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# **A calculation framework and tools to estimate freight rate and carbon emissions for road transport**

Master's thesis in Supply Chain Management

Yinfan Hu

Daqi Liu (University of Gothenburg)

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS  
DIVISION OF SERVICE MANAGEMENT AND LOGISTICS

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Daqi Liu

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Report no. E2020:104  
Department of Technology Management and Economics  
Chalmers University of Technology  
SE-412 96 Göteborg  
Sweden  
Telephone + 46 (0)31-772 1000

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# A calculation framework and tools to estimate freight rate and carbon emissions for road transport

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Department of Technology Management and Economics  
Chalmers University of Technology

## SUMMARY

The high-quality estimation methods for the freight rate and carbon emissions of road transport are not only important to improve a company's performance but also valuable to academia. This research designed a framework embedded in a user-friendly computer tool to estimate the road freight rate and transport carbon emissions. This tool is tested by estimating freight rates for various scenarios to meet the business and operational demand of a case company, The Volvo Group. The framework is designed based on the cost breakdown theory, which comprises of two sections. The first section estimates the road freight rate, while the second section estimates the carbon emissions. Firstly, all cost elements for both sections are identified. Each cost element is then studied and the most suitable estimation method for each cost element is selected. Besides, considering the constraints and settings of Volvo, specific sets of calculation methods are designed to acquire the estimated freight rate and carbon emissions for different transport set-ups at Volvo.

In order to transform the theoretical framework into a user-friendly computer tool, two types of tools, one using Excel spreadsheets and the other using the Excel VBA are developed for the case company. The validation of the framework is conducted through the estimation of a set of scenarios at the case company. The framework could demonstrate the rate structure and the carbon emissions for the scenarios. Further, it could help the company to identify the major cost elements and prioritize efforts in achieving cost savings. The differences between the bid prices and the estimated freight rates are analyzed and interpreted from the aspects including imbalanced flow, relative power, and operation-efficiency among carriers. In the case company, the imbalanced flow and different features among carriers are proved to have more influence on the freight rate, while the relative power is not regarded as a source of gaps.

**Keywords:** cost breakdown theory, cost elements, road freight rate, transport carbon emissions, transport service purchasing, Excel VBA, estimation framework



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*Daqi Liu & Yinfan Hu*

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## **Abbreviation**

ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road

ARR: Annual Rate of Return

CDC: Central Distribution Center

DC: Distribution Center

DDS: Dedicated Delivery Service

FD: Footprint Design

FTL: Full Truck Load

GHG: Greenhouse Gas

GTO: (Volvo) Group Trucks Operations

LP: Logistics Purchasing

LSP: Logistics Service Provider

LTL: Less Than Truck Load

PL: Production Logistics

PLI: Price Level Index

POA: Period of Availability

RDC: Regional Distribution Center

SDC: Support Distribution Center

SML: Service Market Logistics

VBA: Visual Basic for Applications

Volvo: Volvo Group



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# 1 Introduction

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*The chapter begins with an introduction to the research background, which gives general knowledge of this thesis and targets the existing gaps. Then the research objective is set, followed by three research questions to be answered. After that, the scope of the thesis is determined. The last section gives an overview of the structure of the whole thesis.*

---

## 1.1 Research background

Transportation is a key activity in the supply chain which is normally the largest cost source in logistics operations, thus it is important to better manage the transportation activity (Goetschalckx, 2011). Among six transport modes (road, sea, rail, inland waterway, pipeline, air), road transport is dominant in terms of volume. In 2017, the freight transport performed by road makes up 50% of total freight volume, which is measured in ton-km, in the EU (European Commission, 2019).

Road transport accounts for around 70% of the total transportation cost and over 40% of the logistics cost, which means large saving potentials are located in road freight transport (Joo, Min, & Smith, 2017). Given the significant impact of road freight transport, it is important to operate it in a cost-efficient way which aims to achieve the expected output with the lowest possible cost (Cowie, 2009). From the shippers' perspective, the cost of road transport depends on the contract rate they negotiate with carriers. A better rate means the shipper will not be overcharged, at the same time the carriers are still profitable so that the service quality is ensured (Kovács, 2017). To achieve a mutually satisfactory rate in the purchasing process, the high-quality estimation and analysis of rate structure are important for the shippers (Joo, Min, & Smith, 2017; Shin & Pak, 2016). However, shippers normally have little knowledge of the road freight rate. In Europe, the freight rate for a certain route is contracted based on a single payment at a particular time. This pricing method increases the difficulty of shippers in identifying the fairness of the freight rate and ascertaining the root causes for the rate increases (Joo, Min, & Smith, 2017). From the carriers' perspective, the road transport industry is characterized by severe competition and rapidly growing technologies. To stay competitive in the market, the road freight carriers also need to be cost-efficient in their operations so that they can provide high-quality services to shippers at a lower rate. In this process, knowing the accurate cost information is important (Baykasoğlu & Kaplanoğlu, 2008).

Road freight transport is of great importance not only from a financial perspective but also from an environmental perspective. At the EU level, greenhouse gas emissions generated from road transport sector has consecutively increased from 2013 to 2017, and the largest part of this increase was caused by the consumption of diesel by heavy-duty truck and light-duty truck (European Environment Agency, 2019). The environmental impact brought by road freight

transport makes relevant companies pay more attention to road transport emissions. From the shippers' side, four reasons led them to pay more attention to transport sustainability: increasing brand value, avoiding misusing precious resources, reacting to government intervention, and international standards (Guiffrida, Datta, Dey, LaGuardia, & Srinivasan, 2011). Two surveys conducted in Sweden in 2003 and 2012 respectively show that the majority of shippers (70%) consider environmental impact, which is represented by CO<sub>2</sub> emissions, into consideration when purchasing transport services. Environmental related items include using trucks with a low emissions standard, implementing an Environmental Management System (Lammgård & Andersson, 2014). The transport carriers also get pressure from customers which is the primary reason for them to evaluate the environmental performance of transport operation (Rossi, Colicchia, Cozzolino, & Christopher, 2013). The raised concern on environmental impact from road transport means it is not enough to only evaluate the financial cost when providing or purchasing road freight transport services. An evaluation of environmental costs should also be included.

Even though knowing the financial cost and environmental cost of road freight transport is of great importance, firms often face challenges in estimating them. Some companies are estimating road transport rates only based on the individual experience of transport managers (Kovács, 2017). This might result from the challenges faced by companies in getting reliable and satisfactory rate figures. The road freight rate is largely affected by operating conditions, such as regional impact and policies. A rate calculation method should be flexible enough to address these dynamics (Barnes & Langworthy, 2004). The current existing benchmarking method and time-series method take a large amount of historical data to forecast current or future rates with econometric models. However, these methods can only get a total rate and cannot present the detailed cost structure to help companies identify root causes for rate change (Joo, Min, & Smith, 2017; Miller, 2019). Another method is to breakdown the total rate into profits together with other cost elements, such as fuel cost, labor cost. Some literature uses this breakdown method to estimate road freight transport cost from public sector perspective which will result in a different cost structure compared with the business perspective, thus not suitable for a company to use (Holguin-Veras, Gonzalez-Calderon, Lawrence, Brooks, & Tavasszy, 2013; Litman, 2009). From an environmental perspective, some methods and tools are existing to calculate the environmental impact of road freight transport (HOMER Energy, 2014; Network for Transport Measure, 2015; Wang, Hu, Wu, Pan, & Zhang, 2012). Some of them integrate the calculation of carbon emissions with freight rate estimation, although the details of rate estimation are limited.

To conclude, for both shippers and carriers, it is crucial to have a good understanding of total road freight rate and detailed rate structure to achieve cost-efficiency in operations. Besides, it is also important to know the environmental impact of road freight transport. However, currently there lacks the framework and tool to provide the company with detailed rate information and environmental performance of road freight transport. In this report, this gap will be addressed.



### 1.2 Objective and research questions

The objective of this thesis is to establish a framework that can estimate the road freight rate and transport carbon emissions for road shipments using the cost breakdown theory.

To fulfill the objective, three research questions should be answered:

**1) What cost elements should be included when estimating the rate and carbon emissions of road freight transport?**

In order to estimate the road freight rate and emissions of road freight transport, all the relevant elements should be identified and included in the estimation framework, such as fuel cost, driver cost.

**2) How is each cost element in the framework calculated?**

After identifying all the cost elements, the calculation method should be formed. This question contains two parts. The first part is what kinds of data are needed to calculate the cost element, and the second part is what is the calculation formula from data to the cost element.

**3) How can the freight rate estimation framework be embedded into a user-friendly application tool?**

To make the theoretical framework more applicable in testing and future implementation, a user-friendly tool should be developed so that the stakeholders that are interested in it could easily test and use this tool.

### 1.3 Research scope

To focus on the research objective and deliver the outcomes within the limited time of this thesis research, it is necessary to set the scope for this thesis.

1) This thesis only looks into road transport, while other transport modes will not be included. In the following chapter, when “ferry” or “intermodal” is mentioned, it refers to water transport or rail transport for the whole trailer. The road transport operator will give a total price to the ferry company or rail company. This research will not go further into the structure of this total price.

2) Only costs related to road transport are considered in the framework. Costs generated by other logistics activities, such as salaries for loaders at the terminal, are not included. Inventory cost is also not within the scope. This limit is set to separate transport activity from the logistics system and investigate the pure transport cost. This thesis will not investigate any other activities outside the boundary.

3) Although greenhouse gas (GHG) consists of many components, such as carbon dioxide, nitrous oxide, and methane. In this thesis, only carbon dioxide is calculated as an indicator of GHG emissions because it is the most widespread greenhouse gas (Petro & Konečný, 2017) .

4) The types of road transport services studied in this research are four road transport services at Volvo, Full-Truck-Load (FTL), Less-Than-Truck-Load (LTL), Dedicated Delivery Service (DDS), and Express, which will be further introduced in chapter 4.

### 1.4 Thesis outline

The thesis outline is introduced as below to bring the readers a concise overview of the structure of the thesis paper, as is shown in Figure 1-1:

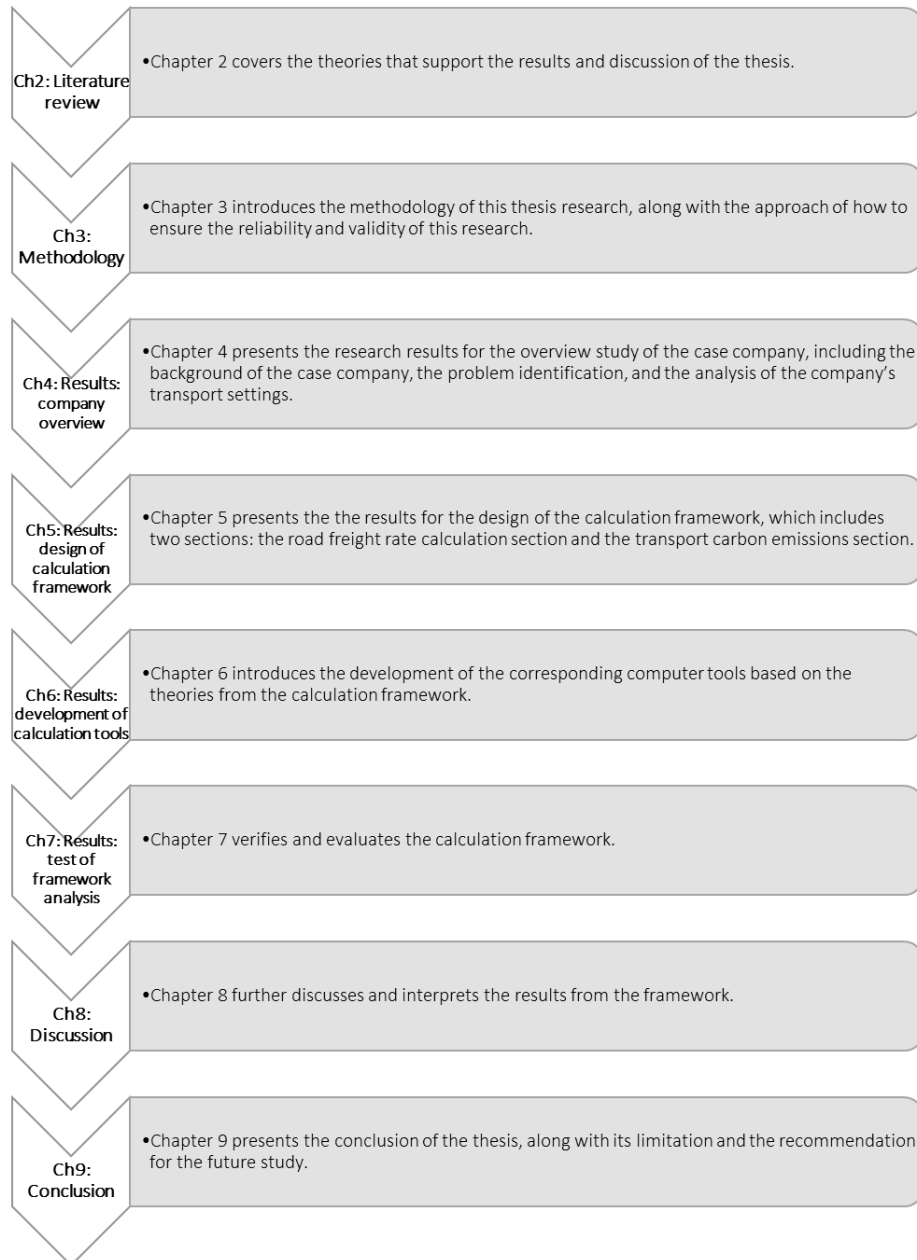


Figure 1-1 Thesis outline

## 2 Literature review

---

*This chapter covers the theories that support the results and discussion of the thesis. In the first section, the cost breakdown theory is introduced. In the second section, existing studies on the estimation of road freight costs are reviewed. In the next section, other factors that might influence the road freight rate are discussed. The second last section presents existing theories and methods of estimating carbon emissions from road transport and the last section briefly introduces VBA which is applied in this research.*

---

### 2.1 Cost breakdown theory

In order to identify the cost elements that contribute to the overall road freight rate, cost breakdown theory is applied. As one of the most common methods for analyzing the cost, cost breakdown can be implemented by developing a cost breakdown structure, which is used to break down the various elements of cost (Garrett, 2008).

Figure 2-1 shows a basic cost breakdown structure. When implementing the cost breakdown method, based on the basic theory that “price (rate) is made up by the component of cost and the component of profit”, the first breakdown process can be made which breaks the overall price or rate into two components: cost and profit. Then, following the breakdown structure, a second breakdown can be made which specifically focuses on dividing the cost component into two categories: direct cost and indirect cost. While direct cost refers to the cost that is directly associated with a specific cost item (e.g. a task, service, or material), the indirect cost cannot be directly tied to a specific cost item (Barnes & Langworthy, 2004). The cost elements that belong to direct cost or indirect cost can vary from case to case. However, some cost elements should normally be included in either one of the two categories, such as labor cost, material cost, subcontracting cost, overhead, other direct cost (ODC), and governance and administration (G&A) (Garrett, 2008). Even though reaching this third layer of the cost breakdown structure could be detailed enough from some cost breakdown cases, for some other more complex cases, a third breakdown can be made to determine the more reasonable cost elements for estimation and calculation, as is shown in the fourth layer of Figure 2-1.

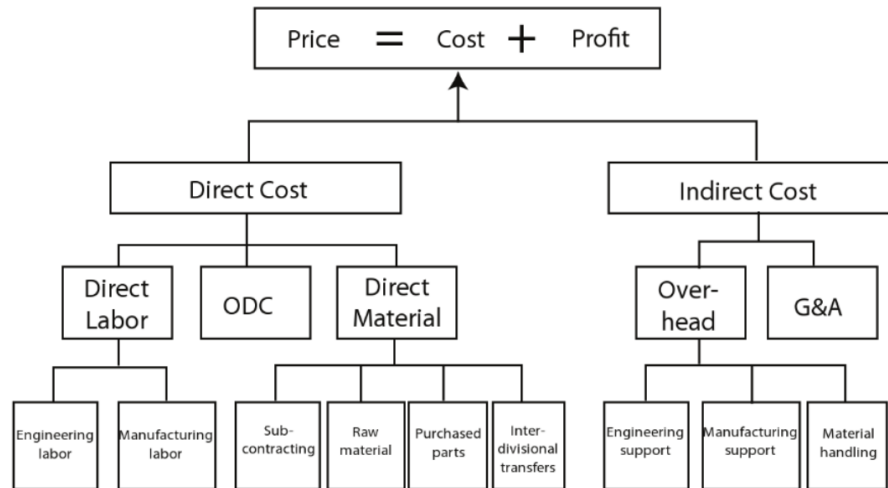


Figure 2-1 A structure of cost breakdown (Garrett, 2008)

When conducting a cost breakdown analysis, three principles should be considered to ensure the reasonableness and validity of the newly broken-down cost elements:

- Is this cost element generally recognized as necessary in conducting the business operation in this specific case?
- Is this cost element consistent with sound business practice, law, and regulation?
- Is this cost element duplicated with other cost elements, either partially or entirely, i.e. will it result in double-counting of cost?

Following those three principles, the determination should be made about whether a certain cost element is qualified for being a result of a specific cost breakdown process (Garrett, 2008).

## 2.2 Estimation of road freight cost

### 2.2.1 Cost classification

Cost elements in road freight transport have different attributes so that they can be classified in different ways. Some common types of cost elements in the literature are summarized below and will be further explained.

- 1) Fixed and variable costs
- 2) Direct and indirect costs
- 3) Internal and external costs

Classifying the costs elements into fixed costs and variable costs is the most common method in existing studies on road freight cost estimation (Holguin-Veras, Gonzalez-Calderon, Lawrence, Brooks, & Tavasszy, 2013; Berwick & Farooq, 2003; Litman, 2009; Sternad, 2019; Casavant, 1993). Variable costs are incremental costs that can go up and down according to the change in company activities or consumptions. In the context of road freight transport, variable costs are directly influenced by the vehicle mileage, such as fuel cost and tire cost. Variable costs are also called marginal costs, indicating the cost value could increase or decreased based on the amount

of output. (Holguin-Veras, Gonzalez-Calderon, Lawrence, Brooks, & Tavasszy, 2013). On the contrary, fixed costs do not change depending on the level of output and will incur during the decision period even the output is zero. Typical fixed costs are truck investment, insurance (Holguin-Veras, Gonzalez-Calderon, Lawrence, Brooks, & Tavasszy, 2013). Rastogi and Arvis (2014) and Sternad (2019) apply this classification method in the analysis of transport cost structure.

Direct costs are the costs that can be directly allocated with a specific cost item such as service, material, while indirect costs cannot be directly associated with a specific cost item (Holguin-Veras, Gonzalez-Calderon, Lawrence, Brooks, & Tavasszy, 2013). Litman (2009) explains indirect costs with indirect impacts which means there are several steps between activity and ultimate results. The cost-breakdown method proposed in Garrett (2008) divides the total cost into the direct and indirect costs.

Internal costs are the costs borne by the transport users, while external costs are the cost to society. External costs occur when the activities performed by one group influence another group and this influence is not fully considered by the first group (Ortolani, Persona, & Sgarbossa, 2011). Typical external costs caused by road transport include noise and carbon dioxide emissions (Ortolani, Persona, & Sgarbossa, 2011; Litman, 2009).

The three methods are independent and can be combined when using. For example, Jacyna and Wasiak (2015) applied a classification method with two criteria. The costs incurred in road transport are first divided into fixed costs and variable costs. Within each category, the costs are further divided based on direct and indirect costs. Litman (2009) divided cost elements into four categories: internal fixed costs, internal variable costs, external fixed costs, and external variable costs.

To summarize, all three methods are implemented in previous studies and there are no strict rules on choosing which classification method. The distinction between fixed and variable costs is more commonly used. From a business perspective, the freight rate consists of internal costs while the environmental performance consists of external costs.

### **2.2.2 Cost elements and estimation methods**

The academic studies on estimating road freight costs from a business perspective are limited. Casavant (1993) proposed the basic theory of calculating costs and applied it to trucking costs. Eleven cost elements were discussed in this article where the labor cost, cost of capital, overhead, and depreciation were clearly defined in particular. However, Casavant (1993) only stated theories of estimating cost elements without providing any practical formulas or case studies. The research of Berwick and Farooq (2003) is a further development of theories proposed by Casavant (1993). It considered the same cost elements as Casavant (1993) and applied the theories to develop the calculation methods for each of the elements. More importantly, a stand-alone truck costing model was developed using Microsoft Visual Basic for Window which can not only estimate trucking cost based on data input but also make sensitivity analysis of several parameters, such as fuel and trip distance (Berwick & Farooq, 2003). However, the calculation method and the software model were developed in the context of the US and the article didn't test

the model with an example. Barnes and Langworthy (2004) studied several variable costs (fuel cost, repair and maintenance, tires, and depreciation) in operating personal vehicles and trucks. Although the number of researched cost elements was limited, more detailed analysis and data input were given. Finally, a comparison of each cost element among three types of vehicles (automobile, van, commercial truck) was made. The commercial truck was shown to be the most expensive for each of the researched cost elements (Barnes & Langworthy, 2004). Jacyna and Wasiak (2015) considered 14 different cost elements when estimating road transport costs. The calculation formulas for vehicle depreciation, cost of capital, ecological cost was given, while the calculation theories for other cost elements were discussed. A case study was conducted that compared each cost element as well as the total cost of using four types of the truck to carry the same shipment from Mszczonów (PL) to Hamburg (DE). Kovács (2017) considered six cost elements when calculating the cost to fulfill a road transport task. The calculation model has two major differences compared with previous literature. The first is the cost incurring during waiting time at stops is considered. The second is the cost of capital is further divided into two categories based on if the operator owns the truck or leases the truck, which can make the model applicable to assist the decision-making on self-operation or outsourcing (Kovács, 2017). Sternad (2019) calculated the truck cost over one year instead of for each shipment task. The total cost was divided into 8 different elements with definitions and calculation methods. Then the cost structure was presented, and relations between average cost and vehicle mileage were analyzed.

The cost elements considered in the above literature and whether the corresponding calculation methods are given are summarized in Table 2-1.

Table 2-1 Summary of cost elements in the literature

Cost Elements	Casavant (1993)		Berwick & Farooq (2003)		Barnes & Langworthy (2004)		Jacyna & Wasiak (2015)		Kovács (2017)		Sternad (2019)	
	Inclusion	Calculation method	Inclusion	Calculation method	Inclusion	Calculation method	Inclusion	Calculation method	Inclusion	Calculation method	Inclusion	Calculation method
Cost of capital	×		×	×			×	×				
Vehicle registration fee	×		×	×							×	×
Vehicle insurance	×		×	×			×				×	×
Vehicle tax	×		×	×			×					
Vehicle garage/housing	×											
Vehicle depreciation	×		×	×	×	×	×	×			×	×
Periodical inspection							×					
Maintenance and repairs	×		×	×	×	×	×		×	×	×	×
Fuel cost	×		×	×	×	×	×	×	×	×	×	
Wear of tires	×		×	×	×	×	×	×				
Ecological fee							×	×				
Park cost									×	×		
Road toll							×	×	×	×	×	×
Driver labor salary	×		×	×			×		×	×	×	×
Driver night cost							×					
Driver diets and accommodation							×				×	×
Driver overtime							×					
Overhead	×		×	×							×	×
Cost during the waiting time									×	×		

From Table 2-1, it could be seen that fuel cost, maintenance, and repair cost are considered in all literature. Driver cost, tire cost, depreciation, cost of capital, insurance, and tax are considered in most literature. Although most literature considers driver cost, only two of them give more detailed information on how it is structured (Kovács, 2017; Snyder, 2019). Period inspection and the ecological fee are considered only by Jacyna and Wasiak (2015) and other literature considers them as part of maintenance and road toll. Overhead as an important indirect cost, is included by three articles. Cost during waiting time is only considered by one article although it is an important cost component during a road shipment.

To summarize, this section reviews current literature in comprehensively estimate road freight cost from a business perspective. The number of articles in this area is quite limited. Different articles comprise different cost elements, but none of them include all the cost elements and provide practical calculation methods for each cost element.

### 2.2.3 The cost structure of road freight transport

Sternad (2019) has analyzed 8 cost elements of road freight transport over one year in Slovenia. The result shows that fuel cost takes the largest share of the total cost, from 27% to 31% depending on the annual mileage of the vehicle. The toll cost and labor cost come after fuel cost and both of them account for around 20% of the total cost. The fourth-largest part is the indirect cost followed by depreciation cost. The least three cost elements are maintenance, insurance, and registration, all of which make up less than 5% of the total cost (Sternad, 2019). The article compared the cost structure of vehicles with four different levels of yearly mileage. The result shows there is a slight difference in the cost structure. For example, with the increase of yearly mileage, the share of fuel cost increases a bit, while the depreciation cost drops slightly.

A survey conducted by Rastogi and Arvis (2014) shows the cost structure of four Kyrgyz carriers when operating road transport in Europe. The survey comprises four cost categories, fuel costs, labor costs, capital costs, and other costs. Results show the average cost of the four carriers differs from region to region. For example, the fuel cost is the largest share in Lithuania, Poland, Hungary, the Czech Republic, Slovak Republic, Bulgaria, and Romania, accounting for more than 30% of the total cost. However, in EU 15, the labor cost is the largest cost element and in Russia, the capital cost takes the most share (Rastogi & Arvis, 2014).

Jacyna and Wasiak (2015) analyzed the cost structure of a road shipment from Mszczonów (PL) to Hamburg (DE) with four different vehicles. The fuel cost is the largest part regardless of which type of vehicle is used, accounting for around 35% of the total cost. The second and third are labor costs and road fees with a share of 27% and 14% to the overall costs respectively. The result clearly shows the influence of the vehicle on the cost structure. For example, the average fuel consumption of vehicle 4 for running 1 km is 5 liters less than vehicle 1, which results in a saving of 300 EUR in the fuel cost.

The analysis made by Maibach, Peter, and Sutter (2006) also addressed the different cost structures of different countries. In EU15, the labor cost takes the largest proportion while the



fuel cost comes to the second. However, in Eastern Europe, the fuel cost accounts for the most share, and labor costs come to the second. This finding is consistent with the result obtained by Rastogi and Arvis (2014). Besides, Maibach, Peter, and Sutter (2006) presented the operating distance also influences the cost structure of road shipment. The data from Germany shows the share of the labor cost of the truck carrying short-distance tasks is 49.6% to the total cost, while the number is 38.7% for the truck carrying long-distance tasks.

In addition to the comparison of each specific cost element, the comparison between fixed and variable costs is made in some studies. Sternad (2019) stated the variable costs make up around 60% in total costs and its share increases to 70% with the yearly mileage of the truck increasing from 96,000km to 144,000km. Cowie (2009) also stated the fixed costs in road freight transport tend to be relatively low, at around 25% of the total costs. The figure provided by Cowie (2009) also included the costs at the terminal which are not included in this thesis. Besides, the share fixed costs in LTL transport is a bit higher compared with in FTL because of the time spent on serving the depots (Cowie, 2009). In contrast, Kovács (2017) got a different conclusion. By comparing the variable costs per mile calculated by their methods with the total road freight cost per mile obtained from a routinely used external source, they concluded variable costs are 43% of the total costs.

To summarize, there is no consistent conclusion on how the cost structure of road freight transport looks like because it is impacted by factors such as regions, vehicles, shipments, yearly mileage. However, it could still be concluded that fuel cost, labor cost. Toll cost varies based on the operating countries. As for the comparison of fixed and variable costs, there is no consensus on which outweighs the other.

## **2.3 Other factors that influence freight rate**

### **2.3.1 Trade imbalance – backhaul problem**

Backhaul means to haul a shipment or empty trailer/container back from the destination to the origin (Reichert & Vachal, 2000; Fekpe, Alam, Foody, & Gopalakrishna, 2002). In reality, the backhaul doesn't need to strictly follow the loaded trip. Instead, the backhaul could be more flexible, as indicated in Figure 2-2. The backhaul problem is a common phenomenon in road freight transport because the volume of the transported goods is not balanced among locations so that the transport flow is dominant in one direction. Due to this imbalanced flow, carriers may find it is difficult to organize the flow for the return trip (Demirel, Van Ommeren, & Rietveld, 2010).

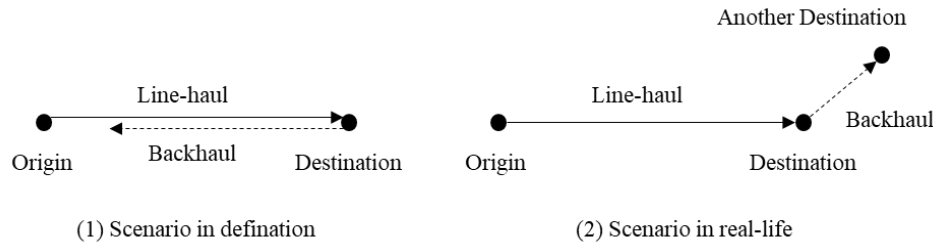


Figure 2-2 Illustration of backhaul planning

Some literature has recognized the influence of the backhaul trip on the front-haul prices. Wilson (1987) proposed that the probability of organizing backhaul flow varies across regions and markets and the front-haul prices should cover the backhaul costs. If there is a large possibility of organizing backflow, the front prices should be adjusted downward. Demirel, Van Ommeren, and Rietveld (2010) also stated positive backhaul prices should be paid to carriers as a compensation for the expected search time when organizing the backward transport flow. A researched example found the German companies normally pay for the increased transport costs between Germany and the Netherlands because Germany companies import more goods from the Netherlands (Demirel, Van Ommeren, & Rietveld, 2010). This interesting finding further supports that the imbalanced goods flow will impact the road freight rate.

Cooper, Woods, and Lee (2008) summarized four methods of accounting backhaul influence when analyzing the environmental impacts of truck transport:

- 1) Stated the backhaul is not included
- 2) Assume a backhaul factor of 30% - 60% of the energy use and emissions of the front-haul
- 3) Provide models for partially loaded or empty vehicle
- 4) Assume the backhaul is equivalent to front-haul

To summarize, the backhaul problem is common in the transport network and has a direct influence on the front-haul rates. Therefore, it should be considered, although none of the literature reviewed in section 2.2.2 has taken it into account.

### 2.3.2 Stakeholder interaction

The road freight rate is the outcome of negotiation between buyer companies and transport service providers. Purchasing negotiation is affected by three variables: time, power, and relation (Shin & Pak, 2016).

Information is the core of negotiation. Better use of information is more likely to bring a mutually beneficial agreement. The information in negotiation could be assessed from three perspectives. The first is the quality of information which is of great importance because it influences the risk level. High-quality information could reduce uncertainties and lead to a better decision. The second is the quantity of information. Adequate information will enable control over the negotiation process. The more information a party has, the more possibility it has to win the negotiation. The last is the flow of information, which indicates the symmetry of information.

There is an idea that symmetric information flow could facilitate negotiation because an equal exchange of information could satisfy both parties (Shin & Pak, 2016).

Power is interpreted as the relative dependency between parties. For example, if the supplier is more dependent on its buyer than the buyer on the supplier, the buyer has more power over the supplier. The power shows to what extent one party can influence and be influenced by the counterparty (Batt, 2003). Power is critical to the outcome negotiation because the party with more power can force the other one to make a concession even though the other tends not to concede. There are five sources of power in the negotiation process. The first one is expert power which means when a party has expertise in technical and administration that makes it difficult to replace, the party poses expert power. The second is referent power. It is decided by the attraction of one party to the other party. This attraction comes from mannerisms, friendliness, and desire to build up a relationship. The third is the legitimate power which comes from the relative position of two parties. The fourth is reward power which comes from the potential benefits such as additional resources if an agreement is reached. The last one is coercive power which in contrast comes from potential punishment (Shin & Pak, 2016).

Time is also an important constraint in negotiation. Time pressure could facilitate negotiating parties to concede to reach an agreement but is also negatively influence the quality of the outcome (Shin & Pak, 2016).

As an outcome of purchasing negotiation, road freight rates are also affected by these three factors. Therefore, it is not enough to understand the freight rate simply from the accounting perspective. The impact of business operations should also be considered.

### 2.3.3 Size of carriers

Even carry the same shipment between the same locations with the same equipment, the freight rate could also vary across different carriers depending on the size of the transport company. Casavant (1993) stated the cost per mile of road freight shipment would decrease with the increase in the firm size. The reason for this pattern includes a larger firm is more likely to buy the insurance policy or purchase truck fleets with higher discounts. Also, larger companies have more demands, meaning it is easier for them to organize transport flow in backhaul (Casavant, 1993). This phenomenon could be interpreted by the impact of economies of scale (Cowie, 2009). The long-run average cost (LRAC) at first falls with the increase of firm size which results from bulk buying, improved productivity, financial economies. However, after falling to an optimum level, the average cost will rise with the increase of firm size because of more management layers, decreasing return to scale (Cowie, 2009).

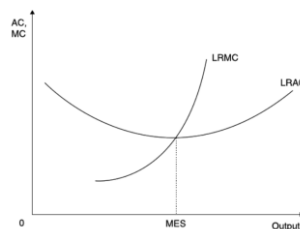


Figure 2-3 Long run average and marginal costs (Source: Cowie (2009))

As stated in section 2.3.1, the probability for backhaul transport will influence the freight rate. In the LTL industry, the average cost in the long-run declines at a diminishing speed with the increase of firm size (Giordano, 2008). Miller and Muir (2020) summarized the reasons why larger carriers can operate road transport in lower average costs in the FTL industry. The first reason is a larger carrier can better pool demand variance which means compared with small carriers, large carriers can achieve the same level of capacity availability with reserving a smaller marginal equipment capacity. The second reason is larger transport companies are more applicable to invest in information technologies and the high demands can ensure the utilization of IT/IS. The third reason is larger carriers have more ability and more likelihood to cooperate with shippers that have more volume. The last reason is carriers with large size can better achieve the economies of density by reducing the waiting time for drivers to be assigned to the next shipment (Miller & Muir, 2020).

## 2.4 Carbon emissions calculation for road transport

Many studies have been conducted regarding how to effectively calculate road transport carbon emissions. While some of them focus on the on-road section carbon emissions of the transport process, others focus on the handling operations section carbon emissions of the transport process.

A method called Methodology for calculating transportation emissions and energy consumption (MEET) is designed to calculate carbon emissions and energy consumption for road transportation. The final result produced through this method is in the metric of “the rate of carbon emissions per kilometer”. By classifying the vehicles into several categories based on their weight, the rate of emissions per kilometer is assigned to each specific category of the vehicle based on an average vehicle speed-dependent regression  $e_r(v) = K + av + bv^2 + cv^3 + dv^{-1} + ev^{-2} + fv^{-3}$ , where  $e_r(v)$  is the rate of carbon emissions for an unloaded goods vehicle on a road with zero gradients. The parameters K, and a to f are predefined coefficients whose values vary from one category of vehicle to another and have been specified according to each category. Meanwhile, for this method, there are also two other sets of coefficients that respectively work for when the road gradient effect and loading effect are taking into account. However, as this MEET method is designed in 1999, the applicability of those coefficients to be used today is uncertain; also, this method has not stressed the carbon emissions impact from different types of fuel for the vehicle (Demir, Bektas, & Laporte, 2014). Another method for calculating the road transport carbon emissions, the Ecological transport information tool (ECOTRANSIT), provides a calculation approach that has taken the upstream energy consumption portion into account, which is the energy consumed during the production of the fuel used in road transport. The calculation approach can be performed in three processes. The first process is to calculate the final energy consumption as “per net ton kilometer ( $ECF_{ton\ kilometer}$ )” by the equation  $ECF_{ton\ kilometer} = ECF_{kilometer} / (CP * CU)$ , in which  $ECF_{ton\ kilometer}$  refers to the “final energy consumption per net ton kilometer”, CP refers to the “payload capacity” and CU refers to the “capacity utilization”. The second process is to calculate the “upstream energy consumption per net ton kilometer ( $ECU_{ton\ kilometer}$ )” by the equation  $ECU_{ton\ kilometer} = ECF_{kilometer} * ECU_{EC}$ , in which  $ECU_{EC}$  refers to “the energy related

upstream energy consumption”. The last process is to calculate the total energy consumption as  $F(D, M) = D * M * (ECF_{ton\ kilometer} + ECU_{ton\ kilometer})$ , in which M refers to “the mass of freight transported (ton)”. In this method, the effect of the loading factor has been taken into consideration and integrated into the calculation process, while the effects of gradient and driving patterns are not included. This method can be a good source to calculate the carbon emissions for road transport if the upstream energy consumption carbon emissions should be included (Demir, Bektas, & Laporte, 2014). One method that has been used mainly by the business operators of transport service is the Network for Transport Measures (NTM). In this method, an assumption has been stressed that all carbon is transformed into  $CO_2$ . With this assumption the carbon content (in mass-%) is multiplied with the fuel density and the molecular weight relations,  $(\frac{12+16+16}{12} = \frac{44}{12})$  (as the molecular weight of  $CO_2 = 44$  and Carbon = 12)), the emission factor can be acquired with a unit of “kg/l”. Then using the emission factor to multiple with the fuel consumption (liter) during the trip, the figure of the carbon emissions during this specific trip can be obtained (Network for Transport Measure, 2015). This method gives the flexibility to whether the calculation should take other effective factors such as gradient and loading into account since all the impacts of those factors can be reflected by the corresponding figure of fuel consumption. There are also some other studies focusing on the warehousing and transshipment processes section carbon emissions. Rüdiger, Schön, and Dobers (2016) conducted a study aiming at defining a comprehensive carbon emissions assessment method for the logistics facilities and handling processes. After clearly determining the system boundaries and scope for the logistics facilities and the handling processes, a carbon emissions calculation theory based on the multiplied result of the measured (statistical) values on the quantities of energy and resource consumption and the emission conversion factor is established. Thereafter, the total carbon emissions result can be distributed to each handling process and logistics facility.

## 2.5 Visual Basic for Applications

Visual Basic for Applications (VBA) is an object-oriented programming language developed by Microsoft that can be integrated with all Microsoft Office applications (Mansfield, 2013). In this research, only the VBA integrated within Microsoft Excel will be focused. With the help of VBA, many tasks could be accomplished, such as creating custom command, creating complete and macro-driven functions (Walkenbach, 2013). VBA has the following advantages that make it popular:

- 1) VBA is a complete programming language, which means it can recognize all variable types, handle tasks like working with strings, managing dynamic fields, and applying a recursive function (Kofler, 2008). It is applicable to achieve the functions needed in this research.
- 2) VBA can be accessed and edited with Excel and it also has a good interaction with Excel. Currently, most data and process related to purchasing at the case company is stored in Excel. Therefore, tools developed with VBA could be integrated with the current business process more easily.

- 3) VBA is event-oriented. When using VBA, developers don't need to worry about the management of events. They only need to develop the macros and the macros will be triggered automatically when related buttons are clicked (Kofler, 2008). This feature reduces the difficulty in creating the interaction between users and tools.

### 3 Methodology

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*In this chapter, the methodology of this thesis research will be presented. In the first section, the research outline of this thesis is demonstrated. Then, following the research onion model and based on the research questions of this thesis, the research elements such as research approach, methodological choice, research strategy, time horizon, and data collection will be discussed. Besides, a comprehensive research outline along with the validity and reliability of this research will be interpreted.*

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#### 3.1 Research outline

According to the research plan and the sequence of how this thesis is conducted, the thesis research is divided into four stages and seven processes, as is shown in Figure 3-1. The first stage is the theoretical part of the thesis which is designed to answer the first and the second research question. The first process in the first stage is corresponding to the first research question, while the second process is designed for the second question. The third stage answers the third research question. The last two stages are the case study part in which the estimation framework and tools will be tested with the data from the case company, Volvo.

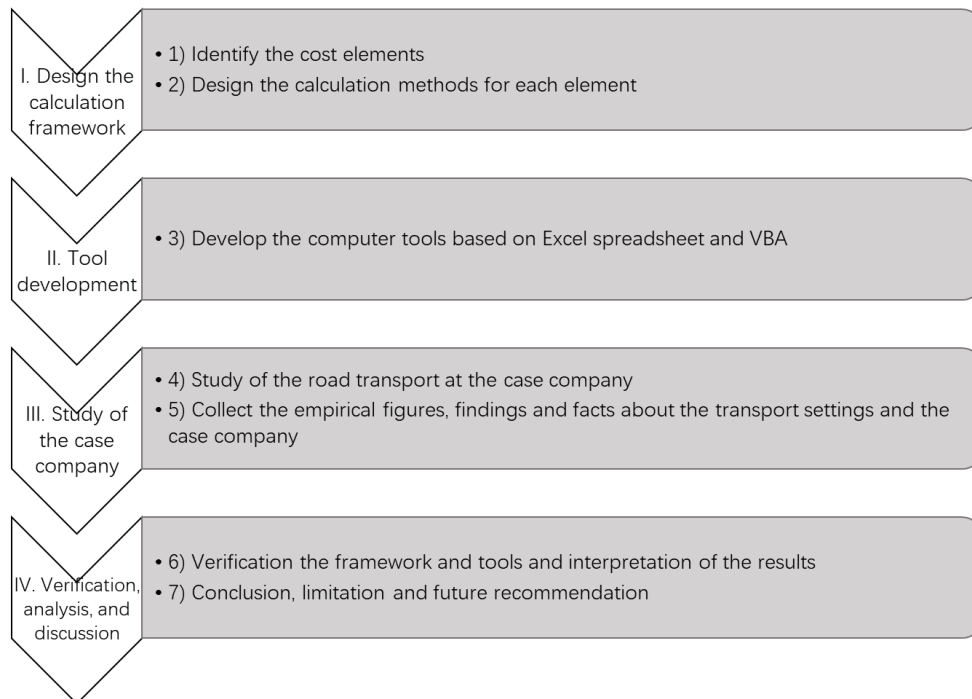


Figure 3-1 Research outline

### 3.2 The research onion model

The research onion model is a methodological model for academic research which contains five layers of different research elements: research approach, methodological choice, research strategy, time horizon, and data collection. For each layer, it stands for a stage of methodology related choice that a researcher must carefully consider and select to implement the suitable actions and secure the credibility of the research. As is shown in Figure 3-1, beginning from looking into the topmost layer of this “research onion” (the research approach), then moving to the more inside layers sequentially, the results acquired from this process would contribute to the logical and effective methodology design of research (Saunders, Lewis, & Thornhill, 2009).

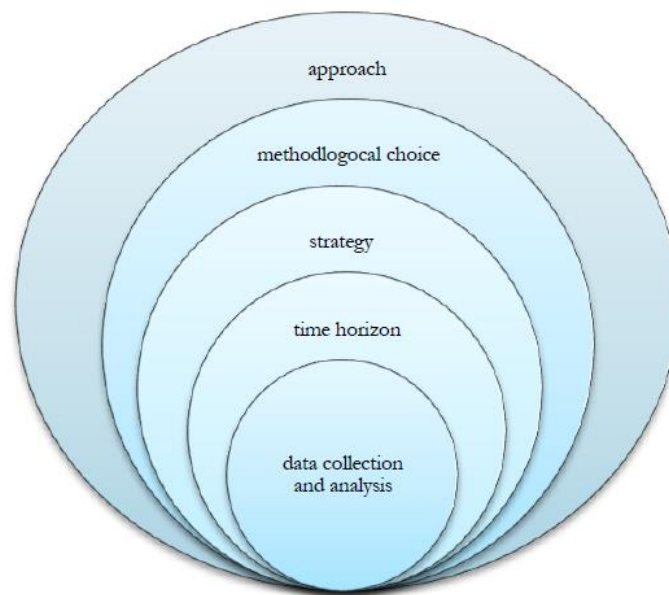


Figure 3-2 Research onion model (Saunders, Lewis, & Thornhill, 2009).

### 3.3 Research approach

The research approach that can be applied to research could be inductive or deductive, depending on the research purposes, questions, limitations, and so on (Saunders, Lewis, & Thornhill, 2009). Inductive approach refers to the research approach whose flow is generally from specific to generic, i.e. starting from the study of specific data to findings of theory and conceptual framework. In addition, the inductive approach can be conducted when the prior theoretical knowledge is limited. The deductive approach refers to the research approach whose flow is, on the other hand, from generic to specific, i.e. start with theory and then continue to the research questions which are tested by data. As a vital prerequisite for this approach, sufficient prior theoretical knowledge is needed (Saunders, Lewis, & Thornhill, 2009).



Considering the research questions of this thesis and the possible prior theoretical knowledge that could be acquired for this study, a deductive approach is applied to this thesis research. Because the literature review and information acquired from Volvo have enriched the researchers with sufficient prior theoretical knowledge regarding different sections of this research, such as cost breakdown theory, road transport services, and calculation methods for each identified cost element. Starting with those theories and methods, the researchers design and implement their framework for answering the research questions, together with the verification processes by using the appropriate data. To apply the deductive research approach, the thesis will start with studying the theories on estimating freight rate and carbon emissions of road transport. Then, a general theoretical framework will be built up together with user-friendly tools based on the framework. The part is generic and corresponds to the first and second research questions. After that, the research narrows down to a specific part which is the test and verification of the framework and tools by data the case company Volvo Group.

### 3.4 Methodological choice

For the methodological choice of research, quantitative methods and qualitative methods could be the options to apply. When it comes to the methodological choice for specific research, the researchers need to make decisions on whether both of the methods are in need for the study or only one of them is in need; if both quantitative and qualitative methods are in need, should they weigh equally or should one of them dominate the other. For this decision of method selection and combination, there are three types of choice:

- mono-method: apply either quantitative methods or qualitative methods
  - mixed-method: equally apply quantitative methods and qualitative methods, such as in the process of data collection and data analysis; compensate for the limitation of each other
  - multi-method: applying both quantitative and qualitative methods for the research.
- However, during some processes such as data collection and data analysis, only one kind of method will be applied (Saunders, Lewis, & Thornhill, 2009).

In addition, while mixed-method uses both the quantitative methods and qualitative methods all the way together to establish a particular and single set of data and findings, the multi-method is implemented in the research which is commonly divided into different sections, and each section may focus on either of the two methods to produce a set of data and findings for that stage (Uwe, 2011).

As is shown in Figure 3-1 in Section 3.1, there are seven research processes for this thesis. For each process, at least one of the methods between quantitative methods and qualitative methods should be applied. The second and sixth processes will apply quantitative research methods because the second process will reflect the second research question which is the calculation methods for cost elements and the sixth process is the test of the framework. The other processes will apply qualitative methods. As a result, the methodological choice of multi-method will be applied.

### 3.5 Research strategy

Research strategy refers to what type of structure and research design will be implemented in a research study in order to achieve the research objective and answer the research questions. Typical research strategies for academic research include experiment, survey, case study, action research, grounded theory, ethnography, archival research, and narrative inquiry. In some cases, there can be more than one research strategy selected for certain research (Saunders, Lewis, & Thornhill, 2009). With the consideration of the research purpose, the selection of the research approach, and methodological choice, the research strategy of case study is selected for this thesis research.

The research strategy of case study is defined as an empirical inquiry that examines a phenomenon in its real-life context, especially when the boundaries between the phenomenon and context are not evident (Yin, 2017). In this thesis research, which is exploratory research of designing a theoretical calculation framework with the further aim to resolve the demands and problems from the case company, the research strategy of case study enables the researchers to build up the investigation from multi-perspectives, select the suitable methods for this specific phenomenon, as well as examine the findings in the real-life context of the research scope together with the conclusions that have the potential to be generalized (Baxter & Jack, 2008).

The four transport services at Volvo are selected as cases, which is a multiple-case design (Yin, 2017). They are Full-Truck-Load (FTL), Less-Than-Truck-Load (LTL), Dedicated Delivery Service (DDS), and Express. They will be further introduced in chapter 4. The four cases will be studied and investigate following the order:

- 1) Understand how the services are organized and what are the features of each of them.
- 2) Collect the tested data of transport services
- 3) Test the framework and tools with data of the four cases
- 4) Discuss the results of each case and make a comparison among all the cases

### 3.6 Time horizon

The time horizon of the research refers to the constraint of time scope for conducting the research, which can be determined as cross-sectional or longitudinal. While cross-sectional horizon focuses on a time scope of a specific time and the findings within that scope, longitudinal horizon focuses on a time scope of a certain period when data collection and analysis should be continued and examined over time (Saunders, Lewis, & Thornhill, 2009). When it comes to the time horizon for this thesis research, the cross-sectional horizon should be applied, and the time scope for the researchers to conduct this study is limited to the specific period for this thesis.

### 3.7 Data collection

In the process of data collection, the data in need for this research is divided into two categories: primary data and secondary data. Primary data refers to the information that the researchers

gather through firsthand. Secondary data refers to the information from secondary sources, which is not directly acquired by the researchers (Rabianski, 2003). The methods for acquiring primary data and secondary data are also different. In the following sections 3.7.1 and 3.7.2, the specific methods for acquiring the primary data and secondary data in need of this thesis research will be presented and discussed.

In addition, and for emphasis, data collection in this section refers to not only the data for developing the calculation framework, but also the data in need for testing and verifying the framework, as well as the data for resolving the problems and demands from the case company Volvo Group.

### 3.7.1 Primary data

The primary data in need for this thesis research is mainly from the following three aspects:

- 1) Data, information, and theories that are needed for designing the calculation framework, regarding not only the cost elements but also the calculation method for each cost element
- 2) Supportive data as data input to test and verify the calculation framework
- 3) Critical data and information to resolve the specific problems and demands from the case company

To acquire the above vital primary data, the method of interview will be applied.

#### Interview

According to (Kajornboon, 2005), interview is an efficient and common-used way to collect data and acquire knowledge from individuals. There are three types of interviews: structured interview (also called standardized interview), semi-structured interview, and unstructured interview (Kajornboon, 2005). Structured interview refers to “the interview in which all respondents are asked the same questions with the same wording and in the same sequence”. Structured interview gives more control to the researchers over the topics and the format of the interview (Kajornboon, 2005). During a semi-structured interview, interviewers have a set of questions to address, but the questions can be rephrased, or additional questions can be added in the process. This type of interview gives interviewers more opportunities to probe the knowledge and opinions of interviewees (Kajornboon, 2005). When it comes to the unstructured interview, interviewers mainly take the role of listeners while interviewees take the lead and speak freely and openly. This method is particularly suitable at the beginning stage when interviewees have little knowledge (Kajornboon, 2005).

In order to acquire the primary data mentioned above, several semi-structured interviews and unstructured interviews have been arranged with Volvo personnel from the functions of Logistics Purchasing (LP) and Footprint Design(FD). The selection of the interviewees is based on their expertise and availability according to schedule, as is shown in Table 2-1.

Table 3-1 Contextual information of the conducted interviews

No.	Function/ Team	Respondents	Interview type	Subject	Duration
1	LP	Logistics purchaser	Unstructured interview	General information about the Volvo Group Trucks Operations and the department of LP, along with the demand from LP for this study	60 min
2	FD	Supply chain analyst	Unstructured interview	General information about FD, along with the demand from FD for this study	60min
3	FD	Supply chain analyst	Unstructured interview	Information and settings about the five types of transport set-ups within Volvo	45min
4	LP & FD	Logistics purchaser & Supply chain analyst	Unstructured interview	Some empirical figures, findings, and facts about the transport settings and operations within Volvo Group	60min
5	LP & FD	Logistics purchaser & Supply chain analyst	Semi-structured interview	Some empirical figures, findings, and facts about the transport settings and operations within Volvo Group	40min

Unstructured interviews were arranged at the very initial phase of the thesis research because the researchers needed to build up the fundamental knowledge and understanding of concepts within Volvo Group and the two functions. Through those unstructured interviews, primary data such as the demands and problems from the two functions, the information and definitions of the five Volvo transport set-ups, and some proposed cost elements have been understood and acquired. After the initial phase, semi-structured interview was conducted to acquire the primary data which is more topic-specific and targeted-based, such as some empirical figures as input for the calculation framework and suggestions for designing the calculation framework. The question list for the semi-structured interview is presented in Appendix C: Question list for semi-structured interview. By having accomplished each specific interview, information and data have been collected and categorized, while some of the results directly contributed to the thesis research, others have turned out to be the questions for the next interview in which they would be discussed further.

### 3.7.2 Secondary data

The secondary data in need for this thesis research is mainly from the following four aspects:

- 1) General information about the case company Volvo Group, logistics purchasing function, and footprint design team.
- 2) Information about transport services at Volvo
- 3) Some empirical figures, findings, and facts about the transport situations and operations within Volvo Group
- 4) Information regarding the general research background and methods

In order to acquire the above secondary data, the data collection process will start from the following aspects:

### **Literature review**

Literature review is a process where researchers describe prior studies and evaluate current states to further motivate the research objective and justify research questions. It is a good way to provide an overview of the researched area or issue, reveal the gaps that need further investigation, and address research questions (Snyder, 2019). In this thesis research, literature review is conducted to present the general research background, identify suitable research methods, and support the design of the calculation framework. Data sources such as Google Scholar, ScienceDirect, and SpringerLink are used for the literature review to collect the materials of dissertations, books, academic journals, commercial and governmental reports, etc. Keywords related to cost breakdown theory, cost elements, road freight rate, transport carbon emissions, etc., are used to search the materials during the literature review process.

### **Additional external data sources**

To acquire the vital secondary data of some specific figures, regulations, and route information, additional external data sources rather than the ones for literature review have also been used, such as some website (e.g. European Commission websites) and official databases and statistics (e.g. EU statistics database). In addition, a geography route engine database, PTV Map & Guide, is used in this research to provide the up-to-date route data for testing and verifying the calculation framework.

### **Internal data sources from Volvo Group**

For some specific secondary data regarding the case company Volvo Group and its business operations, the internal data sources such as some Volvo internal database, materials (e.g. reports, slides, contracts), bid/price records, and invoices will be the sources to acquire such data and information. However, because some of such secondary data is the confidential data of Volvo Group and is not allowed to share with the public, in this thesis paper, the researchers will put such data in anonymity.

## **3.8 Reliability and validity**

According to Saunders et al. (2009), reliability and validity are the two basic pillars that need to be considered when assessing the quality and applicability of research with both quantitative and qualitative methods. While reliability refers to “the absence of differences in the results if the

research is repeated”, validity refers to “the extent to which the research findings accurately reflect the phenomena under study” (Hussey & Collis, 2013). To ensure the reliability and validity of this thesis research, triangulation will be implemented. Triangulation refers to applying multiple sources of data, different research methods, and/or more than one researcher to investigate the same phenomenon in research (Hussey & Collis, 2013).

Processes have been taken to secure the reliability of the research. First, for each transport service at Volvo, at least 8 transport shipments have been used in testing. In total, 8 samples with 26 shipments are randomly selected and tested. The verification of multiple increases the reliability of the research. Second, when designing the calculation framework, the majority of the methods and theories applied are the common and public ones that are accessible through open sources, e.g. research paper, public statistics, databases, reports. Third, for the data and information acquired from the internal sources of Volvo, a track of record for the relevant sources is noted, including interview questions and interviewers, databases, reports, slides, etc. This makes the verification and reproduction of the research feasible in the future by other researchers. Besides, the two researchers for this thesis have also cross-checked each section with the same set of research methods that have been applied, which works as an internal check process for reliability. Last but not least, an outline for this research is demonstrated in section 3.1 as a clear process map for other researchers to refer to when replicating a study.

When it comes to ensuring the validity of this research, methods have been used by the researchers to secure the research measures that are intended to be studied. For example, the output of the framework is tested with the true bid price from the case company Volvo. The differences between the estimated result and the true bid price are shown and analyzed in chapter 7 and chapter 8. Besides, more than one source has been applied when collecting the data, information, and theories to ensure that the result of the collection is error-free and valid. In addition, verification and comparison of this new-designed calculation framework with the other valid tool and the figures, in reality, are conducted to evaluate the extent of how this new-designed calculation framework performs and how valid it is for answering the research questions.

## 4 Company overview

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*In this chapter, the basic information of the case company is presented, along with the description of its functions which are relevant to the thesis research. Then the demands from the relevant functions for this thesis are presented. In the following sections, the settings of the road transport network and the transport set-ups at Volvo are introduced.*

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### 4.1 Company background and function description

#### **Volvo Group**

Volvo Group is one of the world's leading manufacturers of trucks, buses, construction equipment, marine engines, and industrial engines. In addition to the sales of vehicles, equipment, and machines, Volvo Group also offers various types of services such as insurance, rental services, spare parts, repairs, preventive maintenance, service agreements, and assistance services. With business operations and customers around the world, the company is dedicated to shaping the future landscape of sustainable transport and infrastructure solutions. The Volvo Group's products have been developed to contribute to efficient transport and infrastructure solutions to provide benefits for not only its customers but also the society and the environment.

#### **Volvo Group Trucks Operations**

The Volvo Group Trucks Operations (GTO) is an affiliate of Volvo Group, which is responsible for the production of the Volvo products, the supply of spare parts to Volvo's customers, as well as the design, operations, and optimization of Volvo's supply chain network. In the organization of GTO, two functions that are relevant to this thesis research are Production Logistics (PL) and Service Market Logistics (SML).

#### **Production Logistics (PL)**

PL is a function responsible for the production-related end-to-end logistics operations within Volvo Group (e.g. material transport, inbound and outbound logistics management, production planning), which ensures the secured and cost-efficient material flow to the production activities in the different Volvo plants around the world.

#### **Service Market Logistics (SML)**

SML is a function responsible for the aftermarket logistics operations of Volvo Group (e.g. aftermarket material planning, dealer inventory management, urgent parts delivery order fulfillment). SML develops, manages, and optimizes service part availability and distribution to Volvo's customers with world-class services focusing on delivery precision, quality, continuous improvement, and cost-efficiency.

### The department of Logistics Purchasing

The department of Logistics Purchasing (LP) aims to provide optimized logistics solutions through logistics service purchasing projects for both SML and PL to facilitate operational success and sustainable transport performance. Each year, LP spends a substantial amount of money on purchasing the suitable logistics service for Volvo Group, including segments of road, air, sea, and rail transport. Among those segments, the road transport segment accounts for a large and significant share. To increase competitiveness in the purchasing process and keep good control over budget, several tools and methods have been implemented to bring and secure the most cost-efficient and best-performing logistics service from the logistics service providers (LSPs). In the meantime, several areas for improvement have also been identified for the LP, with relevant projects and researches ongoing for better results.

### The team of Footprint Design

Footprint Design (FD) is a team within SML, who is in charge of reviewing the performance of different aftermarket supply chain and proposing practical suggestions for the improvement. The mission of FD is to secure Volvo Group has the most cost-efficient aftermarket footprint to provide high-quality service for its customers. To achieve its mission, FD needs to accomplish several categories of tasks, which include performing the supply chain performance reviews (assessments) for each region, improving the tools and models for the supply chain review activities, proposing suggestions for the optimization of certain supply chains, developing business intelligence report based on the trends and status for supply chain set-ups, as well as building up new business tools for the SML's operations.

As a summary of the organizational structure for the functions mentioned above, Figure 4-1 is shown:

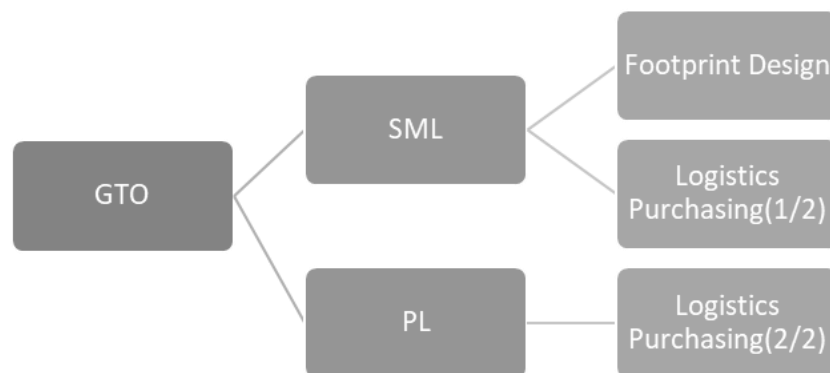


Figure 4-1 Structure of the organizational functions (within the scope of the thesis)



## 4.2 Problem description

### Demand from Logistics Purchasing

LP would like to have an estimation framework that can not only estimate the overall road freight rate for the road transport lanes<sup>1</sup> within Volvo's transport network but also provide the estimated results of cost figures for each cost element involved in the transport lane. LP is also interested in having a new source to acquire the transport carbon emissions figures for each lane to support their purchasing operations. In addition, an applicable tool based on this framework that can be integrated with the current business process should be developed.

By establishing the estimation framework and the applicable tool, purchasers and purchasing analysts will have a new source to acquire a reliable and fact-based overall road freight rate as well as the figures of each cost element towards each transport lane. Moreover, this new tool may also bring changes to the way of how purchasers conduct their business operations. One example could be that with the cost figure for each cost element, a target-based strategy can be enabled for the purchasers when having negotiations with the LSPs because the purchasers can focus on the cost figure on certain cost elements. Another example could be that with the exact cost figure of each cost element and the percentage of how much each cost element has taken up from the overall road freight rate, potential and prioritize efforts for savings towards the specific cost element can be identified. Therefore, having such an estimation framework for calculating the road freight rate is desired for LP to reach the more cost-saving and fact-based targets for transport service purchasing.

### Demand from Footprint Design

As one of the main assignments for FD, supply chain review is a project which assesses and compares the current performance of the specific supply chain, e.g. warehouse and critical site locations, routing selections. For a supply chain review, many processes from collecting data input to scenario analysis are involved; and at the end of these processes, suggestions for improving this specific supply chain are given by FD. Currently, FD is using two important metrics for the supply chain review: the lead time and the cost. When it comes to the metric of cost, transport cost is one of the important portions of the total cost figure. However, till now the FD team has not yet had a monetary measuring unit (e.g. SEK, EUR) for reflecting the transport cost; instead, the team has been using the unit of "ton-km" as an alternative.

Although "ton-km", which is calculated with yearly demand and distance can reflect the cost of the supply chain scenario to some extent, it may be not precise enough to reflect the real cost of the monetary value of the supply chain scenario. For example, the "ton-km" in scenario A shows 4% higher than scenario B. However, scenario A is operated in a region where the labor cost is lower than the region of scenario B; besides, in scenario A there is also less road toll fee than scenario B, the actual cost for scenario A may be lower than that of scenario B. As a result, the FD team needs a better metric which can reflect the transport cost with its true monetary value.

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<sup>1</sup> The term "lane" in Volvo's context refers to the selected route for the road transport between the origin and the destination.

With the calculation framework that can provide the estimated road freight rate figures for the lanes involved in the reviews, such optimization can be achieved. As a result, FD would be able to upgrade its metric for reflecting the road transport cost and improve the credibility of the review's outcome.

## 4.3 Road transport at Volvo

### 4.3.1 Overview of the transport network

#### Overview of transport network (Production Logistics)

In the transport network of PL, on one end are the suppliers, and on the other end are the dealers. However, when it comes to the scope of this thesis research, only the inbound transport lanes between the suppliers and the production plants are considered, which are the transport lanes to deliver the parts and materials for production. The network is shown in Figure 4-2.

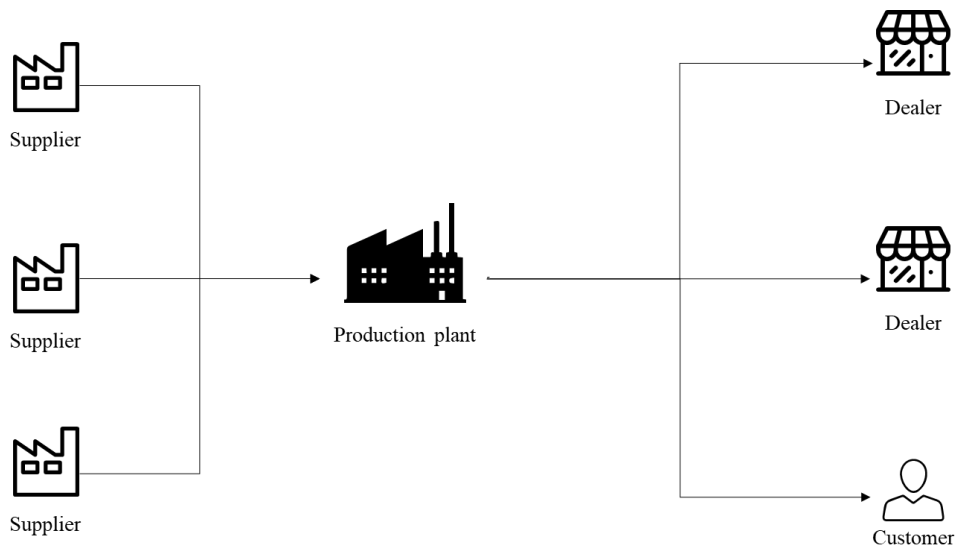


Figure 4-2 Transport network for PL

The parts and materials are collected from the suppliers and then delivered to the production plants. The corresponding transport flow of this process is called inbound transport for PL.

#### Overview of transport network (Service Market Logistics)

In the transport network of SML, on one end are the suppliers, and on the other end are the dealers. Between them, there are three types of distribution centers to secure the supply. The network is shown in Figure 4-3.

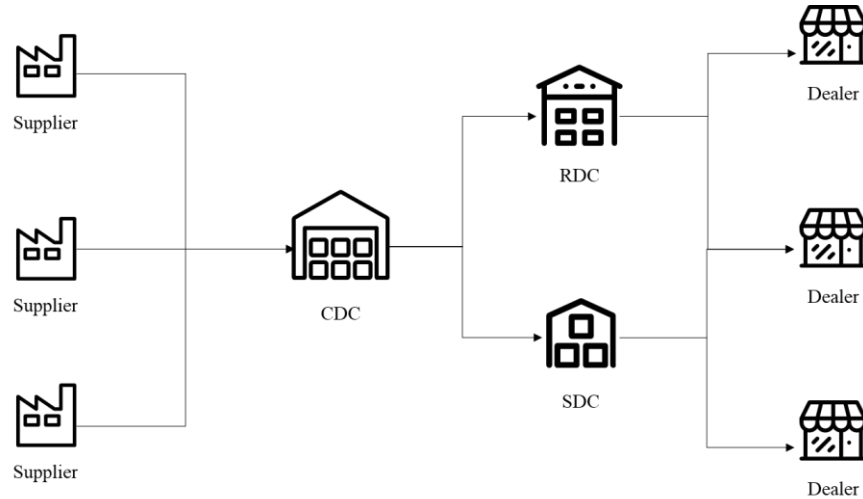


Figure 4-3 Transport network for SML

Central Distribution Centers (CDCs) are normally the largest distribution centers that are directly supplied by the suppliers. The corresponding transport flow of this process is called inbound transport for SML, while the transport flow that delivers the stock out from the CDCs is called outbound transport for SML. CDC is responsible for refilling Support Distribution Centers (SDCs) and Regional Distribution Centers (RDCs). In the following chapter, Distribution Centers (DCs) will be used to refer to all three types of distribution centers.

SDCs exist mainly in Europe and are located close to dealers to ensure a quick response to urgent orders from dealers. SDCs keep a low level of inventory as they get refilled from CDCs daily.

Regional Distribution Centers (RDC) have similar functions as SDCs but they normally keep more stock because one of the purposes to set up RDCs is to reduce the lead time from CDCs to the dealers caused by the long trip distance and other processes such as passing the customs. RDCs not only refill the stock for dealers but also respond to the emergency orders from dealers.

### 4.3.2 Transport set-ups at Volvo

Volvo has defined five types of road transport set-ups in the transport network. They are Full-Truck-Load (FTL), Less-Than-Truck-Load (LTL), Dedicated Delivery Service (DDS), Express, and Milk-run. It is necessary to understand those different transport set-ups before establishing suitable calculation methods for the road freight rate and transport carbon emissions. The major features of each transport set-up are summarized in followed by the more detailed descriptions.

Table 4-1 Features of transport set-ups

Transport set-up	FTL	LTL	DDS	Express	Milk-run
Will it be studied in this research	Yes	Yes	Yes	Yes	No
Full loads or part loads	Full Loads	Part Loads	Fixed Capacity + Part Loads	Full Loads	Full Loads
Order type	Refill stocks at DCs, plants, and dealers	Refill stocks at DCs and dealers	Emergency orders from DCs to dealers	Extra emergency orders from DCs or other dealers to dealers	Inbound transport to production plants, Orders from DCs to dealers
Cross-dock <sup>2</sup>	No	Yes	Yes	No	No
Digital platform booking/ transaction <sup>3</sup>	Yes	Yes	Yes	Yes	Yes
Backhaul <sup>4</sup> (if applied)	Yes	Yes	Yes	Yes	No
Backward trip <sup>5</sup> (if applied)	Yes	No	No	Yes	No
Additional drop trailer (WoW) <sup>6</sup> (if applied)	Yes	No	No	No	No

<sup>2</sup> Cross-dock refers to the operation that part of the inbound materials for a hub is unload and reload to another vehicle for another outbound delivery.

<sup>3</sup> Digital platform cost is the fee paid to the platform where the transaction between shipper and carrier happens.

<sup>4</sup> Backhaul is to haul a shipment or empty load over part of the route it has traveled from.

<sup>5</sup> Backward trip will be applied instead of backhaul if the trip to be calculated is a round trip and there are cargos in the return trip.

<sup>6</sup> Additional drop trailer is the operation that a trailer is left at a location for some time for a later trailer pick-up.

## 1) Full-truck-load

The FTL transport set-ups at Volvo follows the common definition of the term. It means the cargo shipped is large enough to fill the entire capacity of the trailer(s). Therefore, the full capacity of the trailer(s) is purchased. The transport can directly happen between origin and destination without any additional sorting or handling in between, therefore no cross-dock operations are needed. Volvo uses FTL transport to refill stocks for not only production plants and CDCs but also SDCs and RDCs. Volvo negotiates a fixed price with LSPs for FTL transport. In addition, cost generated from the operations such as digital platform booking, backhaul, backward trip, and additional drop trailer should be taken into consideration, if any of the relevant operations are applied in a specific lane. The outline of the FTL set-up is shown in Figure 4-4.

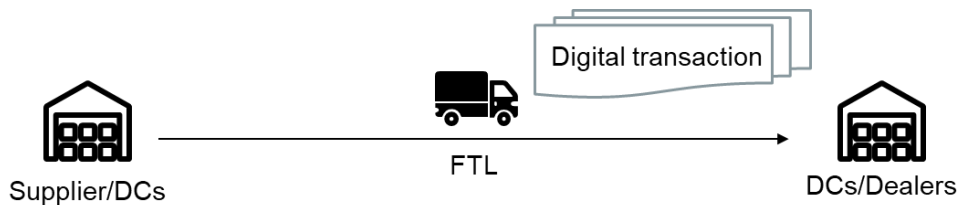


Figure 4-4 FTL set-up outline

## 2) Less-than-truck-load

The LTL transport at Volvo is also consistent with the common definition of the term which refers to a shipment that cannot fill the entire capacity of the trailer(s) and additional handling is needed to make utilization of spare spaces in the truck. For LTL transport, Volvo will get a tariff price from the LSPs. However, the LSPs can only provide limited information regarding how they handle the shipment, such as the location of the carrier's distribution hub and handling time. Other information, such as whom Volvo will share the rest of capacity with, cannot be known. Cost generated by the operations of cross-dock, digital platform booking, and backhaul should be considered in the LTL set-up, while backward trip and additional drop trailer are not taken into consideration according to Volvo's scope. LTL transport is also used to refill stock for production plants, CDCs, SDCs, and RDCs. The outline of the LTL set-up is shown in Figure 4-5.

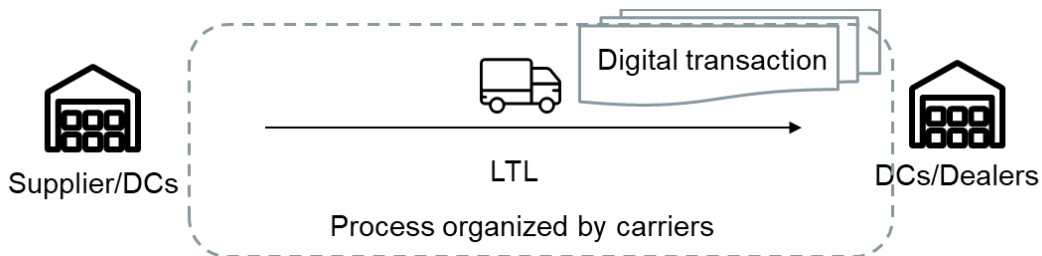


Figure 4-5 LTL set-up outline

### 3) Dedicated delivery service

DDS is used to ship emergency orders from DCs to dealers. The order is placed on the day before late afternoon and will be shipped to the dealer the next morning. DDS consists of two legs. The first leg goes from a DC to carrier's logistics hub, while the second leg is from the carrier's hub to dealers. The structure of DDS is shown in Figure 4-6.

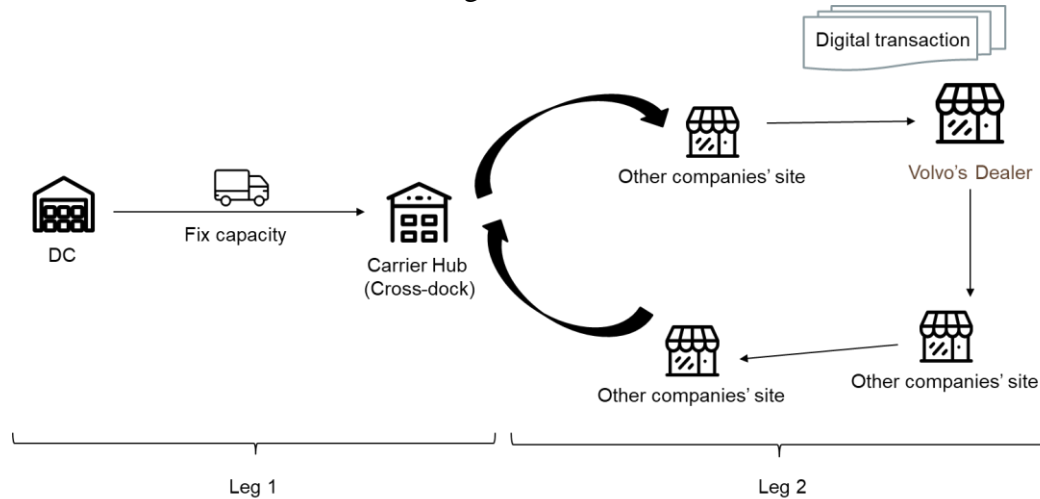


Figure 4-6 DDS set-up outline

For the first leg, Volvo normally buys a fixed capacity of a truck from the carrier, which could be seen as an LTL transport. The second leg is a distribution fully operated by the carrier. The Distribution vehicle will not be dedicated to Volvo, but Volvo doesn't know whom it will share the capacity with. DDS is featured by the special time requirements. Another feature is that usually the two legs are operated by the same carrier and Volvo will negotiate a price unit (usually EUR/kg) for two legs as an entirety with the carrier. However, sometimes the two legs are operated by two different carriers and there will be two separate payments for each leg to each carrier. Similar to the LTL set-up, cost generated by the operations of cross-dock, digital platform booking, and backhaul should be considered in the DDS set-up, while backward trip and additional drop trailer are not taken into consideration for DDS set-up according to Volvo's scope.

### 4) Express

Express is used to ship extra emergency orders placed by the dealers which need to be fulfilled as soon as possible. The shipment might come from either one of the DCs or even another dealer, depending on the availability of the item. The vehicle used in the express is normally dedicated to Volvo, which is similar to FTL. The main difference between the Express set-up and the FTL set-up is the vehicle type. Besides, there is no additional drop trailer for the Express set-up. Express set-up is mostly conducted by vans or taxis (passenger vehicles), while the major vehicles used in FTL is truck with trailer. The outline of the Express set-up is shown in Figure 4-7.

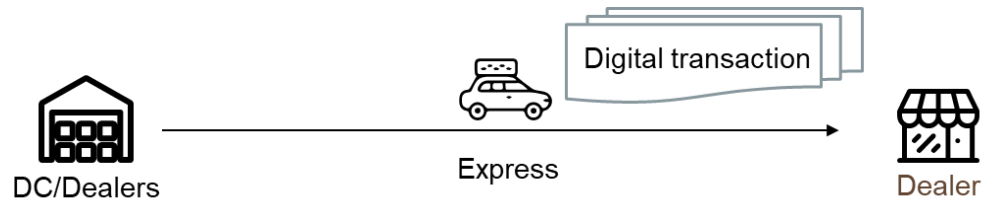


Figure 4-7 Express set-up outline

### 5) Milk-run

At Volvo, the milk-run set-up is further divided into two types: Dynamic Loads and Same Day Delivery. Dynamic Loads is inbound milk-run from suppliers to production plants, while Same Day Delivery ships orders from DCs to dealers. Milk-runs are also fully outsourced to carriers. The difference between the milk-run set-up and the leg 2 of DDS (distribution) is that in the milk-run set-up, the crew, the vehicle, and the route are all dedicated to Volvo. That means the vehicle will only carry Volvo's cargo and visit Volvo's sites during a milk-run cycle. However, this set-up will not be included in the scope of this thesis research.

## 5 Design of calculation framework

*In the first section of this chapter, the basic theoretical framework consisting of two sections and 20 cost elements will be designed. The calculation method for each cost element will be presented. After that, to connect the basic framework with the transport set-ups to be calculated, modules are introduced as an intermediate. The relation between modules and cost elements, modules, and set-ups are introduced together with the calculation method for each module.*

### 5.1 Basic framework

As shown in Figure 5-1, the basic framework is composed of two sections: the road freight rate calculation section and the transport carbon emissions section. In total, 20 cost elements are identified and will be discussed later. 18 of them belong to the road freight rate section and 2 of them belong to the carbon emission section.

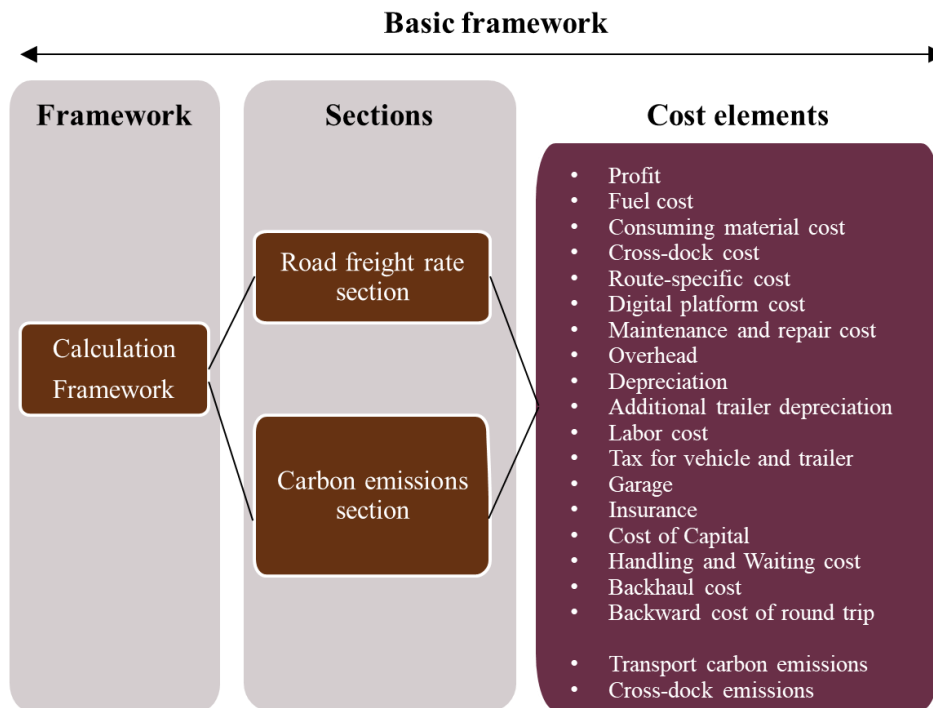


Figure 5-1 Structure of the basic framework

#### 5.1.1 Design of Road freight section

Based on the method of cost breakdown analysis mentioned in section 2.1 and the setting for the transport set-ups at Volvo, a cost breakdown analysis that involves three stages is conducted to acquire the cost elements for calculation. In total, 18 cost elements are identified in the road freight rate section and further categorized into 5 types, as shown in Figure 5-2. In the following



subsections, the calculation method for each cost element will be introduced following the sequence to three break-down.

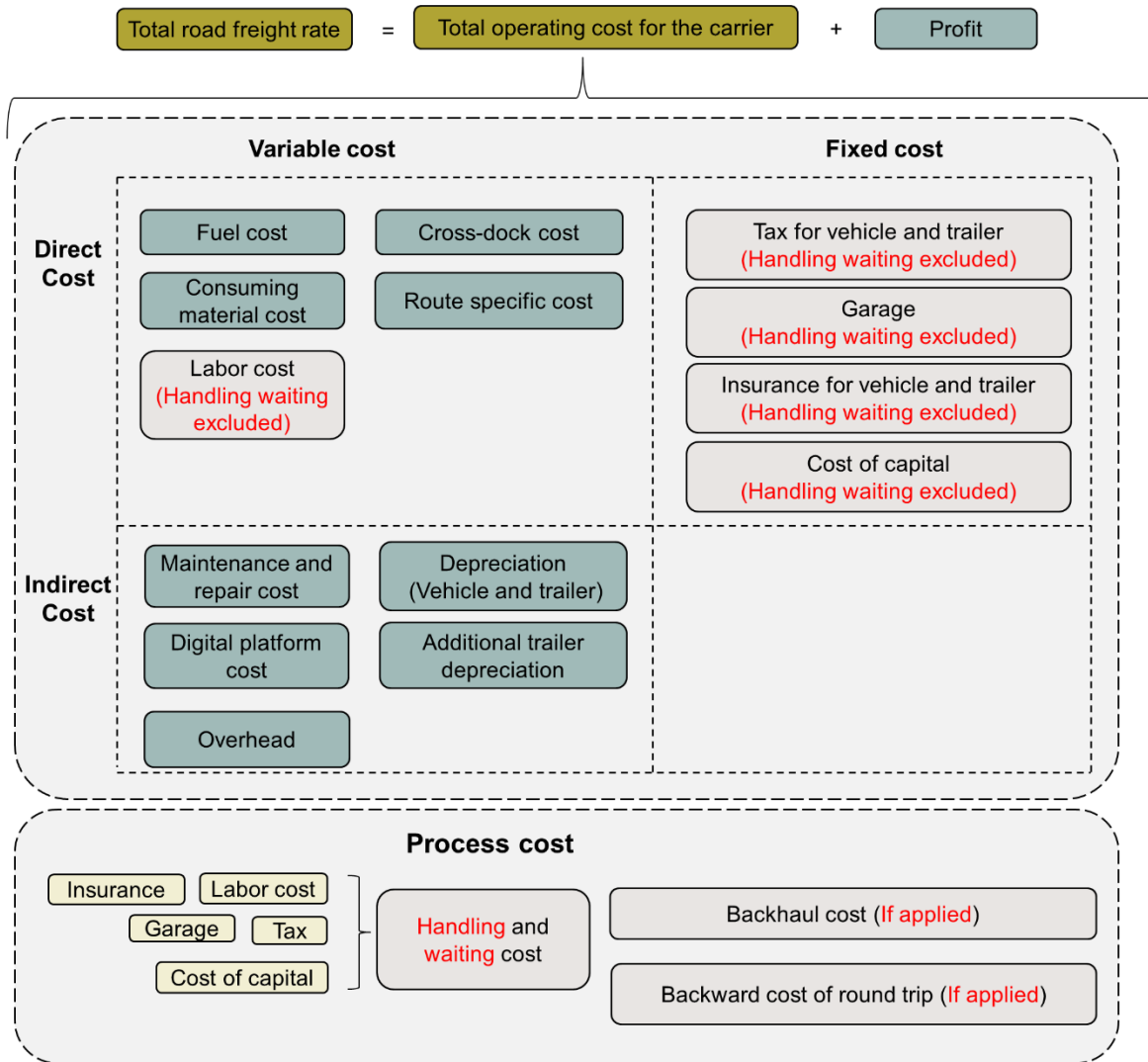


Figure 5-2 Cost elements in road freight rate section

### 5.1.1.1 First breakdown

For the first breakdown, the overall road freight rate is divided into two components: the total cost and the profit.

#### 1) Profit

In this thesis research and from the perspective of Volvo, profit refers to the estimated profit figure that the LSP would want to earn from running a certain lane for Volvo. Although from the buying company's perspective the profit is additional costs, it is needed to have a sustainable relation with carriers. The profit is a subject metrics, depending on the operating situation of carriers, bargaining power of the shipper. In the estimation of freight rate, it is reasonable to use

an average profit of the industry or look for the profit percentage from the carriers' financial report. In this research, a percentage estimated by Volvo is used.

### **5.1.1.2 Second breakdown**

For the second breakdown, the total cost is broken down into two cost categories: direct cost and indirect cost. Based on the basic structure of cost breakdown in Figure 2-1, the three principles of effective cost breakdown analysis, the summary of cost element in previous studies (Table 2-1), and the Volvo internal materials regarding analysis for cost elements of transport set-ups, 9 new cost elements are acquired. They are fuel cost, consuming material cost, cross-dock cost, route-specific cost from the direct cost category; digital platform cost, maintenance and repair cost, other overhead (overhead cost), depreciation of vehicle and trailer, additional trailer depreciation from the indirect cost category.

#### **2) Fuel cost**

Fuel cost is defined as the cost of fuel consumed by the vehicle for operating the transport service. Fuel cost is primarily determined by fuel consumption, fuel price, and travel distance (Barnes & Langworthy, 2004). Fuel consumption is further influenced by the type of vehicle. Normally, a truck with a 13.6m trailer consumes more diesel compared with a van of 5 tons. The average fuel consumption could be obtained from the vehicle specification document and it will be used as the basic figure for further adjustment. Furthermore, fuel consumption is also determined by a set of driving conditions, such as refiling stations, road traffic (Barnes & Langworthy, 2004; Jacyna & Wasiak, 2015).

The fuel consumption is higher when driving in the city road compared with driving in the motorway. This happens because the vehicle needs to continuously change the speed, even stop and start several times due to complex traffic in the city area (Barnes & Langworthy, 2004). This influence is concluded as a traffic density index when calculating the fuel cost. In the freight transport set-up at Volvo, the origin and destination could be either at an industrial area, a logistics park, or a dealer near the city area. Therefore, an assumption is made that:

*Assumption 1: the first and last x km of the trip is the part with higher traffic density and will result in a% more fuel consumption compared with the motorway.*

If the total distance is less than 2 \* x km, then the whole trip has more fuel consumption than the basic value.

Besides traffic conditions, other factors that might impact fuel consumption include driver's behaviors, road roughness, and temperatures (Network for Transport Measure, 2015; Walnum & Simonsen, 2015). However, in the cost estimation phase, it is hard to foresee these factors for a trip that will happen in the future. Thereby, they will not be considered in the calculation.

The final formula for fuel cost calculation is:

$$\text{Fuel Cost} = \begin{cases} TD * FC * FP + a * 2x * FC * FP & TD > 2x \\ TD * (1 + a) * FC * FP & TD \leq 2x \end{cases} \quad 5-1$$

(Source: Own elaboration)

TD: Trp distance (km)

FC: Fuel consumption (liter/km)

FP: Fuel price (EUR/liter)

a: Extra fuel consumption (%)

x: the distance of high – density traffic part (km)

### 3) Maintenance and repair cost

Maintenance and repair are categorized as one cost element, which is composed of two parts, parts usage and labor hours. Besides, it is also impacted by other factors, such as the age of the vehicle, the practice of the repairman, and operating conditions, together with the variety for truck parts, increasing the difficulty in expressing the process of maintenance and repair in a mathematical model and calculating real maintenance and repair costs (Berwick & Farooq, 2003). Another common practice in estimating maintenance and repair cost is to use an average cost unit which is normally price per kilometer. In this framework, the latter method is adopted and this average number is called a basic unit for maintenance and repair cost.

Both parts price and labor cost are different in different countries, which means maintenance and repair cost is country-related. To reflect the variation among countries, the basic unit is multiplied with a country-specific index which is calculated from the Price Level Indices (PLIs). To implement the country index, an assumption is made:

*Assumption 2: The country-specific index for maintenance and repair depends on the country of the transport-service provider.*

#### Country specific index

The country-specific index is obtained from Price Level Indices (PLIs) which provides a comparison of countries' price levels relative to the EU average (Eurostat, 2020). The PLIs are divided into several groups, such as food and non-alcoholic beverage, clothing, electricity, and transport services (Eurostat, 2020). Considering the topic of this research, the PLIs for transport services are selected. The index for a country A is calculated by:

$$\text{Country – specific index of country A} = \frac{PLIA}{PLICBU} \quad 5-2$$

*PLIA: price level indices of country A*

*PLICBU: price level indices of country for the basic cost unit*

With the above information, the formula for maintenance and repair cost is:

$$\text{Maintenance and Repair Cost} = CI * BU * TD \quad 5-3$$

(Source: Own elaboration)

CI: Country index

BU: Basic cost unit (EUR/km)

TD: Trip distance (km)

### 4) Consuming material cost

Consuming material cost is defined as the cost of different equipment related materials that are consumed during each trip. In this thesis research, tires and lubricants are the consuming materials that have been taken into consideration.

In the calculation process, consuming material consists of two parts, tires and lubricants, which are both consumed by distance. The first method to calculate the consuming material cost follows the same process as the method for maintenance and repair cost. The assumption is made that:

*Assumption 3: The country-specific index for consuming material depends on the country of the transport-service provider.*

The formula is:

$$\text{Consuming Material Cost} = CI * (TBU + LBU) * TD \quad 5-4$$

CI: Country – specific index

TBU: Tire basic cost unit (EUR/km)

LBU: Lubricants basic cost unit (EUR/km)

TD: Trip distance (km)

The CI (country-specific index) is calculated from formula 5-2. The consumption of tires and lubricants is that they are less complex than the process of maintenance and repair and are more similar to the logic of fuel consumption. Therefore, it is possible to go one step further to estimate the cost unit in formula 5-4.

The cost of tires is impacted by vehicle type. For example, a 13.6m standard truck normally has 10 tires, while a delivery van with 1.5 tons capacity only has 4. Further, it is also impacted by the lifetime distance. As for each tire, its lifetime depends on the road roughness, weather, and drivers' behaviors. Even under the same conditions, the durability of a tire will vary from brand to brand, tire to tire. The tire company normally gives a suggested life distance. In the estimation, an average price level and average lifetime distance of a tire from the market are adopted in the calculation. Therefore, the tire cost could be obtained by:

$$\text{Tire Cost} = \text{NoT} * \frac{\text{TireP}}{\text{TireLD}} * TD \quad 5-5$$

(Source: Archondo-Callao and Faiz (1994); Berwick & Farooq (2003))

NoT: Number of tires

TireP: Tire price (EUR/tire)

TireLD: Tire lifetime distance (km)

TD: Trip distance (km)

The lubricant cost is dependent on the lubricant consumption of a certain vehicle, lubricant price, and trip distance. There is no standard lubricant price on the market, as fuel price. However, it is reasonable to use an average figure.

$$\text{Lubricant Cost} = LC * LP * TD \quad 5-6$$

(Source: Archondo-Callao and Faiz (1994))

LC: Lubricant consumption (liter/km)

LP: Lubricant price (EUR/liter)

TD: Trip distance (km)

In this research, considering the available data at the case company, formula 5-4 is adopted.

## 5) Cross-dock cost

If the cargo needs to go through the cross-dock process at a logistics hub, the corresponding cost will be generated. However, if the hub is internal at the case company, the cost will not be included in the rate. Therefore, the cost for cross-dock is:

$$\text{Cross – dock cost} = \begin{cases} 0 & \text{Internal hub} \\ CDU * CW & \text{External hub} \end{cases} \quad 5-7$$

CDU: Cost unit for cross – dock (EUR/kg)

CW: Cargo weight (kg)

The CDU (Cost unit for cross-dock) is a fixed number at the case company based on their internal research.

## 6) Route-specific cost

Route specific cost is a route-related cost that consists of two parts, on-road charge and inter-modal fee.

On-road charge occurs when the vehicle needs to pass a tunnel, bridge, and a certain road with the toll. The standard road charge is set differently in different countries and varies based on the type of vehicle. For example, in Germany, the price for passage tunnel increases with the increase of truck height of the truck (Tolls.eu, 2020).

As interpreted in section 1.3 of chapter 1, the inter-modal fee is a fixed price paid to ferry operator or rail operator. A typical example of an intermodal fee at the case company is the waterway between the Port of Gothenburg and Port of Gent. As stated in section 1.3 of chapter 1, the inter-modal in this research is the transportation of the whole truck or trailer without any additional loading and unloading and the detailed cost structure of the inter-modal fee will not be investigated.

The logic for calculating route-specific cost is to sum all the fees occurred in each charged section within the whole route, which could be indicated in:

$$\text{Route – specific Cost} = \sum_i PRS_i + \sum_j PIS_j \quad 5-8$$

*PRS: Price for on – road charge section*

*PIS: Price for inter – modal fee section*

Although formula 5-8 shows the calculation logic, it is rather difficult to use because this requires large manual work to check the charged sections along the route and look for the corresponding prices. It becomes even more difficult when the route is not domestic because different countries have different standards for toll charges. Therefore, another practical method to get real-time route-specific costs is to connect with external databases, such as commercial toll engines.

### 7) Digital platform cost

Digital platform cost is the fee paid to the platform where the transaction between shipper and carrier happens. The traditional way of transactions is through e-mail, thus the digital platform cost will be zero. At the case company, it is common now the transaction happens in a third-party platform and there will be a fixed cost for it.

$$\text{Digital platform cost} = \begin{cases} 0 & E - mail \\ X & Thrid - party platform \end{cases} \quad 5-9$$

*(Source: Own elaboration)*

### 8) Other overhead

Other overhead (overhead cost) is also a kind of indirect cost including advertising, office equipment, and other elements (Berwick & Farooq, 2003). Overhead consists of not only the part that cannot be attributable to specific units of output, i.e. fixed cost, but also some parts that can be seen as variable costs (Casavant, 1993). In this research, the overhead is seen as a cost on the top of other costs, which could be calculated by:

$$\text{Other Overhead} = OP * (FC + LC + RSC + MRC + CMC + DC + TC + GC + IC + GC + CC) \quad 5-10$$

OP: Percentage of other overhead

FC: Fuel cost (EUR)

LC: Labor cost (EUR)

RSC: Route specific cost (EUR)

MRC: Maintenance and repair cost (EUR)

CMC: Consuming material cost (EUR)

DC: Depreciation cost (EUR)

TC: Tax cost (EUR)

GC: Garage cost (EUR)

IC: Insurance cost (EUR)

CC: Cost of capital (EUR)

The cost elements mentioned in 5-10 will all be calculated in the following sections.

### 9) Depreciation of vehicle and trailer (Depreciation cost)

The depreciation cost is calculated for both trucks and trailers if the equipment for transport includes a trailer.

### Truck Depreciation

In reality, the value of a vehicle depreciates with both mileage and age (Butler Jr, 1983; Ross, 1960). However, it is common that only one of them is considered when estimating vehicle operating costs as long as the whole value during usage is properly divided by the time or distance (Barnes & Langworthy, 2004; Berwick & Farooq, 2003; Sternad, 2019). In this calculation framework, the depreciation cost of the truck is calculated based on mileage, which means it is categorized as a variable cost. The reason is that the vehicle in the estimation is in the high-intensity of use, thus the depreciation caused by wear and tear will be dominant.

Some research figures that the depreciation process is not a straight line over the lifetime period. Instead, it is a concave curve with a higher rate at first and a lower rate later (Electrification Coalition, 2010). However, in the cost estimation phase, it is hard to predict the age or used mileage for the vehicle that is going to run the trip. Some studies also treat the depreciation rate as constant (Jacyna & Wasiak, 2015; Sternad, 2019). In this research, this assumption is kept that:

*Assumption 4: The depreciation of a vehicle is line-based, i.e. the depreciation rate is constant.*

The salvage value of the vehicle is also critical in calculating the depreciation cost since it will determine the value of the vehicle during the usage period. A vehicle normally has a suggested lifetime distance. If the driven distance has exceeded the lifetime distance, the vehicle should be scrapped. If a vehicle has run out of the lifetime distance, it still has a salvage value for recycling. For transport-service providers, normally they will not use up all the lifetime distance. Instead, they will run a car for a certain number of years and sells it in the second-hand market. An assumption is made that:

*Assumption 5: The selling value of a vehicle depends on the left distance for driving and the minimum will the salvage value when all lifetime distance is used up.*

With assumption 4 and assumption 5, the selling value for a vehicle is:

$$\text{Selling Value of Vehicle (SVV)} = \text{Vkl} * \left( \frac{\text{VLD} - \text{AM} * \text{VRY}}{\text{VLD}} + \text{VSVP} \right) \quad 5-11$$

Further, the depreciation cost of the vehicle could be calculated by the following formula:

$$\text{Depreciation Cost of Vehicle} = \frac{\text{Vkl} - \text{SVV}}{\text{AM} * \text{VRY}} * \text{TD} \quad 5-12$$

The final formula is obtained by joining equations 5-11 and 5-12 .

$$\text{Depreciation Cost of Vehicle} = \text{Vkl} * \left( \frac{1}{\text{VLD}} - \frac{\text{VSVP}}{\text{AM} * \text{VRT}} \right) * \text{TD} \quad 5-13$$

Vkl: Vehicle investment (EUR)

VLD: Vehicle lifetime distance (km)

VSVP: Vehicle salvage value percentage when all the distance has used up

AM: Annual mileage (km)

VRV: Running time of the vehicle for transport operator(days/year)

TD: Trip distance (km)

AM (Annual mileage) is the distance that a vehicle can drive per year, which is calculated from formula 5-14:

$$\text{Annual Mileage} = \text{TPD} * \text{TD} * 2 \quad 5-14$$

TPD: Trips per day

TD: Trip distance (km)

In the formula above, TPD (Trips per day) is calculated from the formula 5-21 with the corresponding assumptions.

### Trailer Depreciation

If a trailer is used in the transport, the depreciation for the trailer should also be included and it follows the same calculation logic and vehicle. Therefore, the equation is:

$$\text{Depreciation Cost of Trailer (DCT)} = \text{TrI} * \left( \frac{1}{\text{TLD}} - \frac{\text{TSVP}}{\text{AM} * \text{TRT}} \right) * \text{TD} \quad 5-15$$

*(Source: Own elaboration)*

TrI: Trailer investment (EUR)

TLD: Trailer lifetime distance (km)

TSVP: Trailer Salvage value percentage when all the distance has used up

AM: Annual mileage (km)

TRT: Running time of the trailer for transport operator(year)

TD: Trip distance (km)

### Depreciation Cost

With results from equation 5-13 and 5-15, the depreciation cost is:

$$\text{Depreciation Cost of Trailer} = \text{DCV} + \text{DCT} \quad 5-16$$

DCV: Depreciation cost for the vehicle (EUR)

DCT: Depreciation cost for the trailer (EUR)

## 10) Additional trailer depreciation

Besides ordinary depreciation, the trailer has another part of depreciation cost which occurs when the trailer stands for waiting during custom, intermodal, and drop trailer process. Although in these processes, the trailer doesn't move with the truck, it still has depreciation related to how many days it stands. The formula is:

$$\text{Additional trailer depreciation cost} = \frac{\text{TrI}}{\text{TrBD} * \text{TrOY}} * (\text{DRT} + \text{CD} + \text{IMT}) \quad 5-17$$

TrI: Trailer investment (EUR)

TrBD: Trailer business days per year (days)



TrOY: Trailer owning years (years)

DRT: Drop trailer time (days) (both drop trailer time at both destination and origin)

CD: Custome time (days)

IMT: Inter – modal time (days)

### 5.1.1.3 Third breakdown

According to the demand of Volvo that the waiting and handling cost, which refers to the total cost generated by the garage, tax, labor cost, cost of capital and insurance during the waiting and handing time, should be calculated separately as an individual cost element, those five cost elements of garage, tax, labor cost, cost of capital and insurance need to be broken down for a further step. Besides, backhaul cost and the backward trip cost for a round trip should also be considered, which are the costs that take all the relevant cost elements into account during the process of backhaul or backward trip. Thus, the third breakdown is formed.

For the third breakdown, the cost elements of waiting and handling cost, backhaul cost, and backward trip cost are formed, along with the newly broken-down cost elements of labor cost, tax for vehicle and trailer, garage, insurance for vehicle and trailer, and cost of capital, which have separated their portions of the handling and waiting time.

#### 11) Labor cost

The labor cost in this research only refers to the payment for the vehicle drivers. No labor cost for other personnel is considered. Besides, two points should be noticed before the calculation. The labor cost calculated in this section is the cost during driving time. The labor cost occurs in waiting and handling is categorized in waiting and handling cost. What's more, the labor cost here is only the cost from the origin to destination (one-way). The labor cost that happens in backhaul is categorized in backhaul cost.

#### Yearly Gross Income and Daily Compensation

Labor cost is calculated based on an hourly rate. The cost of a driver consists of four parts: basic salary, overtime payment, bonus, and travel allowance. Basic salary, overtime payment, and bonus form the gross income for a driver. Travel allowance is set to cover the daily expense during the trip, including meals and accommodation (Comité National Routier, 2018). Both gross income and travel allowance are subject to countries. A driver from France normally gets more gross income compared with a driver from the Czech Republic. In this calculation, an assumption is made that:

*Assumption 6: the gross income of the driver depends on the country of the transport service provider*

Travel allowance is related to the living expense of each country. The allowance for a trip is set based on the countries that this route goes through. If the driver needs to spend one day in France, the allowance for this day should meet the living standard in France, even though the driver and transport company both come from the Czech Republic (Comité National Routier, 2018).

## Driver working time

The yearly gross salary and daily travel compensation are obtained from the internal database of Volvo. The next step is to calculate the hourly cost, which requires the working time of a driver for one year. The working time could be divided into two parts: driving time and others. Others include break, period of availability (POA), and other work (Department forTransport, 2017).

$$\text{Driver working time} = \text{Driver driving time} + \text{Others} \quad 5-18$$

$$\text{Others} = \text{Break} + \text{POA} + \text{Other work} \quad 5-19$$

EU has set the limitation on driving time and working time per day for a driver. If only one driver drives the vehicle, which is called “Solo”, the driving time on average cannot exceed 9 hours per day and the working time cannot exceed 13 hours per day. If two drivers are driving the vehicle, called “Team”, the time cycle for calculation is changed from 24 hours (1 day) to 30 hours. Within a time cycle, each of them can drive 10 hours for maximum and there is an additional one 1 hour for other work. Therefore, when there are two drivers in the cabin, the driving time limit is 20 hours and the working time limit is 21 hours during a time cycle of 30 hours. The illustration of the driver working hour limit is shown in Table 5-1 and Table 5-2.

Table 5-1 Working hours for one driver (Source: Department forTransport (2017))

24h Period				
Driving Time	Break	Driving Time	Other Work	Rest
		13 h		11h

Table 5-2 Working hours for two drivers (Source: Department forTransport (2017))

	Driver 1	Driver 2
Time Cycle of 30h	Other work 1h	Daily Rest 1h
	Driving 4.5h	Availablity 4.5h
	Break + Availablity 4.5h	Driving 4.5h
	Driving 4.5h	Break + Availablity 4.5h
	Break + Availablity 4.5h	Driving 4.5h
	Driving 1h	Break + Availablity 1h
	Break 1h	Driving 1h
	Daily Rest 9h	Daily Rest 9h

To calculate the actual working time of the driver, two assumptions are made:

*Assumption 7: The vehicle only runs this route for the whole year and there is no limit on the number of trips per year.*

*Assumption 8: The vehicle goes from the origin with cargo and returns in empty, and there will be no stop in the back trip. The whole process is called one trip.*

With two assumptions above, the working hours for a driver per day can be obtained by:

$$\text{Driver working hours per day} = \text{Trips per day} * \text{Duration of one trip} \quad 5-20$$

Where:

$$\text{Trips per day} = 1 / \left( \frac{TD * 2}{DTL * AveS} + \frac{HWT}{WTL} \right) \quad 5-21$$

$$\text{Duration of one trip} = \frac{TP * 2}{AveS} + HWT \quad 5-22$$

TD: Trip distance (km)

AveS: Average speed (km/h)

DTL: Driving time limit (hours); in the EU, it is 9 hours per day

HWT: Handling and waiting time (hours)

WTL: Working time limit (hours); in the EU, it is 13 hours per day

Then the working hours per year is calculated with the formula:

$$\text{Driver working hours per year} = \text{DWHD} * \text{DWDY} \quad 5-23$$

DWHD: Driver working hours per day (hours/day)

DWDY: Driver working days per year (days/year)

### Average Speed

In formula 5-21 and 5-22, an important input is an average speed of this trip which will also appear in formulas in the following sections. Average speed is used to calculate the driving time of this trip. Many factors could influence the average speed. The first one is the speed limit regulation, which is set differently in different countries. In Italy, for a vehicle over 12 tons, the maximum speed in the urban area is 50km/h and 80 km/h on the motorway, while in Sweden, the maximum speed is 90km/h on the motorway (European Commission, 2020). Besides policies speed limit, other factors could also impact the average speed in real operations, such as traffic conditions, accidents. However, in this estimating framework, it is reasonable to ignore these arbitrary factors and focus on the influence of the speed limit.

### Team index

It has mentioned in the calculation above that sometimes there could be two drivers driving in turns for one trip. However, according to a conversation with Volvo's employee, the transport company will not pay double salaries in this case. Instead, the payment is a bit lower than the doubled figure, which is indicated as the team index in the calculation. In this research, the ratio

between the output of two drivers and one driver is used as the value for the team index. The formula is:

$$\text{Team index} = \frac{\frac{DWHT}{WTLT}}{\frac{DWHS}{WTLS}} \quad 5-24$$

DWHT: Driver working hours (Team) (hours/day)

WTLT: Working time limit (Team); in the EU, it is 21 hours per day

DWHS: Driver working hours (Solo) (hours/day)

WTLS: Working time limit (Solo); in the EU, it is 13 hours per day

In this formula, DWHT and DWHS are calculated from formula 5-20, 5-21, and 5-22, with the different driving time limits and working limit corresponding to Solo and Team.

### HAZMAT and night work

HAZMAT refers to any substance that could cause harm to people, property, and the environment (Yilmaz, Serpil, & Aplak, 2016). Most member states of the EU follow the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), which requires the driver to take basic training and get a certificate to be applicable in handling HAZMAT goods (European Commission, 2008). Therefore, the driver for a shipment with HAZMAT is more costly than an ordinary driver, which is indicated as a HAZMAT index in the calculation.

Night work will negatively influence the health of drivers and raise the risk of accidents. Therefore, drivers should be compensated for driving at night (European Commission, 2002). In this thesis, the extra cost resulting from night work is indicated as night premium factor.

### Hourly rate and labor cost

With the results from the calculations above, the hourly rate of a driver could be calculated by the following formula:

$$\text{Labor Hourly Rate (LHR)} = \frac{GI}{DWHY} + \frac{DC}{DWHY} \quad 5-25$$

GI: Yealy gross income (EUR/year)

DWHY: Driver working hours per year (hours/year)

DC: Daily compensation (EUR/day)

DWHD: Driver working hours per day (hours/day)

$$\text{Labor cost} = \text{LHR} \times \frac{TD}{\text{AveS}} \quad 5-26$$

TD: Trip distance (km)

LHR: Labor hourly rate (EUR/h)

AveS: Average speed (km/h)

Where DWHY (Driver working hours per year) is calculated from formula 5-23 and DWHD (Driver working hours per day) is calculated from formula 5-20, 5-21, and 5-22.

### 12) Tax for vehicle and trailer

The tax cost calculated in this section is the cost during the driving time, while the part occurs during the waiting and handling time will be included in waiting and handling cost.

The yearly tax differs among different vehicle types. In some countries, such as the Netherlands and Finland, the lorry with more axles and more weight will be charged more in tax. What's more, the tax also varies from country to country since different countries are applying different tax calculation system (European Commission, 2020). Then the tax cost for one trip could be calculated by first dividing the yearly tax with the yearly working hours to get the hourly rate, then timing the traveling time of this trip. The formula is written as:

$$\text{Hourly Rate of Tax Cost (HRTC)} = \frac{YT}{DWHD * VRT} \quad 5-27$$

$$\text{Tax Cost} = \text{HRTC} * \frac{TD}{\text{AveS}} \quad 5-28$$

YT: Yearly tax (EUR)

DWHD: Driver working hours per day (hours/day)

VRT: Running time of the vehicle for transport operator(days/year)

HRTC: Hourly rate of tax cost (EUR/h)

TD: Trip distance (km)

AveS: Average speed (km/h)

In the formula above, DWHD (driver working hours per day) could be obtained with formula 5-20, 5-21, and 5-22.

### 13) Garage cost

Garage cost refers to the price that the vehicle operator needs to pay to use the garage facility (Casavant, 1993). The calculation of garage cost follows a similar logic as tax cost. This section only calculates the garage cost during the driving time and the cost occurs in waiting and handling time is categorized in waiting and handling time.

$$\text{Hourly Rate of Garage Cost (HRGC)} = \frac{YG}{DWH * VRT} \quad 5-29$$

$$\text{Garage Cost} = \text{HRGC} * \frac{TD}{\text{AveS}} \quad 5-30$$

YG: Yearly garage cost (EUR)

DWH: Driver working hours per day (hours/day)

VRT: Running time of the vehicle for transport operator(days/year)

HRGC: Hourly rate of garage cost (EUR/h)

TD: Trip distance (km)

AveS: Average speed (km/h)

In the formula above, DWH (driver working hours per day) could be obtained with formula 5-20, 5-21, and 5-22.

### 14) Insurance for vehicle and trailer

In the EU, all motor vehicles must be covered by third party insurance to cover the loss caused by accidents (European Parliament, Council of the European Union, 2009). Insurance cost calculation follows a similar logic as tax cost. The insurance cost obtained in this section is also the cost during the driving time, while the cost occurs during the waiting and handling time will be involved in the waiting and handling cost.

$$\text{Hourly Rate of Insurance Cost (HRIC)} = \frac{YI}{DWH \cdot VRT} \quad 5-31$$

$$\text{Insurance Cost} = HRIC * \frac{TD}{AveS} \quad 5-32$$

YI: Yearly Insurance (EUR)

DWH: Driver working hours per day (hours/day)

VRT: Running time of the vehicle for transport operator(days/year)

HRIC: Hourly rate of insurance cost (EUR/h)

TD: Trip distance (km)

AveS: Average speed (km/h)

In the formula above, DWH (driver working hours per day) could be obtained with formula 5-20, 5-21, and 5-22.

### 15) Cost of capital

Cost of capital is a type of fixed cost which results from two sources, vehicle ownership, and payment terms. The cost of capital caused by vehicle ownership is understood as either opportunity cost or expected return of long-term investment during a certain period, while the cost of capital generated by payment terms is either opportunity cost or expected return for transport-service provider paying for clients during the negotiated period (Casavant, 1993). Therefore, the calculation of the cost of capital could be seen as the reverse calculation of the Accounting Rate of Return (ARR) which is the expected rate of return for a certain investment. This relationship could be expressed as:

$$ARR = \frac{AP}{AI} * 100\% \quad 5-33$$

*Source:* (Erickson, 2013; Velnampy, 2005)

$$\text{Overall Cost of Capital (AP)} = AI * CCP(ARR) \quad 5-34$$

*Source:* (Berwick & Farooq, 2003)

AP: Average profit(EUR)

AI: Average investment (EUR)

CCP: Cost of capital percentage

In the calculation, the term “cost of capital percentage” in formula 5-34 is used to indicate the expected return rate of investment and is the same as ARR in formula 5-33. Same as tax, insurance, and garage cost, only the cost occurs during driving time is calculated in this section.

### Cost of capital from ownership

The transport-service provider could have two options in owning a vehicle, buying, or leasing for a certain period (Berwick & Farooq, 2003). The carrier could apply either one of them or a mixed strategy. In the calculation, an assumption is made that:

*Assumption 9: The transport-service provider owns the vehicle by purchasing.*

The average investment consists of two parts, initial investment and salvage value. Salvage value is accounted as part of average investment because this is the part of the value that could be made in resale at any time but is held during this period (Erickson, 2013) . Therefore, the cost of capital resulted from vehicle ownership is calculated by:

$$\text{Hourly Rate of Cost of Capital from Vehicle Ownership} = \frac{\frac{VI+VSV}{2} * CCP}{VRT * DWHD} \quad 5-35$$

$$\text{Cost of Capital from Vehicle Ownership} = HRCCV * \frac{TD}{AveS} \quad 5-36$$

Source: (Erickson, 2013)

VI: Vehicle investment (EUR)

VSV: Vehicle salvage value (EUR)

CCP: Cost of capital percentage

DWHD: Driver working hours per day (hours/day)

VRT: Running time of the vehicle for transport operator(days/year)

HRCCV: Hourly rate of the cost of capital from vehicle ownership (EUR/h)

TD: Trip distance (km)

AveS: Average speed (km/h)

In the formula above, DWHD (driver working hours per day) could be obtained with formula 5-20, 5-21, and 5-22.

### Cost of capital from payment terms

There are three types of payment terms, advance payment, cash payment, and credit payment (Velnampy, 2005). In this calculation, credit payment, which is a permissible day in payment, is focused as it causes capital cost for the transport service provider. The delay is negotiated by the purchasing company and service provider. To simplify the calculation, an assumption is made that:

*Assumption 8: A year has 360 days when calculating the cost of capital generated from payment terms.*

Taking payment term of 90 days as an example and a simplified cash flow of transport-service provider could be visualized as:

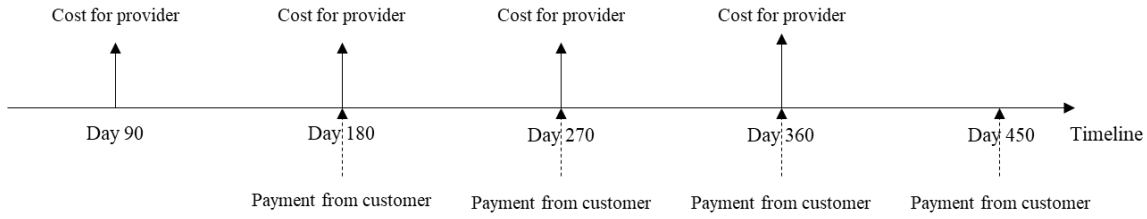


Figure 5-3 Illustration of payment terms

From Figure 5-3, it could be understood that the transport-service provider holds the variable costs of 90 days for one year (360 days), which is the annual cost of capital cost by payment terms. Four types of variable costs are included, labor cost, fuel cost, maintenance and repair cost, and consuming material cost. Therefore, the cost of capital caused by the credit payment term is calculated as:

$$\text{Hourly Rate of Cost of Capital from Payment Terms} = \frac{AFC + ALC + AMRC + APMC}{360/PTD} * \frac{1}{VRT * DWHD} * CCP \quad 5-37$$

$$\text{Cost of Capital from Payment Terms} = HRCCPT * \frac{TD}{AveS} \quad 5-38$$

AFC: Annual fuel cost (EUR)

ALC: Annual labor cost (EUR)

AMRC: Annual maintenance and repair cost (EUR)

APMC: Annual consuming cost (EUR)

PTD: Payment term days (day)

DWHD: Driver working hours per day (hours/day)

VRT: Running time of the vehicle for transport operator(days/year)

CCP: Cost of capital percentage

HRCCPT: Hourly Rate of Cost of Capital from Payment Terms (ERU/h)

TD: Trip distance (km)

AveS: Average speed (km/h)

Where:

$$\text{Annual Fuel Cost} = AM * FC * FP \quad 5-39$$

$$\text{Annual Labor Cost} = GI + DC * DWDY \quad 5-40$$

$$\text{Annual Maintenance and Repair Cost} = AM * CI * MRBU \quad 5-41$$

$$\text{Annual Consuming Material Cost} = AM * CI * (TBU + LBU) \quad 5-42$$

AM: Annual mileage (km)

FC: Fuel consumption (l/km)

FP: Fuel price (EUR/liter)

GI: Yealy gross income (EUR/year)



DWDY: Driver working hours per year (hours/year)

DC: Daily compensation (EUR/day)

CI: Country – specific index

MRBU: Maintenance and repair basic cost unit (EUR/km)

TBU: Tire basic cost unit (EUR/km)

LBU: Lubricant basic cost unit (EUR/km)

AM (Annual mileage) can be calculated with formula 5-14 in the section of depreciation cost.

With the results from formula 5-36 and 5-38, the cost of capital is obtained by:

$$\text{Cost of Capital} = \text{CCPVO} + \text{CCPPT} \quad 5-43$$

CCPVO: Cost of capital from vehicle ownership (EUR)

CCPPT: Cost of capital from payment terms (EUR)

### 16) Handling and waiting cost

Handling and waiting cost occurs during the loading and unloading process to collect and deliver cargo at stops along the route. During the loading and unloading process, the vehicle stands still, thus the distance-based cost would not be generated, such as fuel cost, consuming material cost. The time-related cost occurs during waiting and handling time, including labor cost, tax cost, insurance cost, garage cost, cost of capital. The hourly rate for those cost elements has been got from previous sections. Another factor to obtain handling and waiting cost is handling and waiting time, which is determined by the no of stops and average waiting time at each stop. Therefore, the handling and waiting cost could be calculated by:

$$\text{Handling and waiting cost} = (\text{LHR} + \text{THR} + \text{IHR} + \text{GHR} + \text{CCPVOHR} + \text{CCPPTHR}) * (\text{NoS} * \text{AHWT}) \quad 5-44$$

LHR: Hourly rate of labor cost(EUR/h)

THR: Hourly rate of tax cost(EUR/h)

IHR: Hourly rate of insurance cost(EUR/h)

GHR: Hourly rate of garage cost(EUR/h)

CCPVOHR: Hourly rate of the cost of capital from vehicle ownership (EUR/h)

CCPPTHR: Hourly rate of the cost of capital from payment terms (EUR/h)

NoS: Number of stops (include origin and destination)

AHWT: Average handling and waiting time at each stop (h)

In the formula, LHR, THR, IHR, CCPVOHR, and CCPPTHR can be calculated from formula 5-25, 5-27, 5-29, 5-31, 5-35, and 5-38 respectively.

### 17) Backhaul cost

Backhaul is to haul a shipment or empty load over part of the route it has traveled from (Reichert & Vachal, 2000; Fekpe, Alam, Foody, & Gopalakrishna, 2002). Cooper et al., (2008) has discussed four methods in dealing with the cost generated by the backhaul trip. In this research,

the second method is applied which is to assume a backhaul factor as the percentage of the cost in the front-trip.

The backhaul factor between origin and destination depends on the relative cargo flow of the two countries. If the destination is a 'net producer country' which means the flow out is larger than the flow in, there will be a larger opportunity to organize a backhaul trip with a higher filling degree (Mentzer, 1986). Therefore, the backhaul factor will be lower in this case. Therefore, the backhaul cost is calculated by multiplying the backhaul factor with the cost of front-trip:

$$\text{Backhaul Cost} = \text{BP} * (\text{FC} + \text{LC} + \text{RSC} + \text{MRC} + \text{CMC} + \text{DC} + \text{TC} + \text{GC} + \text{IC} + \text{GC} + \text{CC} + \text{OC}) \quad 5-45$$

*Source:* (Cooper, Woods, & Lee, 2008)

BP: Backhaul percentage

FC: Fuel cost (EUR)

LC: Labor cost (EUR)

RSC: Route specific cost (EUR)

MRC: Maintenance and repair cost (EUR)

CMC: Consuming material cost (EUR)

DC: Depreciation cost (EUR)

TC: Tax cost (EUR)

GC: Garage cost (EUR)

IC: Insurance cost (EUR)

CC: Cost of capital (EUR)

OC: Other overhead (EUR)

### 18) Backward trip cost

If the trip to be calculated is a round trip which means there are cargos in the return, backward trip cost will be applied and backhaul cost will not be included. An assumption is made for the backward trip:

*Assumption 9: The route of the backward trip is the same as the route of front-haul.*

This assumption makes sure the trip distance and route-specific cost will remain the same in the backward trip. Therefore, the backward trip cost is:

$$\text{Backward trip cost} = \text{FC} + \text{LC} + \text{RSC} + \text{MRC} + \text{CMC} + \text{DC} + \text{TC} + \text{GC} + \text{IC} + \text{GC} + \text{CC} + \text{OC} \quad 5-46$$

FC: Fuel cost (EUR)

LC: Labor cost (EUR)

RSC: Route specific cost (EUR)

MRC: Maintenance and repair cost (EUR)

CMC: Consuming material cost (EUR)

DC: Depreciation cost (EUR)

TC: Tax cost (EUR)

GC: Garage cost (EUR)

IC: Insurance cost (EUR)

CC: Cost of capital (EUR)

OC: Other overhead (EUR)

### 5.1.2 Design of Carbon emission section

The total carbon emissions are broken down into two elements: transport-related carbon emissions, and cross-dock related carbon emissions, as shown in Figure 5-4.

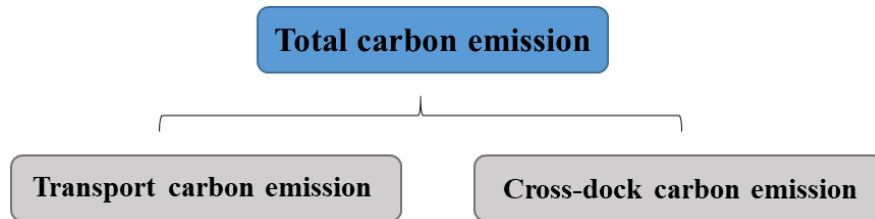


Figure 5-4 Breakdown of carbon emissions

#### 19) Transport carbon emissions

The carbon emissions generated during transport mainly result from fuel consumption. Besides the difference in fuel consumption level among different vehicle types, the carbon emissions of a vehicle could also vary from brand to brand, version to version, depending on the technology the vehicle used. However, in this research, only the basic carbon emissions caused by fuel consumption is considered. More advanced differences will be ignored. An assumption is made that:

*Assumption 13: All the carbon in the fuel is burned fully and converts to carbon dioxide.*

The carbon emissions are determined by the fuel consumption level of the vehicle as well as the carbon content and density of the fuel type (Network for Transport Measure, 2015). Carbon content refers to the carbon content of the fuel as a percentage of its mass (HOMER Energy, 2014). Both carbon content and fuel density can be obtained from the public data source on fuel information. In this research, the density of diesel is 0.832 kg/L (Engineering ToolBox, 2003), while the carbon density of 86.2% (Ecoscore, 2020). The carbon emissions happen during transport can be calculated by:

$$\text{Transport Carbon Emissions} = \text{TD} * \text{FC} * \text{FD} * \text{CC} * \text{MWR} \quad 5-47$$

*Source:* (Network for Transport Measure, 2015)

FC: Fuel consumption (liter/km)

FD: Fuel density (kg/liter)

CC: Carbon content (%)

MWR: Molecular weight relations

TD: Trip distance (km)

In formula 5-47, MWR (Molecular weight relations) is equal to 44/12. This variable is used to convert the weight of carbon to the weight of carbon dioxide.

## 20) Cross-dock carbon emissions

If the route to be calculated consists of cross-dock at the logistics hub, the carbon emissions in this process should also be included. Assessing the carbon emissions level at logistics facilities is a complex process because the emissions level differs from the type of the facility and functions performed in the facility (Rüdiger, Schön, & Dobers, 2016; Dobers, Ehrler, Davydenko, Rüdiger, & Clausen, 2019). In this research, the cargo being transported needs to quickly go through the cross-dock process at the logistics hub and be shipped to the destination within the lead time. Therefore, the logistics hub is a transshipment terminal with a focus on the cross-dock process. The carbon emissions from cross-dock is calculated by:

$$\text{Cross – dock Carbon Emissions} = \text{CDCEU} * \text{WS} \quad 5-48$$

*Source:* (Dobers, Ehrler, Davydenko, Rüdiger, & Clausen, 2019; Rüdiger, Schön, & Dobers, 2016)

CDCEU: Cross – dock carbon emissions unit (EUR/kg)

WS: Weight of the shipment (kg)

### 5.1.3 Summary of fact data

The data source used to estimate the cost elements in the basic framework is summarized in Table 5-3.

Table 5-3 Source of fact data in estimating freight rate

Section	Data type	Example	Source
Road freight rate section	Vehicle-related data	Truck investment; fuel consumption...	Internal database of Volvo
	Country-related data	Working time	Department for Transport (2017)
		Gross salary, daily compensation	Internal database of Volvo
	Profit		An estimated percentage from Volvo
	Route-related data	Distance, toll cost...	External toll engine used by Volvo
	Lane setting	Single/round, drop trailer, origin, destination	Bid information of Volvo
	Cross-dock cost unit		Figure provided by Volvo
Carbon emission section	Booking platform cost unit		Figure provided by Volvo
	Fuel consumption		Volvo internal database
	Fuel-related data	Carbon content, fuel density	Engineering ToolBox (2003)
			Ecoscore (2020)
	Cross-dock carbon emission unit		Dobers et al., (2019) Rüdiger et al., (2016)

## 5.2 Calculation of Modules and set-ups

### 5.2.1 The design of modules

Each transport set-up consists of several activities. For example, the DDS set-up includes line-haul transport, cross-dock, and distribution. Different activities should comprise different cost elements and be calculated in different ways. To build up the connection between the calculation methods for cost elements and the estimation of the total rate for each transport set-up, modules are introduced as intermediate.

The modules are derived from the activities in each transport set-up. They are designed to build connections between transport set-ups and the basic framework. The relations are shown in Figure 5-5. Each module includes a set of relevant cost elements, while different modules can be combined to form a transport set-up. The division of the modules and the cost elements included in each module are established according to the analysis of the four Volvo's transport set-ups, which has been introduced in section 4.3.2. As is shown in Figure 5-5, five modules are introduced for the road freight rate section, the FTL line-haul module, the LTL line-haul module, the Distribution module, the Cross-dock module, and the Digital platform module. Four modules are introduced for the carbon emission section, FTL line-haul carbon emissions module, LTL line-haul carbon emissions module, distribution carbon emissions module, and cross-dock carbon emissions module.

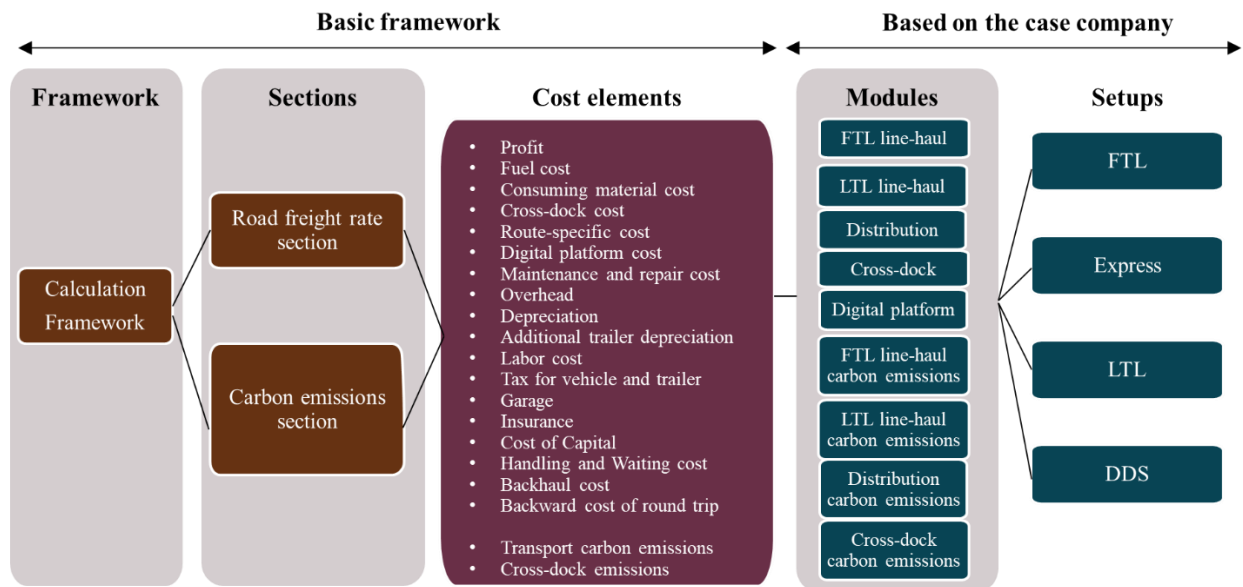



Figure 5-5 Basic framework, modules, and set-ups

## 5.2.2 Modules and set-ups in road freight rate section

### 5.2.2.1 Cost elements in modules

In Table 5-4, the cost elements included in each module are listed. The left column is the 18 cost element in the road freight rate section, while the top row is the name of modules in the section. If the cell is marked by “Y”, it means the cost element is included in the corresponding module. For example, the FTL line-haul module includes all the cost elements, and LTL line-haul module includes the cost elements besides additional trailer depreciation and backward cost a round trip.



	FTL line-haul MOD	LTL line-haul MOD	Distribution MOD	Cross-dock MOD	Digital platform MOD
1) Profit	Y	Y	Y		
2) Fuel cost	Y	Y	Y		
3) Consuming material	Y	Y	Y		
4) Cross-dock cost				Y	
5) Route specific cost	Y	Y	Y		
6) Digital platform cost					Y
7) Maintenance and repair cost	Y	Y	Y		
8) Other overhead	Y	Y	Y		
9) Depreciation (Vehicle and trailer)	Y	Y	Y		
10) Additional trailer depreciation	Y				
11) Labor cost	Y	Y	Y		
12) Tax for vehicle and trailer	Y	Y	Y		
13) Garage	Y	Y	Y		
14) Insurance for vehicle and trailer	Y	Y	Y		
15) Cost of capital	Y	Y	Y		
16) Handling and waiting cost	Y	Y	Y		
17) Backhaul cost (if applied)	Y	Y			
18) Backward cost of round trip (if applied)	Y				

Table 5-4 The modules and cost elements included

### 5.2.2.2 Set-ups and modules

The following figures illustrate the connection and relation between the set-ups and the modules, i.e. how the modules are combined to form each transport set-up at the case company.

### FTL set-up

The FTL set-up, according to the set-up introduction mentioned in section 4.3.2 can be seen as a combination following the sequence of an FTL line-haul module and a digital platform module, as is shown in Figure 5-6.

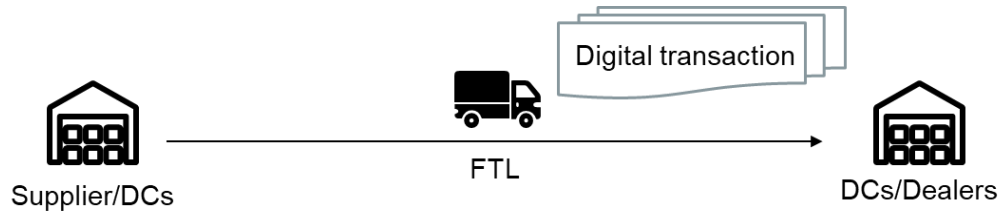


Figure 5-6 FTL set-up and modules involved

### Express set-up

The Express set-up is similar to the FTL set-up, with the only difference of vehicle type that is used for the delivery, as is introduced in section 4.3.2. As a result, the Express set-up can also be seen as a combination following the sequence of an FTL line-haul module and a Digital platform module.

### LTL set-up:

The LTL set-up, according to set-up introduction mentioned in section 4.3.2 can be seen as a combination following the sequence of a (pick-up) Distribution module, a Cross-dock module, an LTL line-haul module, a Cross-dock module, and a (delivery) Distribution module; plus a Digital platform module, as is shown in Figure 5-7.

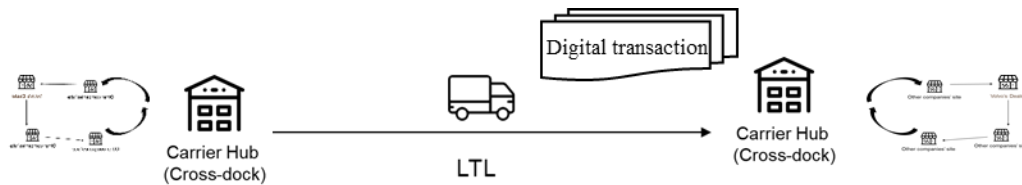


Figure 5-7 LTL set-up and modules involved

### DDS set-up

The DDS set-up, according to the set-up introduction mentioned in section 4.3.2 can be seen as a combination following the sequence of an LTL line-haul module, a Cross-dock module, and a Distribution module; plus a Digital platform module, as is shown in Figure 5-8.

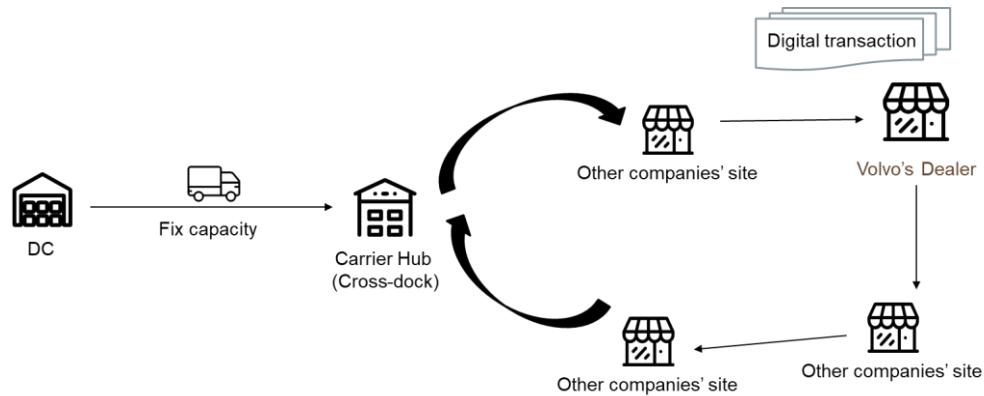


Figure 5-8 DDS set-up and modules involved

The result for the road freight rate calculation of each set-up is the sum-up result of the road freight rate calculation figure from all the corresponding modules in the set-up. In the next section, the method of how to calculate all the cost elements within a specific module will be illustrated.

### 5.2.2.3 Calculation method for each module

#### 1) FTL line-haul module

In the FTL line-haul module, the whole vehicle is dedicated to the shipment, thus all the cost will be allocated to the shipment. Therefore, the cost of the FTL line-haul module is the sum-up of all the cost elements.

$$\text{Cost of FTL linehaul module} = FC + LC + RSC + MRC + ATD + CMC + DC + TC + GC + IC + GC + CC + OC + \begin{cases} BHC \\ BWC \end{cases} \quad 5-49$$

FC: Fuel cost (EUR)

LC: Labor cost (EUR)

RSC: Route specific cost (EUR)

MRC: Maintenance and repair cost (EUR)

MRC: Additional trailer depreciation cost (EUR)

CMC: Consuming material cost (EUR)

DC: Depreciation cost (EUR)

TC: Tax cost (EUR)

GC: Garage cost (EUR)

IC: Insurance cost (EUR)

CC: Cost of capital (EUR)

BHC: Backhaul cost (EUR)

BWC: Backward trip cost(EUR)

OC: Other overhead (EUR)

The cost elements in the formula are calculated from formulas in section 5.1.1. Only one of BHC (backhaul cost) and BWC (Backward trip cost) will be applicable, depending on if it is a single trip or round trip.

#### 2) LTL line-haul module



In LTL line-haul, the cost for the vehicle is the same as an FTL line-haul transport. However, the shipment only accounts for a part of the whole loads so that only part of the total cost should be allocated to the shipment. The allocation is based on the share of the shipment size to the loads in the vehicle. The assumption is made that:

*Assumption 10: The filling degree of the vehicle in LTL line-haul is 100% since the transport-service provider will manage to fill the vehicle through cross-dock.*

The size of the shipment is the chargeable weight of the shipment, which is the larger value between the actual weight and volumetric weight. Volumetric weight is a calculation converting the volume to weight to reflect the density of the cargo. A less dense item usually occupies more volume of the vehicle than the weight, thus it is more reasonable to charge it by volumetric weight rather than the actual weight (Borderlinx, 2020). The convert is done by a dim factor which is different for different transport modes and in different regions. In the EU, the dim factor is normally  $1m^3 = 333kg$  for road freight transport (DB Schenker, 2019).

$$\text{Charge Payload} = \text{Max}(\text{AC}, \text{DF} * \text{VS}) \quad 5-50$$

AC: Actual weight (kg)

DF: Dim factor

VS: Volume of the cargo ( $m^3$ )

Therefore, the cost of LTL line-haul is calculated by:

$$\text{CLTLM} = (\text{FC} + \text{LC} + \text{RSC} + \text{MRC} + \text{CMC} + \text{DC} + \text{TC} + \text{GC} + \text{IC} + \text{GC} + \text{CC} + \text{OC} + \text{BHC}) * \frac{\text{CP}}{\text{VC}} \quad 5-51$$

FC: Fuel cost (EUR)

LC: Labor cost (EUR)

RSC: Route specific cost (EUR)

MRC: Maintenance and repair cost (EUR)

CMC: Consuming material cost (EUR)

DC: Depreciation cost (EUR)

TC: Tax cost (EUR)

GC: Garage cost (EUR)

IC: Insurance cost (EUR)

CC: Cost of capital (EUR)

BHC: Backhaul cost (EUR)

CP: Chargeable payload (EUR)

OC: Other overhead (EUR)

VC: Vehicle capacity (kg)

CP (chargeable payload) is calculated from formula 5-50.

### 3) Distribution module

The Distribution module is more complex in reality than the FTL line-haul and LTL line-haul module, because a distribution cycle includes not only the destination of the shipment but also the sites for other customers of the transport-service provider. The stops and loads of distribution are

unknown in the cost estimating phase for both the shipper and the carrier. There are two main changes in the cost calculation of the distribution module.

### Change in variables

Two assumptions that influence the value of variables are made to make the calculation viable.

*Assumption 11 The length of a distribution cycle is  $x$  km on average.*

*Assumption 12: The average speed of a distribution cycle is  $v$  km/h.*

With assumption 11 and assumption 12, the maximum number of stops in a distribution cycle can be calculated by:

$$\text{No of stops} = \frac{DWHD - \frac{x}{v} - HWTH}{HWTS} \quad 5-52$$

DWHD: Driver working hours per day (hour/day)

$x$ : Trip distance of a distribution cycle(km)

$v$ : Average speed of the distribution cycle (km/h)

HWTH: Handling and waiting time at the hub (hour)

HWTS: Handling and waiting time at each stop (hour)

The total handling and waiting time of a distribution cycle is

$$\text{Handling and waiting time} = \text{NoS} * \text{HWTS} + \text{HWTH} \quad 5-53$$

NoS: Number of stops

HWTH: Handling and waiting time at the hub (hour)

HWTS: Handling and waiting time at each stop (hour)

In the calculation of each cost element, the new values of trip distance, average speed, and handling and waiting time should be used.

### Share of the shipment

Same as the logic in the LTL line-haul module, the shipment only accounts for a proportion of the total cost of the vehicle depending on the share of the shipment size to the loads. However, in distribution transport, the filling degree is keeping changing. In a delivery distribution, the filling degree normally keeps decreasing, while in a pick-up distribution, the filling degree keeps increasing. If a distribution cycle includes both collection and delivery, the filling degree will fluctuate. Therefore, the assumption in the LTL line-haul module will not be applicable. It is more reasonable to assume a certain filling degree level. The relationship between vehicle capacity, loads, and size of this shipment is shown in Figure 5-9:

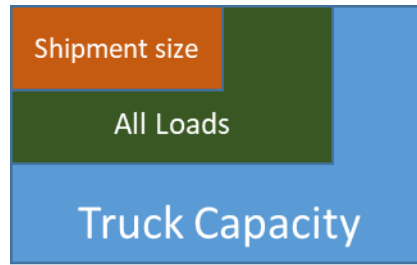


Figure 5-9 Relations of capacity, loads and shipment size

The cost of the distribution module is calculated by:

$$\text{CMRM} = (\text{FC} + \text{LC} + \text{RSC} + \text{MRC} + \text{CMC} + \text{DC} + \text{TC} + \text{GC} + \text{IC} + \text{GC} + \text{CC} + \text{OC}) * \text{SSFS} \quad 5-54$$

Where

$$\text{SSFS} = \frac{\text{CP}/\text{VC}}{\text{VFD}} \quad 5-55$$

CMRM: Cost of the distribution module (EUR)

SSFS: Share of the shipment to the loads

CP: Chargeable payload (kg)

VC: Vehicle capacity (kg)

VFD: Vehicle filling degree

FC: Fuel cost (EUR)

LC: Labor cost (EUR)

RSC: Route specific cost (EUR)

MRC: Maintenance and repair cost (EUR)

CMC: Consuming material cost (EUR)

DC: Depreciation cost (EUR)

TC: Tax cost (EUR)

GC: Garage cost (EUR)

IC: Insurance cost (EUR)

CC: Cost of capital (EUR)

OC: Other overhead (EUR)

CP (Chargeable payload) could be obtained through formula 5-50.

#### 4) Cross-dock module

As introduced in the previous section, there is only one cost element under the cross-dock module. Therefore, the cost of the module is:

$$\text{Cost of cross – dock module} = \text{CDC} \quad 5-56$$

CDC: Cross – dock cost (EUR)

Cross-dock cost is calculated from formula 5-7.

## 5) Digital platform module

Same as the cross-dock module, there is only one element within the digital platform module. Therefore, the cost of digital platform module is

$$\text{Cost of digital platform module} = \text{DPC} \quad 5-57$$

DPC: Digital platform cost (EUR)

DPC (Digital platform cost) is calculated from formula 5-9

### 5.2.3 Modules and set-ups in road freight rate section

#### 5.2.3.1 Set-ups and modules

The module split in the carbon emissions section follows a similar method as section 5.2.2. However, as the digital platform does not generate any carbon emissions considered in the set-up, only four modules are split compared with the five modules in the road freight rate section. They are the FTL line-haul carbon emissions module, LTL line-haul carbon emissions module, Distribution carbon emissions module, and Cross-dock carbon emissions module.

Therefore, in the carbon emissions section, the FTL set-up can be seen as a single FTL line-haul carbon emissions module. Similarly, the Express set-up can also be seen as a single FTL line-haul carbon emissions module. The LTL set-up can be seen as a combination following the sequence of a Distribution carbon emissions module, a Cross-dock carbon emissions module, an LTL line-haul carbon emissions, a Cross-dock carbon emissions module, and a Distribution carbon emissions module. The DDS set-up can be seen as a combination following the sequence of an LTL line-haul carbon emissions module, a Cross-dock carbon emissions module, and a Distribution carbon emissions module.

Similarly to the calculation method for the set-ups of the road freight rate section, the result for the transport carbon emissions calculation of each set-up is the sum-up result of the emissions figures from all the corresponding modules in the set-up. In the next section, the method of how to calculate the carbon emissions within a specific module will be illustrated.

#### 5.2.3.2 Calculation method for each module

##### 1) FTL line-haul carbon emissions module

The carbon emissions in the FTL line-haul carbon emission module is only generated by transport.

$$\text{FTL line – haul carbon emissions} = \text{TCE} \quad 5-58$$

TCE: Transport carbon emissions (kg)

TCE is calculated from formula 5-47.

## 2) LTL line-haul carbon emissions module

The carbon emissions generated by the vehicle during the LTL line-haul carbon emission module should be allocated based on the share of the shipment. The assumption is still valid here.

$$\text{LTL line – haul carbon emissions} = \text{TCE} * \frac{CP}{VC} \quad 5-59$$

*(Source: Own elaboration)*

CP: Chargeable payload (kg)

VC: Vehicle capacity (kg)

TCE: Transport carbon emissions (kg)

TCE is calculated from formula 5-47.

## 3) Distribution carbon emissions module

In the Distribution carbon emissions module, the carbon emissions are allocated based on the share of the shipment size to the loads.

$$\text{Milk – run carbon emissions} = \text{TCE} * \frac{CP/VC}{VFD} \quad 5-60$$

*(Source: Own elaboration)*

CP: Chargeable payload (kg)

VC: Vehicle capacity (kg)

VFD: Vehicle filling degree

TCE: Transport carbon emissions (kg)

## 4) Cross-dock carbon emissions module

In the module of cross-dock carbon emissions, there is only one element.

$$\text{Cross – dock carbon emission} = \text{CDCE} \quad 5-61$$

CDCE: Cross – dock carbon emissions (kg)

CDCE could be obtained from formula 5-48.

## 6 Development of calculation tools

*To apply the theoretical framework of road freight rate and carbon emissions calculation, two different tools, which are tailored to the business context of the case company, are developed. The first tool is developed based on Visual Basic for Applications (VBA) in Excel and is called a “VBA-based tool”, while the second one is based on spreadsheets of Excel and is called a “spreadsheet-based tool”. The structure and features of both tools are presented in this chapter.*

### 6.1 Calculation tool in VBA

#### 6.1.1 Structure of the VBA-based tool

The structure of the VBA-based tool is shown in Figure 6-1

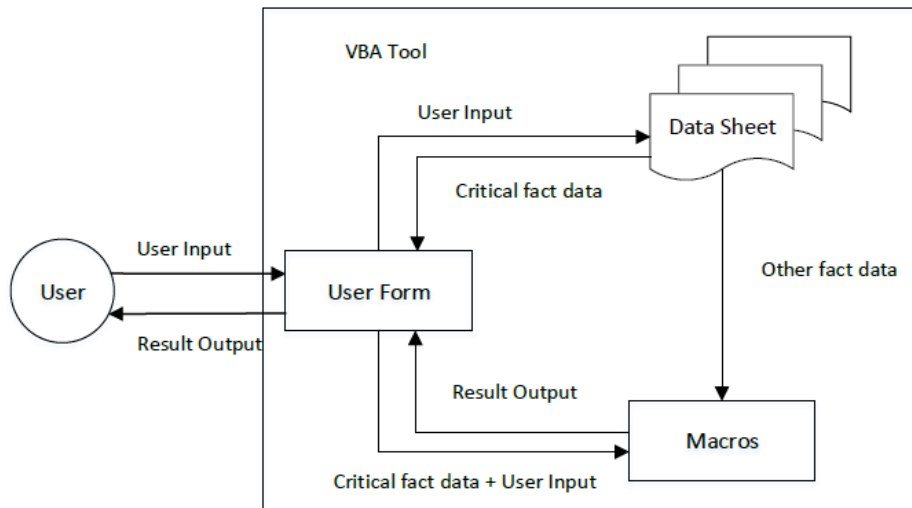


Figure 6-1 Structure of VBA-based tool

*(Source: Own elaboration)*

There are three parts in the VBA-based tool, user form, macros, and datasheets. The role of three parts and the connections among them are presented in the following.

#### User Form

User form is the window where the interaction between users and the VBA-based tool happens. It will be achieved by using the “UserForm” object in VBA. Users need to select the transport set-up they want to calculate and input required data about the route in the user form, such as destination and origin. The user form can present some important fact data retrieved from fact data sheets to the user.

### Datasheets

Datasheets are a set of spreadsheets where fact data is stored, which could be understood as a database. The types of data that are included in datasheets are shown in Table 6-1.

Table 6-1 Types of data in datasheets

<b>Data types</b>	<b>Example</b>
Vehicle-related data	Fuel consumption, vehicle investment...
Country-related data	Driver yearly income, driver working days per year...
Route-related data	All the pairs of origin and destination in the case company...
Operation-related data	Booking platform information...

With the user input from the user form, all the related fact data in the datasheets will be retrieved. Some of them are transferred to the user form and are presented to the user, which is called critical fact data, such as distance, driver salary. These data plays a critical role in the calculation and impact the final output significantly, thus needs to be checked by the users to see if they are correctly updated. The user may even need to adjust some critical data based on their needs. The other fact data will be directly fed to macros for cost calculation.

### Macros

Macros are a set of functions and procedures used in the calculation of rate and carbon emission. It is the core part of this model. Macros take critical fact data and user input from the user form, together with some fact data from datasheets as input. After calculation, macros output results to the user form.

#### 6.1.2 Process flow of the VBA-based tool

The flowchart of the VBA-based tool is shown in Figure 6-2.

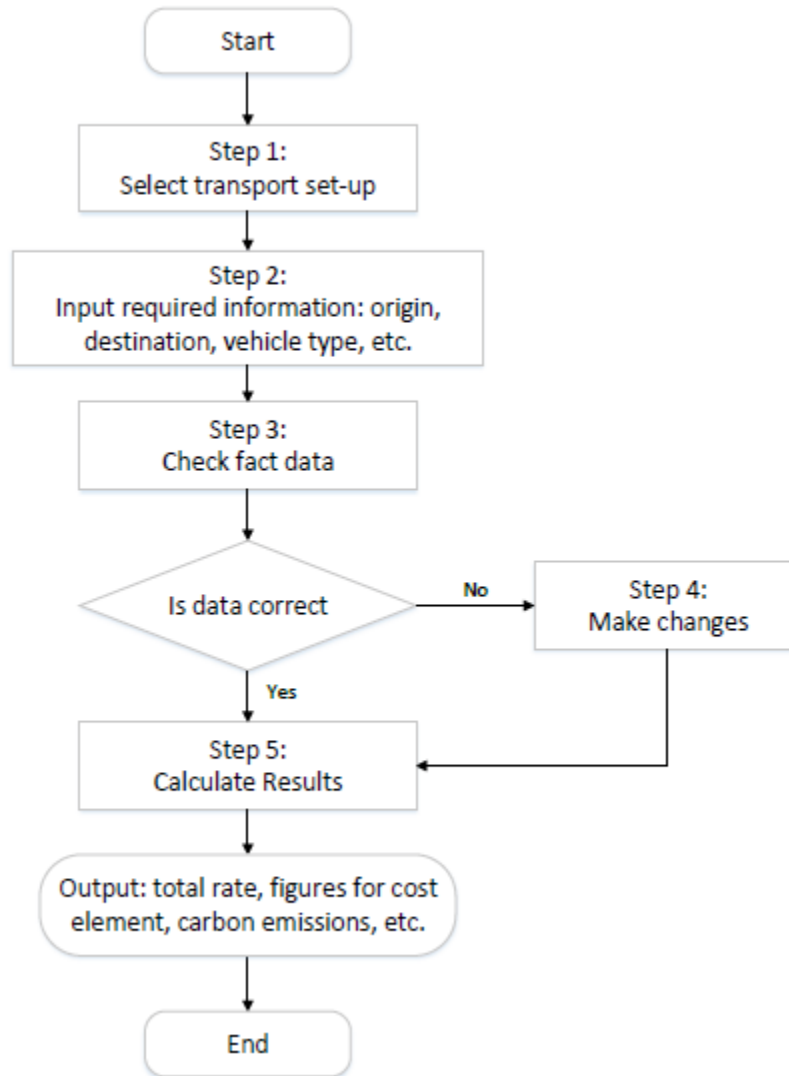


Figure 6-2 Process flowchart of the VBA-based tool

The process flow of VBA-based tool is divided into five steps:

Step1: The user selects one of the four set-ups from the drop-down list

Step2: The user inputs all the basic information of the lane to be calculated, such as origin and destination.

Step3: The user clicks the button “Get Data”. Then critical fact data will be retrieved from data sheets and shown in the user form. The user can check if the data is correct and reasonable.

Step4: The user can change the fact data if needed.

Step5: The user clicks the button “Cal”. Then the results will be calculated and shown in a new sheet.



## 6.2 Spreadsheet-based Tool

### 6.2.1 Structure of spreadsheet-based tool

Unlike the VBA-based tool which integrates all five set-ups into one file, five different files, i.e. workbooks of Excel, are created for five transport set-ups respectively, and each of them contains a copy of all the fact data. The reason for this design is that the calculation process in the spreadsheet takes much more space than in VBA. If all the five set-ups are put in one file, it would cause trouble for the user in sorting out relevant information. The structure of the spreadsheet-based tool is shown in Figure 6-3.

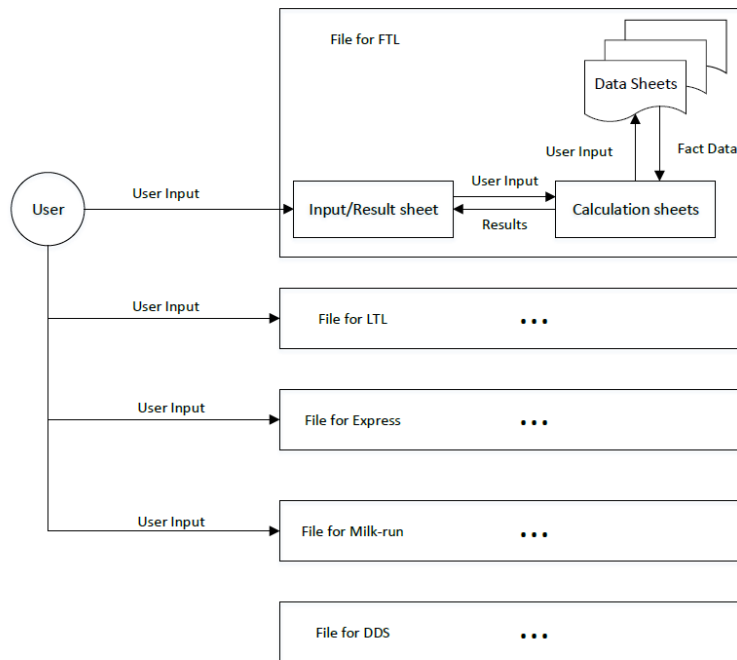


Figure 6-3 Structure of spreadsheet-based calculation

(Source: Own elaboration)

In the spreadsheet-based tool, the five files have a similar structure. Within one file, there are three parts, an input and result sheet, datasheets, and calculation sheets. The function of each part and their relations are explained in the following.

#### Input and Result Sheet

The input and result sheet is the sheet where the user types in all the needed information for calculation. The results calculated from calculation sheets are transferred to this sheet and are added together to get the final results. The idea is the user only needs to interact with this sheet, although the most calculation happens in other sheets.

#### Datasheets

Datasheets in the spreadsheet-based tool play the same role as in the VBA-based tool, with the same data included as in Table 6-1.

### Calculation Sheets

Calculation sheets are a set of worksheets in Excel that conduct the calculation for each element and each module in freight rate and carbon emission. There will be one sheet specifically one element or one module, and it will get needed data for calculating from input and result sheet. Then the data typed by the user will be used to retrieve fact data from datasheets. After gathering all the data, calculation sheets will calculate corresponding costs or carbon emissions which will be transferred back to the input and result data.

#### 6.2.2 Process flow of the spreadsheet-based tool

The process flow chart of the spreadsheet-based tool is shown.

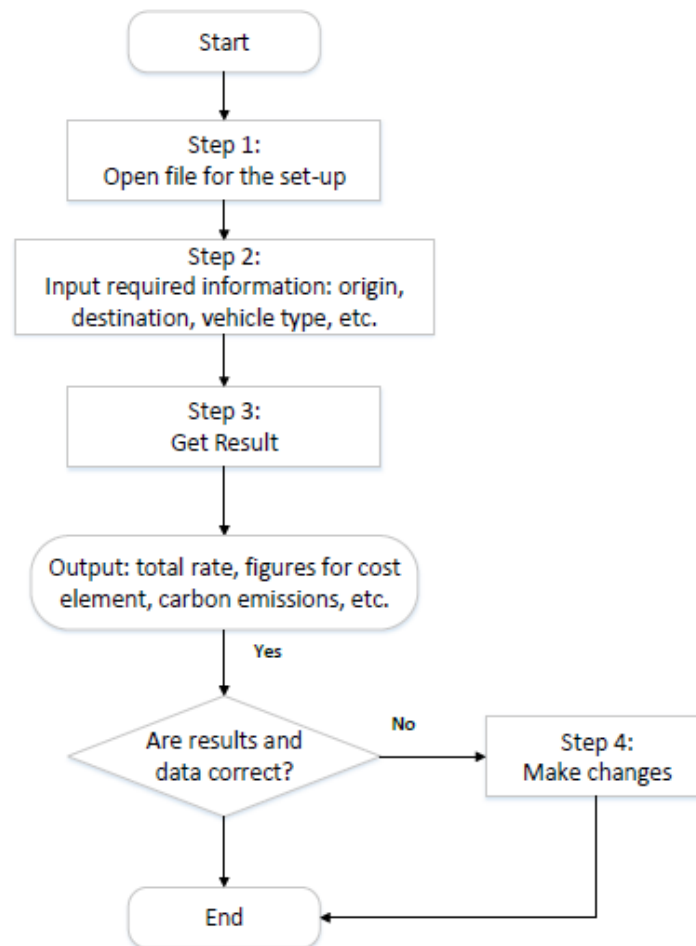


Figure 6-4 Process flowchart of the VBA-based tool

The process of using the spreadsheet-based tool includes four steps:

Step 1: The user selects and opens the corresponding file of the transport set-up to be calculated.

Step 2: The user types in the basic information of the lane, such as origin and destination.

Step 3: The results will be obtained and shown once all the required information is fed.

Step 4: The user can check the results and go into other sheets to change fact data if needed.

### 6.3 Comparison and discussion

The VBA-based tool and spreadsheet-based tool are built up with the same framework of calculating freight rate and carbon. They also share the same fact data. However, the techniques they are applying give them different features so that they are suitable in different environments.

The VBA-based tool is more user-friendly because the user only needs to interact with a well-organized user form, the calculation process and data needed in between are written in macros and invisible to the user. The interface of the VBA-based tool is closer to standard software compared with spreadsheets, thus it can be used as a demo if further development of advanced software is needed. However, the VBA-based tool is only applicable for lane-by-lane calculation, which means it cannot take a batch of lanes at the same time and make the calculation.

In contrast, the spreadsheet-based tool is much less condensed compared with the VBA tool because all the calculations and intermediate data are presented in the sheets. However, this also provides the user with easier access to check the intermediate results of the calculation. The most advantage of the spreadsheet-based tool is it can take a set of lane information and carry out calculations in batches.

In conclusion, the relations and features of the two tools are illustrated in Figure 6-5.

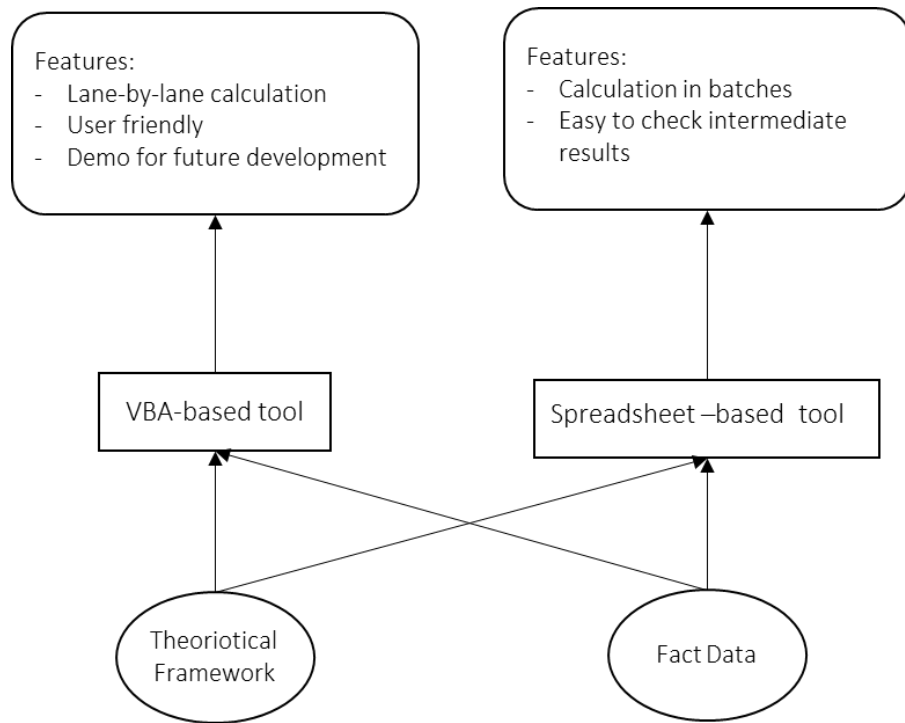


Figure 6-5 Comparison of two tools

The screenshots of the interface of both tools are demonstrated in Appendix A and screenshots of codes are shown in Appendix B.

## 7 Test of framework analysis

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*In this chapter, several routes from the case company are selected as samples to test the estimation framework and tool. The detailed breakdown structure of the freight rate will be illustrated and carbon emissions generated from this transport will be shown. Besides, the estimated freight rates, current bid prices, and estimated rates obtained from an internal tool at the case company will be compared. Express set-up will not be included in the analysis due to limited data. This section will only illustrate figures, more detailed comparison and discussion will be done in Chapter 8.*

---

### 7.1 Rate structure and carbon emission

In this section, in total eight samples for three set-ups at the case company (FTL, LTL, and DDS) will be tested. Although the calculation logic for Express is built up in chapter 4, it will not be included in this section due to data availability. All the tested samples are summarized in the following table.

Table 7-1 Summary of tested samples

Set-up	FTL				LTL		DDS	
Tested Samples	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
	Lane A	Lane B	Average of 8 single trips	Average of 2 round trips	Lane C	Average of 8 lanes	Lane D	Average of 8 lanes
Domestic/International	Domestic	International	Mix	Mix	Domestic	Domestic	Domestic	Domestic
LSP Country	Sweden	Czech republic	Mix	Mix	Sweden	Sweden	Sweden	Sweden
Shipment Weight	Full truck	Full truck	Full truck	Full truck	17505kg	Mix	438.9kg	Mix

#### 7.1.1 Full-Truck-Load

Under the FTL set-up of the case company, two lanes are selected as a sample to illustrate the rate structure of individual shipment. Then, the average rate structure of ten randomly selected lanes is presented. The first lane, which is marked as lane A, is a domestic transport in Sweden with a trip distance of 153km. The second lane marked as lane B is a cross-border transport which is 411km long. Other than the difference in trip distance, origin, and destination, two lanes are carried by different types of vehicle and lane B has a drop trailer setting at the origin, while lane A does not. The difference between the two lanes are summarized in Table 7-2

Table 7-2 Information on Lane A and Lane B

	Domestic/ International	Equipment	Drop Trailer	LSP Country
<b>Lane A</b>	Domestic	HCT 25,25m truck and trailer	Yes	Sweden
<b>Lane B</b>	International	Mega13.6m truck and trailer	No	Czech republic

Because of confidential issues, more detailed information on lane A and lane B cannot be provided and the percentage of each element instead of the exact cost figures will be presented in the following chapter.

### 1) Sample 1: Rate structure of Lane A

The rate structure lane A is shown in Figure 7-1. Fuel cost accounts for most of the total rate (26.31%), followed by labor cost and the cost occurs during handling and waiting time (21.81% and 15.81% respectively). The top three elements make up over 60% of the freight rate. Because lane A is a domestic route and doesn't apply drop trailer practice, the route-specific cost and additional trailer cost is zero. From Figure 7-2, it could be seen that variable cost has the most influence on the overall rate, while fixed cost only accounts for less than 5% of the total rate.

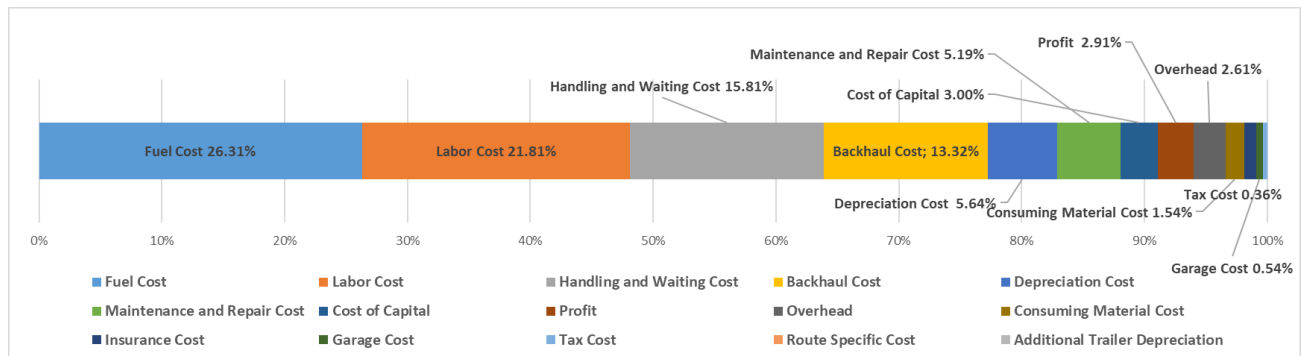


Figure 7-1 Rate structure of lane A

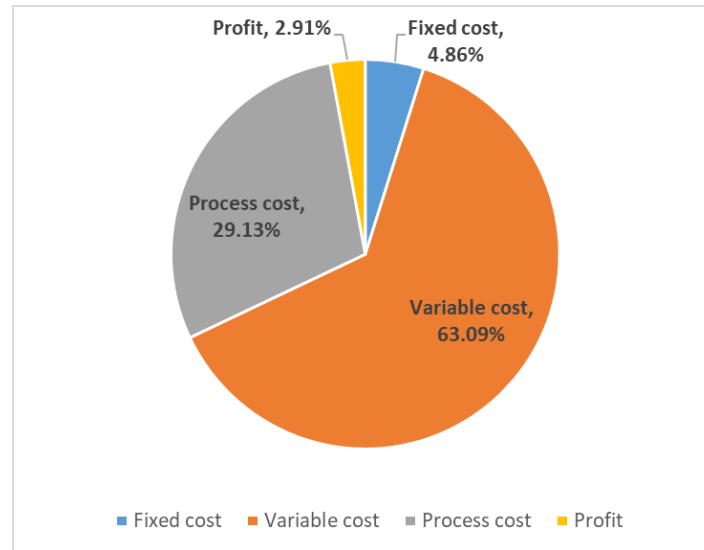


Figure 7-2 Comparison of different categories of lane A

## 2) Sample 2: Rate structure of lane B

The structure of lane B is shown in Figure 7-3. Same as the rate structure of lane A, fuel cost accounts for the largest part, over 30% to the total rate. The labor cost is still the second largest element, representing 11% of the overall rate. The third-largest share comes to route-specific cost which is followed by additional-trailer depreciation cost. These four elements cover nearly 60% of the total rate.

From Figure 7-4, it could be noticed that fixed cost still has much less impact on the overall cost compared with process cost and variable cost. Variable cost is still dominant, accounting for around 80% of the overall rate.

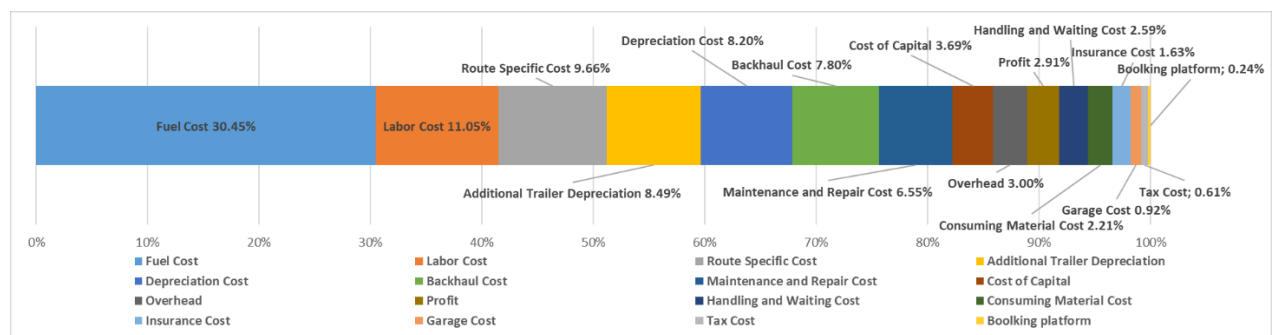


Figure 7-3 Rate structure of lane B

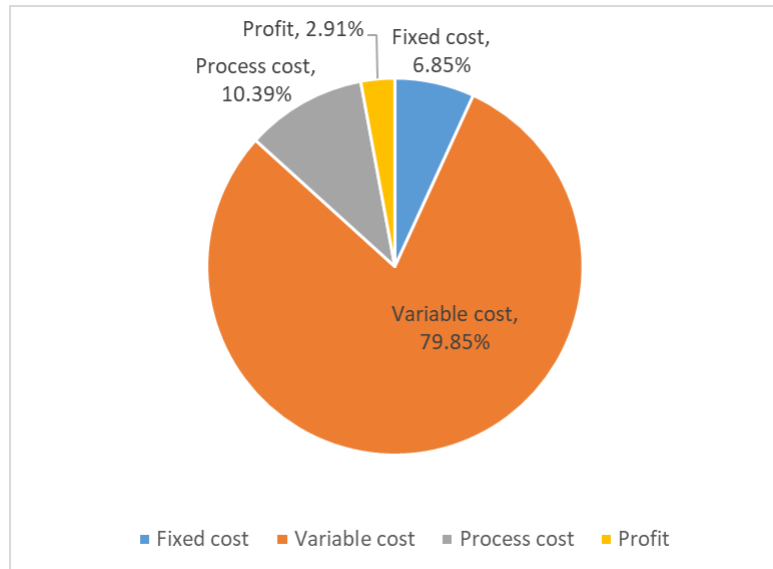


Figure 7-4 Comparison of cost categories of lane B

### 3) Sample 3: Average rate structure of 10 lanes

The randomly selected lanes have a mix of domestic and international transport. 8 of them are single trips, while 2 of them are round trips meaning the rates include the shipment for both directions. The basic information of the 10 lanes is summarized in table Table 7-3.

Table 7-3 Summary of information of 10 lanes

Lane	Domestic/ International	Equipment	Drop Trailer	LSP Country	Single/Round
1	Domestic	HCT 25,25m truck and trailer	Yes	Sweden	Single
2	International	Mega 13.6m truck and trailer	No	Czech republic	Single
3	International	Mega 13.6m truck and trailer	Yes	Czech republic	Single
4	International	Mega 13.6m truck and trailer	Yes	Czech republic	Single
5	Domestic	HCT 25,25m truck and trailer	No	Sweden	Round
6	International	Standard 13.m truck and trailer	No	Poland	Round
7	International	Mega 13.6m truck and trailer	No	Czech republic	Single
8	Domestic	Mega 13.6m truck and trailer	No	Germany	Single
9	International	Standard 13.m truck and trailer	No	Czech republic	Single
10	International	Mega 13.6m truck and trailer	No	Slovakia	Single

The analysis of the average rate structure is further divided into two groups, single trips, and round trips. The reason is that in round trips, the backward trip cost is almost half of the total rate, but this cost element is zero in the single trip. Therefore, the high share of backward trip costs in the round trip settings will be distorted if they are averaged with the lanes that have a single trip setting. The distortion will also happen to backhaul cost if the single trip setting is analyzed with the round trip setting because there is no backhaul cost in the round trip. Figure 7-5 shows that for single-trip lanes, the fuel cost is still the largest share to the overall rate (28.82%) followed by



labor cost which accounts for 14% on average. The backhaul cost in a single trip has an obvious influence on the total rate with a share of 9.14% on average. As for the two round trips, the backward cost during round trip accounts for nearly 48.93% of the total rate. Expect the cost during the backward trip, fuel cost and labor cost still rank as the first two largest cost elements, with the proportion of 18.29% and 10.36% respectively.

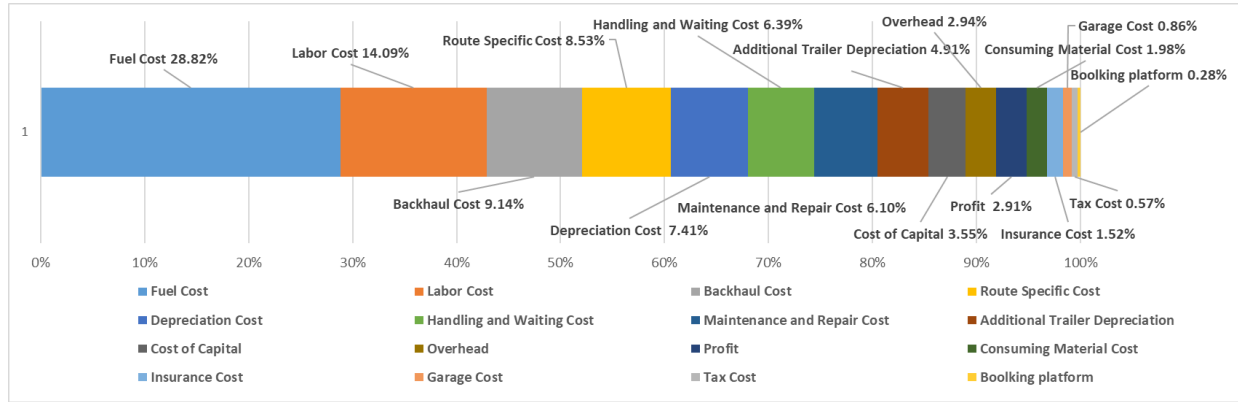


Figure 7-5 Rate structure of 8 lanes with single trip

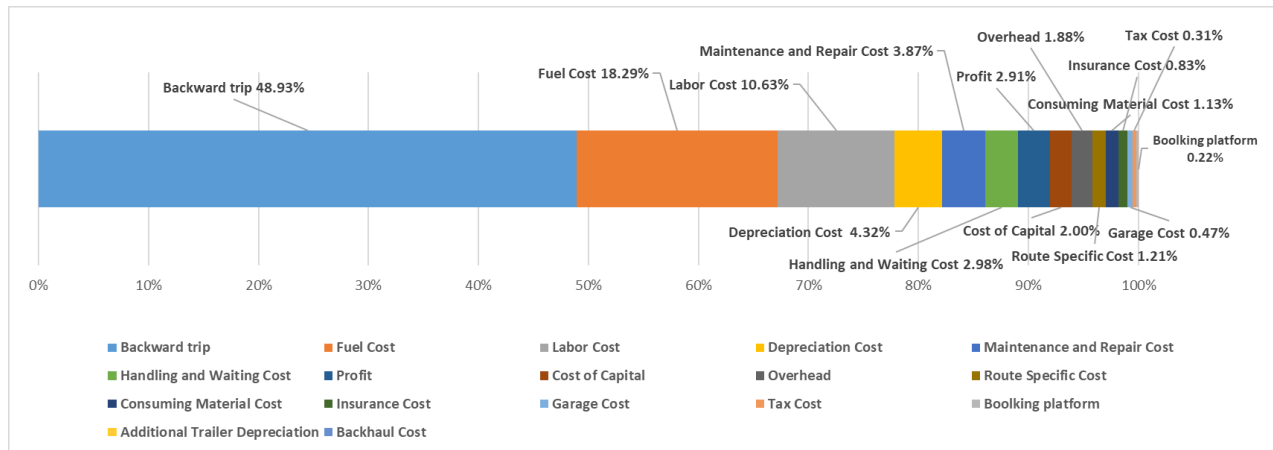


Figure 7-6 Rate structure of 2 lanes with round trip

#### 4) Carbon emissions of FTL set-up

The carbon emissions of lane A, lane B, and average carbon emissions of 10 lanes are summarized in Table 7-4.

Table 7-4 Carbon emissions of FTL set-up

	Lane A	Lane B	Average of 8 single trips	Average of 2 round trips
Carbon Emissions (kg)	201.17	656.43	508.73	425.55

## 7.1.2 Less-Than-Truck-Load

A domestic lane in Sweden, which is marked as lane C, is selected as an example to test the estimation framework of LTL. Then the average cost structure of 8 randomly selected lanes in Sweden is presented.

### 1) Sample 4: Rate structure of lane C

Lane C is a domestic lane with the shipment weighs 17505kg. The result in Figure 7-7 shows that an LTL shipment has a very different cost structure compared with FTL shipment. The largest part is the cross-dock cost, representing near 30% of the total rate. Handling and waiting cost is the second significant part, accounting for 19.42% of the total rate. The third and fourth elements are labor cost and fuel cost with a share of 17,68% and 15,11% respectively. Those four elements make up more than 80% of the whole rate. Comparing different cost categories, it could be found that even though the handling and waiting cost becomes the second largest component, variable costs are still dominant due to the high share of the cross-dock cost. Fixed costs only account for 3.43% of the total rate.

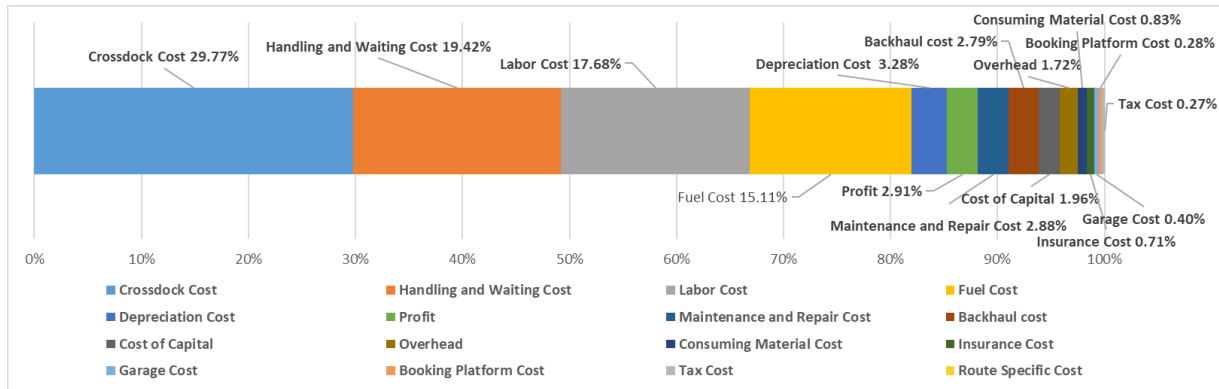


Figure 7-7 Rate structure of lane C

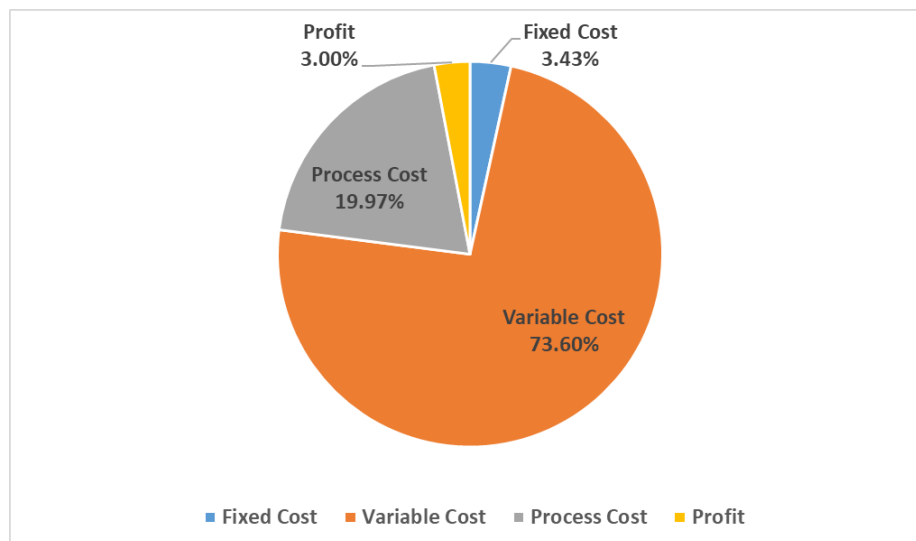


Figure 7-8 Comparison of cost categories of lane C

## 2) Sample 5: Average rate structure of 8 lanes

Eight lanes are selected randomly to estimate the average rate structure of LTL shipment. Because of the limited information in the location of carriers' hubs, all the selected lanes are domestic shipments within Sweden. The result in Figure 7-9 shows that on average, cross-dock is still the most significant part, with a share of 33.14%. The second and third components are labor cost and handling and waiting cost, each of them accounting for around 18% of the overall rate. The fuel cost comes to the fourth position with a share of only 9.34% compared with its high contribution to the rate of FTL lanes.

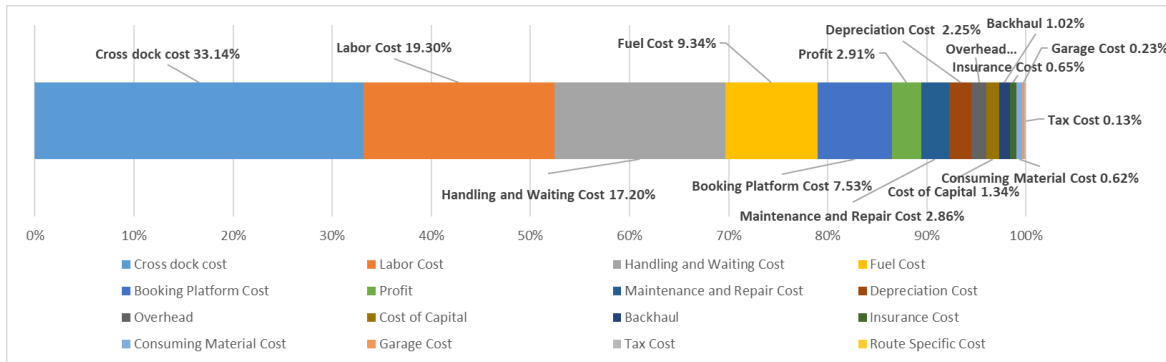


Figure 7-9 Rate structure of 8 LTL lanes

## 3) Carbon emissions of LTL set-up

The carbon emission generated by lane C and the average carbon emissions from 8 LTL lanes is presented in the following table.

Table 7-5 Carbon emissions of LTL set-up

	Lane C	Average of 8 LTL trips
Carbon Emissions (kg)	436.37	77.25

### 7.1.3 Dedicated Delivery Service

Similar to LTL, a domestic lane in Sweden, which is marked as lane D, is selected as an example to illustrate the rate structure of DDS set-up at the case company. Then the average cost structure of 8 randomly selected lanes in Sweden is presented.

#### 1) Sample 6: Rate structure of lane D

Lane D is a domestic lane in Sweden with a weight of 438.9kg. The first leg is carried by a standard truck and trailer, while the second leg is by a delivery van of 5 tons. Both of the two legs are operated by one carrier.

Figure 7-10 shows the detailed rate structure of lane D, including both the first and the second leg. It could be seen that the largest part is handling and waiting cost, with a share of 27.69%. The following is labor cost accounting for 27.36% to the total rate. The third place is fuel cost, followed by cross-dock cost. The top four cost elements represent nearly 80% of the overall rate.

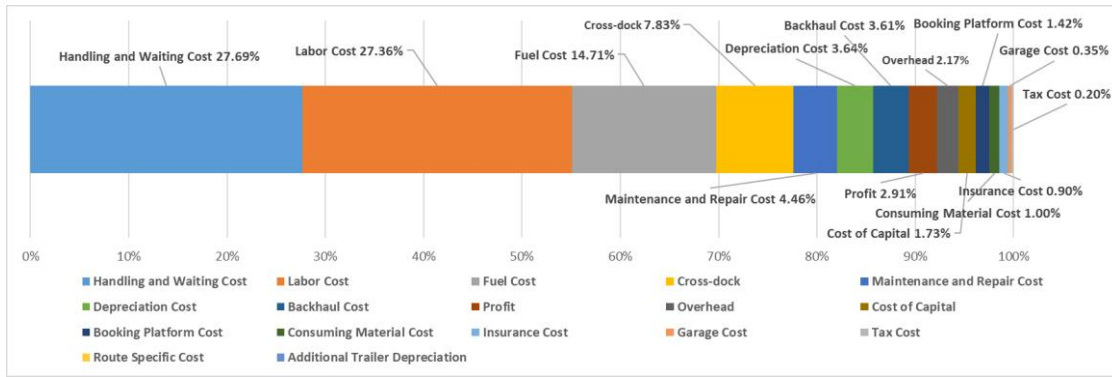


Figure 7-10 Rate structure of lane D

Figure 7-11 shows that the variable costs still have the largest influence on the total rate and fixed costs account for only 3.19% of the whole rate, which is constant with the finding for tested lanes in other set-ups.

In Figure 7-12, a comparison of the rate for different parts of lane D is made. Although in the first leg, the vehicle used is more costly and the distance is longer, the overall rate in the second leg, i.e. the distribution part, is higher. The cross-dock and platform transactions make up a small part of the total rate.

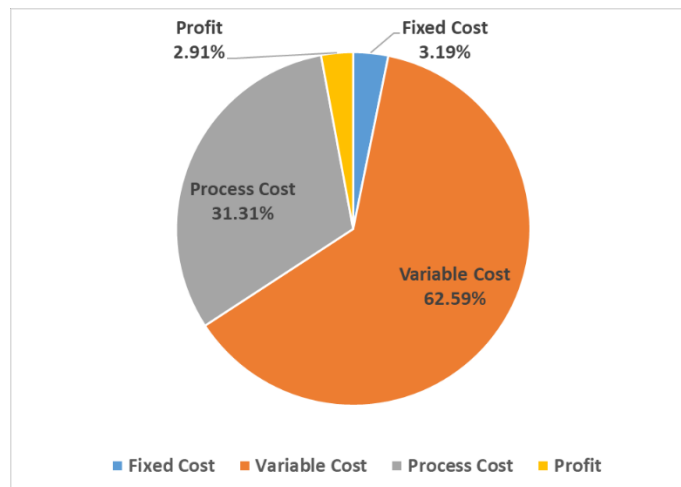


Figure 7-11 Comparison of element categories of lane D

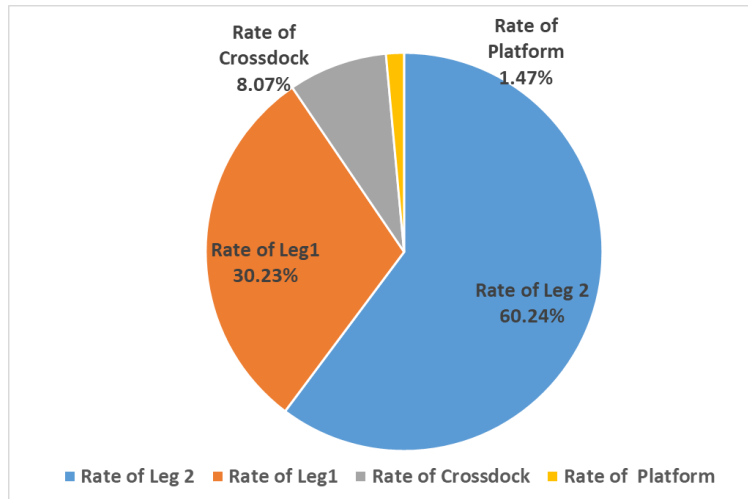


Figure 7-12 Rate for different parts of lane D

## 2) Sample 8: Average rate structure of 8 lanes

Eight lanes are selected randomly to estimate the average rate structure of the DDS set-up at the case company. All the selected lanes are domestic shipments within Sweden due to data availability. The top four cost elements are labor cost, handling and waiting cost, cross-dock cost, and fuel cost, which represent nearly 80% of the total rate. Labor cost has the most influence on average, accounting for 26.83% of the total price. The second is handling and waiting cost followed by cross-dock cost and fuel cost.

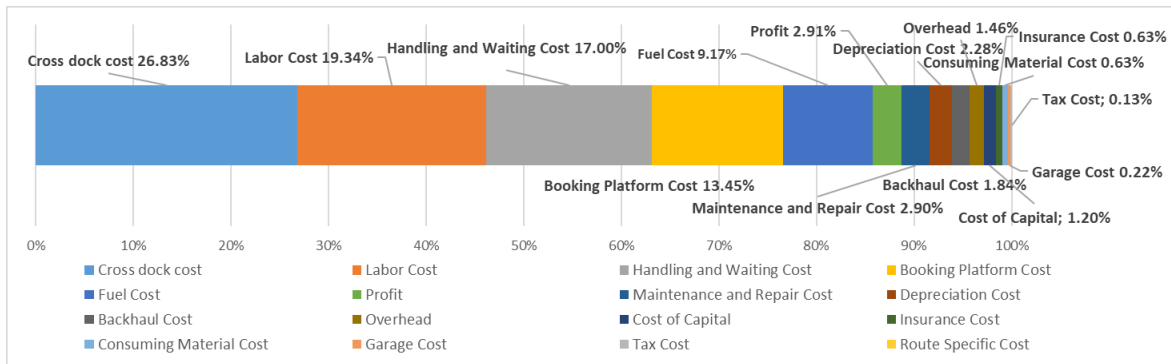


Figure 7-13 Rate structure of 8 DDS lanes

## 3) Carbon emissions of DDS set-up

The carbon emission generated by lane D and the average carbon emissions from 8 DDS lanes is presented in the following table.

Table 7-6 Carbon emissions of DDS set-up

	Lane D	Average of 8 DDS trips
Carbon Emissions (kg)	28.11	16.45

## 7.2 Comparison of current bid prices

In this section, the overall freight rate estimated by the framework for each lane is compared with the current bid prices and the rates obtained from another tool at the case company. The lanes used in the comparison are the same lanes used in the analysis of the rate structure. Therefore, there will be 10 lanes in FTL (corresponding to Sample 3 and Sample 4 in Table 7-1), 8 lanes in LTL, and DDS (corresponding to Sample 6 and Sample 8 in Table 7-1). The purpose is to identify the gaps between estimated rates and current prices and explain the reasons behind the gap. Since the bid prices are very sensitive in business, the percentage concerning real prices is presented. If the estimated rates are lower than the current prices, the gap is defined as negative. Otherwise, the gap is positive. In addition, the mean absolute percentage error (MAPE) is used as an index to better show the variation between the estimated rate and real bid price. The MAPE is calculated by:

$$\text{MAPE} = \frac{|ER - RBP|}{RBP} \times 100\% \quad 7-1$$

ER: Estimated rate

RBP: The real bid price

The results of the comparison for FTL, LTL, DDS are shown in Figure 7-14, Figure 7-15, Figure 7-16 respectively. For each lane, the left bar is the estimated rate obtained by the framework. The bar in the middle represents the current bid prices, while the right column is the result obtained from an internal tool of Volvo. The MAPE results for FTL, LTL, DDS are shown in Figure 7-17, Figure 7-18, and Figure 7-19. In those figures, the left bar is the APE of the results from the framework compared with bid prices, while the right column is the APE of the estimated rate from the internal tool compared with bid prices.

The result shows there are always differences between bid prices and estimated results. In FTL set-up, the results from the framework and the internal tool are either both higher or both lower than the bid prices. The estimated rates are lower than current bids for 7 lanes, while the other three exceed the bid prices. The largest negative gap between estimated rates and bid prices appears for lane 9, 73.54% compared with 100%. The largest positive gap is 128.47% compared with 100% which appears in lane 10. In general, the MAPE of FTL of the framework is 15.67% compared with the bid price. In LTL, the bid prices are also either higher than both estimated rates or lower. But both the largest positive gap (149.11% compared to 100%) and the largest negative gap (46.52% compared to 100%) is higher than in FTL. The MAPE of the LTL framework is 23.64%. In DDS, the differences among the three results are more irregular. There are some lanes of which the bid prices are located between the estimated rates and results from the internal tool, such as lane 3, lane 5, lane 6, and lane 7. In lane 2, the estimated rate is 226.22% compared with 100% of the bid price, which is the largest gap. The MAPE of DDS samples is 34.17% which is larger than FTL and LTL samples.

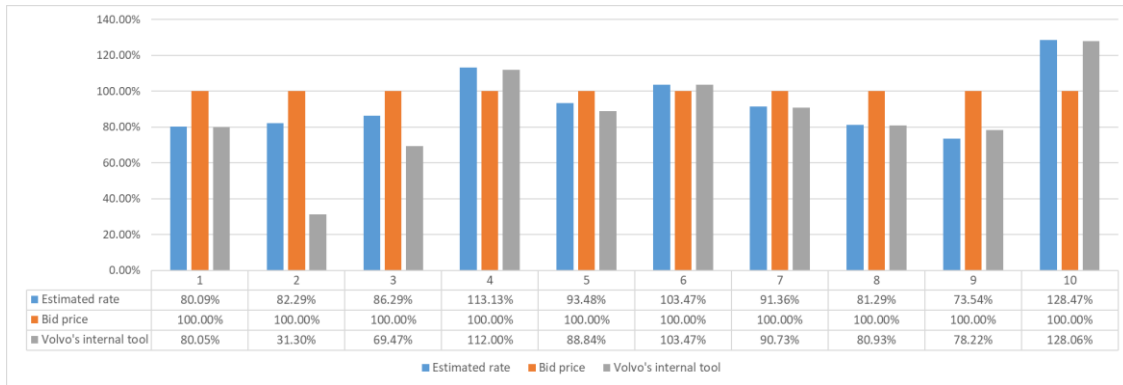


Figure 7-14 Comparison of FTL lanes

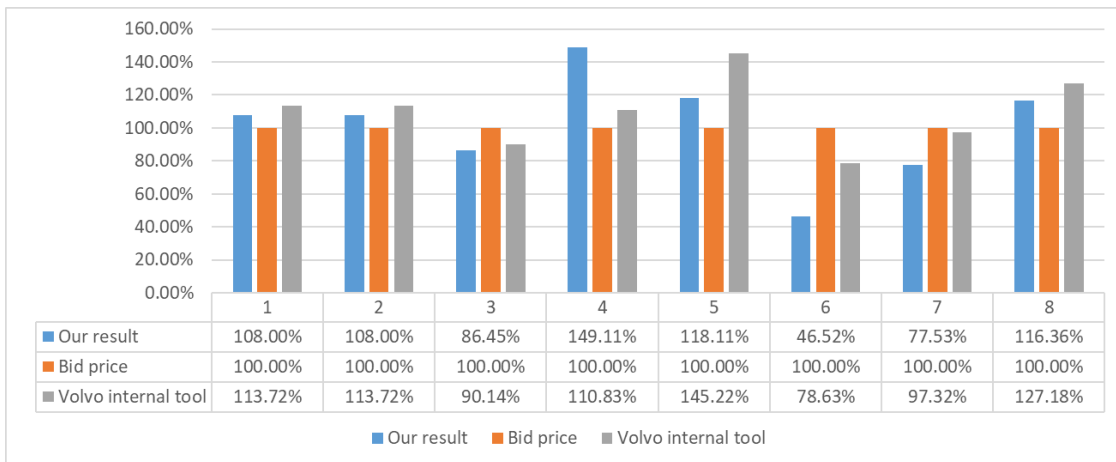


Figure 7-15 Comparison of LTL lanes

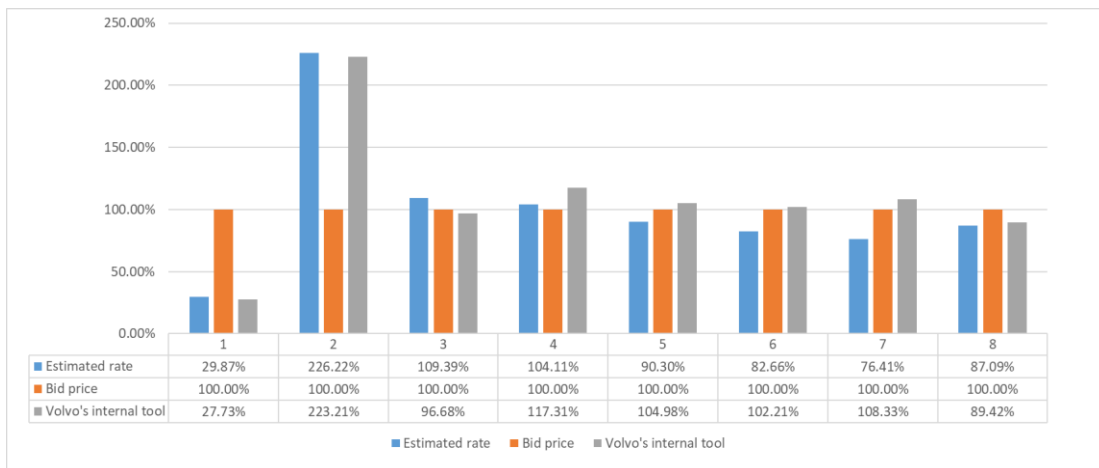


Figure 7-16 Comparison of DDS lanes

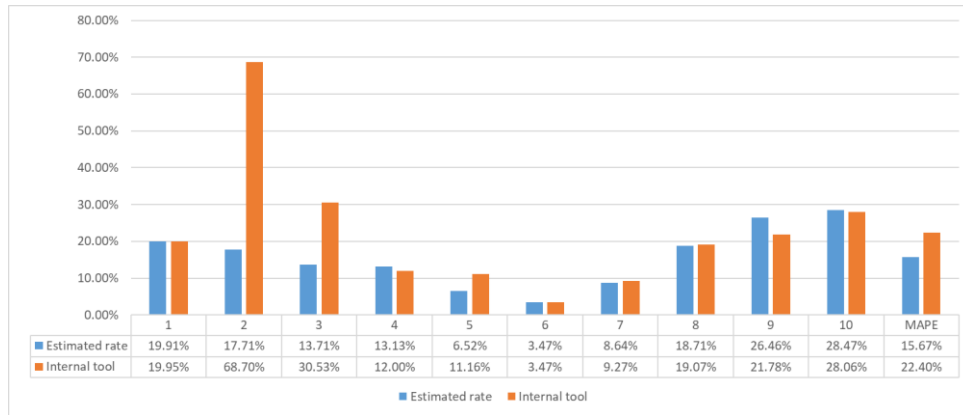


Figure 7-17 MAPE of FTL lanes

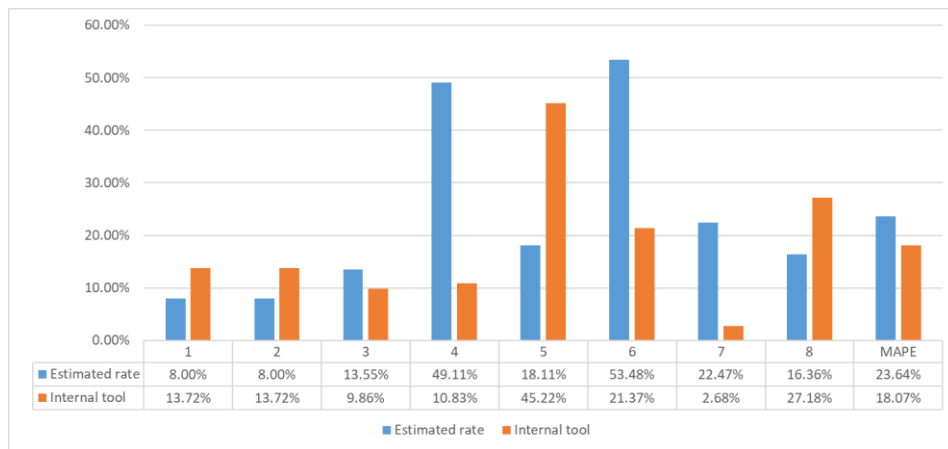


Figure 7-18 MAPE of LTL lanes

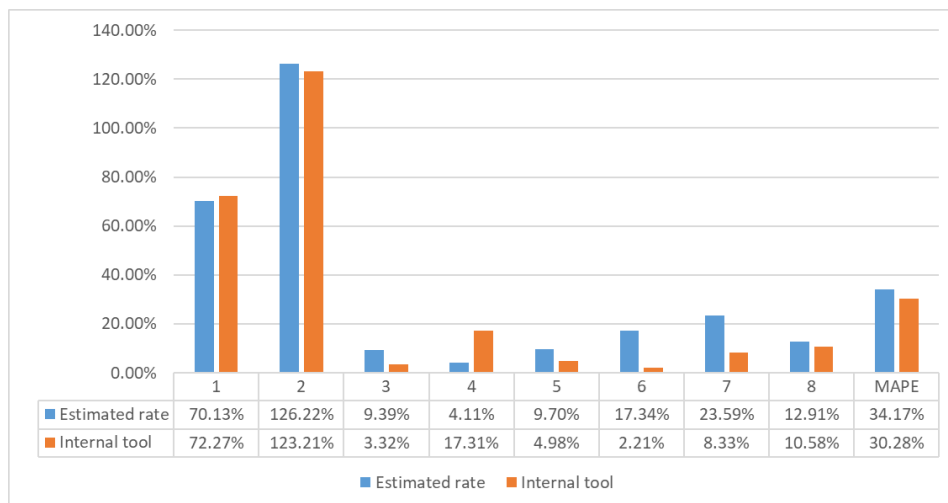


Figure 7-19 MAPE of DDS lanes



## 8 Discussion

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*In this chapter, the results of the thesis will be further interpreted and discussed with a comparison with previous studies. In the first section, the rate structures obtained in section 7.1 are summarized. Further, the root causes of different cost structures in different lanes are analyzed. In the second section, the gaps between estimated rates and bid prices are interpreted.*

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### 8.1 Rate structure

The rate structures of all the 8 samples analyzed in section 7.1 are summarized in Table 8-1. Under each analyzed structure, the top four largest cost elements are marked with gray. If a cell is filled by “N/A”, it means this cost element is not applicable in this set-up.

## Discussion

Table 8-1 Summary of analyzed rate structures

Set-up	FTL				LTL		DDS	
Sample NO	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Lane No	Lane A	Lane B	Average of 8 single trips	Average of 2 round trips	Lane C	Average of 8 lanes	Lane D	Average of 8 lanes
<b>Domestic/ International</b>	Domestic	International	Mix	Mix	Domestic	Domestic	Domestic	Domestic
<b>LSP Country</b>	Sweden	Czech republic	Mix	Mix	Sweden	Sweden	Sweden	Sweden
<b>Shipment Weight</b>	Full truck	Full truck	Full truck	Full truck	17505kg	Mix	438.9kg	Mix
<b>Variable Costs (EUR)</b>								
Fuel Cost	26,31%	30,45%	28,82%	18,29%	15,11%	9,34%	14,71%	9,17%
Labor Cost	21,81%	11,05%	14,09%	10,63%	17,68%	19,30%	27,36%	19,34%
Route Specific Cost	0,00%	9,66%	8,53%	1,21%	0,00%	0,00%	0,00%	0,00%
Depreciation Cost	5,64%	8,20%	7,41%	4,32%	3,28%	2,25%	3,64%	2,28%
Maintenance and Repair Cost	5,19%	6,55%	6,10%	3,87%	2,88%	2,86%	4,46%	2,90%
Additional Trailer Depreciation	0,00%	8,49%	4,91%	0,00%	N/A	N/A	0,00%	N/A
Overhead	2,61%	3,00%	2,94%	1,88%	1,72%	1,47%	2,17%	1,46%
Consuming Material Cost	1,54%	2,21%	1,98%	1,13%	0,83%	0,62%	1,00%	0,63%
Booking Platform Cost	0,00%	0,24%	0,28%	0,22%	0,28%	7,53%	1,42%	13,45%
Cross-dock Cost	N/A	N/A	N/A	N/A	29,77%	33,14%	7,83%	26,83%
Sum of variable cost	63,09%	79,85%	75,05%	41,56%	71,55%	76,50%	62,59%	76,06%
<b>Fixed Cost (EUR)</b>								
Cost of Capital	3,00%	3,69%	3,55%	2,00%	1,96%	1,34%	1,73%	1,20%
Insurance Cost	0,96%	1,63%	1,52%	0,83%	0,71%	0,65%	0,90%	0,63%
Garage Cost	0,54%	0,92%	0,86%	0,47%	0,40%	0,23%	0,35%	0,22%
Tax Cost	0,36%	0,61%	0,57%	0,31%	0,27%	0,13%	0,20%	0,13%
Sum of fixed cost	4,86%	6,85%	6,50%	3,62%	3,33%	2,36%	3,19%	2,19%
<b>Process cost (EUR)</b>								
Backhaul Cost	13,32%	7,80%	9,14%	N/A	2,79%	1,02%	3,61%	1,84%
Handling and Waiting Cost	15,81%	2,59%	6,39%	2,98%	19,42%	17,20%	27,69%	17,00%
Backward trip	N/A	N/A	N/A	48,93%	N/A	N/A	N/A	N/A
Sum of process cost	29,13%	10,39%	15,54%	51,92%	22,21%	18,23%	31,31%	18,84%
<b>Profit (EUR)</b>								
Profit	2,91%	2,91%	2,91%	2,91%	2,91%	2,91%	2,91%	2,91%
<b>Carbon Emissions</b>	201,17	656,43	508,73	425,55	436,37	77,25	28,11	16,45

### Cost elements

It is quite obvious from the table that regardless of which transport set-up it is, labor cost and fuel cost are always important as they ranked in the top four largest in almost all samples (except the fuel cost in the average analysis of 8 DDS routes). This is consistent with the results from Sternad (2019) which shows that fuel cost and labor cost are the first and second-largest among eight cost elements in road freight transport. The surveys made by Rastogi and Arvis (2014) and Maibach, Peter, and Sutter (2006) both give similar results showing the significant share of fuel and labor costs to the road freight rate in all European countries. However, the importance of other cost elements highly depends on set-ups and specific settings for each shipment.

Another cost element that should not be neglected is the backhaul, which accounts for around 10% of the total rate in FTL. This share of backhaul cost varies across different routes indicating the different possibilities between different countries. As presented by Demirel, Van Ommeren and Rietveld (2010), Cooper, Woods, and Lee (2008), and Wilson (1987), the likelihood of organizing backflow differs for different locations and this difference will be reflected in the freight rate price of the front-haul trip.

Different set-ups vary significantly in cost structures. If the backward cost in round trips is ignored, in all analyzed samples under of set-ups, the fuel cost is always the largest part followed labor cost, which addresses the significant impact of fuel economy and driver cost in FTL operations. This finding is also consistent with a case study conducted by Jacyna and Wasiak (2015) which estimated the FTL cost from Mszczonów (PL) to Hamburg (DE) and showed the fuel cost and labor are top two largest cost components. Although the fuel cost and the labor cost are still important in LTL and DDS set-ups, they become less influential compared with FTL set-up. In these two set-ups, cross-dock cost, and handling and waiting cost always rank in the top four among all cost elements. Cross-dock cost takes the largest share except in lane D while handling and waiting cost is the largest cost element for lane D, the second largest for lane C, and the third-largest in both two average cost structures. The difference in dominant cost elements in different set-ups could be explained from the perspective of transport activities. In FTL transport, there are only 2 stops, origin, and destination. Most time the truck is driving on the road which results in a higher share of distance-related costs, such as fuel cost. In LTL and DDS set-ups, the distribution part contains many stops to serve and increase the time in handling and waiting, therefore the share of costs during this time becomes large. As for the cross-dock cost, it is explained by how handling is charged in carriers' hub. According to Volvo's employee, the handling cost at the hub is charged based on the number of package units. If there is one package unit, regardless of how much weight it is, the handling unit is a fixed number. In the LTL and DDS, some shipments are low in total weight but package in a few handling units, leading to the high cost of handling at the carrier hub. Another cost item that has an increased share in LTL and DDS is booking platform cost. The reason behind this is similar to the cross-dock cost that booking platform cost is a fixed number for each transaction regardless of the weight of the shipment. Driver cost happens no matter during driving or waiting at stops, it is always a big share in road freight transport.

Within each transport set-up, there are some differences between the cost structure of each lane, which could be interpreted from the specific setting of each lane. In FTL, lane B is a cross-border route crossing more toll sections than lane A which is domestic and without toll section. It results in high route-specific cost in B which is the third-largest share after fuel and labor cost. In the average analysis of 8 single trips, the route-specific cost accounts for more than 8% of the total rate, ranking in the fourth position. Although the route-specific cost varies from route to route as indicated in the name, the analysis of the yearly road freight rate in Sternad (2019) suggests the high share of road toll cost, ranking at the third place of eight cost elements. In the operation of lane B, the trailer will be dropped at the destination for around 5 days. Although this setting brings more convenience for loading and unloading, it also brings trailer depreciation costs. The share of the labor cost of lane B in FTL set-up is much smaller compared with the other lanes. This is because the lane B is carried by the carrier from the Czech Republic, while the other three lanes are driven by domestic drivers in Sweden. The survey on European truck driver wages shows the Czech Republic has much lower driver wages compared with Swedish driver (Maibach, Peter, & Sutter, 2006; Comité National Routier, 2018).

### **Fixed and variable costs**

Expect in the round trip of FTL where process costs represent more than half of the total cost due to high backward costs, variable costs are always dominant with a share of 60% - 75% to the total rate. In FTL, the high share of variable costs results from large fuel cost and labor cost, while in LTL and DDS, it results from a high share of cross-dock cost. This result is similar to the finding in Sternad (2019) showing the variable costs represent a proportion of 60% - 70% to the total road freight cost. Although Cowie (2009) also stated variable costs are the larger part compared with fixed costs in road cargo transport, it shows the share of fixed costs could reach 25% which is much larger than the figure obtained in Table 8-1. The variation in the share of fixed cost might from two reasons. The first reason is the research scope of road transport costs. Cowie (2009) included the capital cost of the terminal into road freight cost which is beyond the scope of this research. The second reason is the different ways of classifying cost elements. For example, in this thesis, the depreciation cost is calculated with running distance instead of usage time, therefore it is classified as a variable cost. However, Sternad (2019) classified the depreciation cost as a fixed cost based on their experience and calculation method. Kovács (2017) got the opposite conclusion that variable costs only share 43% of the total rate. The deviation might come from they compare the variable costs calculated by their methods with a total rate figure obtained from an external source. This comparison could be inconsistent because the calculation methods used by the external source is unknown. To conclude, this research concludes variable costs are still more influential than fixed costs, although the share of fixed costs is slightly different based on how the research classified fixed costs and variable cost.

## **8.2 Gaps with bid prices**

In this section, the gaps between bid prices and estimated results which are shown in section 7.2 will be discussed and interpreted with the theories from literature and information from Volvo.

When the estimated rate is lower than the bid prices, the saving potentials could be targeted. Although road freight cost is a large spend, it is quite common that shipper companies have difficulty in analyzing root causes of the overall rate and cannot identify the fairness of road freight rate (Joo, Min, & Smith, 2017). In Europe, even though there are some regulations on transport tariffs in Central and Eastern Europe, still few freight rates have been regulated. With fewer restrictions on freight transport pricing, shippers find it hard to figure out what is a reasonable price range to target (Joo, Min, & Smith, 2017). The gaps identified here will help shippers to have a preferable target in the procurement process of road transport service. The detailed rate structure will increase the quantity and quality of the information in the negotiation process. As indicated by Shin & Pak (2016), high-quality information will lower the uncertainties and the party with more information is more likely to control the process and reach a satisfactory result.

In LTL and DDS, gaps are more significant and there are some cases where the estimated rate is higher than the bid price. This pattern is discussed from three perspectives.

The first is the ability of different carriers in organizing backflow. Although in the framework the backhaul cost has been considered, it is only based on the average possibility of getting a backflow between locations. In real operations, the ability to organize backhaul flow differs across markets and companies. Casavant (1993) stated that larger companies have more likelihood of having a higher filling degree in the backhaul trip because of their larger customer base. Cooper, Woods, and Lee (2008) presented carriers have their strength in different markets which could lead to different abilities in the backhaul organization. The relative advantage in backhaul flow will result in a lower bid price.

The relative power between the shipper and the carrier might also influence the actual bid. As Shin & Pak (2016) stated, the party with more power could make the other party accept what they may prefer not to accept. Therefore, an assumption is made that the lower bid price could result from the influence of the case company on the carrier. However, this assumption is proved false after talking with Volvo's employee. In the purchasing process at Volvo, there are few cases carriers need to operate at a loss for some lanes in order to get into Volvo's business.

The third reason is the different operating situations at different carriers. This framework is based on an average estimation which cannot reflect the real operation for different carriers. For example, a carrier of large size might have more discount on purchasing trucks, thus the corresponding costs, such as depreciation and cost of capital, are lower. A carrier that has more customers within a certain region could be more cost-efficient on organizing distribution. Casavant (1993) also analyzed the firms with longer age or larger size is more likely to achieve economies of scale and have a lower transport cost. Rastogi and Arvis (2014) interviewed four different road transport companies operating in the same country and found their cost structures vary significantly. Therefore, different features among carriers might lead to the deviation of estimated rates from bid prices.

To conclude, the gaps between estimated rates and bid prices could be interpreted by targeted saving potential, ability in organizing backhaul flow, and the different operating situations at

## Discussion

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different carriers. However, the comparative power in the negotiation is proved to have little impact on the bid prices at the case company.

## 9 Conclusion and future recommendations

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*In this chapter, conclusions and contributions will be first presented. The research questions will be answered. In the last section, suggestions and recommendations for the future relevant research will be given.*

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### 9.1 Conclusion

This thesis research has established a calculation framework that estimates the road freight rate and transport carbon emissions for road shipments. This theoretical framework is embedded into a user-friendly tool and tested with the data from the case company, Volvo Group. Through the use of proper methodology, the purpose is achieved, and three research questions are answered which summaries the outcome of the thesis. This part will start with a reflection on the research question and then conclude the thesis.

*RQ1: What cost elements should be included when estimating the rate and carbon emissions of road freight transport?*

By applying the cost breakdown method, a calculation framework for estimating the on-road freight rate and transport carbon emissions is designed. In total, 20 elements are identified in the framework. 18 of them are used in the estimation of freight rate, while the other 2 are used to estimate carbon emissions. The 18 cost elements are divided into three categories, fixed costs, variable costs, and process costs. The costs during the backhaul process and handling and waiting time are explicitly considered, which is a difference compared with other literature. And those two elements are proved to have an obvious influence on the total rate.

*RQ2: How is each cost element in the framework calculated?*

For each of the 20 cost elements, the theory for estimation method is introduced and the corresponding formulas are established. The data sources used in the calculation are summarized also. Compared with previous studies on the estimation of road freight rate, the framework has provided more details in the calculation theories and methods.

*RQ3: How can the freight rate estimation framework be embedded into a user-friendly application tool?*

The established theoretical framework is embedded into two computer tools, based on spreadsheets and VBA in Excel respectively. The two tools share the same theories and input data. However, different environments give them different features. The spreadsheet-based tool can take a set of structured information and output results in batches, while the VBA-based tool is more condense and more like a standard software. Both of them are applicable in estimating the freight rate and carbon emissions for a given road shipment.

The framework and the tool are tested with 8 samples from the case company Volvo. The results of the test and verification show the framework can provide three types of information, detailed rate structure, comparison with bid prices, and carbon emissions. The detailed rate structure could help the company to understand how the total rate is structured and identify the root causes for the change of the rate structure. The shipper company could discuss the rate structure with carriers to seek a lower rate, while the carrier can also use the rate structure to identify the opportunity in savings on operation cost. By comparing the estimated rate with the bid price, the saving potentials could be identified. In this comparison, there are some cases where gaps are significant, or estimate rates are higher than bid prices. This phenomenon is explained from three assumptions, imbalanced flow, relative power, and different characteristics across different carriers. Although the framework has considered backhaul cost, in reality, the possibility of organizing cargos might vary from carrier to carrier, which will influence the real bid price. The interaction between stakeholders and the features of carriers will also impact the bid price and bring gaps between estimated rates and real prices. The calculated carbon emissions could help the company in identifying the environmental impact of the transport and assisting them in choosing a better road transport solution.

To conclude, this research has established a framework to estimate freight rate and carbon emissions for road transport. Based on the theoretical framework, two kinds of tools are further developed. The framework and the tools are tested with data from the case company Volvo Group. Compared with the previous studies and tools, the framework built up in this tool includes more cost elements, such as backhaul cost, handling and waiting cost. These cost elements could have a significant influence on the total rate as shown in the results of verification. The theories for the estimation of each cost element are presented at a more detailed level and the calculation methods for all cost elements are provided. All the stakeholders interested in the framework could follow the calculation logic and process. Besides, this thesis also researches how the theoretical framework could be developed into easy-to-use computing tools. The last contribution is that the thesis presents a case study that tests the framework with real operation data from the case company and shows how such a framework could be integrated into the business context and be helpful to a company's operation by providing high-quality information.

## 9.2 Future research and recommendations

In the last section of the thesis research, several proposals for the future improvement of the current calculation framework as well as recommendations for further research are given.

As for the transport carbon emissions section of the calculation framework, it can be further developed into a general emissions calculation framework which calculates not only the carbon emissions but also other environmentally hazardous substances, such as sulfide, nitrogen oxides, etc. Besides, with consideration of other environmental-related cost elements, along with the cost elements in the social and economic aspects, this section can be further expanded into a section for calculating the overall transport sustainable cost for different lines and set-ups.



In this thesis, in total 18 cost elements have been discussed and the calculation method for each cost element is given. The method for calculation is selected with consideration of data availability and the case company's requirement on the level of details. There are alternative calculation methods for some elements that could have a better simulation of reality. For example, considering the depreciation process as a concave curve instead of a straight. From this perspective, the calculation framework could be further upgraded.

Besides, the thesis applies a breakdown method in freight rate estimation but doesn't make a comparison between this method and other existing methods, such as time-series or benchmarking. A systematic comparison between different methods could be done in the future.

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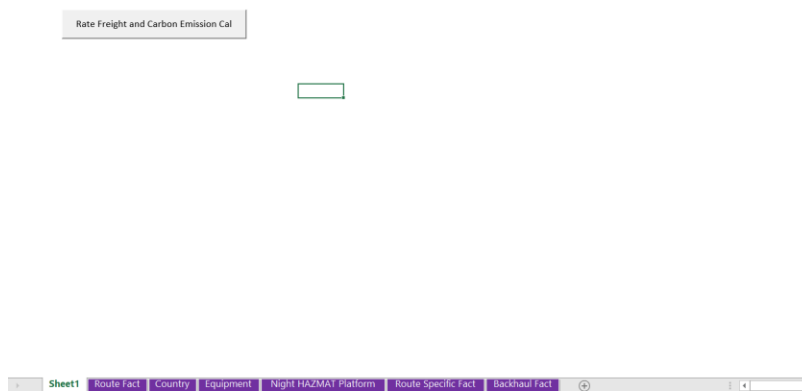
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# Appendix A: Demonstration of tools

## 1. VBA-based tool

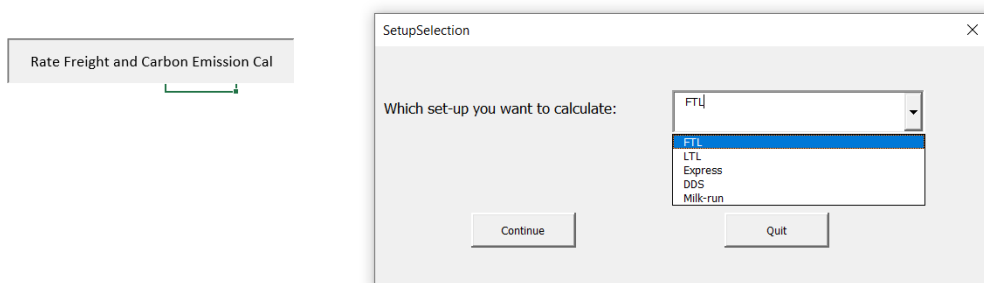
### 1) Main Page

The main page of the VBA-based tool consists of two parts. The first part is the first sheet with a button that could guide the user to the user form. The second part is datasheets which are the sheets after “sheet 1”. They play the role of a database and should be updated occasionally.



### User form of transport set-up selection

After clicking the button “Rate Freight and Carbon Emissions Cal”, the first user form “SetupSelection” will pop up where the user could select one of the five transport set-ups in the combo box.



### User form of FTL set-up

If “FTL” is selected in the first user form, and the user form “FTL” for inputting information will come out after clicking the “Continue” button. The “FTL” user form has two pages. In the first

## Appendix A: Demonstration of tools

page “Data1”, there are two areas, user input and fact data, while in the second page “Data2”, there is only fact data area. The user needs to provide all the needed information by either selecting from combo boxes or typing in the text boxes in the “User Input” area. After that, the user needs to click the “Get Data” button at the bottom to retrieve critical fact data from datasheets according to the information he/she has provided.

Two of the critical fact data, distance and fuel index, are presented on the first page because they are even more important than the other critical fact data. The other critical fact data are presented on the second page.

If the user has checked all the information and makes sure they are correct, he/she can get the results by clicking the button “Cal!” at the bottom.

The image shows two screenshots of the FTL software interface. The top screenshot displays the 'Data1' tab, which is divided into two main sections: 'User Input' and 'Fact Data'. The 'User Input' section includes fields for Origin (Post Code), From Country (USA), Destination (Post Code), To Country (USA), LSP Country (USA), Equipment Type (Mega), Booking Platform (Transportation), Routing (Eurobridge), Custom (II), Team Setting (Solo), HAZMAT (II), Night Premium (II), Single/Round Trip (Single), Total WoW, Total WoW in Backward, No. of Stops (OD Included), No. of Stops in Backward (OD Included), Fuel Index, Road Distance (PTV), Pre-Carriage Distance, and On-Carriage Distance. The 'Fact Data' section is currently empty. The bottom screenshot displays the 'Data2' tab, which contains a 'Fact Data' section with fields for Average Speed (km/h), Yearly Gross Salary (EUR), Daily Compensation (EUR), HAZMAT Index, Night Premium Index, Platform Cost (EUR), Payment Term (Day), Custom Time (Day), Bridge Time (Day), On road charge (PTV) (EUR), Ferry Charge (EUR), and Estimated Profit Percentage. Both screenshots feature a 'Get Data' button, a 'Cal!' button, and a 'Quit' button at the bottom.

## 2. Spreadsheets-based tool

### Input and Result Sheet



[illegible]

AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO
FTL Results		FTL Intermediate Results													Cost Elements (Variable)									
Expected Road Damage Should Cost (Euro/Angle Bridge Loads Should Cost (Euro/Angle Bridge Exha		FTL Operating Cost (Euro/Angle Bridge Loads		Operating Cost (Euro/Angle Bridge Fee Endorse Percentage				Fuel Cost		Labor Cost		Maintenance and Repair Co		Consuming Material		Course Specific		C						

[illegible]

[illegible]

## Appendix B: VBA Code

Due to the limit on pages, only screenshots of part of the codes will be shown.

```
Private Sub Calculate_Click()  
    Dim TripDistance As Double, AveSpeed As Double, DrivingTime As Double, EquipmentType As String, LSPCountry As String  
    Dim YearlySalary As Double, DailyCompensation As Double, HAZMAT As Double, NightDel As Double, TeamSetting As String  
    Dim ForStops As Integer, BackStops As Integer 'Variable for handling and waiting  
    Dim CapitalPercentage As Double, ProfitPercentage As Double, PaymentTerm As Integer 'variable for cost of capital  
    Dim CustomTime As Double, BridgeTime As Double, ForWoW As Double, BackWoW As Double 'variable for depreciation  
    Dim RoadCharge As Double, FerryCharge As Double 'variable for route specific  
    Dim OCountry As String, DCountry As String  
    Dim FuelCost As Double, MaintenanceCost As Double, ConsumingCost As Double, LaborCost As Double, TaxCost As Double  
    Dim Depreciation As Double, AdditionalDepre As Double, CapitalCost As Double, RoadSpecific As Double, HandlingCost As Double  
    Dim AveWorking As Double, AnnualMileage As Double  
    Dim ResultArray1 As Variant, ResultArray2() As Variant, CostArray() As Variant, n As Integer, i As Integer  
    Dim OperatingCost As Double, ShouldCost As Double  
  
    'The variable that appears in userForm should be given the value here so that the function for cost element can be  
    AverageSpeed = Val(FTL.AverageSpeed.Value)  
    EquipmentType = FTL.EquipmentType.Value  
    Routing = FTL.Routing.Value  
    LSPCountry = FTL.LSPCountry.Value  
    OCountry = FTL.FromCountry.Value  
    DCountry = FTL.ToCountry.Value  
  
    If Routing = "Eurobridge" Or Routing = "Anglobridge UK-EU" Or Routing = "Anglobridge EU-UK" Then 'Distance based on  
        TripDistance = Val(FTL.PreDistance.Value) + Val(FTL.OnDistance.Value)  
    Else  
        TripDistance = Val(FTL.Distance.Value)  
    End If  
  
    FuelIndex = CDBl(FTL.FuelIndex.Text)  
    YearlySalary = FTL.YearlySalary.Value  
    DailyCompensation = FTL.DailyCompensation.Value  
  
    PaymentTerm = FTL.PaymentTerm.Value  
    ProfitPercentage = CDBl(FTL.ProfitPercentage.Value)  
  
    DrivingTime = TripDistance / AverageSpeed  
  
    'Fuel Cost  
    FuelCost = CalFuelCost(TripDistance, EquipmentType, FuelIndex)  
    n = n + 1  
    ReDim Preserve CostArray(n) As Variant  
    CostArray(n) = FuelCost  
  
    'Maintenance Repair Consuming Cost  
    ResultArray1 = CalMaintenanceConsumingCost(TripDistance, EquipmentType, LSPCountry)  
    MaintenanceCost = ResultArray1(1, 1)  
    ConsumingCost = ResultArray1(2, 1)  
    n = n + 2  
    ReDim Preserve CostArray(n) As Variant  
    CostArray(n - 1) = MaintenanceCost  
    CostArray(n) = ConsumingCost  
  
    'platform cost  
    PlatformCost = FTL.PlatformCost.Value  
    n = n + 1  
    ReDim Preserve CostArray(n) As Variant  
    CostArray(n) = PlatformCost  
  
    'LaborCost and Average working hours per day and Annual Mileage  
    ResultArray2 = CallLaborCost(LSPCountry, YearlySalary, DailyCompensation, HAZMAT, NightDel, TeamSetting)  
    LaborCost = ResultArray2(1, 1)  
    AveWorking = ResultArray2(2, 1)  
    AnnualMileage = ResultArray2(3, 1)  
    n = n + 1
```

## Appendix B: VBA Code

---

```
'Cost of Capital
CapitalCost = CalCapital(EquipmentType, LSPCountry, AveWorking, AnnualMileage, YearlySalary, DailyCompensation, F
n = n + 1
ReDim Preserve CostArray(n) As Variant
CostArray(n) = CapitalCost

'Depreciation Cost
Depreciation = CalDepre(EquipmentType, TripDistance)
n = n + 1
ReDim Preserve CostArray(n) As Variant
CostArray(n) = Depreciation

'RouteSpecific Cost
RoadCharge = FTL.OnRoadCharge.Value
FerryCharge = FTL.FerryCharge.Value
RoadSpecific = RoadCharge + FerryCharge
n = n + 1
ReDim Preserve CostArray(n) As Variant
CostArray(n) = RoadSpecific

'Handling and Waiting Cost
HandlingCost = CalHandlingCost(ForStops, DrivingTime, TaxCost, LaborCost, InsuranceCost, GarageCost, CapitalCost)
n = n + 1
ReDim Preserve CostArray(n) As Variant
CostArray(n) = HandlingCost

'Additional Depreciation
AdditionalDepre = CalAdditionalDepre(EquipmentType, CustomTime, BridgeTime, ForWoW)
n = n + 1
ReDim Preserve CostArray(n) As Variant
CostArray(n) = AdditionalDepre

Function CalFuelCost(TripDistance As Double, EquipmentType As String, FuelIndex As Double) As Double
    Dim FuelConsumption As Double, TrafficDensity As Double, ColumnNo As Variant, findcell As Range
    TrafficDensity = 0.14
    Sheets("Equipment").Activate

    Set findcell = Rows(1).Find(EquipmentType, LookAt:=xlWhole) 'look for the consumption of this truck type
    If Not findcell Is Nothing Then
        ColumnNo = findcell.Column
        FuelConsumption = ActiveSheet.Cells(5, ColumnNo)
    End If

    If TripDistance <= 100 Then
        CalFuelCost = FuelConsumption * TripDistance * TrafficDensity * FuelIndex
    Else
        CalFuelCost = TrafficDensity * FuelConsumption * 100 * FuelIndex + FuelConsumption * TripDistance * FuelIn
    End If
End Function

Function CalMaintenanceConsumingCost(TripDistance As Double, EquipmentType As String, LSPCountry As String) As Var
    Dim MaintenanceUnit As Double, TiresUnit As Double, LubricantUnit As Double, MaintenanceIndex As Double, Consu
    Dim CostArray(2, 1) As Double
    Dim ColumnNo As Integer, RowNo As Integer, findcell As Range

    Sheets("Equipment").Activate
    Set findcell = Rows(1).Find(EquipmentType, LookAt:=xlWhole) 'look for the unit of this truck type
    If Not findcell Is Nothing Then
        ColumnNo = findcell.Column
        MaintenanceUnit = ActiveSheet.Cells(8, ColumnNo) + ActiveSheet.Cells(16, ColumnNo)
        TiresUnit = ActiveSheet.Cells(7, ColumnNo) + ActiveSheet.Cells(15, ColumnNo)
        LubricantUnit = ActiveSheet.Cells(6, ColumnNo) + ActiveSheet.Cells(14, ColumnNo)
```

## Appendix B: VBA Code

---

End Function

---

```
Function CallLaborCost(LSPCountry As String, YearlySalary As Double, DailyCompensation As Double, HAZMATIndex As Double
    Dim DrivingLimitTeam As Integer, WorkingLimitTeam As Integer, DrivingLimitSolo As Integer, WorkingLimitSolo As Integer
    Dim ExtraStopTime As Double, LoadingUnloading As Double
    Dim TeamIndex As Double, AnnualMileage As Double, HandlingTime As Double, AveWorking As Double, AveWorkingTeam As Double
    Dim RowNo As Integer, CostArray(3, 1) As Variant, findcell As Range
```

```
    LoadingUnloading = 1
    ExtraStopTime = 0.5
    DrivingLimitTeam = 20
    WorkingLimitTeam = 21
    DrivingLimitSolo = 9
    WorkingLimitSolo = 13
```

```
    Worksheets("Country").Activate
    Set findcell = Columns("A").Find(LSPCountry, LookAt:=xlWhole)
    If Not findcell Is Nothing Then
        RowNo = findcell.Row
        DriverDays = Range("E" & RowNo).Value
    End If
```

```
    HandlingTime = LoadingUnloading * 2 + ExtraStopTime * (Stops - 2) 'handling and waiting time, used for AveWorkingT
```

```
    'Calculate TeamIndex
    AveWorking = CalAveWorking(DrivingTime, DrivingLimitSolo, WorkingLimitSolo, HandlingTime)
    AnnualMileage = AveWorking / (DrivingTime * 2 + HandlingTime) * TripDistance * 2
```

```
    If TeamSetting = "Solo" Then
        TeamIndex = 1
    Else
```

```
Function CalTIG(EquipmentType As String, LSPCountry As String, AveWorking As Double, DrivingTime As Double) As Variant
    Dim YearlyTax As Double, YearlyInsurance As Integer, YearlyGarage As Integer, VehicleDays As Integer
    Dim ResultArray(3, 1) As Variant, ColumnNo As Integer, RowNo As Integer, findcell As Range
```

```
    Sheets("Equipment").Activate
    Set findcell = Rows(1).Find(EquipmentType, LookAt:=xlWhole) 'look for the unit of this truck type
    If Not findcell Is Nothing Then
        ColumnNo = findcell.Column
        YearlyTax = ActiveSheet.Cells(9, ColumnNo)
        YearlyInsurance = ActiveSheet.Cells(10, ColumnNo)
        YearlyGarage = ActiveSheet.Cells(11, ColumnNo)
    End If
```

```
    Worksheets("Country").Activate 'look for vehicle working days
    Set findcell = Columns("A").Find(LSPCountry, LookAt:=xlWhole)
    If Not findcell Is Nothing Then
        RowNo = findcell.Row
        VehicleDays = Range("D" & RowNo).Value
    End If
```

```
    ResultArray(1, 1) = YearlyTax / AveWorking / VehicleDays * DrivingTime
    ResultArray(2, 1) = YearlyInsurance / AveWorking / VehicleDays * DrivingTime
    ResultArray(3, 1) = YearlyGarage / AveWorking / VehicleDays * DrivingTime
```

```
    CalTIG = ResultArray
```

End Function

---

```
Function CalDepre(EquipmentType As String, TripDistance As Double) As Double
    Dim VehicleInv As Double, VehicleDiscount As Double, VehicleEndValue As Double, TrailerInv As Double, TrailerDis
```

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## **Appendix C: Question list for the semi-structured interview**

- Could you explain more about the set-up DDS and its two legs?
- Could you explain more about the following three terms used in the Volvo transport set-ups: “backhaul”, “backward trip of a round trip” and “drop trailer (WoW)”? Also, could you explain more about how they are considered in each of the transport set-ups?
- Does Volvo own any hub on its own which can conduct the cross-dock operation or all the hub are externally outsourced? If there are hubs owned by Volvo, should the cost generated by the internal hubs be considered in this calculation framework?
- Could you give us more information regarding the route engine we are using and the data it can provide? How do you trust with this route engine?
- Could you explain more about the digital platform cost that the calculation framework should consider?
- Could you explain more about the “payment term” of Volvo?
- How do you think that this new tool/ framework for estimating the road freight rate can contribute to your business operations?
- What other functions would you like to have within this calculation framework and the applicable tools?
- What other internal data sources (e.g. reports, slides, database) can you share with us for this study?

## **Appendix C: Question list for the semi-structured interview**

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- Can you introduce the current tool for estimating the road freight rate? How does this current tool perform and how do you trust in this current tool?
- What could be the reasons for the gap between the real bid and the estimated rate for a lane? Any insight from the business relation or other non-technical reasons?
- Anything else that you would like to mention or stress?