capacity by adding more unloading docks or improving unloading speed. For Wednesday to Friday, as Table 4-11 shows, if trucks could arrive more evenly, the unloading capability of Plant B could be more fully utilized.

4.2.3 Interrelations Between the Time Slot Delivery and Truck Waiting Time Cost

The study used the data from 15 working days' (Plant B) in February to investigate the interrelations between the time slot delivery and truck waiting time cost. The waiting time cost calculation tool which was used to estimate statistics result has been described in detail in Chapter 3.5. For international trucks, the waiting time cost of every commenced 30-minute period is P_{eu} ; and for domestic trucks, the waiting time cost of every commenced 30-minute period is P_{se} . For confidential reasons, the input parameters for the two case plants are hidden from this article and some practical data has been used instead.

Table 4-12 indicates 15 days waiting time costs of Plant B, the CV of Trucks' Arrival and the ratio between unloading volume and unloading capacity are presented. It also shows the Interrelations between the trucks arriving distribution and truck waiting time cost. Based on the result, the following three statements can be concluded in the scope of collected data:

- When the unloading volume is over unloading capacity, no matter how much the CV of trucks' arrival, the waiting time cost always occurs and the value is very high.
- When the unloading volume is between 70% and 100% of unloading capacity, the waiting time cost is related to the CV of trucks' arrival. Even though a waiting time cost occurs, the value is far lower than over capacity scenario.

• When the unloading volume is less than 70% of unloading capacity, there is very high probability that waiting time costs will not arise.

	CV of Trucks' Arrival	Unloading volume/ Unloading Capacity	Waiting time Cost
Day 1	0,86	125%	329 <i>P</i> _{eu} ~ <i>P</i> _{se}
Day 2	0,39	121%	135 $P_{eu} \sim P_{se}$
Day 3	0,52	111%	127 $P_{eu} \sim P_{se}$
Day 4	0,64	93%	9 <i>P_{eu}∼P_{se}</i>
Day 5	0,59	93%	2 $P_{eu} \sim P_{se}$
Day 6	0,60	92%	0
Day 7	0,75	79%	0
Day 8	0,85	73%	6 <i>P_{eu}~P_{se}</i>
Day 9	0,64	72%	0
Day 10	0,66	65%	0
Day 11	0,61	64%	0
Day 12	0,70	61%	0
Day 13	1,05	60%	0
Day 14	0,89	57%	0
Day 15	1,32	51%	0

Table 4-8. Statistical Data of CV, Unloading Utilization, and Waiting Time Cost

4.3 Personnel Contact Quality

There are several key performance indicators to measure carriers' service level, such as delivery precision, lead time, damage rate, etc. However, from the plants perspective, the personnel contact quality can also be seen as a service performance that impacts customer experience a lot. The Plants, as the users of logistics service, experience the inbound logistics service by receiving goods from different carriers every day. The third research question in this study concerns the cost related to personnel contact quality and what Logistics Purchasing can do to impact carriers to improve this performance. In this case, for plants, the personnel contact quality of logistics companies mainly refers to truck drivers' behaviours. According to the interviews in the two case plants, there are two main concerns about the personnel contact quality for truck drivers: language barriers and incorrect documentation.

4.3.1 Language Barrier

Language barriers mainly exist in some logistics companies running businesses from particular origin countries to Sweden, such as Poland, Hungary, Russia, Latvia, etc.; Swedish and Nordic logistics companies do not appear to have such language barriers. Due to the mother tongue, education level, working environment, and other factors, for some logistics companies, it is hard to recruit English-speaking truck drivers (Feely and Harzing, 2003). If the contract required all drivers to speak at least entry level English, it would increase the labour cost for logistics companies, and ultimately lead to an increase in Volvo logistics costs.

According to the interviews with material handling in B, foreign truck drivers who don't speak English or the domestic language (Swedish in this case), caused a language barrier in good reception process, which created a longer time on communication and document handling. There is no relevant statistics, an employee at material handling estimated that the statistic was around 1/3 of drivers encountered a language problem that delayed the good reception process, mainly from Poland, Eastern Germany, etc. This estimated number has been agreed by the transport manager in Plant A.

One interviewee from Plant A logistics process management stated that goods reception without any deviations (e.g., goods damage, wrong delivery, etc.) and communication barriers usually takes 8-15 minutes per truck, while in the scenario that truck driver has a language barrier but no other deviation it takes 15-25 minutes per truck. Goods reception with some deviations but not communication issues between the driver and operators take 10-25 minutes per truck, and with both deviations and a language barrier, it takes 20-45 minutes per truck.

Referring to Volvo Standard Operating Procedures, the logistics companies must equip all drivers with a means of communication (i.e., mobile phone), in order to communicate with the office in case the driver is unable to communicate in English.

4.3.2 Incorrect Documentation

Incorrect documentation is another daily issue in personnel contact quality. Generally, the consignor hands over transport documents to the truck driver during pick-up. The required documentation is listed in Table 29. These transport documents are put in separate envelopes for each individual consignee, with the suffix clearly marked on the envelope. The truck driver

is responsible for checking these transport documents, keeping and delivering them to the consignee with shipments.

Mandatory documentation	Other Documentation	
 For DDT, the Proof of Collection 	Packaging Material Receipt	
Document (POC)	Letter of Credit	
 For OCT, the Loading List 	 Invoice(s) 	
 Legal freight document pernominated 	Customs documents	
Congaree	Dangerous goods documentation	
Dispatch notes	Other documents required by Consignee	

 Table 4-9. Required transport documents

One interviewee from the material controller in Plant B mentioned, in the case of LTL and MLK services, since there are different cargo owners' shipments in the same trailer, the careless handling can frequently cause missing and wrong documentation. The processing time of the inaccurate documents may increase the waiting time of other trucks in the queue. On the other hand, the supplier manager mentioned that it would be difficult to distinguish the fault of incorrect documentation between the consignor and the driver unless the envelope was damaged or lost.

4.3.3 Overview of the survey results of drivers' language barrier

In total, the survey was sent out to 30 participants from 24 logistics companies. However, only 5 participants responded. All respondents stated the drivers from their company should speak at least entry level English and/or domestic languages. According to survey results, 5 logistics companies equipped drivers with a device that has a translation function; 4 logistics companies have settled support call for drivers' language barriers, and 4 logistics companies state that the waiting time to get language support by phone should be under 15 minutes, 1 logistics company needs around 15-30 minutes to answer the support call.

4.3.4 The cost of Personnel Contact Quality in Goods Receiving

According to interviewees from Plant A, the time wasted on language barriers can vary from 2-10 minutes during the registration, and in the case of some other deviations (e.g., wrong delivery, drive to a wrong place) the time wasted on language barriers could even go up to 10-20 minutes.

Cost in Registration

The data from Plant A interviews shows that the cost per minute in goods reception is 7-8 SEK per minute, based on the average blue collar cost (450 SEK/hour). The cost of language barriers in the registration process is:

$$4_{PdR} =)_{PRd} * \acute{e} * B_{PRd} * +$$

Where,

 $)_{PRd}$ = the number of people in the registration;

 \acute{e} = if language barrier incurred when a truck arrived at the reception then \acute{e} equals 1, otherwise \acute{e} equals 0;

 B_{PRd} = time per person impacted by the language barrier in the registration process;

+ = cost of one minute's work (7.5 SEK)

For example, in Plant A, the average truck number per day is around 40, and 1/3 of truck drivers have language barriers. So in the registration process, the average number of truck drivers who has language barrier per day can be calculated as 13.

There are two people working in each registration position; the extra time wasted due to the language barrier is from 2 to 10 minutes. In that case, the cost in the registration process for one work day is shown in Figure 4-11.



Figure 4-11 Language Barrier cost in Registration

4.3.4.2 Cost in other Deviations

The language barriers could lead to some deviations in some operating processes, such as the security guidance, navigation to unloading docks, etc. According to the interview from Plant A, the average time cost in these deviations is 20 minutes. The cost formula in the deviations can be expressed as.

$$4_{eR\ddot{a}} =)_{eR\ddot{a}} * \acute{e} * B_{eR\ddot{a}} * +$$

 $)_{\dot{e}R\ddot{a}}$ = the number of people involved in the deviations;

 \acute{e} = if language barrier incurred when a truck arrived at the reception then \acute{e} equals 1, otherwise \acute{e} equals 0;

 B_{eRa} = time per person impacted by the language barrier in these deviations;

+ = cost of one minute's work= 7.5 SEK

Since the number of workers involved in these deviations is uncertain, the cost in other deviations per day is shown in Figure 4-12.



Figure 4-12 Language Barrier cost in other deviations

The above data and calculations are based on interviewees' working experience without statistical records. Therefore, the reliability of the data needs to be checked and traced in the future.

The cost of wasting time on incorrect documentation also mainly occurs in registration. The registrar needs to remark the documents' error in the system, and confirm the information of documents and cargos with suppliers. Because of missing statistical data of incorrect documentation, it is difficult to estimate this part of the cost.

4.4 CO₂ Emission Evaluation

This section explains the emissions accounting methods that are used by VGLS, highlighting the need for methodological improvements as well as better data coverage and quality. All the information was collected from the company documentations and interviews.

The Volvo Group commitment with WWF Climate Savers is to reduce CO₂ emissions by 20% by 2020. VGLS is entirely responsible for handling all transport for the Volvo Group. The commitment related to CO₂ emission reduction for transportation and logistics services for Volvo Group freight and transportation, inbound and outbound, is set to a reduction of 20% by 2020, compared to 2013 level. Currently, VLGS intends to decrease CO₂ emission in the following six ways:

- 1. Reduce the frequency of transport
- 2. Choose lower emission transport modes where possible
- 3. Optimize logistics route planning
- 4. Improve fill rate and synergies in co-loading in different transportation set-ups
- 5. Increase the load capacity by choosing larger means of transport where it is possible
- 6. Encourage the usage of lower emission fuels (e.g., biogas for trucks, electricity for trains, LNG for short sea transports) and a fuel-efficient driving behaviour

In order to see the environmental effects of transportation, VGLS collected the following data

to calculate the CO_2 emission: distance traveled by each vehicle, CO_2 emissions factor (g/ton·km) corresponding to each transport mode and region, the gross weight of the goods transported. Then calculate the CO_2 emission in each transport activity based on the function:

*Total Emission = Distance * Weight of goods transported * Emission factor*

Considering there are a lot of multimodal transport between different countries, it is necessary to break down the transport service into individual transport legs. For example, a shipment that is collected from a supplier by a truck, then shipped by a container ship to another continent, and finally delivered by a truck to the vehicle assembly plant. In this case, the multimodal transport can be divided into 3 transport legs. The minimum information needed to define a leg would be the start and finish points, the mode of transport and the description and weight of the goods carried.

In sourcing projects stage 3 (Gate 3), analysists in LP collect CO₂ emission factors from each bidding company, calculate CO₂ emissions in each scenario, and compare the recommended scenario with the current scenario. One interviewee from LP argued that VGLS ignored the difference between different logistics companies by using the global average rather than carrier specific emission factors to calculate the total CO₂ emissions. It was suggested that VGLS should choose carrier specific level emission factors in order to get a more accurate result. On the other hand, purchasing greener logistics service supplier where possible should be considered as one of the methods to achieve VGLS CO₂ reduction goal.

Process	Gross weight of goods	Type of data for distance	Given transport mode decides which emission factor to use	Distances	
Transport Material Manufacturing	Gross weight in kilograms for each transport	 For each Start and stop address of each transport order Goods gross weight in kg Main transport mode used 	Road (country default value or carrier specific) Container sea transport (VGLS)	 Distance data bases used calculating from start to end address (zipcode or city). Air: Minimum 1-5 airports per country Sea: 1 port per country Road: zipcodes or cities All air and sea transports also contain a road leg 1 and 3. 	
Transport Material IB CDC			 global average) Air (global default) Rail (Green cargo) 		
Transport packaging			Road (country default value or carrier specific) Container sea transport (VGLS		
Distribute Products			 average) Road (country default value or carrier specific) Ro-Ro sea transport (VGLS average) 		
Refill Parts			- Road (country default value or carrier specific)		
Distribute Parts			 Container sea transport (VGLS average) Air (global default) 		

Table 4-10. Calculation model - Data needed per transport (Volvo, 2016)

4.4.1 Main Flows for Ro-Ro Shipments

According to the interview from LP and the internal document, the Ro-Ro shipments are mainly transported in the deep sea. Different loading and unloading ports for the Ro-Ro shipment are shown in the following.

• Shipment from EMEA:

Wallhamn (Sweden) to Pyongtaek (Korea) Wallhamn (Sweden) to Shanghai (China)

• Shipment from APAC:

Masan (Korea) to Antwerp (Belgium) Masan (Korea) to Savannah (US)

- Shipment from the US: Baltimore(US) to Callao(Peru)
- Shipment from Britain: Paranaque(Britain) to Cartagena (Colombia)

4.4.2 CO₂ Evaluation Based on the Performance of the Main Engine

In this case, a 5000 CEU (Car Equivalent Unit) Pure car and truck carrier (PCTC) is selected as an example. For this PCTC, the capability of carrying Ro-Ro shipment is 40500 m², or it can carry 5000 standard cars. The standard speed of this vessel is 20kn. The power of the main engine is 14520KW in standard speed. The engine efficiency (*bsfc*) is 170g/Kwh at 20kn, in this case, the engine efficiency is defined as a constant.

4.4.3 Define the Distance and Time at Port

In this calculation, the travelled distance information comes from the AIS database. The transport route is from Baltimore (the US) to Callao (Peru), the distance is 3317.34 mi or 6134.71 km. Since the study only concerns the performance of the vessel's CO₂ estimation at

sea, the time at the port should be excluded. The time at the port can be provided by the carrier. In this case, the time at the port is 8 days 3 hours, or 195 hours.

4.4.4 Fuel consumption calculation

According to the equation 3-10, the power of the main engine is proportional to the third power of the speed.

$$o \sim "^r G$$
 $o = o "^r$

Where, P is the power of the main engine, v is the speed and k is a constant. In this calculation, the power of the main engine is 14520 kw at 20 kn. Therefore, the constant k can be calculated as 1.82.

According to the equation 3-9, the fuel consumption can be expressed as.

$$A4 = \delta''_{eN^*}]VY + *Z$$

Equation 4-2

Where k is the constant which equals 1.82, v_{op} is the operating speed,]VY+ is the engine efficiency, which is 170g/Kwh in this calculation, D is the distance travelled.

In Figure 4-13, it clearly shows that the operating speed has an obvious effect on the fuel consumption at sea.



Figure 4-13 Fuel Consumption at Different Speed

4.4.5 CO₂ Emission Calculation

According to the equation 4-3, the EEOI of the main engine, which expresses the unity of the CO2 emission per tonne/ TEU/ m2 mile for the main engine, can be calculated as.

$$\hat{-Rnd.nR} = \frac{A4 * 4A}{E_{QOPde} * Z}$$

Where, *FC* is the fuel consumption, *CF* is fuel mass to CO_2 mass conversion factor, M_{cargo} is the ship's capability and *D* is the travelled distance.

In this calculation the fuel is HFO and the conversion factor CF is 3.1144, the ship capacity 40500 m², the travelled distance is 3317.34 mile.

The CO₂ emission due to the certain cargo owner's goods is decided by the amount of the cargo and the fill rate (α) of the vessel.

In this example, if the carrier is fully loaded. The mass of CO₂ emission can be calculated as.

$$E_{Qe} = * * ^{A}_{Rnd.nR} * Z$$

Where, m is a number of the specific cargo owner's goods, which occupy the whole capability of the vessel; $EEOI_{engine}$ is the Energy Efficiency Operational Indicator of the engine, D is the travelled distance, which is 3317.34 mile.

The total amount of CO_2 emission is shown in Figure 4-14, which presents that the CO_2 emissions vary due to the change of average operating speed of the carrier.



Figure 4-14 the relationship between CO₂ emission and average speed

If the carried goods for the certain cargo owner (e.g., Volvo Group) is part of the whole ship's capability, fill rate should be considered in the CO_2 calculation.

For example, assuming the carried goods for the specific cargo owner occupy 40% of the ship's capability; the fill rate, α , is in the range of 60% - 100%.

The mass of CO₂ emission for the specific cargo owner can be calculated as follows.

$$E_{Qe} = \frac{ \underbrace{* * ^{\ }}_{- Rn.d.n} * Z}{\ddot{o}}$$

Where, m is a number of the specific cargo owner's goods, which occupy 40% of whole capability (40500 m²) of the vessel; *EEOI*_{engine} is the EEOI of the engine, which equals 4.13 g CO_2/m^2 mile in this scenario; *D* is the travelled distance, which is 3317.34 mile; α is the fill rate.

The total emission of the CO₂ is shown in Figure 4-15.



Figure 4-15 CO₂ emission at Different Utilization Rate of the Carried Capacity

5 Discussion

This Chapter discusses the limitations and results of this study, from both method and data analysis perspective. Furthermore, some recommendations for LP and case plants are presented.

5.1 Alternative Logistics Solution

Limitation

In this study, the parcel service is selected as a potential alternative logistics solution for delivering light weight inbound parts. Since the delivery deviation and lead time of the international parcel service vary depending on the origin area of the transportation, one domestic parcel service provider in Sweden is selected in this thesis. In this research, all transport flows are from the domestic material suppliers to the consignee (the Plant A). For the delivered goods, this thesis focuses on the transportation of small amounts of light weight parts. In other words, the parts are suitable to be filled in the EMB 100 box and have a high potential to be delivered as one THU in the LTL service.

Key Findings

According to the statistics in 2016 from the case plant, 6.2% of arrived trucks only carried one THU in the LTL service, when shipping only one K1 pallet fully loaded with EMB100 via LTL, the freight rate will be charged as the minimum charge. For the parcel service, the freight of a shipment, which contains several EMB 100 boxes, depends on the total weight of these boxes.

The most obvious finding to emerge from the analysis is that the parcel service has the advantage in the freight expense and the total cost saving between parcel service and LTL service would be different due to the uncertainty of the average number of delivered packages (loaded EMB 100). Since the average number of EMB 100 per delivery varies from 1 to 30, the parcel service can save 78% to 32% of the freight cost in LTL services. The trend of saving goes up through the decrease of the average delivery packages per time.

Practice Implications

The findings in this research indicate that the parcel service has advantages in freight rate when delivering smaller amounts of light weight goods compared with the LTL service. The comparative advantage of parcel service can help the case plant to reduce the transport cost and avoid unnecessary transport cost on packages. Furthermore, the practice implication, related to the first research question, for the LP is that it can increase the understanding of the settlement of the freight rate in different logistics services and help to understand the needs of the service user better.

However, some limitation of the parcel service should be considered. First of all, different logistics services would impact the operating process of the plant in different ways. For example, in the warehouse of the case plant, the EMB 100 boxes are kept in the K1 pallet. If the packages delivered by parcel service without the wood pallet replace part of LTL service, the sorting and distributing activities would be changed for the new service. Secondly, the
service deviations of the two services should be considered. For the parcel service, the risk of delivery safety, like damage rate, and cargo lost is not clear. Along with this, the cost of recycling and transporting the pallet is not considered in this thesis. For the LTL service, this is an overhead cost in the total cost of the logistics expenses.

Future Works

For the future works, since the number of average packages per time has an essential impact on the freight cost, the relative data should be recorded, and the further research should investigate more plants of Volvo Group. For the global sourcing projects, freight rates from the international areas and services performance which includes lead time should be considered in the further studies.

5.2 Time Slot Delivery

Limitation

It is essential to point out that the evaluation of waiting time cost is based on the waiting time cost calculation model, which can be seen as approximations to the real condition. The data related to unloading speeds used in waiting time calculations are based on empirical data which was stated by interviewees. Plant B's truck arrival data is manually recorded by workers; some information is blank or missing. Therefore, the results of waiting time costs should be considered just analytical approximations to the actual waiting time costs. In addition, all unloading speeds were defined with the fixed value for the case plants (i.e., the unloading speed of Plant A is different to Plant B), which is regardless of the type of packaging material, the break time, and other possible impact factors. Thus, the results in the waiting time cost calculation model are likely to be either over- or underestimated.

Moreover, the calculation model cannot distinguish whether the truck comes from Sweden or foreign countries, while the surcharge of waiting time for domestic road service and International road service is different, the result cannot be separated into the domestic and International rate.

It is Volvo Logistics Service who pay the waiting time surcharges for case plants. Since these surcharges cannot be assigned to the owned party (i.e., consignors or consignees), there is no collected data in the organization of the actual waiting time costs. Therefore, the calculation model cannot be calibrated by comparing the differences between the estimated results and actual data.

Besides, the sample size of the evaluation of non-coordinated time slot deliveries is only 3 weeks (15 working days) in February 2017; trucks arriving between 24:00 to 6:00 or during the weekends are excluded in this study.

Key Findings

The uncoordinated delivery time slot will cause the unevenness of trucks' daily arrival, which could lead to the waste of unloading capacity, and increase the possibility of waiting time cost and workers' overtime pay occurring. Two case plants' truck arrival distributions have been indicated in Figure 9 and 10. The waiting time costs have been calculated via the calculation model. For Plant A, Monday is the peak time during the week, and 100% of Mondays in February 2017 incur waiting time costs. Underused capacity on other four weekdays is relatively average. For Plant B, Tuesday is the busiest day for goods receiving, and all Tuesdays in February have waiting time costs. Theoretically, Plant B has a high possibility to have waiting time cost around $130P_{eu}$ -P_{se}. Monday is the second busiest day in a week, as the calculation results showed, on 50% of Mondays waiting time costs occurred. On other three weekdays, Friday is the less busy day, Wednesday and Thursday also have a certain underused unloading capacity.

Through the data analysis of Plant B's trucks arrival distributions and waiting time costs. It is apparent that a fixed time slot delivery setting can prevent trucks from arriving at the same time of the same day, thereby reducing the frequency and amount of waiting time costs. At the same time, it is also advantageous for the plant to plan the unloading activities and to arrange the workload (i.e., the number of workers can be reduced for some time). However, there is also some limitations of the fixed time slot delivery. First, the accuracy and reliability of trucks arriving time are out of warranty, which means the performance of arrival within the commitment time slots are all dependent on the carriers' initiatives. Second, the fixed time slot cannot precisely plan the number of arriving trucks on each hour; it can only more or less balance the flow of arriving trucks. Therefore, the waiting time costs cannot be prevented entirely by scheduling fixed time slot deliveries, especially for those days the unloading volume is over unloading capacity.

On the other hand, except the free charged fixed time slot delivery, a specified time slot delivery with a surcharge was also mentioned. Although a specified time slot delivery can be accurate to one hour level, and achieve over 95% delivery precision, the total cost of setting specified time slot deliveries is far more expensive than the total cost of waiting time surcharges. Furthermore, if the number of arriving trucks was far beyond the plants' unloading capacity, even the specified time slot delivery cannot prevent the waiting time costs.

Practical Implications

There are two main practical contributions related to time slot delivery. Firstly, the Calculation Tables of Queueing System and VBA functions used for the case plant may be applied to other Volvo plants elsewhere. By using this calculation model, an estimate of waiting time and unloading dock utilization can be modelled, and the cost of trucks waiting time can be projected. Moreover, the analysis of the time slot delivery and waiting time cost enhance our understanding of the efficiency of setting a schedule of arriving trucks.

Future Works

For LP, when knowing the costs of waiting time, the purchasers can ask the carriers for whether they can offer a fixed time slot delivery as a good will, especially for those plants which have such requirements. This is done because it can save waiting time costs, and contribute to utilizing unloading capacity for plants. While for the specified time slot delivery with surcharges, from a total cost perspective, it is unnecessary to be considered in future sourcing projects, unless in some particular situations.

For the plant with the congestion issue for arriving trucks, setting the time slot can balance the waiting time costs when unloading volume is less than unloading capacity. Balancing arriving trucks on the daily level (i.e. adjusting some unloading volume from Monday to Wednesday), and within one day, starting at 6:30 am seems to be a good solution based on data from Plant A. Besides, increasing unloading capacity by adding unloading docks, and improving the operating efficiency are also potential solutions.

Apart from that, since the data from Plant B is hand writing recorded, some data (i.e. arrival time) are missing or unclear, and it can cause errors in the data analysis. For VGLS, the optimization of logistics digitalization should be considered in the future works, as it starts to gain attention in the global supply chain logistics. The first stage of the digitalization is to transform the traditional information management into digitized information management. In traditional information management, the information is recorded from the paperwork to the computer manually. With the support of the digitalization, a variety of the internal management data can be collected automatically by technologies, such as bar code technology, automatic identification technology, cloud technology and other application.

These data can be used as a reliable basis for the business decision-making and improve the performance of the enterprise management.

5.3 Personnel Contact Quality

Limitation

The reason for deriving a cost calculation for personnel contact quality in goods receiving process was to understand the costs that arise upon truck drivers' improper behaviours. Carriers' personnel contact quality can be monitored and reported by the organization. The reliability of cost calculation is limited by the following points. Firstly, all statistics of time spending language barrier are based on interviewees' feedback, empirical findings from case plants, which lack statistical records. Secondly, the frequency of language barriers with deviation is difficult to estimate. Besides, another limitation of this research is the low response rate of carriers surveyed. Only five logistics companies answered the questionnaire; the non-response bias can affect how well data represents carriers' service level.

Key Findings

As the research result indicated, the time wasted on language barriers can vary from half an hour to two hours per day during the entire goods receiving process. The variation of related costs substantially depends on how many workers have been impacted by the language barriers, and whether other trucks are impacted (i.e., extend the waiting time in the queue). In the case that two workers in registration were impacted by truck drivers' language barriers, the cost of personnel contact quality varied from 375 to 2700 SEK per work day.

As survey results presented, all of 5 logistics companies who replied to the survey stated that their drivers should speak at least entry level English and/or domestic language. Meanwhile, according to LP purchasers' feedback, a lot of logistics companies claimed they hired drivers who speak English, and if language barriers arose, the plant should report the service issue to supplier management, then the supplier manager will contact logistics companies to improve it. However, according to the interview with supplier management, since there is no item in SOP states that drivers should have English and/or domestic language skills, it is hard to require carriers to solve this issue.

The study also finds that in supplier management's evaluation, that Carrier N's performance was bad according to their monthly delivery precision. However, as the feedback from the interviewee who works in registration, Carrier N's performance was one of the best, because their drivers behaved professionally. They are familiar with the goods receiving process and transport documents, speak English and comply with the safety rules of the plant. The reason of this mismatch is because the different department has different acceptance criteria's when evaluating carriers' performance. For supplier management, delivery precision is one of the most important indicators, both early and late of the commitment delivery day are not acceptable. However, trucks drivers' behaviours are not included in the evaluation. While for workers who work in cargo handling department, the delivery precision does not impact their daily work, but truck drivers' behaviours do.

Practical Implications

The findings from this study contribute to capitalizing personnel contact quality in goods reception. The inner customers' needs of personnel contact quality have been conveyed to VGLS. The study result is relevant to material handling, contract-makers, and supplier management.

Future Works

There is no doubt that the delivery precision should be one of the key performance indicators of carriers' service performance. However, as the results showed, truck drivers' improper behaviours should not be ignored by VGLS, because it does impact plants goods reception efficiency and incurs costs every day. Logistics companies have the responsibility to train drivers to be familiar with plants' unloading process, follow plants' security rules, and use translation devices when they have language barriers. It is essential to write down the requirement of truck drivers' behaviour into SOP so that supplier management can ask carriers to attach importance to these service issues and improve personnel contact quality.

5.4 CO₂ Emission Evaluation for Ro-Ro and LCL Shipments

Limitation

The emission factors for the road transportation and FCL shipment in the sea segment have been developed, however, the emission factors for the Ro-Ro shipment and LCL shipment are not implemented. In this research, a reasonable method is expected to be developed for evaluating the CO₂ emissions in the transportation of Ro-Ro shipments and LCL shipments. However, for the Ro-Ro shipments, some data for the evaluation model is needed to be disclosed from the carrier. Although credible data can be obtained from the carrier theoretically, there is no corresponding contractual provision or SOP which is agreed by the carrier. Since the transportation of LCL shipments is purchased from forwarding companies, who are not run by shipping lines by themselves. The VGLS cannot achieve vessels' information directly. Therefore, the CO₂emission factor based on the average level of shipping lanes is suggested to be applied in the emission evaluation.

Key Findings

According to the internal document from Volvo Group, Volvo Group aims at reducing 20% of CO₂ emissions by 2020 compared with the emission level in 2012. Transportation is an important source of CO₂ emissions. Therefore, it is necessary to master the CO₂ emission from the transportation service in Volvo. Through comparing the environmental performance of the propulsion system in the CO₂ evaluation model, the power of the main engine is affected heavily by the operation speed at sea, and the performance of the main engine has a direct impact on the emissions of the propulsion system. According to the example calculation in the analysis part, the fuel consumption is proportional to the squared value of the speed. For a certain carrier, the slow steaming at sea can save a large amount of bunker, which indicates a slow speed service can reduce the CO₂ emission. As the same time, the utilization of ship's capacity also impacts the CO₂ emission due to the carried cargo; the result has been shown in Figure 4-14. The high utilization of the ship capacity is more environmentally-friendly than the low utilization situation.

Practical Implications

The fourth research question results in developing reasonable CO_2 evaluation models for Ro-Ro shipment and LCL shipment. This work could complement the existing CO_2 evolution model for Volvo. This study of the CO_2 emission due to the propulsion system can help LP to understand which parameter can impact the CO_2 emission most effectively, and require the carrier to accept a green transport way through the contractual way, for example, require a maximum speed in the rule of contract.

Future Works

For the recent model, LP needs to collect much data from the carrier in the sourcing process. It is not easy to have direct information about the carrier's history performance at current status. However, The EU MRV (Monitoring, Reporting, and Verification) regulation can change the status quo. The EU MRV, which came into effect on 1 July 2015, requires operators and the ship owners to monitor, report and verify the CO₂ emission information of vessels. These vessels are defined as the displacement of the vessel is more than 5000 gross tonnage (GT) and voyage can pass through any ports in EU and EFTA (including Norway and Iceland) (DNV-GL, 2017). According to the (DNV-GL, 2017), the verified CO₂ emission data, with additional

data, are required to send to a central database managed by the European Maritime Safety Agency (EMSA) and this emission information is planned to be published on 30 June 2019 from European Commission. In addition, the information will be updated yearly. This is important for Volvo's future works, it is necessary to focus on the process and learn how to obtain valid information from EU-MRV (DNV-GL, 2017).

6 Conclusion

This chapter reviews the purpose of this thesis, summaries and highlights the most important findings to the research questions, and presents the recommended future research.

The purpose of this thesis is to investigate the contributions that LP can make to reduce the total cost for the Volvo Group. To fulfil this purpose, firstly, the study has compared the cost differences between LTL service and parcel service of light-weight shipments in the inbound flow. Secondly, the study also has developed a calculation tool for the waiting time cost, and analysed the interrelations between the time slot delivery and waiting time. Thirdly, the cost of personnel contact quality in goods reception has been estimated and discussed. Finally, a CO_2 evaluation model has been developed, which aims at estimating the CO_2 emission of the sea transportation.

6.1 Answers to ResearchQuestions

RQ 1: Should LP purchase Parcel Service as a standard service for light-weight shipments?

According to the results in Section 4.1. LP should purchase parcel service for light weight shipment in the perspective of freight cost. In the research process, the light weight shipment is defined as the small amount of delivered EMB 100 carton boxes filled with parts. The "small amount" means the delivered number of packages can only be put into one K1 pallet.

The research results indicate that by delivering loaded EMB 100, that parcel service can save 30% to 80% freight cost comparing the existing LTL service on delivering light weight shipment. If the average delivered number of EMB 100 is less, the parcel service has more advantages.

RQ 2-1: What is the cost of uncoordinated delivery time slot, and should LP consider the time slot delivery as one of service performance in the future inbound sourcing projects?

As mentioned in Section 5.2, the cost of uncoordinated delivery time slot caused the unevenness of trucks' daily arrival, which leads to the waste of unloading capacity, and increase the possibility of waiting time cost and workers' overtime pay occurring.

To answer this question, the process of goods receiving was presented in Figure 7. The overview of goods reception makes a distinction between the internal logistics and the external logistics. It contains the time and manpower required for each activity in goods reception, which are essential factors to measure the cost of waiting time and language barriers. An Excel sheet and two Excel VBA functions have been created to compute the number of waiting trucks, the length of waiting time, and the waiting time cost per day.

Based on the analysed results, the authors think that the specified time slot delivery with surcharge should not be considered as one of the services in the future inbound sourcing projects. However, it is necessary for LP to understand whether the carrier is able to offer a general time slot delivery to plants as a good will. To answer this question, a survey has been

conducted from logistics companies, and the cost of specified time slot delivery and waiting time cost has been compared, which shows that the total cost of setting specified time slot deliveries is far more expensive than the total cost of waiting time surcharges. The interrelations between time slot delivery and waiting time cost has also been analysed in this thesis, that the specified time slot delivery cannot prevent the waiting time costs when the number of arriving trucks is far beyond the plants' unloading capacity.

RQ 3-1 What is the cost of personnel contact quality in goods reception, and what LP can do to enforce carriers to improve personnel contact quality?

The cost of personnel contact quality in goods reception can be expressed as the cost of time wasted on truck drivers' improper behaviours, such as language barriers, losing documents, and not following security rules. As Figure 13 illustrated, the daily cost on language barriers of a plant is over 375 SEK and increased with the number of workers impacted.

To standardize and improve logistics companies' personnel contact quality, the requirement of the truck drivers' behaviours should be written into SOP. If the carriers state that their drivers' language skills during the bidding, the commitment of the carrier needs to be written in the SOP or the contract.

RQ 4 How to evaluate CO₂ emission for sea transport carriers?

In order to improve the VGLS's existing CO_2 evaluation model on logistics transportation. CO_2 evaluation models are created for Ro-Ro shipment transportation and LCL transportation in the sea segment separately.

For Ro-Ro shipments, the method of EEOI (Energy Efficiency Operational Indicator) is referred to. According to the (Committee, 2009), the parameters for computing the EEOI are based on the records of history operations at sea (sea log). This information is not easy to be collected so far. However, the performance information for the transporting vessel is tangible; the engine class is used to calculate the CO₂ emission in Ro-Ro shipments transportation. A simulation of an example PCTC vessel is processed in Section 4.4; the result shows that the operation speed has an essential impact on the CO₂ emission of the vessel's propulsion system and a slow steaming at sea can make an obvious contribution to the emission reduction. In addition, to select the carrier with better engine performance, the LP in Volvo Group can also help to set an environmental speed in the sourcing project, for example, setting the maximum speed requirement in the contract.

For the LCL service, since the forwarding company is responsible for the connection of the direct carrier, the LP has limited control to select the logistics service provider. In the evaluation model for LCL shipments transportation, the average industry emission factor for different lanes is used. The calculation model is shown in the Section 3.3.4.

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Appendix A - Interviews

Respondents	Division	Title
Fredrik Vråmo	Logistics Purchasing	Director commodity & sourcing management
Daniel Vahlberg	Logistics Purchasing	Purchaser
Susanne Jonasson	Logistics Purchasing	Purchaser Manager
Wiklund Melina	Logistics Purchasing	Purchasing Analyst
Gutierrez Natalie	Logistics Purchasing	Purchasing Analyst
Laestadius Joel	Logistics Purchasing	Sourcing and Commodity Buyer
Fantou Ghislain	Logistics Purchasing	Purchase Manager Outbound South Europe
Torbjörn Ingemarsson	Plant A	Transport Manager
Raymond Touma	Plant A	Logistics Process Management
Erick Flores	Supply Chain Management	Inbound Analyst
Stefan Morell	Plant B	Material Handling
Susanne Tyden	Plant B	Marterial Handling
Camilla Westerholm	Plant B	Material Controller
Pieter Naert	TNO	Transport Developer
Dzudzevic Emir	TNO	Transport Developer
Beqqali Himdi Mohamed Karim	Business Control	Invoice & Cost Controller
Halsenius Sanna	Supplier Management	Supplier Manager
Fält Patrik	Supplier Management	Supplier Manager

Appendix B – Survey Questionnaire

Logistics Service Survey

This survey is related to specific time window services and drivers' language barriers. The result will be used in our master thesis anonymously. It has only 10 questions and will take you 2-3 mins to answer, thank you for your time.

Name of company*_____

1. Does your company offer the service that you can commit to deliver shipments on a specified (pre-defined) time window in the EU market?

- **O** Yes, we offer such a standard service.
- **O** Yes, we can offer a goodwill service but that cannot be SOP (Standard Operating Procedures).
- **O** No, we don't offer such a service.
- O Not sure.

2. What kind of road transportation does the service of committing to deliver on a specified (pre-defined) time window in the EU market include? (Multiple choice)

- **O** FTL (Full truck load)
- O LTL (Less than truck load)
- O Milk run
- O Express
- O Other:_____

3. Which of the following time windows has your company settled on for a specified time delivery? (multiple choice)

- **O** 1 hours (e.g. from 9.00 am to 9.59 am)
- **O** 2 hours (e.g. from 9.00 am to 10.59 am)
- O 3-5 hours (e.g. from 9.00 am to 13.59 pm)
- O over 5 hours
- **O** We don't offer such a service.

4. Which of the following delivery precisions can the company achieve for the time window mentioned in the previous question?

- **O** over 98%
- **O** 95%-98%
- **O** 90%-95%
- O Less than 90%
- **O** There is no standard for this service.

5. Does this specified delivery time have a surcharge?

- **O** Yes, we have a standard surcharge of a specified delivery time.
- **O** Yes, the surcharge is settled case by case.
- **O** No, this is a goodwill service, so there is no surcharge.
- O Not sure.

6. What is the standard surcharge of a specified delivery time?

Your answer: _____

7. Which of the following are in your opinion challenges related to providing specified commitment time by your company? (Multiple choice)

- **O** Route planning
- **O** cannot provide a reliable service
- **O** It is difficult to estimate the delivery time.
- **O** It is difficult to deliver shipments in a specified time for long distance transportation.
- O Other:

8. Does the company have a language skill requirement for their drivers (courier)? (Multiple choice)

- **O** Yes, drivers should speak at least entry level English and/or domestic language.
- **O** No, there is no language skill requirement for the driver or courier so far.

9. When drivers meet language barriers during their work (e.g., pick up or delivery activity), which of the following solutions are in the company SOP? (Multiple choice)

- **O** The driver can call customer service or other-specific contact persons for translation support.
- **O** The company provides a device with translation function (e.g. smartphone)
- **O** There is no SOP for this problem.
- O Other:_____

10. How long does the driver have to wait (in average) to get language support by phone from your company?

- O Under 15 mins
- O 15-30 mins
- O above 30 mins
- O Not sure

Appendix C – Code of VBA Function

Rem This function is written by feiran Rem This function is used to estimate the waiting cost of trucks with in one month

Function truckWaitingCostEstimatorMonth(ByVal arriveTimes As Range, ByVal packageNum As Range) As String

a = MsgBox("Truch Waiting Cost Simulater Version 4")

```
'get input parameter from
                                  user
    Dim numSlot As Integer
    Dim processTimePerPackage As Double
    Dim prepareTime As Integer
    Dim halfHourCost As Integer
    numSlot = InputBox("Number of unloading position: ", "Enter a Number")
    processTimePerPackage = InputBox("Operating time per THU: ", "Enter a Number")
prepareTime = InputBox("Operating time per truck ", "Enter a Number")
    halfHourCost = InputBox("cost of waiting time (every 30 mins after 2 hours): ",
"Enter a Number")
    'data arrays and necessary parameters
    Dim total Number As Integer
    total Number = arriveTimes. Rows. Count
    Dim aTimes() As Integer
    Dim pNum() As Double
    Dim numberOfDay As Integer
    ReDim aTimes(totalNumber - 1), pNum(totalNumber - 1)
For i = 0 To totalNumber - 1
         aTimes(i) = arriveTimes. Parent. Cells(arriveTimes. row + i, arriveTimes. column)
         pNum(i) = packageNum.Parent.Cells(packageNum.row + i, packageNum.column)
    Next
    Dim finalResult As String
    finalResult = "Results:
    'start to process data for each day
    Dim currentIndex, lastIndex As Integer
    currentIndex = 0
    lastIndex = 0
    number0fDay = 1
    Do While currentIndex < totalNumber
         currentIndex = currentIndex + 1
         Do While currentIndex < totalNumber - 1 And aTimes(currentIndex) >=
aTimes(currentIndex - 1)
            currentIndex = currentIndex + 1
         Loop
         If currentIndex = totalNumber - 1 Then
              currentIndex = currentIndex + 1
         End If
         'prepare data for one day
         Dim number0fTruck As Integer
         Dim aTimesPD() As Integer
         Dim pNumPD() As Double
         numberOfTruck = currentIndex - lastIndex
ReDim aTimesPD(numberOfTruck - 1), pNumPD(numberOfTruck - 1)
         For i = lastIndex To currentIndex - 1
             aTimesPD(i - lastIndex) = aTimes(i)
             pNumPD(i - lastIndex) = pNum(i)
         Next
         MsgBox ("Number of Truck in Day: " & numberOfDay & " is: " & numberOfTruck)
         'call daily calculate function
         Dim tempR As String
```

 $\label{eq:constraint} tempR = dailyCalculator(aTimesPD, pNumPD, numSlot, processTimePerPackage, halfHourCost, prepareTime, numberOfTruck)$

```
numberOfDay = numberOfDay + 1
lastIndex = currentIndex
finalResult = finalResult & ";" & tempR
MsgBox (finalResult)
Loop
```

truckWaitingCostEstimatorMonth = finalResult

End Function

Function dailyCalculator(aTimes() As Integer, pNum() As Double, numSlot As Integer, processTimePerPackage As Double, halfHourCost As Integer, prepareTime As Integer, numberCars As Integer)

```
'get input parameter from user
Dim waitingTimes() As Double
Dim slots() As Double
'claculate exceeded capacity every hour
Dim exceedCapacities(17) As Integer
    For i = 0 To 17
    exceedCapacities(i) = 0
Next
Dim startTime As Integer
startTime = 360
Dim startTimes() As Integer
'initilize work slots, arrive and waiting times
ReDim slots(numSlot - 1)
For i = 0 To numSlot - 1
    slots(i) = 0
Next
ReDim waitingTimes(numberCars - 1), startTimes(numberCars - 1)
'start to calculate the waiting time of each truck
Dim pastTime As Integer
Dim diff As Integer
pastTime = startTime
For i = 0 To numberCars - 1
    diff = aTimes(i) - pastTime
    'MsgBox ("The Time diff is: " & diff)
    'unload truchs with giveing time
    For n = 0 To numSlot - 1
        slots(n) = slots(n) - diff
        If slots(n) < 0 Then
            slots(n) = 0
        End If
    Next
    pastTime = aTimes(i)
    'MsgBox ("The previous arrive time is: " & pastTime)
    'find smallest slot
    Dim sIndex As Integer
    sIndex = 0
    For n = 0 To numSlot - 1
        If slots(n) < slots(sIndex) Then</pre>
            sIndex = n
        End If
    Next
    'MsgBox ("The selected index is: " & sIndex)
    'add processing time to the slot and record waiting time
    waitingTimes(i) = slots(sIndex)
    startTimes(i) = pastTime + slots(sIndex)
```

```
slots(sIndex) = slots(sIndex) + pNum(i) * processTimePerPackage + prepareTime
         Dim currentSlots As String
         currentSlots = "|
         For n = 0 To numSlot - 1
              currentSlots = currentSlots & slots(n) & " | "
         Next
          'MsgBox ("Car number: " & i & " Current Slot: " & currentSlots & "waiting time:
   & waitingTimes(i))
    Next
     'prepare resutls
    Dim result(18) As Double
     'calculate the total cost
     For i = 0 To numberCars - 1
         Dim exceedTime As Double
         exceedTime = waitingTimes(i) - 120
         If exceedTime < 0 Then
              exceedTime = 0
         End If
         'MsgBox ("Car number: " & i & " The exceed waiting time is: " & exceedTime)
         Dim exceedCount As Double
         exceedCount = WorksheetFunction. Ceiling(exceedTime / 30, 1)
'MsgBox ("Car number: " & i & " The exceed count is: " & exceedCount)
result(0) = result(0) + exceedCount * halfHourCost
'MsgBox ("Car number: " & i & " The total waiting cost is: " &
truckWaitingCostEstimator)
     Next
     dailyCalculator = result(0)
    MsgBox ("The total waiting cost is: " & result(0))
    For i = 0 To 17
         Dim currentHour As Integer
         currentHour = 6 + i
          'MsgBox ("the current hour is: " & currentHour)
         For n = 0 To numberCars - 1
              Dim arriveHour, startHour As Integer
              Dim dArriveHour, dStartHour As Double
              dArriveHour = aTimes(n) / 60
              dStartHour = startTimes(n) / 60
              arriveHour = WorksheetFunction. Floor(dArriveHour, 1)
              startHour = WorksheetFunction.Floor(dStartHour, 1)
'MsgBox ("the arrive hour is: " & arriveHour & " the start hour is: " &
startHour)
              If (arriveHour <= currentHour) And (startHour > currentHour) Then
                        'MsgBox ("Car number: " & n & " arrived at hour: " & arriveHour & "
but be unloaded at hour: " & startHour)
                       exceedCapacities(i) = exceedCapacities(i) + 1
              End If
         Next
    Next
     Dim overallExceedCap As String
     overallExceedCap = "| '
    Dim averageExceedCap As Double
    averageExceedCap = 0
     For n = 0 To 17
         overallExceedCap = overallExceedCap & exceedCapacities(n) & " | "
         averageExceedCap = averageExceedCap + exceedCapacities(n)
         result(n + 1) = exceedCapacities(n)
         dailyCalculator = dailyCalculator & ", " & exceedCapacities(n)
     Next
     averageExceedCap = averageExceedCap / 18
     'dailyCalculator = dailyCalculator & ", " & averageExceedCap
     MsgBox ("Overall capacity exceed map: " & overallExceedCap)
```

```
'MsgBox ("Average exceeded capacity per hour is: " & averageExceedCap)
```

'truckWaitingCostEstimator = result

End Function