



UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master Degree in International Business and Trade

The true costs of internationally purchasing of energy storage systems
in the Electromobility sector

-A case study of Volvo Trucks battery supply chain-

Graduate School

Master Degree Project 2019

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Abstract

Prior studies which are written in the field of the total cost of ownership (TCO) have focused on the application of TCO concept on mature industry sectors. The argument for the usefulness of TCO is mainly based on the fact that in the case of a mature industry the structure of supply chain can be easily and effectively identified. However, few numbers of researches have applied the concept of TCO on relatively new and emerging industrial sectors. Our study tends to use the concept of TCO to identify major costs that incurred during the international purchasing of energy storage systems [immature product] at a multinational company located in Sweden and operating in the commercial vehicle industry. This investigation was based on conducting interviews at Volvo Trucks Electromobility Purchasing department. The result shows that there are seven cost factors in addition to the purchase price have been incurred during the international purchase of energy storage systems. In the immature electric vehicle industry sector, we could find that the reliability of the ‘*make-buy*’ decision that can be made based only on the value of TCO is restricted by other decision-influencing factors. Yet, we believe that through the concept of TCO the real cost of international procurement can be reliably assessed. This study adds to the existing literature by enhancing the understanding of the interconnected theoretical fields: MNC supply chain management and total cost of ownership.

Keywords: *Total cost of ownership, International purchasing, Global supply chain, Electromobility, Energy storage systems (batteries), “Make or buy” decisions.*

Acknowledgment

We would like to express our sincerest gratitude to the team of the Electromobility Purchasing at Volvo Trucks for their valuable insights provided to make this research reliable and efficient. Their contributions have been of paramount importance. In addition, our sincerest appreciation to Julien Chabanne and Mathias Le Saux for their unlimited support for providing us with valuable and necessary information regarding the battery sector.

Last but not least, we would like to send our gratitude to our supervisor Ramsin Yakob, who has guided us through the research process and assisted us to increase the quality of our thesis.

Gothenburg, 7th June 2019

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List of abbreviations

B2B – business to business

BEV - Battery electric vehicle

BMS - Battery management system

GTP - Group Trucks Purchasing

HEV - Hybrid electric vehicles

ICE - Internal combustion engine

IP - Intellectual property

MNC - Multinational Company

NPV - Net present value

OEM - Original equipment provider

PD - Project development

PSL - Potential supplier list

SCM - Supply chain management

SQE - Supply quality engineer

TCO - Total cost of ownership

USMCA - USA Mexico Canada trade agreement

1. Introduction

This chapter provides an introduction in the subject's background, which leads to the problem discussion. Following the problem discussion, the proposed research question of the study is presented, and lastly, the delimitations of the study are outlined.

1.1 Background

During the last few decades, the main governmental strategies regarding the international trade of commodities kept the tariffs on imports low (Bown, 2018). Since the 1980s, the phenomena of “re-globalization” has been widely and internationally supported (Findlay and O'Rourke, 2009). To facilitate the decreasing trade barriers between countries, the World Trade Organisation (WTO) has created the General Agreement on Tariffs and Trade 1994 (GATT) to oversee the multilateral trading system (WTO, n.d. a). Up until today, 164 countries have become a member of the GATT 1994 (WTO, n.d. b). Thanks to the re-globalization, low tariffs duties supports domestic access to foreign-produced components and improves the competitiveness of domestic industries (Findlay and O'Rourke, 2009). As a result, firms have expanded their supply chain across borders and have started to source globally. Countries have decreased trade barriers of imported intermediates and taken legal responsibility via international trade agreements to keep the barriers low on international trade (Bown, 2018).

However, not everybody was benefited positively from the effects of the re-globalization. As Findlay and O'Rourke (2009) put it, according to the Heckscher–Ohlin theory, in wealthy countries the unskilled workers have more “*protectionist minded*”, as they tend to believe that their interests are being hurt by international trade. This tendency of growing protectionism, among the blue-collar workers in the wealthy countries, could be sufficient on its own to result in a backlash in the growing international trade tendency, even if the negative beliefs of the people are not accurate (Findlay and O'Rourke, 2009). By today, the prediction of Findlay and O'Rourke (2009) about a forthcoming “*anti-globalization*” wave among the wealthy countries has been confirmed in many aspects. Two very good examples of this phenomena are the Brexit, the impending withdrawal of the United Kingdom from the European Union in 2019, and the election of president Donald Trump in the USA in 2017 (Sampson, 2017; Lighthizer, 2018).

The United States has the world's largest nominal trade deficit (Amadeo, 2019). The deficit in goods was approximately \$807 billion in 2017 which means that during the last two decades the amount of trade deficit has more than quadrupled (World Bank, n.d.). Thus, the Trump administration's main and most urgent aim is to reduce the trade deficit mainly with protectionist measures (Taylor, 2018; Lighthizer, 2018). As a part of the new and more protectionist international trade policy, up until today (February 2019), the US has declared three rounds of tariffs on Chinese goods, which are worth all together more than \$250 billion (BBC News, 2019). The new duties vary from 10% to 25% and are applicable for a wide sort of industrial and consumer goods, from handbags to railway equipment (BBC News, 2019). The dispute between China and the US covers many aspects of the international trade, such as the enormous US trade deficit with China, \$375.6 billion in 2017 (Ustr, n.d.), or China's weak protections for intellectual property (Worland, 2018). Another evidence showing the new and more protectionist international trade policy of the US is the intention to replace the North American Free Trade Agreement (NAFTA) with the United States-Mexico-Canada Agreement (USMCA). This agreement contains inter alia stricter country of origin rules in the automobile sector (Bryan, 2018). Furthermore, Trump has signed an executive order in January 2017 to withdraw the US from the agreement to join the Trans-Pacific Partnership, which would have been a free-trade agreement between the US and eleven other countries in the Pacific Ocean region (Taylor, 2018). It is not a surprise that the possible negative effects of the changed international trade policy, practicing by the US, have become an urgent issue in the global trade as well (Partington, 2018).

1.2 Problem discussion

The intensifying protectionist way of organizing international trade barriers by the US has already caused substantial uncertainty among multinational companies (Farrer, 2018). One part of this uncertainty is driven by, e.g. a fragile temporary truce of a possible trade war between the US and China (The Economist, 2018). This current phenomena with the trade barriers made the situation of MNCs harder, since during the last two decades the international sourcing has become a very attractive way to reduce the company's cost base as taking advantage of generally lower location factors in low-cost countries (Weber, Hiete, Laurel and Rentz, 2010). Thus, companies have to consider different trends and outcomes of the changing international business climate in order to make strategic and long term decisions (Kennerley and Neely, 2003). This gives MNCs two choices either they risk their future businesses by continuing their intensive globalization, or start to localize their activities [sourcing, producing and maybe even

innovating where they sell] in order to eliminate the possible consequences of an increasing protectionist international business climate (Ghemawat, 2017). Further, even if a worldwide trade war will not occur in the short run, the so far accepted and stricter trade regulations make the international and global trade more expensive. Therefore, companies are going to continually assess and compares the cost of a localized and internally produced material with the cost of an international sourcing of the identical material. Based on that assessment and comparison, companies can then choose the supply chain structure that enables them to overcome the new challenges in a most efficient way, i.e. with lower costs. Further, protectionism makes multinational companies that are starting to operate in a new sector uncertain about the reliability and profitability of the outcome of adopting the same strategies used and optimized in a developed industry sector under a liberalized international trade environment.

The emergence of the Electromobility within the automotive industry is unavoidable in the next decades, as the old technology of combustion engine-driven trucks, cars and buses cannot fulfil the criteria that are necessary to decarbonize the world economy (Thiel, Nijs, Simoes, Schmidt, Zyl, and Schmid, 2016). Thus, according to automotive industry observers, this particular vehicle industry segment is at the dawn of a “*paradigm change*” (Auvinen, Järvi, Kloetzke, Kugler, Bühne, Heintl, Kurte and Esser, 2016). This means, that the Electromobility is considered a relatively new and currently emerging industrial sector (Smith, Sanborn and Slaughter, 2017). As the implementation of the new technology changes fundamentally the automotive industry, it requires significant changes in the way that commercial vehicles are manufactured and the vehicle industry supply chains are organized (Altenburg, Schamp, and Chaudhary, 2015).

The end products [electric vehicles] are considered complex manufactured goods that consists of the contribution of several different special industry segments, for example, the involvement of battery cells from the chemical industry into the automobile sector (Wood Mackenzie, 2018). Since those different special industry segments are located in different regions around the world, it means that the supply chain of batteries spreads over different countries and even continents. In this way, the supply chain of batteries can be described as a global supply chain (GSC) (Manuj and Mentzer, 2008). In the Electromobility sector, GSC has not developed yet, and the number of its actors, especially in the production chain, is still limited (McKinsey and Company, 2018). Accordingly, the chance to structure a supply chain, which is more capable to mitigate the risk arisen by the currently turbulent international trade climate, is much more

favourable in the case of the Electromobility sector than in the case of a mature industry sector, which already has a stable operating supply chain and is characterised by strong relational rents (Dyer and Singh, 1998). Since such change is coming, it is predictable that new alliances will occur between different market players whose cooperation was not typical before, especially, in the automotive industry (Altenburg et al. 2015). A good example of the transformation of such a relationship is the involvement of companies in the battery industry with those in the automotive industry due to the accelerating demand of electrified vehicles [using batteries to propel a vehicle] (Frost, 2018).

The changing and unstable international trade climate influence not just the fully operating MNCs but the new and emerging enterprises such as those operating in the Electromobility sector, where the supply chain footprint is quite in its initial phase and not fully developed yet (Ghemawat, 2001; Manuj and Mentzer, 2008). Due to the emergence of protectionist trade barriers, cost and risk assessment should be conducted in order to be able to evaluate the cost-effectiveness of a concentrated and dispersed supply chain setup (Jensen and Petersen, 2013). Therefore, the emphasis should be more on efficient procurements [lower purchasing costs] that can comply with the altering business circumstances (Bhamu and Singh Sangwan, 2014). In order to identify the true costs for purchasing any material, a method of total cost of ownership (TCO) would be used. This method is considered by many researchers as a reliable and comprehensive method to identify the true purchasing costs that are incurred in the procurement of materials from a domestic and even offshore suppliers (Ferrin and Plank, 2002). This method has been emphasized by its efficiency in identifying both the direct and indirect costs that are incurred for each purchase situation of a particular component/material (Ellram, 1993; Ferrin and Plank, 2002).

1.3 Purpose and the research question

The purpose of this study is to investigate and contribute to the understanding of how the currently increasing trade barriers influence, not only the costs of the relatively new and emerging Electromobility sector but also, the decision of internally produce or externally source materials. More precisely, the aim is to identify and understand the most influential cost factors that are incurred when an Electromobility company decides to purchase specific component [batteries] from external suppliers. Thus, the research question has been formulated to fulfil the aim of this research as follows:

What cost factors are essential in an OEM's purchasing decision to source energy storage systems in a de-liberalizing international trade environment?

In order to find answers to the research question, we perform a single case study on the company of Volvo Trucks, a multinational corporation within the commercial vehicle industry, at its entrance stage in the Electromobility sector. In accordance, the authors of this study intend to contribute to the understanding of a relatively novel study field by observing what kind of cost factors influence the cost of ownership of the international supply of batteries.

1.4 Delimitations

The focus of this study is on the upstream activities of the supply chain of energy storage systems [batteries]. Upstream activities, which indicate to the supply of materials and spare parts, can also refer to other activities such as manufacturing, assembly, or design, depending on which activities are performed externally (by supplier) or internally (in-house) (Min and Zhou, 2002). The fact that we focus only on one component namely the batteries can mean additional limitation to our study. Besides the batteries, the Electromobility purchasing department involves other externally sourced components e.g. electric motor drive system or transmission. The procurement of those components entails different supply chain and costs. A further delimitation is driven by the fact that the industry sector that we have conducted the study in is rapidly changing. It can occur that even during the duration of the observation, which is approximately 5 months, things have been changed.

2. Literature Review

The following chapter starts by discussing the theoretical contributions in global supply chain and its relation to the total cost of ownership concept. Following, many cost drivers of total cost of ownership have been highlighted to map the most conventional costs in case of purchasing. Lastly, a conceptual framework is developed by connecting the theoretical fields of global supply chain with the total cost of ownership.

2.1 Global supply chain management

There are many definitions to define the supply chain. According to New (1997), the supply chain refers to purchasing, distribution and materials management. It can also refer to a network of a production process that can be domestic or global (Albino, Izzo & Kühtz, 2002). There are several factors that differentiate between local and global supply chain (Meixell and Gargeya, 2005), such as the geographic distances, the varying regulations and political environments, and/or the cultural distances (Aydin, Cattani, and Druehl, 2014). This means that the global supply chain is more complex than the local one (Meixell and Gargeya, 2005). A supply chain can be characterized by its upstream activities taking place between the original equipment manufacturer (OEM) and its suppliers, and downstream activities taking place between the OEM and its customers (Frohlich and Westbrook, 2001; Cavinato, 1992). The focus of this study is on the upstream activities of the supply chain.

As markets became global in the 1990s, many companies had begun to face some challenges in terms of getting a service or product from the right place at the right time with the right price (Li, Ragu-Nathan and Subba Rao, 2006). It became clear for them that it was not sufficient to increase only their own efficiency in order to increase their competitiveness, but the efficiency should be extended to cover their supply chain as well (Gunasekaran, Patel & Mcgaughey, 2004).

The absorption and application of supply chain management (SCM) have become a cornerstone for staying competitive in the international market. Global supply chain involves several activities and many actors; it builds up a complex system that has to be managed by all actors (Li et al., 2006, Benita M. Beamon, 1999). The main purpose of SCM is to facilitate the cooperation between the firms that results in fewer costs or higher added-value products (Cavinato, 1992).

2.2 Total Cost of Ownership in the management of supply chain

As it has already been discussed above, the complexity of the SCM is exceptionally deep, therefore the scope of the literature related to the global supply chain management is also very diversified. The concept of SCM tends to consist of e.g. purchasing and supply management, logistics and transportation, operation management, risk management, knowledge and information management, and corporate social responsibility management, to name a few (Carter and Jennings, 2002; New, 1997; Li et al., 2006). As it is visualized in Figure 1, within the purchasing segment, it can be found that the sub-chapters of the global supply chain contain several methods for selecting suppliers such as the Total Cost of Ownership (TCO), the Life-Cycle Costing, the Zero-Based Pricing, and the Cost-Based Supplier Performance Evaluation (Meixell and Gargeya, 2005; Ronchi, Caniato and Luzzini, 2015; Afonso, 2018). Every method, except TCO, has some additional limitations which make it less popular among researchers and industries (Ellram, 1994, Noorbakhsh, Boehl and Brown, 2019). Therefore, the limitations of these methods make TCO the most appropriate one for this study. TCO is applied as a tool in the Electromobility supply chain to identify costs in international procurements. Furthermore, while TCO can be applied as a selection tool for a supplier, it can also be applied in the decision-making process of “make or buy” (Mathew, Lim, Ma, Sands, Cholette, and Borghesani, 2019). This is because when comparing the best supplier setup with the cost of internal production, a decision can be made between either externalizing or internalizing the production. When comparing the advantages of internalization, such as a lower risk of knowledge leakage and/or no free riding; with the advantages of externalisation, such as more access to specialised expertise, and more economies of scale and scope; a firm can have a more comprehensive picture regarding ‘*make or buy*’ decisions (OECD, 2013). Hence, a value chain activity, e.g. production, would be carried out internally if the advantages of internalization exceed the ones from externalization, and vice versa (OECD, 2013).

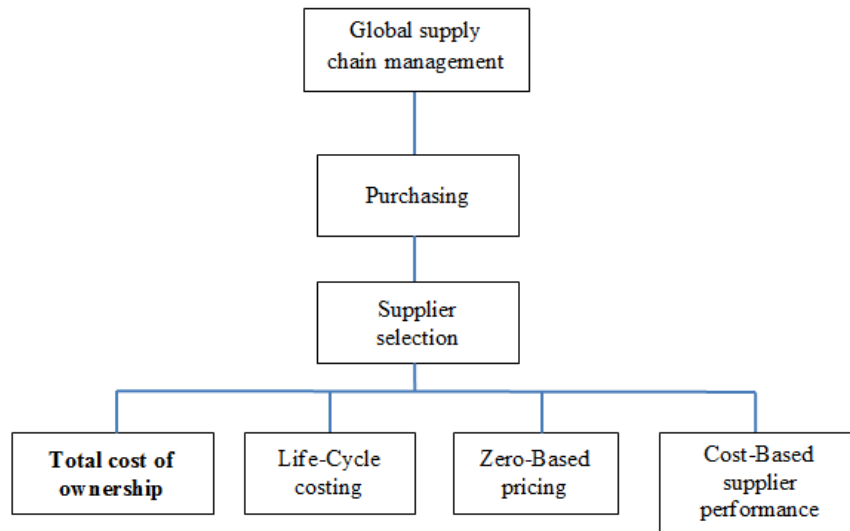


Figure 1: Methods of supplier selection under the management of supply chain. Designed by us based on literature review.

2.3 Total Cost of Ownership [TCO]

The procurement division has been given a significant role by many corporations in recent years (Degraeve and Roodhooft, 1999; Cousins and Spekman, 2003; Zachariassen and Arlbjørn, 2011) since it has been observed that the purchasing costs constitute a large proportion [around 60-70%] of the costs of the good sold (Herberling, 1993; Cousins, Lamming, Lawson, and Squire, 2008). More specifically, Van Weele (2005) observes that the overall costs of goods sold for electronics and automotive industries have reached 80% of the total value of a product. The purchasing costs can be categorized as direct cost, which refers to related costs of purchasing a particular component such as the purchase price and the cost of inbound logistics (Zachariassen and Arlbjørn, 2011); and indirect costs, which refers to all the expenses that have an indirect impact on the purchaser such as inter alia company visits (Zachariassen and Arlbjørn, 2011) and/or downtime costs resulted from insufficient quality (Ellram & Siferd, 1993). Buying firms have started to focus more on indirect costs beside the direct ones in order to increase their competitiveness in their current and potential markets (Zachariassen and Arlbjørn, 2011; Martens, Walterbusch, and Teuteberg, 2012). Since TCO can observe efficiently the overall costs including the hidden ones (indirect), it has been adopted by many firms (Ellram, 1994; Ellram and Siferd 1998; Martens et al. 2012).

The total cost of ownership approach stems from the early literature on purchasing in Harriman's paper in 1928 and has been adopted by firms since the late eighties (Ellram and Siferd, 1993). TCO is defined by Ellram (1994, p. 171) as "*the true cost of doing business with*

a particular supplier". TCO is a tool that considers the costs from the creation of an idea of purchasing a particular material(s), to the point where it is delivered to the added-value-process or to the final customer (Ellram, 1993; Ellram, 1995). To put it differently, Anderson and Narus (2004, p.98) define it as "*the sum of the purchase price plus all expenses incurred during the productive lifetime of a product or a service minus its salvage or resale price*". This means, that TCO tackles a wide range of costs besides the purchasing price of a purchased component/material (Ellram, 1994).

2.3.1 TCO Classifications

According to Ellram (1995), TCO has been classified into two approaches: the dollar-based and the value-based. The dollar-based approach refers to the actual costs that relate to the relevant elements of TCO. For example, a TCO for a component which equals \$15.00, refers to all costs that have been incurred during the procurement of that goods such as quality costs and logistics costs besides the price of the bought component. On the other hand, a value-based approach deals with non-monetary measures such as costs related to the reliability of the delivery, and/or the number of quality failure (Ellram, 1995). According to Piscopo, Johnston, and Bellenger's (2008), qualitative factors such as on-time delivery and material quality could be given a monetary (numerical) value based on the amount of extra value they might generate. In this case, suppliers are being given ranks based on their overall costs (Piscopo et al., 2008).

Researchers for TCO have made many models during the last twenty years to tackle all the costs related to different purchased components or purchase situations. Ellram (1993) suggests that TCO components (costs) can be divided into three groups: pre-transaction costs, transaction costs, and post-transaction costs. Ellram and Siferd (1993) suggest that TCO components can be divided into six broad categories: quality, management, delivery, service, communications, and the purchase price. Ferrin and Plank (2002) suggest a TCO model with thirteen main categories: operation costs, quality costs, logistics costs, costs related to technological advantage, costs related to supplier reliability and capability, maintenance costs, inventory costs, life-cycle costs, customer related costs, opportunity cost, transaction cost, and other costs (miscellaneous) besides the initial price. While Anderson and Narus (2004) propose that all TCO components are placed under three classifications: (1) acquisition expenses, which include search costs, processing orders and delivery cost; (2) conversion costs, which include all the costs regarding the handling and storing components, implementation into the production process, and the maintenance; (3) disposal costs, which refer to all activities phasing

out the remains of the item after being used. Degraeve, Roodhooft, and Van Doveren (2005) suggest that TCO models should include all the costs related to quality, logistics, administration, storage, communication, services, and defects. Lycette & Lowenstein (2011) propose that their cost drivers for a TCO are the ones related to the acquisition, preventive maintenance, repair (corrective maintenance), technology refresh (upgrading), training & education, resale value or disposal, facilities, and last but not least the logistics and downtime mitigation. Piscopo et al. (2008) suggest that in addition to the acquisition expenses, conversion and disposal costs, an accurate TCO should include the purchase price and salvage/resale value of the purchased component as well.

A unique way of applying TCO in a supplier selection has been conducted by Degraeve and Roodhooft (1999), who have combined TCO perspective with activity-based costing. The scholars have created a hierarchical structure of activities which involves costs during the purchasing process. According to their findings, there are three basic levels of activities that include different cost driving factors. The first level is the supplier-level activities that describe costs incurred whenever the buying company uses a supplier as a source to get the resources. Examples of those costs are the ones that are related to quality auditing, labour work (purchasing staff), and development costs. The second level is the order-level activities that comprise costs incurring each time a request for an order is placed with a specific partner and covers inter alia costs related to reception, invoicing and transportation. The third level is the unit-level that takes into consideration every cost that associates with the purchasing unit, where the procurement decision has been made. It includes costs related to the internal and external failure such as a production breakdown due to a defect of the purchased component.

In overall, the existing literature is varied in applying TCO for different purchases ranging from commodities and complicated products (Ellram and Siferd, 1998; Ferrin and Plank, 2002; Zachariassen and Arlbjørn, 2011; Al-Alawi and Bradley, 2013), to simpler products and services (Degraeve, Roodhooft, and Van Doveren, 2005; Ronchi et al. 2015). This variation can be considered as the main reason behind the discrepancy of TCO models. This discrepancy is necessary since it is believed that none of the TCO models fits for all the purchase situations and scenarios (Ellram and Siferd, 1998). Using an identical model of TCO (a single model) by many firms with different business activities could harm the buyer-supplier relationship and won't reflect reliably the true TCO (Zachariassen and Arlbjørn, 2011). Even though the respondents in Ferrin and Plank's study (2002) have stressed on having different TCO models dealing with different commodities, it has been noticed that most, if not all, TCO models have

used some similar cost factors (Martens et al., 2012). Nevertheless, any differentiation of TCO models depends significantly on the purchased component or the purchase situation (Ellram, 1995).

When investigating the components of different TCO models, it is found that pre-transaction costs, transaction costs and post-transaction costs, developed by Ellram (1993), cover the widest range of possibly incurred costs, as it is represented in the following sections.

Pre-transaction Costs

Pre-transaction costs refer to all costs starting from generating an idea about purchasing an item up to the point, but not including, an order placement. Furthermore, according to Ellram (1993), pre-transaction costs could include the costs of investigating the supplying company to check its status whether it is qualified or not regarding the reliability of quality and delivery date. Examples of such costs could be the ones generated from visiting a plant, and the cost resulted from the time spending by a procurement manager to negotiate with current/potential suppliers (Degraeve, Labro and Roodhooft, 2000). Pre-transaction costs could also include the costs of making a supplier familiar with the buying companies' operations and activities in order to be capable to provide them with an item that matches exactly with the need of that item (Ellram, 1993).

Transaction Costs

According to Ellram (1993), transaction costs refer to all costs from the time of placing an order for purchasing an item to the point of receiving that order. This includes the cost of preparing and following up the order, paying the bill, getting the order to the buying firm, inspecting the accuracy and the quality of the purchased item, moving the purchased item to the next process of value-adding, sending back the defective item to the supplying firm, and last but not least following-up the correction. Thus, transaction costs could be interpreted to include: operation costs, quality costs, logistics costs, and last but not least administrative costs.

Post-transaction Costs

Post-transaction costs refer to all costs incurred after the purchased component has been delivered to the buying firm such as the costs related to a quality shortcoming or the activities related to repairing any defects (Ellram, 1993). These costs could include maintenance costs, warranty costs, disposal costs, depreciation, and indirect labour costs (ibid.).

2.3.2 Conventional TCO components

The review of TCO literature points out that logistics and quality costs are the most common costs that are being included in most, if not all, TCO models. TCO models in the literature have been varied regarding their cost drivers. Therefore, the most common costs acknowledged in the literature regarding TCO models have been sorted out and outlined as it follows:

Inbound logistics Costs

Inbound logistics costs are the costs that start from moving raw materials from vendors to the firm's storage place and then move raw materials again to the plant for manufacturing. Inventory costs include inbound logistics costs of material handling, transportation, order processing, and storage space (Su, Yang, Tu, and Lin, 2018). Therefore, the costs related to inbound logistics consist of those related to moving purchased raw materials, items, and/or components across a country or through borders from a supplier's entity to a buying firm. It involves mainly transportation costs and some other fees related to international logistics activities. The greater the distance the higher the cost especially in the international logistics (Tibben-Lembke, 1998; Ghemawat, 2001).

Administrative Costs

Administrative costs refer to costs related to supplier selection and evaluation process (Dogan and Aydin, 2011). These costs include any cost related to tariffs, duties, entry costs, partnering process and overhead expenses (Ellram, 1993).

Quality Costs

Quality costs are the ones that have been defined as '*... costs that are incurred to prevent a shortfall in quality and a failure to meet customer requirements, as well as costs incurred when quality does, in fact, fail to meet customer requirements*' (Krishnan, Agus & Husain, 2000, p.1). These costs are usually associated with curbing, identifying and correcting the defective practices (Mukhopadhyay, 2004). According to Dogan and Aydin (2011), quality costs are those associated with activities such as the durability of goods, quality of components/raw materials, rework, scrap, and the ones that related to rejection and correction. Moreover, there is a consensus between researchers that the quality-related costs represent a considerable proportion of a company's total cost (Giakatis, Enkawa & Washitani, 2001). Quality costs have been estimated in the literature to be between 5%-30% of the cost of goods sold (Giakatis, et al., 2001). Based on this percentage, quality costs carry a substantial proportion of the

competitiveness of a firm (Chen & Tang, 1992). Equally important is the fact that quality costs are both the visible ones such as those that relate directly to the quality of a component, and the 'invisible' or 'hidden' ones (Yang, 2008), which have been defined as the costs that go beyond the visible ones such as (1) the costs related to delays and obsolete inventory (Harry and Schroeder, 2000); (2) the inefficiency of production equipment (Giakatis et al., 2001); (3) market loss and/or delay of delivery (Han & Lee, 2002), to name a few. Moreover, some researchers have estimated that the amount of hidden costs of quality is three times more than the visible ones (Giakatis et al., 2001; Han & Lee, 2002).

Operation Costs

Operation costs are the ones that involve costs related to all activities regarding: (1) assembly, manufacturing and/or production; (2) direct and indirect labour; (3) long-term operation; (4) inventory; (5) lead time, and/or (6) the expenses related to different type of equipment (Dogan and Aydin, 2011).

The Purchase Price

This cost is often called the capital cost (Lycette & Lowenstein, 2011), as it represents the cost of procurement of an item, equipment, raw material, etc. In the case of the international/domestic supply chain, it represents the price paid by a buying firm to its supplier in terms of purchasing material/component(s) that are required for its operations. The purchase price, according to microeconomic theories, is determined by the level of supply and demand of the supplied product. For instance, the price of a product will increase if the level of demand rise or if the level of supply decreases. On the other hand, when there is an oversupply of a particular product, the price of that product will decrease significantly, keeping the demand level constant (Pindyck and Rubinfeld, 2014).

2.3.3 Benefits of TCO

The increasing offshore competitions have pushed many firms to adjust their strategies to keep and sustain their market positions (Saccani, Perona and Bacchetti, 2017). This can be either through differentiating their products, improving their quality (Narver, Slater, MacLachlan, 2004), and/or seeking efficient ways to reduce their costs of ownership (Settanni, Newnes, Thenent, Parry, and Goh, 2014). One way of reducing the overall costs is by identifying all the costs: both the direct and the indirect ones. TCO is considered an efficient method for tackling and identifying all those costs (Ellram, 1995; Degraeve and Roodhooft, 1999; Wouters,

Anderson and Wynstra, 2005; Ronchi et al., 2015). According to Dogan and Aydin (2011), TCO could be used to select a proper supplier for the buying company by specifying the cost structure for each purchase situation. TCO can be used to benchmark the supplying companies based on the cost drivers related to each supplying firm (Ellram, 1994). Moreover, the results of TCO can be shared with suppliers in order to negotiate prices, suggest specific improvements, arrange future purchase and make strategic alliances with the potential ones (Ellram, and Siferd, 1993; Ellram, 1995; Hurkens, Valk, and Wynstra, 2006; Zachariassen and Arlbjørn, 2011). Moreover, the emphasis on the supplier's cost structure could create opportunities for cost developments which might result in cost savings for both the buying and supplying companies (Ronchi et al., 2015). Companies have also used TCO for making decisions regarding make-or-buy situations, in which companies compare the total cost of outsourcing with the total cost of owning a particular product (Maltz & Ellram, 1997). This means that TCO could assist buying companies in their decision regarding externalizing or internalizing their activities and operations. Moreover, there is a shared belief by researchers that it could be costly if a company disregard TCO calculation. For instance, if a company doesn't take TCO calculation into consideration, that company could miss out major hidden costs that might appear later on (Ellram, 1995).

Suppliers can be considered as main contributors to the competitiveness of a buying firm (Hopkins, 2010) since the suppliers' performances [based on their products] determine significantly the success of a buyer in the market (Bhutta and Huq, 2002). Reducing the purchase price of a component is considered one way for increasing the competitiveness of the buying company. However, lowering the purchase price provided by a supplying company might bring around extra costs to the buyer if the company is unreliable in its delivery or quality (Ellram, and Siferd, 1993; Degraeve and Roodhooft, 1999; Dogan and Aydin, 2011). That is, if the performance of a supplying company is unreliable, this increases the value of TCO since extra costs might incur to fix any failure/delay. Nevertheless, higher value of TCO doesn't necessarily mean that a supplying company lacks competitiveness regarding its quality or delivery time, but such a high value might be based on the fact that a particular supplying company locates in a remote location and thus TCO has higher inbound logistics costs (Visani, Barbieri, Di Lascio, Raffoni, and Vigo, 2016).

2.3.4 Limitation of TCO

Even though many studies have shown how TCO can support effectively different sourcing decision-making, there is a limited adoption of TCO models in B2B (business-to-business)

contexts (Ellram, 1994; Wouters et al., 2005; Hurkens, Valk and Wynstra, 2006; Weber, Hiete, Lauer, and Rentz, 2010; Visani et al., 2016). For instance, a study conducted by Wouters et al., (2005) among Dutch firms shows that many purchasing managers have little experience regarding applying TCO. The reasons behind its limitation and unpopularity could be, according to Ellram (1995), that determining cost elements and gathering the relevant data to calculate the TCO for a component/material can be a complicated and time-consuming process. The difficulty in reaching reliable data/information and the lack of readily accessible data and resources are considered to be other main barriers for applying TCO (Ellram, 1994; Garfamy, 2006). A resistance among employees regarding a shift from price-focus to overall cost orientation (cultural change) is considered another limitation for adopting TCO (Ellram, 1994). Not to overlook, the lack of open-book information between the buying and supplying firms could as well induce a hinder for applying efficiently TCO model (Ellram, 1994; Nyaga, Whipple & Lynch, 2010). In addition to the aforementioned limitations, the necessity to develop a unique TCO for each purchased item/purchase situation adds to the complexity of creating a TCO model (Ellram, 1994).

2.4 Conceptual framework

To examine how cost factors influence the setup of the supply chain of a large MNC that is operating in Electromobility, a new and rapidly emerging sector, the following conceptual framework has been created. The conceptual framework is based on the literature review, where global supply chain management and the concept of the total cost of ownership have been discussed. The important elements within the respective fields have been linked together and are graphically presented in Figure 2.

As it is visualized in the graphical model (see Figure 2), we originate the conceptual framework from the structure of the supply chain. As part of the supply chain, a company can either internally make or locally/internationally purchase the batteries. According to our presumption, the setup of any kind (local/global, internal/external) of supply chain involves specific costs that have to be considered by the purchasing company. The structure of the costs in case of internal production would be significantly different compared to international purchasing. Moreover, the structure of the costs will show different patterns when considering both the local and the international purchasing scenario. The arrows coming from the “*international purchasing*” and pointing to the “*cost bubbles*” incorporate the factors that drive the costs in case of international purchasing. On the level of “*cost bubbles*”, the conceptual framework

represents the costs that are incurred during the international procurement of the batteries. In the literature review, the most common purchasing related “*cost bubbles*” (*Inbound Logistic, Administrative, Quality, Operation Costs, and Purchase Price*) have already been highlighted. These conventional costs could still be valid under the circumstances of the international procurement of the batteries. The logic behind this conceptual model is supported by the findings of Ellram’s (1994) that suggests the necessity of creating a unique TCO model for each purchased product or purchase situation. After the identification of all “*cost bubbles*”, the TCO value can be reached through a calculation (sum up) of all the costs incurred regarding the international purchase of a battery. Finally, following the suggestions of the academic literature, the value of TCO will influence the company’s decision about the supply chain structure. The big backward arrow is meant to represent the decision-influencer factor of the TCO’s value regarding the setup of the supply chain. According to the literature review, a buying company can choose objectively the potential suppliers based on the outcome of TCO. The optimal supplier, the one with a lower TCO value, can be situated locally or offshore, thus the TCO can influence the supply chain setup of the buying company. Furthermore, according to Mathew et al. (2019), the best purchasing setup can be compared with the total cost of in-house production. Thus the proper and comprehensive identification of the TCO “*cost bubbles*” can support the decision between “make or buy”, and in this way they significantly determine the structure of the supply chain of batteries.

In order to accurately identify the total cost structure for the battery supply at Volvo Trucks, we have created an activity-based costing approach that has 3 pillars: 1.) identification of cost drivers that influences the “*cost bubbles*” 2.) identification of the “*cost bubbles*”, 3.) determination of the TCO structure for the battery supply. The study-specific framework outlines a comprehensive approach, in which we identify the necessary factors in order to be able to answer the research question, formulated at the beginning of the study: *What cost factors are essential in an OEM’s purchasing decision to source energy storage systems in a de-liberalizing international trade environment?*

Accordingly, the conceptual framework relies on some additional presumptions, which are discussed below. As the study of Ferrin et.al. (2002) explains, because of the demanding nature of TCO, companies lack the ability to effectively identify the most important cost drivers for achieving the value of the total cost of ownership. Thus we intend to utilise the concept of TCO to shed light on the most important costs incurred in the international purchasing of batteries. Further, most of the TCO studies that we came across during the literature review, are

conducted on firms, which operate in conventional or fully established industry segments and have a mature supply chain. However, during this study, the emphasis was on the costs related to battery purchasing in the Electromobility, which is a currently establishing sector of the commercial vehicle industry. Consequently, the sector-specific TCO structure is unobserved yet.

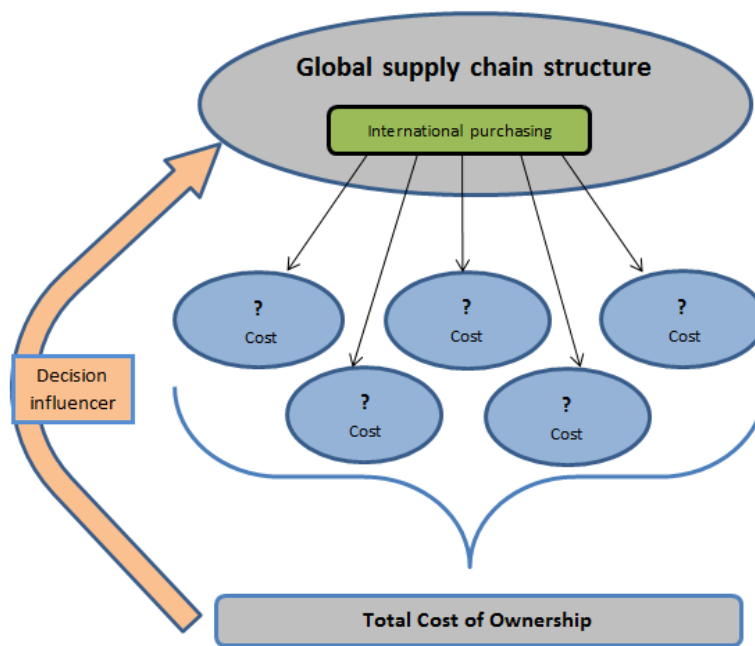


Figure 2: Conceptual model based on the literature – Own illustration

3. Methodology

The aim of this chapter is to discuss the research methodology of this study in details. It outlines the research approach and unit design as well as the reasoning behind the data collection and analysis Hereafter, the quality of the research on ethical considerations will be described.

3.1 Qualitative research method

When carrying out the research studies, two types of research methods can be applied: qualitative or quantitative. According to us, a quantitative study would be difficult or even impossible to conduct in the Electromobility sector since the number of MNCs operating in this sector is very limited. On the other hand, according to Bryman and Bell (2011), a qualitative research approach will provide us with the opportunity to make sense of the subjective and socially constructed meanings expressed about the participants of the study. Further, Saunders, Lewis, and Thornhill (2015, p. 168) highlight that qualitative research approach can be referred as naturalistic because researchers are supposed to operate within a natural research environment in order to establish trust and cooperation, grasp real meanings and comprehensive understanding. Therefore, a qualitative research approach has been chosen. Moreover, our study is considered completely aligned with Saunders et al. (2015) since we have spent five months at the company of Volvo Trucks, not only as “*observers*” but also, as full members of the Electromobility purchasing team. This gives us the opportunity to build trust and cooperation and gain the comprehensive understanding of the purchasing process. The phenomena of research design are characterized by how the authors manage the observation in order to find reliable answers for the research question (Saunders, Lewis, and Thornhill, 2015, p. 163). Further, as Eriksson & Kovalainen (2008) put it, business researches that are intended to give answers to research questions starting with the word *what*, *how* or *why* fall mainly under the umbrella of a qualitative approach. In this way, since the aim of this study is to answer the research question starting with ‘*what*’ the qualitative research is considered the right approach for this purpose.

3.2 Abductive approach

This study applies the abductive research approach, which is a combination of deductive and inductive approach (Bryman and Bell, 2015). This study was initiated with a deductive reasoning where a literature review of existing theory within the field of the supply chain was

carried out (Saunders et al. 2015, p. 145). As we became more familiar with the observed company, we have realized the importance of the costs related to international purchasing. In order to assess reliably all the costs related to international purchasing, we went back to the academic literature to find the main cost drivers of TCO in which the interview questions were based on. Still, during the analysis of the empirical findings, we had to continuously update and revise the literature background because of the emerging of new factors such as the disequilibrium in supply and demand, which was identified as an essential factor. Thus, the actions taken by moving back and forth between the theories and the empirical findings represent an effective combination of deduction and induction, which refers directly to the abductive research approach (Saunders et al. 2015, p. 148).

3.3 Single case study

The number of companies operating in the Electromobility sector is still limited today because the Electromobility sector is a relatively new industry segment. This sector is considered very capital intensive and demands large economies of size (Hofstrand, 2018). Moreover, the number of specialists who works with Electromobility purchasing is also relatively few due to the immaturity of this sector. Because of these restrictive circumstances, a single case study approach— Volvo Trucks in Sweden— was chosen in this study (Bryman and Bell, 2011 p. 59). In addition, it has caused additional constraints for us to conduct a proper in-depth examination of additional companies since these potential companies, which are producing electric trucks, are situated in different countries. Nevertheless, a single case study approach, which is supported by Yin (2014), allows more in-depth analysis of new or unclear topics, and it also preserves the holistic and objective characteristics of real-case events. Additionally, a case study can be categorized as: exploratory, descriptive or explanatory (Yin, 2014). As Saunders et al. (2015, p. 168) argue, exploratory studies are conducted when it comes to answer open questions and to gain an understanding of a topic of interest. As the main purpose of our study is to answer the research question by gaining a sufficient understanding of the true costs incurring during the international purchase, it is most likely considered as an exploratory study (Saunders et al. 2015, p. 174).

3.3.1 Research unit and design

The unit being researched for this study is Volvo Truck, which is categorized as a large and active MNC in the heavy load commercial vehicle industry for several decades. The company can be considered as a new player in the Electromobility sector because, until the late 2010s,

the product portfolio of the company consisted of vehicles with only conventional internal combustion engine (ICE). Inside the company, the Group Truck Purchasing (GTP) department, which is consisted of more than one thousand employees, is responsible for the procurement activities and the management of the supply chain. The purpose of conducting a single case study on the GTP is based on the following reasons. First of all, the opportunity to observe the day-to-day status of a very recent and real phenomena (the establishment of the Electromobility sector) at one of the most significant players on the market can provide a very beneficial background for our study. Secondly, since the first shift from ICE to battery electric vehicles (BEV) in the automotive industry (especially in the truck related automotive industry) is quite recent, thus we have the opportunity to witness that shift based on the international business perspective. Finally, the location of the headquarter of the purchasing department of Volvo Trucks in Gothenburg enabled us to get access to several specialists with both business and engineering background. Furthermore, the location of the site has also facilitated us to actively participate in day-to-day operations of the purchasing department, to know and meet the recent stakeholders of the Electromobility segment, and get involved in strategic conversations with subsidiaries located abroad as well. The combination of all those attributes provided us with beneficial conditions for collecting empirical information.

3.4 Data collection method

The empirical part of this study is based on gathering various primary and secondary data sources. The initial knowledge has been accessed through a literature review based on secondary data and several documents provided by Volvo Trucks. At the beginning of the study, we were not familiar with the Electromobility sector in the automobile industry. Therefore, we were required to review systematically the industry-specific literature in order to acquire efficient knowledge of the respective field. It was followed by the collection of the primary data through semi-structured interviews with the staff of Electromobility department specialized in purchasing and engineering. In order to be aligned with the reality of the observed topic and to guarantee a proper quality of this study, we have applied triangulation (Saunders et al. 2015, p. 730). Consequently, we have collected data through different methods (interviews, written evidence, and observation) with the intention of capturing different dimensions of the same observed phenomena. The critical scope was through examining whether primary data is aligned with the secondary data in order to enhance the reliability of our study. Finally, as it has already been highlighted that the opportunity to immerse in the

organization as complete participants for a longer period of time has provided additional research perspective to our study, namely the observer perspective.

3.4.1 Secondary Data

Secondary data is often utilized in studies that collect primary data too. Secondary data can be collected by a company or other organizations on their own, and thus it is not gathered directly by scholars (Bryman and Bell, 2011, p. 313). The collection and the interpretation of secondary data helped us not only to build up an initial understanding of the context in which the studied company operates, but it also improved our ability to ask relevant questions during the interviews. We had almost unlimited access to the company's network, including strictly confidential materials such as mailing history with stakeholders, minutes of meetings, and last but not least consultancy reports. The available secondary data for our research has contributed greatly to the quality and the reliability of our findings.

3.4.2 Primary Data

Even though that Volvo Trucks is a large MNC and employs around one thousand people in the GTP department on five continents, the number of specialists who work with the Electromobility sector is restricted, especially if one compares it with the number of experts in the internal combustion engine. In the Electromobility purchasing department, only ten persons work with different responsibilities, under the supervision of two managers.

We decided to utilize face-to-face in-depth interviews on-site at Electromobility headquarter of Volvo Trucks in Gothenburg, where the relevant stakeholders are situated. The outcome of a comprehensive interviewee pool enabled us to get a comprehensive picture of the current supply chain of the Electromobility and the position of Volvo Trucks in that chain regarding the batteries. Nevertheless, the number of stakeholders that have relevant information, experience, and knowledge about the cost factors that influence the decisions during the supplier selection is limited. Thus, we could only conduct an interview with ten employees from the Electromobility purchasing department. However, the content of the conducted interviews all together provides rich information [ninety pages of transcription]. In some cases, the findings were complemented by follow-up questions that were mainly communicated in person. All the interviews except one were conducted with the participation of both of us. The list of interviewees is presented in the table below (Table 1).

Manager	Date	Length of interview
Manager A	20.03.2019	65min
Manager B	21.03.2019	45min
Manager C	21.03.2019	45min
Manager D	22.03.2019	50min
Manager E	26.03.2019	45min
Manager F	22.03.2019	45min
Manager G	27.03.2019	50min
Manager H	26.03.2019	65min
Manager I	01.04.2019	40min
Manager J	05.04.2019	60min

Table 1: List of interviews

3.4.3. Benefits of sitting at the company

Being ‘observers’ at the Electromobility purchasing department during conducting our study made us utilize the information more efficiently. This is because a participant observer is able to take an active part in the operation of an organization under some period of time, thereby the researcher can observe behaviours, listen to what is being said during conversations and ask questions. Usually, participant observation relies also on further data collection through interviews and gaining access to confidential documents that otherwise would not be accessible. (Bryman and Bell, 2011, p. 426) According to Saunders et al. (2015, p. 354), the observation method to gather data is somewhat a neglected method in case of business studies, however, it can serve well in studies where it is important to understand what people do. Further, Saunders et al. (2015, p. 358) distinguishes between four different status of the participant observer: if the researcher takes part in an activity or not, and if the researcher’s intention and identity are revealed or not. Since the purpose of this study was clear for the members of the department from the beginning of the study and we have participated actively in the work and in the “life” of the department, we had a participant-as-observer status through this study (Saunders et al. 2015, p. 360).

Nevertheless, the observation method involves some issues, for example, observer error or observer bias that can degrade the validity and reliability of the collected data. However, the three different ways of data collection (interviews, written evidence, and observation) make it possible to draw our attention to any mismatches in the collected data.

3.4.4 Interview process and protocol

All of the interviews were conducted face-to-face at CampX Gothenburg, a new innovative building for Volvo Trucks. Furthermore, since we had already been working on our study close

to most of the participants for months, semi-structured interviews were considered as the most proper way to extract the most valuable information. Semi-structured interviews are considered more informal than strictly structured interviews, which gives the respondents more spaces to talk freely. At the same time, this type of interview gives the interviewers the leeway to ask for clarification at once and made it possible to develop more comprehensive answers. The interviews contained pre-structured questions to develop the conversations and direct them into the scope of the study. After each interview, the questions of the interview guide were analysed and, if necessary, revised, when the respective question proved to be ineffective or a new important issue was discovered to be examined in the subsequent interviews. Our decision on conducting semi-structured interviews is aligned with the argument of Collis and Hussey (2013, p. 133-134). According to them, semi-structured interviews fit well to conduct a case study. This is aligned with the abductive research approach as well (Bryman and Bell, 2015). The formulation of the questions that guided the interviews is based on the key themes identified during the literature review, and the structure of the questions can be found in Appendix 1. All the interviews have been recorded with the prior consent of the respondents, which gave the opportunity to concentrate on the conversation as well as to re-listen to the interviews afterward. This method, according to Collis and Hussey (2013, p. 133-134), allows the researchers to extract more robust and comprehensive interpretations of the gathered data. In addition to this, during the interviews notes were taken for particular interesting information because it facilitated the after work of the transcription process of the records.

3.5 Analytical process

After conducted each interview, we transcribed it soon afterward with the help of records and notes, which were taken during the interviews. The purpose of the transcription was to make the obtained information possible to be analysed. The transcription procedures started right after the first interview and continued under the ongoing interviews. Once, we transcribed all the interviews, final versions of transcriptions were sent to the respondents in order to double-check of their contents (respondent validation). Appropriate changes were made in the case of any mismatch between the perception of the respondents and the final version of transcribed materials. This procedure is considered highly important to preserve the objectivity and credibility of the analysed data since it eliminates the risk that our own subjective interpretation influences and misleads the result of the transcripts (Bryman and Bell, 2011, p. 396).

All interviews were conducted in English. During the analysis of the gathered data, no electronic analytical tool was applied. Instead, we organized all the gathered materials into different themes. For themes (topics) that were not identified in the literature review, we used the managers commonly used names to create a new theme. All the themes were organized afterward to represent different main costs of ownership that were identified during the literature review and the empirical findings that influence directly or indirectly the cost of sourcing batteries. With the help of this process, each theme was developed with relevant Volvo Trucks specific information regarding the costs that are incurring during the external sourcing of batteries.

3.6 Quality assessment

3.6.1 Reliability and validity

The concept of reliability and validity are two basic pillars when it comes to assessing the quality of either quantitative or qualitative researches. Sending the final versions of transcriptions to the respondents in order to double-check of their accuracy and contents means that the collected data has been given the respondent validation before pursuing into the stage of its analysis (Saunders et al. 2015, p. 207). Thus, the given participant validations can increase the trustworthiness of this study. Applying triangulation with the help of observation, secondary and primary data would ensure a further degree of trustworthiness as well. Moreover, the opportunity to revise the study is provided to other researchers, hence the relevant research process such as interview processes, transcripts, and analysis are documented and stored in order to be freely accessible in the future.

3.6.2. Research ethics

Ethical principles have been taken into consideration all over our study. In accordance with Bryman and Bell (2015), we avoid interfering with the interviewees' private lives by asking too personal questions that possibly result in an uncomfortable atmosphere. Since all interviewees are from the Electromobility purchasing team, which is a small team, we decided not to reveal the position title of the interviewees to secure their anonymity. The data and information, which the researchers had access to, are considered strictly confidential and indicate the long-term strategic roadmap of Volvo Trucks in the Electromobility sector. Thus, we had to be exceptionally careful to handle and process the empirical findings in a way that does not harm the company's interests and the future development of the company's operation (Bryman and Bell, 2011 p. 128). Furthermore, all of the respondents during the interviews have

been aware of the objective and the theme of the study prior to their participation, and all have been involved free willingly.

4. Empirical findings

Hereby, the aim is to provide a comprehensive picture of the Electromobility purchasing department's involvement and experience in sourcing batteries. The section first starts with a short background of Volvo Trucks and GTP, then it moves on to the involvement of the company and the purchasing department in the Electromobility sector. Afterward, we discuss Volvo's battery supply and production chain in details. Then, the empirical section concludes with the mapping of the battery purchasing related costs.

4.1 Introduction of Volvo Trucks and GTP

The Volvo Group has started to develop and produce its first trucks in 1926. By today, Volvo Group is among the world leading manufacturers in many sectors such as trucks, construction equipment, buses, and heavy-duty diesel engines; it is also a leading supplier of marine and industrial engines. The main brands of the Group are Volvo Trucks, Volvo Penta, Renault Truck, Nova Bus, Mack and Arquus, to name a few. The main incomes of the Group come from the European market with 41%, following by the North American market 28%, and last but not least the Asian market with 20%. With 64%, Volvo Trucks provides by far the highest proportion of the net sales of the company, ahead of Construction Equipment that contributes 22%, and Busses with 7%. (Volvo Group, 2018 a)

The Group Trucks segment under the umbrella of Volvo Group consists of six brands: Volvo Truck, Terex Trucks, Renault Trucks, Mack, Eicher, UD Trucks and Dongfeng Trucks [a joint venture]. The brands deliver different values tailored for different demands, in this way each of them represents a unique asset. During the recent years, the main aim of Volvo Group has changed from the portfolio (brand) expansion to the creation of a stable organization structure for the corporation, thus contributing to the overall efficiency of the group. Three huge and different organization departments—Group Truck Operation, Group Truck Technology, and Group Truck Purchasing— have been established with different operation fields and responsibilities.

In alignment with the globally increasing importance of the purchasing activities, Group Trucks Purchasing (GTP) department has been established. GTP is responsible for all purchasing procedures and activities related to the truck brands (Volvo Group, 2018 a; GTP, 2018). It has 1400 employees locating in 25 countries on 5 continents. Among its wide

activities, it manages the budget of the purchasing, which is around 140 billion SEK annually. Not to overlook, it's importance in managing the global supplier base of the group which consists of 30,000 suppliers (GTP, 2018). GTP comprises three sub-departments: Powertrain purchasing, Vehicle purchasing, and Indirect Products & Services purchasing.

4.2 Involvement in the Electromobility industry and purchasing

Electromobility has been a strategic focus area for the Volvo Group for 20 years, however, until the late 2010s, the bus segment had only the focus of the Electromobility (Manager A). In February of 2019, the very first fully battery electric vehicle-truck (BEV) has been delivered to the customers. The purchasing activities related to this project started in 2017 (Volvo Intranet, 2019). However, the regular production starts only for a small scale and only for the European market during the second half of 2019 (Volvo Intranet, 2019). The main technical specification that makes BEV (battery electric vehicle) and ICE trucks (internal combustion engine) different is the powertrain system that drives the trucks. The electric motor and the gearbox, which have been developed especially for electric trucks, in addition to the energy storage system (battery), which stores the necessary energy to run the motor, are the main technical earmarks of the electric truck. Today, approximately 60% of the cost of electric trucks comes from the cost of batteries (Manager B and A). Moreover, since the highest added value is based on batteries, these components carry a significant weight among OEMs. Manager J has touched upon this by saying: *“All the market players work very focused on the batteries because the batteries can be one key point that makes a difference between the vehicles.”* Today, Volvo Trucks sources the electric engines, the related transmission systems, and the batteries from external suppliers (Manager H and B). During our observation, the emphasis was on the procurement of battery since this component contributes enormously to the cost of the trucks.

Under the umbrella of the GTP department and inside of the Powertrain Purchasing sub-department, the Electromobility purchasing division is responsible for any electric powertrain related procurement. This division consists of a team of 10 employees under the supervision of two managers. The staff working within this division are both engineers and business people as Manager A said, *“[...] in purchasing we have two different kinds of people, either engineer very much interested in business, or business people that are extremely interested in technique and automotive industry.”* The Electromobility purchasing division was established in 2017, with the purpose of building up and organizing the most efficient supplier base for the

Electromobility. Even though the Electromobility purchasing team is currently a small group of people, it is expected to rapidly expand, thanks to the increasing significance of the Electromobility in the commercial vehicle industry (Manager G).

Regarding the purchasing procedures, Volvo Trucks has to adopt different procedures and process for BEV than those followed in ICE trucks, as Manager A said: “[...] *the electrification of the trucks represents a change, which is the biggest the industry has experienced over the past 100-120 years. So as such, we can not work the same way as we worked for commodities like combustion.*” In the case of the ICE vehicles, the purchasing process, for instance, is well defined and deeply connected to the emission regulations. This means that Volvo Trucks has strict and complex validation procedures to ensure that the trucks are compliant with the emission regulations. However, even though there are no validation procedures regarding BEV trucks, the innovation rate is much higher than the one existed in ICE vehicles. That is, the process of purchasing components for BEV is under pressure because of the rapid technology and developments compared to ICE purchasing, which are more structured. Moreover, the rapidly changing and developing technology regarding batteries influences not only Volvo Trucks but it also makes the market of the batteries turbulent and hardly predictable as Manager B highlighted “[...] *the performance of the batteries, increasing quite quickly. The performance of the batteries can increase by 50 percent every two years and the cost is decreasing also. So the change, the evolution is much quicker at the moment*”.

To mitigate the time pressure on the Electromobility projects, the management has prioritized the emphasis to be more on the cooperation between the people rather than the processes. Therefore, Volvo Group has created a new office site (CampX), where all stakeholders from different departments of Electromobility can work together under the same roof. As Manager A said: “[...] *we get the people not get stuck in the organization silos [...] no silos no boundaries the only thing what matters is that we work together.*” The close and rapid collaboration is inevitable in such a rapidly developing industrial sector since there is no time for email exchanges that can last for days (back and forth) until the valuable information arrives at its final destination (Manager A).

As we had the chance to actively participate in the life of the Electromobility purchasing, we personally had experienced a new way of thinking about the growing importance of the cooperation between people from different departments. When we arrived at the company, the Electromobility purchasing department was situated at a different building which was

relatively separated from the rest of the company's sites. The office was shared between buyers and some of the Electromobility engineering teams. However, the battery engineers were located on another level of the same building. Thus, to meet with some engineers was quite difficult and time demanding. After some email exchanges and timetable coordination from both sides, which might take a couple of days, the meeting could be held. Even the meeting did not take more than ten minutes of conversation, the procedure worked like this. Likewise, the Electromobility purchasing team was sitting close to each other in a "bubble". However, that team was not really involved in the everyday work of other stakeholders who were also parts of the Electromobility projects. This resulted in a weak cross-functional cooperation.

In March of 2019, a completely new office building was set up and installed, and it was based on a new mindset, namely the intensification of cross-functional cooperation. In the new building called CampX, the buyers and their identical engineer counterparts from the departments of Electromobility, autonomous, connectivity and innovative are brought together to work close to each other. Everybody works on the same floor in an open office area, where anyone can see if the person he/she wants to speak to is available or not. Moreover, approximately 50% of the desks are called Flex Desks, meaning that those places can be occupied by anyone from any department who is authorized to work in the CampX. This system results in a huge diversity since employees might get to know new colleagues each day. This benefits Volvo Truck since it deepens the internal cooperation between different people from different departments.

The design and the arrangement of spaces at CampX make brainstorming and conversations happen more spontaneously as it sometimes involved us. During a coffee break, for instance, we could meet some experts other than buyers and could easily conduct 30 minutes long conversations with e.g. a chemistry engineer who was interested in our project, and we, at the same time, were also interested in the work of that engineer (personal experience). The information sharing was quick, spontaneous, valuable and could not happen without the new mindset of internal cooperation. As Manager E summarised this when he said: *"[...] before, you have been more in your own cell in working. Sometimes you talked to development, sometimes to the advanced or quality engineering but here, you are sitting together because you do not have the time to do somethings sometimes. Here you just need to go to the desk of quality or the PD (project development) ask what's happening. [...] so it is really important to have everybody at the same house."*

However, the close collaboration within battery purchasing is not only important internally but externally as well especially with strategic suppliers. To reach quicker development, which is essential in the Electromobility sector, the efficient cooperation with different stakeholders is necessary as Manager A said: “[...] *we need to work together (with suppliers), we need to be less transactional in the way we work with suppliers, [...] much more towards partnership activities*”.

The purchasing department differentiates between four types of suppliers. The first is the *Technology Partner*, who is selected for collaboration with Volvo in technology development activities. The second is the *Concept Supplier*, who is selected for collaboration in development with Volvo during the “integrate & apply technology, and concept development” phases. While the third type is the *Development Supplier*, who is selected for the “solution development”. Finally, is the *Production Supplier*, who provides the product solution to Volvo Group for serial production. (Volvo Trucks Purchasing, 2017) According to Manager G, “[...] *the batteries are development suppliers because we pay them to do the development.*” What matters during the selection of the battery suppliers is to secure that Volvo Group acquires the best competencies (Manager J). To achieve a high level of competency, open-minded people have to work together with absolute transparency regarding batteries knowledge. This mindset and cooperation can bring advantage to Volvo Group and its’ suppliers. To facilitate and leverage such a cooperation, Manager A stated that “*Ultimately we can bring together engineers from the suppliers to sit with us for 6 months - 1 year in one of our premises and we work together as a team [...]. And 6 months later, we will have the best cost, the best technical proposal ever.*”

4.3 Volvo Truck battery supply and production chain

There are two main different battery types that Volvo purchases today. One battery type is for the HEV (hybrid electric vehicles) trucks and busses, and the other is for the BEV trucks and busses. Distinguishing between the two setups is important because the suppliers and the supply chain can alter accordingly, since the characteristics of the two types of batteries are significantly different. The BEV battery has high specific energy while the HEV battery has a high specific power. Since the electric motor with a power supported in HEV trucks and buses are used intermittently and must be capable of producing high power for short periods of time (e.g. during start and acceleration), its battery pack should be optimized for high power. (Pollet, Staffell and Shang, 2012) On the vehicle level, plug-in hybrid electric vehicles have both an

electric motor and a conventional gasoline or diesel propulsion. Compared to a battery electric vehicle, this extends the total driving range but lowers the pure electric-mode distance (Union of Concerned Scientists, 2018). In the case of the Volvo Trucks, the emphasis of this study is mainly on the electric trucks, so the centre of the supply and production chain is the battery type that is necessary for the BEV trucks.

The battery consists of three main parts: cells, modules and a battery pack. The battery pack consists of individual battery cells and modules organized in series and parallel. A cell, which is considered the smallest unit of a battery, consists of four key components including cathode, anode, electrolyte and separator. While the module consists of multiple cells connected in series and/or parallel. A battery pack is assembled by connecting multiple modules together in series or parallel with sensors and controllers including battery management systems and thermal management systems, and then inserted in a housing structure as a final battery product designed specifically for each vehicle model (Samsung SDI, 2016). The components of the battery are illustrated in Figure 3 & 4.

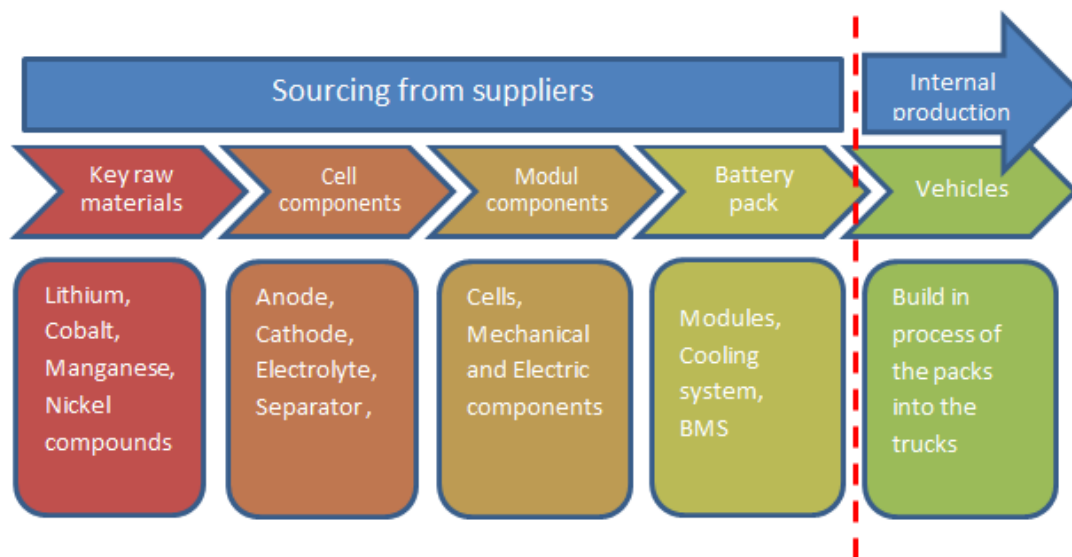


Figure 3: Volvo Trucks' involvement in the supply chain of the batteries. Compiled by us based on primary and secondary data.

4.3.1 Raw Material level

Raw materials are the basic elements behind the cell's electrochemistry. Depending on the cell type, the raw material can make up to 75-90% of the cell's cost (Volvo Group, 2018 b). Graphite, nickel, manganese, lithium and cobalt are the main raw materials for batteries, to name a few. Some of them are hardly accessible, and only a few mines in some countries can

supply the main proportion of the global demand (Manager A and B). The supply of cobalt, for example, is considered the most complex and problematic issue (Manager A and D). This is because the working conditions during the extraction of the cobalt from the ground are heavily questionable in the Democratic Republic of Congo, which has more than 60% of global cobalt resources. The mining industry in that area is infamous about e.g. child labour and the exploitation of the workers (Kara, 2018). Therefore, the mined cobalt is considered a key issue to Volvo Group as Manager C highlighted this issue when he said:

“I still work with suppliers to get certain information who’s their raw materials providers? Do they extract the material? Do they have contracts with them? Do they have sustainability contracts? Do they monitor their activities when they extract the minerals from the ground? Do they use child labor and so on? [...] it’s part of my responsibility to ask those questions and to select the right suppliers.”

Further, the market for cobalt sourcing is heavily fluctuating and unpredictable. China influences the amount of the available refined cobalt supply since the vast majority of the extracted raw material is shipped to its territories (Wood Mackenzie, 2018). By 2027, the demand for cobalt is highly expected to exceed the supply (Dias, Blagoeva, Pavel and Arvanitidis, 2018). And by 2020, it is expected that the disequilibrium between the supply and demand of cobalt to start differentiate significantly (Dias et al., 2018). Manager D stressed on the shortage of the supply of raw materials as he said: *“It can be buying the raw materials or securing the capacity because one of the reasons that the cell manufacturer does not have capacity because of the insufficient extraction of the raw materials.”* However, other raw materials such as Lithium are considered less sensitive since the supply widespread globally, located widely in South America and Australia. But similarly, to the cobalt, the conversion capacity to process spodumene into lithium chemicals is also concentrated in China (Wood Mackenzie, 2018).

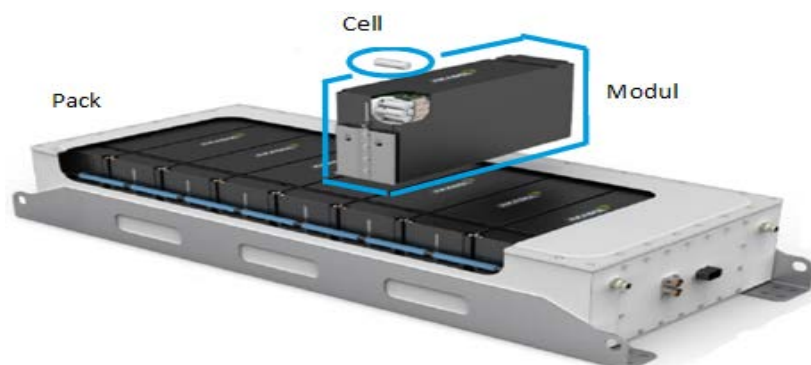


Figure 4: Composition of a battery pack. Modified by us, based on Volvo Trucks information.

4.3.2 Cell level

Cells can be considered the heart of the battery system, where the highest added value is realized (Manager B). The production of the cells requires a huge investment in R&D, a wealth technical background, and last but not least, extremely high expertise in electrochemistry. Cell manufacturers have already accumulated significant R&D knowledge for battery chemistries, which is difficult to acquire by vehicle manufacturers (Klug, 2015). Further, cells require a huge capital intensity in order to be produced, as Manager B put it: *“The capital intensity of the cell production can be clearly understood if one compares it with the capital intensity of e.g. pack production. One cell production line can cost around USD 150 million meanwhile a pack production line is merely USD 10-30 million. Furthermore, it is not worth to build up only one production line of cells because of economic reasons, e.g. in the Hungarian cell factory, they have at least 8 lines.”* Moreover, the cell market is heavily dominated by Asian companies, approximately 80% of the cell manufacturers are exclusively from China, South-Korea or Japan (Woehrle, 2018). From approximately 2016 onwards, Asian companies have started to spread internationally and build up cell factories outside of Asia (Chung, Elgqvist and Santhanagopalan, 2016). Despite the move of international spread, manufacturing capacity for lithium-ion batteries — the chemistry that electric vehicles use — is still heavily concentrated in East Asia (Curry, 2017). Today, the cells, which are the basic elements of the battery packs that Volvo Trucks buys, come significantly from China (Manager D).

According to most of the interviewees, the internal production of the cells by Volvo Trucks is a far-off plan. This is because as Manager I summarised it in his comment: *“We do not have the knowledge, [...]we are not fully capable today to build cells and modules.”* In addition, Volvo lacks the required financial capabilities for such a project, which is extremely essential to start producing cells as Manager E put it: *“We do not have the money, we are not that strong. [...] we do not have the muscles, what we might do as a first stage, is to design the box around the batteries, but the cell is absolutely far away.”*

There are five largest rechargeable lithium-ion cell manufacturers in the world, such as Samsung Chemical, that cover altogether around 72% of the global supply in 2017 (Woehrle, 2018). Battery buyers such as Volvo Trucks is considered a small one comparing to those who produce cells since it has almost a negligible amount of orders, as Manager D said: *“They have a strong power compared to the OEM. OEMs had the power before because they are bigger than the suppliers, but here they are giants, some of them are very giants.”* Moreover, the main reasons for Volvo Trucks to continue depending on external suppliers regarding producing

cells for batteries rather than to make them internally are summarised as Manager C said: *“Maybe buying it externally would cost as much less because of volume effect. Because the supplier already producing much more and they would have a better purchasing power on their own raw materials than you would have if you buy few amounts. There are many things to consider like to build up a plant, to get the knowledge, to train the people for the new commodity and all this require time.”*

Volvo Trucks has different requirements regarding battery setups. This means, that its trucks cannot use cells developed for passenger cars. Moreover, cell manufacturers have begun to differentiate their products [cells] from their competitors. This differentiation is considered very beneficial for the cell manufacturers, and it is totally disadvantageous to the battery buyers. Manager D explained the negative effect of this differentiation when he said: *“Once when you differentiate, you stuck with them because you have adopted your vehicle, your staff to that technology – on that type of cell chemistry and so on. So there is a big fight between OEMS and suppliers, where OEMs try to push the market to standardize at least the same chemistry. And vice versa Panasonic and LG they are so big that they want to lock their customer with their type of cell.”* This means, there are high switching costs for battery buyers; it would be difficult for them as well to benchmark among existing suppliers based mainly on the product price since the products are not identical (Manager D). However, there is a need for Volvo Trucks to continue building up a well business relationship with its cell manufacturer in order to get the cells that are tailored according to its demand, and thus to secure its batteries (ibid.).

4.3.3 Module level

In this study, we are not going to discuss in detail the module level of the production chain since the modules, according to Volvo Trucks, do not play a significant role in the supply chain. In most cases, the module suppliers are the same suppliers that provide either the cells or the battery packs. That is, there are no supplying firms that produce only modules in the supply chain of batteries. The internal production of modules, according to most of the interviewees, could be achievable on the medium-run; Manager I predicted that Volvo Trucks would produce modules in 5-10 years.

4.3.4 Pack level

Currently, Volvo Trucks buys all the battery components from external companies, as Manager A said: *“[...] if we break down the batteries in the three sub-components, the cells and the*

modules come from China, while the pack assembly comes from Germany.” The suppliers of the battery packs are considered smaller companies compared to the cell suppliers, since the production of packs is considered much less complicated and less capital intensive comparing to the cell productions. At the same time, the packs’ production does not require extremely high expertise and knowledge similar to cells’. (Manager B)

The global supply chain of batteries makes the lead time very long. Manager A stressed on this issue when he said: *“We have been calculating the importance of the transport time and the transport time was 90%. So in certain parts, the time you really work on a part is only 10% the rest is transportation.”* Manager G was on the same page with Manager A, and he stressed on this issue as well when he said: *“Now we have a lot of issues regarding the batteries today. [...] it takes 8 weeks on a boat, so it’s preferable to have a supply chain in the same continent.”* Thus, there is an intention to make the battery packs internally in order to reduce the lead time (Manager D). Today, Volvo Trucks buys complete battery packs that are tailored for its demand, and afterward, it only installs them into its vehicles. Installation is considered the only activity that Volvo performs internally (multiple managers).

4.4 Disequilibrium in the battery’s supply and demand

There are significant signs showing that the level of supply for the raw materials will not meet the increasing demands during the next decade. This is because the accelerating production of electric vehicles (Dias et al., 2018). However, the disequilibrium between the supply and demand of those materials can be already sensed it today. This influences the stability of cell markets, which has started to affect many OEMs such as Volvo Trucks. Therefore, there is an intention by Volvo Trucks to secure the supply chain of batteries by investing in some raw materials, especially the scarce ones (Manager D and H).

The cell suppliers are the main actors in the supply chain of batteries, who are directly influenced by the supply of main raw materials. However, the market of cells is also restricted today and only a relatively few suppliers dominate a large proportion of that market. Manager C touched upon this issue when he said: *“The giant already stable companies that produce batteries such as Panasonic for example, are already booked for many years by other automotive companies. So the supply is scarce.”* Thus, it can easily occur that the cell suppliers can dictate to buyers, or even select between “offers” provided by competing buyers. Therefore, the main problem that encounter Volvo Trucks is the level of supply. Manager D emphasized on this when he said: *“It is something in purchasing, that I have never experienced*

yet, is when the supplier says that I'm sorry. I can not work with you because I do not have the capacity.” The booming demand of the passenger cars have also an impact on the supply level of raw materials, and consequently it influences the cells. Manager A highlighted this problem as follows: *“Battery cell companies right now are drained by passenger car activities and deliveries.”* At the same time, cell companies do not give a priority for transportation vehicles (trucks) due to low volume comparing to passenger cars. Manager B has stressed on this as he said: *“The challenge is to how to find suppliers willing to walk with the transportation industry.”* However, since there are many OEMs are heading in producing electric trucks, the gap between the supply and demand for battery cells has started to extend, and a price increase would be a result as Manager H commented: *“One of our suppliers has come back and said he wants to increase the price because the demands of cells and modules increase”*.

4.5 Costs related to purchasing batteries from international suppliers

Buyers at Volvo Trucks examine the supplier quotations not only on the component price but also take into account other sourcing related costs. In most cases, the interviewees expressed that the selection of a supplier is mainly based on the acronyms QDCF-TSR, where Q for quality, D for development, C for the part price, F for features, T for technology, S for sustainability and last but not least, R for risk management. (All interviewees).

4.5.1 Investment Costs

There is a cost behind every investment that Volvo Trucks makes in any of its suppliers' premises (Manager F). Such investments could include the payment for tooling or the investment in a production line in some of its supplier's premises (Manager G). The production line at the supplier premise that Volvo Trucks has invested in should be used only for producing components and items that Volvo demands. This means, that the supplier has a constraint regarding using such a line for producing components for other customers (Manager F). The investment in a supplier site does not mean that Volvo Trucks buys shares or makes joint-venture with a specific supplying company, but it could only refer to a particular purchase of a specific production line (Manager F).

There is a high demand for raw materials regarding the production of battery cells, which makes the level of investment for securing these materials rise significantly (Manager D and H). For instance, to secure the supply of cells, some OEMs have signed a long-term contract with some suppliers of raw material, such as a ten-year purchase of lithium (Manager D and H). According to Manager I, the investment in raw materials is needed to secure the cells,

which are the heart of the battery (Manager H). Even though the investment of raw materials carries risks, such as an unpredictable price decline of raw materials due to any circumstances, Volvo Trucks considers it seriously (Manager H). Moreover, any investment should be grounded on long-term relation/contract as Manager A said: *“We do not invest that time and money to marry battery suppliers for a year or two, that has to last minimum 10 years”*.

Interestingly, Volvo Trucks would not utilize directly from the purchase of raw materials due to the fact that it does not produce cells, but it rather transfers the raw materials to its potential supplier to produce the required cells needed for its vehicle (see Figure 5). Volvo Trucks could be at risk of not getting enough batteries if a battery producer has a shortage of raw materials, as Manager D said: *“Some competitors bought ten years of lithium. They have forecasted that we need this amount so they bought directly the lithium so they supply it to the cell supplier so they can not say I do not have lithium for your cells.”* In addition, such type of investments, according to Manager H, is a way to stabilize the cell prices. If the price of the critical raw materials is stabilized, there is a less likelihood of a price increase on the cell level (Manager H).

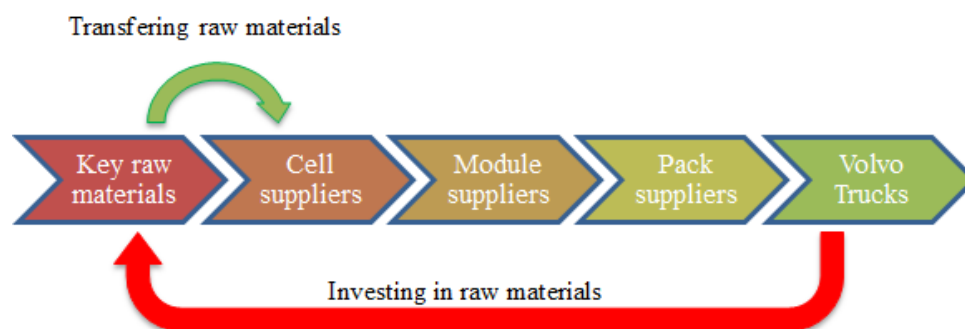


Figure 5: Visualization the cost of investment in raw materials. Compelled by the authors based on the primary empirical findings

The effects of changing international trade environment such as higher tariff rates and changing regional value content regulations, affect battery purchasing (All interviewees). This can be seen when the prices of products and components increase because of new regulations (Manager C). Increasing tariff duties, which are an explicit example of de-liberalized trade climate, has a severe negative impact on Volvo Trucks according to Manager F, who clarified how the buyers at Volvo Trucks would need to adjust their supplier base to make it properly work with the new regulations. According to him, the new regulations might make Volvo Trucks compelled to localize and internalize its operations in different regions in the world. This means that Volvo Trucks could be forced to have, for example, a production line for

battery packs in the North America region in order to meet new regulations of USMCA (the US.-Mexico-Canada Agreement). Manager H stressed on this issue as well when she stated: “[...] *Buy America and NAFTA we should consider. In order to fulfil that, we need to have most likely a cell supplier in the US in order to not be punished by the regulations. But if that won't be the case, so definitely it would add costs. So it can be definitely a risk if we don't manage to find a supplier in the US. This might increase the investment costs that we have to make later on*”.

4.5.2 Logistics Costs

The gathered information from the interviews shows that transportation costs (logistics) have been considered as one of the major costs when a buyer assesses potential suppliers. Transportation costs have been covered under the letter C of the abbreviations QDCF-TSR, where C refers not only to the purchase cost of the batteries but also to other sub-costs such as logistics. Many buyers, including commodity buyers, project buyers, and even senior buyers, consider logistics costs as a significant cost regarding the purchase of batteries (Manager C, H and I). Lead time, as it has already been discussed, plays a significant role in the supplier selection and can be considered as a heavy cost driving factor.

The selection of the battery suppliers and their components can be based on their proximity to one of Volvo plants or depots as Manager A said: “*When we have suppliers too far from our plant, we need to have a pickup point that is less than 48 or 72 hours from our manufacturing facilities, so we do not operate with partners who are too far from a pickup point*”. This considers valid for batteries since they are considered special and sensitive goods. Batteries are considered special due to the fact that its net weight is very heavy (one battery pack = approximately 700 kg/pack). While they are considered sensitive because if it is not transported properly, it can cause e.g. severe environmental disaster during the transportation journey (Manager A and B).

4.5.3 Development Costs

Development costs, which were brought up by almost all interviewees, have been considered critical. The costs resulting from any development activities could add up to the part price. As it has been highlighted, battery suppliers are considered “*development suppliers*” since they are working on the development process, and the product sourced from them are considered more expensive compared to “*production suppliers*”, who mainly provide “*off the shelf*” products (Manager G). Manager F, expressed explicitly that Volvo provides financial resources

to some suppliers for continuous development, or for creating a solution that is customized only for Volvo products. Moreover, Volvo Trucks is significantly interested to gain the knowledge resulted from any development, as Manager A expressed this when he said: *“Suppliers, who have the criteria such as the capability and capacity to carry on any development, are considered the preferred partners to Volvo, [...] what matters right now to select a supplier is not to get the absolute truth of the cost but it’s more to secure that we have the best competencies, the most open-minded people to work together with absolute transparency with all information.”* The development process may take place in the supplier property or at Volvo premises when engineers from the supplying companies come and work with the engineering department of Volvo for a certain period of time (usually 6 months up to 1 year) (Manager A). As a result, the costs generated from the mutual development may increase directly or indirectly the cost of the component/item, since the development might require a huge investment in technology and know-how skills (Manager E).

Product developments make Volvo Trucks keeping its competitiveness in the market by either developing its products to meet the customer preferences or being a first mover to any potential market (Manager F). Developing products is something crucial to Volvo’s success as Manager A commented: *“[...] if we do not make good investments during the good business time, probably we will suffer later on to finance those developments”*. Product investments, especially in the form of developing products and services with suppliers, seem endless because the battery technology is rapidly improving (Manager C). Development costs are also generated when Volvo Trucks wishes to keep specific design or technology for its own use. This can be seen when Volvo Trucks cooperates with a supplier for changing the design of a battery to suit better its trucks. The newly generated design may have a specific intellectual property (IP), which could raise the cost of a product as Manager D said: *“If you want to own an IP then, of course, the supplier charge you more because you own it specifically and he cannot resell it to someone else.”*

There is no doubt that the de-liberalized trade environment would have a certain effect on Volvo Trucks. Manager D, for instance, stressed on this issue when he explained that the new trade barriers would boost the costs of the purchased components, since it would make Volvo Trucks compelled to spread its activities around the globe to comply with each country's de-liberalized regulations (Manager A). This means, there are more time, effort and resources which are required for adaptation, as Manager A summarized the effects of the new regulations: *“If you look in from only one angle then we need to localize parts in all different kind of regions*

on the world. This means that we need to do the same development with potentially different partners, meaning that it takes engineering resources, it takes time, costs money and then you need to produce in all of those regions and then, need to duplicate the production equipment. These are costs, this is one way to see it". Thus, the new regulations resulting from the turbulent trade environment would make Volvo Trucks significantly concerned since it would duplicate its costs with each potential market.

4.5.4 Sustainability Cost

Sustainability has been integrated into all Volvo Group policies and their everyday business decisions. It has been translated into the supplier code of conduct that defines the foundations of sustainability requirements for all supplier in the areas of human rights and working conditions, health and safety, responsible sourcing of raw materials, environmental performance and business ethics (Volvo Group, 2019).

Being sustainable and making the business partners in the supply chain act sustainably as well could result in a cost at the end. This has been emphasized by all the interviewees. There is a possibility of rising costs for potential components if Volvo demands its suppliers to have a sustainable and socially responsible supply chain (second and third-tier) (Manager H and I). The rising costs resulted from sustainability could be at the cost of either a supplier or the buying company. Volvo Trucks is willing to pay more for the purchased material if it is within the sustainability criteria. Pushing the suppliers towards sustainable and socially responsible operations is considered a necessity to keep a good reputation of Volvo Trucks even though this could lead to extra costs (Manager A and G). Manager H emphasized on the issue that the battery supply chain is a very sensitive from the sustainability perspective, as it has already been discussed: *"Regarding the sustainability, mines are in terrible areas so we make sure that we don't get those raw materials from those mines. This might drive costs. If we secure sustainability in the supply chain, this might drive some activity and some costs of course than if we just hope to get a good raw material [...] maybe we need to travel to really secure the supply chain, and maybe we see something we need to act on"*. Manager D added to the importance of interference in the supply chain when necessary as he said: *"If we see that the cell supplier that we want to use, didn't extract the raw materials as we'd like to see, then we should probably step in and do it ourselves because it can penalize us and also the brand image"*.

Keeping the company image as a socially responsible transport solution provider requires cooperation with suppliers who have similar responsibility and sustainability perspective as Volvo Trucks (Volvo Group, 2019). Therefore, fulfilling sustainability requirements is one of the top priorities regarding selecting potential suppliers for the company. If a supplier does not respect corporate social responsibility or sustainability, it can easily influence Volvo's reputation in a negative direction. Manager C underlined the importance of complying with sustainability by saying: *"We want to secure and ensure sustainability in the world: the people, the plant and everyone, has been taken care of in proper and ethical ways"*. To secure Volvo Trucks' expectations towards its suppliers, it applies "sustainability" experts who have to travel to specific locations in the supply chain to make sure that suppliers comply with sustainability that Volvo Trucks is looking forward to seeing in its own supply chain (Manager H and I).

4.5.5 Quality Costs

The expectation of customers regarding the role of quality has raised. Therefore, Volvo Trucks has taken more emphasis on identifying potential problems in terms of quality and taking proactive actions to prevent their occurrences (Volvo Group, 2019). Volvo looks for suppliers who have the capability to achieve continuous quality improvement by using modern tools and methods (Volvo Group, 2019). Even though this could raise the quality level of its products, it could raise, at the same time, its costs as well.

All the purchased components, parts, and even raw materials go through different tests and validation procedures before they are implemented in the end-product (Manager A). Tests may take place by quality engineers either at the property of Volvo Trucks or at the supplier premises (Manager A). According to Manager C, there are many quality tests and inspections to make sure that the sourced components meet the quality standards of Volvo Trucks. Still, there are even more tests regarding the batteries compared to other conventional items since batteries are more sensitive and complex, as Manager D said: *"To applicate batteries on a moving vehicle is something very sensitive. Just imagine, that battery pack has to be stable and safe e.g. in Africa in 50C degrees and in Sweden in -20C degrees"*. In like manner, Manager C emphasized on the fact that since batteries, including cells, modules, and packs are very sensitive and complex items, thus many quality processes should be applied in order to ensure that batteries can be reliably used in the trucks (Manager C).

In general, Volvo Trucks applies quality engineers that are part of the purchasing departments in order to assist buyers in quality questions and verifications, and Electromobility purchasing

is not an exception. There are two quality engineers who spend a significant amount of their working time to visit suppliers on site. According to Manager I, a quality engineer secures that the potential supplier is the right one from the quality perspective since there is a huge cost if an inappropriate supplier has been chosen. Thus, quality assurance is a cost to Volvo Trucks as it requires the quality engineer to go and check regularly a system/component especially, for new suppliers, as Manager E pointed out: “*Usually, our quality engineer goes to every new supplier to check the setup and the safety that supplier has. Afterward, he goes there only if a supplier has some modifications.*”. A quality engineer can at the same time give recommendations to suppliers regarding how to improve the quality and reducing the costs in the supplier’s production if there is any possibility for it (Manager E). Any improvement in the process of production that Volvo Trucks suggests at supplier’s property might lead to a cost saving to Volvo Trucks as well (Volvo Trucks Purchasing, 2008).

Moreover, the supply quality engineer (SQE) who works with *Development Suppliers*, means that he has to check and inspect on-site the battery suppliers’ engineering, validation, and production. Meanwhile, the workload and cooperation with *Production Suppliers* are much less because the focus of the SQE is only on the production process and all the validation inspections take place in Volvo’s facilities (Manager I).

4.5.6 Learning Costs

Another cost that has been emerged during the interviews is the learning cost (all interviewees). This cost is related to the time spent in doing various types of activities in order to purchase the right component or item (Manager C). An excellent example of such an activity is when a buyer at Volvo Trucks digs into more information about a particular component before a request for quotation takes place. Reading consultancy reports; visiting engineering department (if there are some complexity behind that item/component), and paying a visit to the suppliers could be examples of main activities a buyer might do (Manager C). In this stage, a buyer starts learning about a new product from scratch (Manager B). Learning about a market and its players in order to find a potential supplier is considered another activity a buyer does, especially if the company does not have a PSL (Potential Supplier List) for components such as batteries (Manager C). Learning stage could be expanded to cover the process of evaluating potential suppliers and this includes (1) checking their capability and potential capacity, (2) investigating their background; (3) and last but not least conducting a benchmark analyse based on net present value and cost breakdown (Manager C and J).

Cost Breakdown is a tool used by Volvo Trucks to know the real costs of a particular component. A document, called Cost Breakdown data, is sent to a supplying company in order to be filled out with the different costs that incur during the production of a particular component including: the cost of raw materials, direct and indirect labour cost, manufacturing expenses, and sales & administrative cost, to name a few (Manager C; Volvo Trucks Purchasing, 2017). This tool assists buyers at Volvo Trucks for reaching the right supplier (Manager C and J). However, the supplying companies, do not often reveal and share with the buying company all the information regarding their costs, for instance, the cost of production of particular equipment, or the purchase price of raw materials that the supplying company has bought from its suppliers. The reason for omitting such costs is to conceal its margin.

In general, learning process consumes more time when dealing with a new component as Manager A said: *“We have standard lead time in purchasing when it is a new component it is 14 weeks; when it is an existing one it is 10 weeks. But this is really for sourcing activities. Before that, you have a lot of engineering and designing activities”*. Learning process could require as well additional financial resources when a company has to employ new specialists to fill the learning gap as Manager E said: *“We learn from suppliers and we employ new engineers in order to acquire knowledge.”*

4.5.7 Administrative Costs

Manager A referred to the administrative costs as costs related to time and resources that are needed to conduct activities such as purchasing, engineering, logistics, or even manufacturing. This means that administrative costs could consume a lot of time and resources through the whole process of sourcing. Further, administrative costs could be a result of any change in the trade environment or in the supply chain, for example, when a supplier does not deliver according to the pre-agreed conditions. A delay in the delivery of the supply it might result in additional costs for Volvo Trucks as Manager E said: *“[...] the product is not delivered on time you have agreed on. This is additional costs and delays to use the backup plans”*. However, sometimes the administrative costs are expected to be marginal compared to the total purchase as Manager B puts it: *“At the scale of a contract of the battery that’s not much, because these are large contracts, so it’s not going to be really important for the Volvo; it is negligible. But it is time and resource consuming.”*

Furthermore, the turbulent trade environment, such as increasing tariff duties, will have a severe impact on Volvo Trucks according to Manager F. It results in an increase of

administrative costs as Manager B said: “[...] *if you supplying from one country and there is a trade barrier, this adds some cost that is for sure. [...] Percentage of the tax [example of an administrative cost], that you might have to pay if the resource comes from country A or B.*”. That is, the increasing custom duties will be the additional administrative costs that Volvo Trucks will pay when a de-liberalized trade environment starts to emerge.

4.5.8 Purchase price

The purchase price refers to the cost of a component, item or raw material that Volvo Trucks considers during the procurement (all interviewees). The purchase price of a particular component carries a significant role in the supplier selection process. The acronym C of the abbreviations QDCT- SFR (criteria for selecting a supplier), refers directly to the purchase price that Volvo Trucks takes into account when it evaluates the quotations received from supplying companies. Purchase price carries a significant role when Volvo Trucks assesses the quotations received from suppliers. Based on the received prices, it selects the optimal supplier either from domestic or international markets (all interviewees). According to Manager B, the estimated contract (price) of Volvo Trucks for batteries is approximately between 100 and 300 million EUR.

The purchase price could include warranty cost as well. Warranty cost has been considered as a critical cost regarding selecting a supplier (Manager B and G). This cost is considered significant regarding reaching customer satisfaction since it is an unpaid promise to replace a fault component/product over a specific period of time. It was expressed by Manager A when he said: “*There is always one thing that we forget is the warranty cost because we are in immature environment with immature components and if unfortunately, something happens there are some cost afterward to handle the replacement of the part at the customers because at the end of the day the key is the customer satisfaction*”.

The de-liberalized trade environment will have an impact on the purchase price. According to Manager F, Volvo Trucks will have to purchase more expensive parts/components from North American region than in Asia because of the new strict regulations in the U.S. Taking the labour cost into consideration, the components from the North America region would cost more to be produced in comparison with China-made products (complying with USMCA- Local value content). This is because the new regulations raise the minimum wage salaries of workers to a certain level, as Manager G expressed.

4.6 Usage of TCO

The opinions of the interviewees from the Electromobility Purchasing Department have varied regarding whether TCO is a proper tool for evaluating and selecting a supplier or not. Some stressed on its effectiveness regarding identifying the indirect costs as Manager A said: “[...] *TCO brings two main assets. The first one is that you make a decision based on the real cost and then there is no hidden cost.*” Similarly, Manager H stressed on the importance of TCO when dealing with a supplying company. According to her, the backward calculation, which includes all the costs such as the purchase price and logistics among others, has assisted Volvo Trucks in the negotiation with specific suppliers regarding the final price of a battery. That is, TCO could assist Volvo Trucks to re-negotiate the purchase price when it shows this calculation to its supplying company. On the other hand, there are some interviewees who expressed their concerns regarding whether TCO is a proper tool for such a goal. Manager B, for instance, emphasized that TCO is not an appropriate tool since it might overlook some other important criteria regarding selecting a proper supplier, as Manager B expressed this with his own words: *“I think TCO is one tool to help you, but I think it is not the only tool to help you, because it might not capture the whole picture. It is like, you cannot say that you made your decision only on the TCO, but I think TCO is complimentary when you look at the cost perspective.”*

Other tools have been mainly adopted among the buyers in the Electromobility purchasing regarding selecting a potential supplier. One of these tools is the Cost Breakdown, which includes process cost, materials costs, logistics costs, packaging costs and landing costs to name a few. The second tool for evaluating and selecting a supplier is the Net Present Value (NPV). These tools have been efficient in assisting the buyers in Volvo Trucks in choosing the right suppliers with the right price (Manager C). Manager B commented on NPV as he said: *“When you make an NPV calculation you take into account logistic, part price, warranty cost that you might have. For me, it is not really a TCO”.*

5. Analysis

This chapter analyses the most important findings described in the previous chapter in relation to the content of the literature review. The costs that have been emphasized on during the empirical findings are presented and linked together under TCO to reach a revised conceptual framework that illustrates the structure of the supply chain.

5.1 The reason for globally purchasing batteries

Based on the findings of Albino et al. (2002), which identifies the differences between a global and a local network of a production process, it can be stated that the upstream supply chain regarding batteries for Volvo Trucks is a complex global network. This is also consistent with the empirical findings, where the structure of the supply chain regarding batteries has the characteristics of a global supply chain e.g. long geographic distances or varying regulations and political environments that Aydin et al. (2014) has defined. It is important to highlight that since the Electromobility sector is relatively new and immature, the possible supply chain setups for the batteries are quite restricted. The production of cells, which is extremely centralized in China, and the sources of crucial raw materials that are also restricted to a couple of mines and countries would be the main reasons why the supply chain is complex and concentrated. Thus, the avoidance of a complex global supply chain is not possible according to the findings of Meixell and Gargeya (2005). Further, as a consequence of the disequilibrium regarding the battery cells, it can occur that Volvo Trucks cannot simply build up the desirable supply chain which includes its potential suppliers if those suppliers do not want or cannot work with Volvo because their production capacities are fully utilized or they are waiting for a better offer from another OEM.

Currently, Volvo Trucks is only involved in the installation of the complete battery packs on its trucks. The main reasons for a low level of involvement are due to lacking of internal knowledge regarding producing batteries and the low economies of scale that the company could reach through internal production of batteries. The lack of capital was considered another possible reason for not making the company involved in the internalization activities regarding the production of cells. It is clear from the empirical findings that the internal production of battery packs or even the modules can be reached in the medium-run. Volvo Trucks could accumulate more easily and faster the knowledge and expertise that is necessary for the internal

production of these components comparing to the production of cells. Producing cells would need extremely high expertise in electrochemistry, which the company has never worked with before. The lack of sufficient internal knowledge is also highlighted by OECD (2013), that states the importance of the sufficient level of knowledge in case of the internalization of production. Further, Volvo Trucks has to consider the added value of internalizing the production of batteries since it is now specialized in machining and assembling as well as engines and transmissions development. The comparison of the pros and cons of the different way of sourcing is completely aligned with the statements of OECD (2013).

5.2 Supply chain management practices at Volvo

The findings of the conducted case study support the suggestions of Gunasekaran et al. (2004) that the importance of the systematic supply chain management is gradually increasing. Volvo Trucks utilizes supply chain management based on a well-structured strategy since the procurement of batteries does not happen in an ad-hoc basis. Furthermore, Volvo Trucks wants to get involved, not just in tier 1 of the suppliers' operations but, in tier 2-3-4 of the supply chain in order to avoid certain issues, for example, the existence of socially irresponsible suppliers in its supply chain. Volvo Trucks, in general, applies a sophisticated sourcing management strategy that has been in refinement for several years by now. In alignment with the study of Li et al. (2006), a great amount of expertise, know-how, and experience of the supply chain management have been accumulated during the years by Volvo Trucks. These assets are related to ICE (internal combustion engine) vehicles, which have a mature market and a mature supply chain base comparing to BEV's (battery electric vehicle). Volvo Trucks can be considered a beginner in BEV's market and its supply chain. Consequently, ICE's sourcing experiences, knowledge, and purchasing processes can be applied to a limited extent to BEV's.

Volvo Trucks realized the importance of an independent purchasing department by 2017. The restructuration that ended up in an independent purchasing division (Electromobility) at Volvo Trucks is completely aligned with the findings of Degraeve et al. (1999), Cousins et al. (2003) and Zachariassen et al. (2011), where their work shows that due to the gradually increasing role of sourcing, the significance of the purchasing division in the company's success has been increased. This is especially true in the case of BEVs' trucks since the electric drive system and batteries contribute approximately to 60% of the cost of electric-trucks sold. As the Electromobility department is responsible for the purchasing of electric drive systems and

battery packs, the role of its buyers regarding choosing a proper supplier with a proper cost is extremely significant for the success of Volvo electric trucks. Thereby, the findings of Van Weele (2005) regarding the significance of purchasing costs and the efficient supply chain in the automotive industry can be verified in the case of Volvo Trucks as well.

5.3 Direct costs related to battery purchasing

During the analysis of the costs, we utilized the findings of Zachariassen and Arlbjørn (2011) and distinguished between the direct and indirect costs. As Martens et al. (2012) explained in regards to the advantage of TCO, the TCO concept made it possible for us to comprehensively find, not just the direct but also, the hidden (indirect) costs. We could identify the following direct costs based on the empirical findings: Logistics costs, Investment costs, purchase price, and quality costs.

5.3.1 The purchase price of batteries (net price)

According to the literature, the purchase price of the supplied material is one of the five most conventional TCO components. It is not a surprise that Volvo considers the purchase price when selecting battery suppliers since the battery contracts are long-run agreements and usually worth hundreds of millions of Euros. In this way, the empirical findings are in alignment with the findings of Lycette & Lowenstein (2011) about the significance of the purchase price in the procurement of goods. However, it has been discussed in the empirical findings that there is a disequilibrium in the market for the batteries. This results in making Volvo Trucks losing some of its bargaining power against the battery suppliers. This is an exceptional market situation where Volvo Trucks has not experienced for many years comparing to the supply chain of ICE vehicles, which is already mature and the level of supply and demand are somehow stabilized. Because of the booked battery suppliers, it can easily occur that Volvo cannot choose the supplier that it would otherwise prefer. This indicates that Volvo might have to choose and source batteries from a supplier who is more expensive than the others.

Currently, the supply of batteries is heavily influenced by a couple of huge Asian companies, who are able to influence heavily the market price of batteries. According to the market forecasts, the level of supply and demand regarding batteries will further move away from the equilibrium point during the coming years. Thus, this change (increasing of demands with a shortage of supply to meet that demands) will drive up the purchase price, as Pindyck and Rubinfeld (2014) put in. This means, that a higher TCO value will be a result of such instability level of supply and demand.

Moreover, the price can be influenced by a lack of standardized products as it is highlighted in the empirical findings. Today, Volvo Trucks cannot make a reliable decision regarding the purchase of batteries since there are different prices provided by competing suppliers, who produce no-standardized batteries. Every supplier has differentiated its batteries in order, not only to control the price but also, to make the buyer has much higher switching costs.

Equally important is the impact of de-liberalized trade environment on the purchase price of batteries. This can be seen when, for example, the US government enforces that a large percentage of batteries (around 65%) should be produced domestically in order to be exported custom-free to North American region (USMCA). Since that region depends mainly on Asian suppliers for sourcing out batteries, the new regulations will lead to an increasing level of disequilibrium between the supply and demand as there are huge demands for batteries, and at the same time there are few suppliers that can meet these regulations. Thus, a rise in the purchase price will be a consequence (demand > supply), which is in alignment with Pindyck and Rubinfeld (2014).

5.3.2 Logistics Costs

The importance of logistics costs was an expected finding since Volvo Trucks purchases batteries from international suppliers. Thus, this cost plays a large role for the company when evaluating and selecting between international suppliers. According to our findings, logistics cost is considered a direct cost since it carries a significant influence on the total cost of ownership for a component/item. This means that the findings of our study are in line with earlier studies, such as the work of Zachariassen and Arlbjørn (2011), where they consider logistics cost as a direct one. Moreover, our findings are also consistent with the work of Ellram (1993; 1995) —transaction costs and dollar-based approach— since logistics costs are incurred after the stage of placing an order.

What is surprising though is the batteries are considered sensitive and special components to transport. The heavy net weight of one battery pack and the sensitivity of its content increase the logistics cost of this product. According to our findings, the cost of logistics is increased when a supplying company located in a distant place from the plant of Volvo Trucks. This means that our findings are consistent with Tibben-Lembke (1998) and Ghemawat (2001), who underline that the greater the distance the higher the logistics cost. This cost would be much higher if a product is relatively heavy and has a certain level of sensitivity, such as batteries.

5.3.3 Investment costs

During the empirical findings, we could identify two different types of costs under the umbrella of investment costs, namely the cost of investing in production line at suppliers premises, and the cost of investment in main raw materials. These investments are considered crucial regarding producing batteries.

The reason behind the investment in production line at a supplier premises is that Volvo Trucks lacks the knowledge that is necessary for internal production. Therefore, Volvo Trucks considers investing in the production of battery packs at one of its potential suppliers' premises. This investment will, not only facilitate the knowledge transfer for such technology but also, secure the capacity that Volvo needs to its trucks. During the literature review of TCO, we could not meet such a cost, which is considered significant regarding the battery industry. Thereby, according to us, this type of cost factor can be considered as a unique cost for the procurement of batteries. Moreover, based on Degraeve and Doodhooft (1999) findings, the cost of investment in the production line is considered a supplier level activity since the cost is realized due to the external battery sourcing.

The investment in main raw materials for batteries is also considered very crucial in order to secure the long term battery supply. These materials, such as cobalt, can be bought and transferred to battery suppliers in order they have enough capacity to produce batteries for Volvo Trucks. None of the TCO related literature has mentioned that the investment cost has to be taken into account when externally sourcing a material. Compared to the findings of Ellram (1993), we consider this type of cost as a pre-transaction cost since the investment in raw materials has to take place after the generation of the idea of purchasing and investing in such a product and before the order placement.

Moreover, according to our findings, the regulations generated from a de-liberalized trade environment incurs a significant cost for Volvo Trucks. This is because the large percentage of local value content imposed on components such as batteries would make Volvo Trucks compelled to localize and internalize its operations in different regions. The need to launching a production line for battery packs in each region to be complied with the regulation of each country, would raise some costs such as the investment costs. Therefore, we can see a direct impact of a de-liberalized trade environment on the investment costs of MNCs such as Volvo.

5.3.4 Quality Costs

The quality costs, which have been emphasized in the findings, are considered among major costs incurred when Volvo Trucks purchases batteries from an international supplier. These costs are generated from the actions taken by Volvo Trucks in conducting activities regarding the inspection of the quality of the purchased batteries. These activities include, for example, visiting a supplier, observing a process of production/assembly, and/or inspecting a product/component.

Based on the findings of the present study, quality activities are substantially important to avoid unforeseen costs such as a sudden stop of production/assembly process because of a product not meeting the specification that has been demanded by a buying company. Thus, our findings are consistent with the literature, particularly, with the work of Krishnan et al. (2000), who indicate that the quality costs incur to prevent a shortfall in quality or a failure to meet the demands of the customers [buyers].

It takes a lot of measures to ensure that a purchased product has a high level of quality, which is, according to our findings, considered the main factor for the success and competitiveness of Volvo Trucks. This means, that our empirical findings are in line with the work of Chen & Tang (1992) who emphasize that quality issues link significantly with the competitiveness of a buying company. Volvo Trucks conducts many tests and inspections for different components and materials to ensure a high level of quality and thus sustaining its competitiveness. However, batteries require much more tests and inspections than any other conventional material. This is because batteries, for instance, are new, sensitive, and complex components in the automotive industry. Moreover, such tests and inspection are also required to ensure safety. Further, conducting quality ensuring activities causes significant costs to Volvo Trucks, which means that our findings are also consistent with the work of Giakatis et al. (2001) when they demonstrate that the quality-related costs represent a considerable proportion of a company's total cost.

5.4 Indirect costs related to battery purchasing

The other general group of costs is the indirect or hidden costs as Zachariassen and Arlbjørn (2011) specify them. We could find four different types of costs that can be categorized into the indirect costs, namely the Learning related costs, Development costs, Administrative costs, and Sustainability related costs.

5.4.1 Learning cost

Learnings costs, according to the empirical findings, can be distinguished between two types: the cost of learning about the battery, and the cost of learning about its suppliers. When it comes to the cost of learning about the battery, this cost is influenced by the fact that the Electromobility sector in the commercial vehicle industry is relatively a new one. This means that Volvo Trucks has no sufficient time to accumulate the right amount of battery knowledge compared to the ICE segment, which it has already a well-off knowledge. Based on the findings, it takes a lot of efforts, time and asset to know, understand, and become familiar with the components such as batteries. Right decisions in the sourcing of batteries are crucial if Volvo Trucks wants to keep up with its competitors in the market of BEV trucks. However, since the batteries' presence in the automotive industry is such a new thing, the market lacks experts who have ample knowledge and experience in energy storage systems (batteries). Therefore, in order to overcome the lack of knowledge about batteries and to be able to make the right decision, buyers at Volvo Trucks have to, first and foremost, "learn" about those components. If a buyer does not have sufficient knowledge about the technical background of a battery, its advantages and disadvantages, then the right decision cannot be made.

We could not find a similar cost factor during the literature review, where the cost of learning about battery could be included. As Ellram (1993) puts it, pre-transaction costs incur from the generation of an idea of purchasing a component to the point of placing an order, therefore, we believe that the learning cost about batteries has to be part of the it since the idea of purchasing cannot be settled until the buyer starts to know what to source from the suppliers. However, this cost can be considered as a unique cost since it only exists because of the immature technology and supply chain. The cost of learning about the battery is now very significant, nevertheless, this significance is predicted to decrease in the coming years as the Electromobility sector, especially the battery sourcing, will become more mature in the commercial vehicle industry.

The cost of learning about the battery suppliers is the other type of learning cost that could be identified during our findings. This cost is generated because the supply chain of batteries is relatively new and currently emerging. In this way, the business-to-business relations have not fully stabilized yet. Compared to the ICE supply chain, which is stable for many years, the BEV supply chain for Volvo Trucks is forming and evolving right now. Consequently, there is no comprehensive battery supplier list in case of battery purchasing. Thus, the buyers of batteries have already started scouting around the market for battery suppliers. The scouting

process takes a lot of time and effort, and thus it generates costs. The empirical findings of the cost of learning about the battery suppliers are completely aligned with the findings of Ellram (1993), who classify the investigation of supplier base as a per-transaction cost. However, similarly to the cost of learning about battery, the cost of learning about the battery suppliers can also be considered a temporary cost. As we anticipate, the learning cost about battery suppliers will decrease after the supply chain of the batteries becomes mature and when Volvo Trucks builds up a battery supplier base.

5.4.2 Development cost

The performance of batteries is considered a main difference between different electric trucks, which influences the cost and the progress of development. Differentiating batteries, according to our findings, is a main strategy followed by battery producers (suppliers) to produce higher added-value products, control the price of the battery, and to make buyers have higher switching costs. This strategy is in alignment with what Cavinato (1992), who highlights that the purpose of the supply chain management is either cost efficiency maximization or reaching higher added-value products. In order to reach exceptional performance in batteries, Volvo Trucks cannot buy batteries off the shelf, but it has to develop those in cooperation with one of its potential battery suppliers. Furthermore, developing batteries can benefit Volvo by making its trucks outperform its competitors. Thus, the findings of Bhutta and Huq (2002) are verified as they argued for the significance of the supplier performance in the success of the buyer company. However, the development may take place when a company makes any change to the design of its products. This type of development involves extra costs that would not incur in the case of “*off the shelf*” procurement. Costs are incurred, when, for example, Volvo Trucks requires that the battery supplier make some changes to the battery design to suit only Volvo electric trucks. This is because the newly generated design, based on our findings, may have a specific intellectual property (IP), which could raise the cost of a product. This cost is considered a development cost since it is only designed for Volvo products. Moreover, the utilization of the cooperation between Volvo Trucks and supplier engineers, or the protection of the jointly generated intellectual property create costs as well. These costs are considered as development costs.

Since the TCO for conventional materials/components do not contain development cost, we consider the development cost a specific cost regarding the procurement of batteries. According to Ellram’s (1993) cost grouping, development costs can be placed under the pre-

transaction costs since the development of batteries takes place in the stage that comes before the delivery of batteries.

Moreover, according to our findings, the regulations generated from the de-liberalized trade environment would increase the cost of development for Volvo Trucks. This is because when the regulation (USMCA) compels Volvo Trucks and other OEMs to have a large proportion of local contents on their batteries, Volvo Trucks has to demand its new suppliers to do the same development that Volvo has conducted in other regions. This means more time, efforts and costs for each region that has a similar de-liberalized trade environment.

5.4.3 Administrative Costs

Consistent with the literature, this research found that the administrative costs are one among other costs that incur when Volvo Trucks sources batteries from a supplier. We found that the definition of the administrative cost was much broader in the findings than in the literature. For instance, in the studies of Dogan and Aydin (2011) and Ellram (1993), administrative costs are defined as those related mainly to supplier selection, partnering process and overhead expenses. While in the empirical findings the administrative costs refer to costs related to time and resources that are needed to conduct activities such as purchasing, engineering, logistics, or even manufacturing.

The reformation of the conventional purchasing practices, where the emphasis was on the processes not on the cross-functional cooperation, was found to cause severe administrative costs. The improvement of the cross-functional cooperation between the different stakeholder is essential in case of batteries in order to make efficient use of time required for battery purchasing. According to our findings, the administrative costs could also resulted from scouting around the market for new suppliers, negotiating with them, and/or even visiting their premises, which is in alignment with Degraeve, Labro and Roodhooft (2000) regarding the costs incurs resulting from administrative activities regarding the procurement of products.

Increasing tariffs, which is an excellent example of a de-liberalized trade environment has a significant impact on administrative costs. This is consistent with Ellram (1993), where administrative costs are related to tariffs, duties, and entry costs. Thus, the higher the custom duties the more the administrative costs an OEM such as Volvo Trucks would have to tackle.

5.4.4 Sustainability Costs

One unexpected finding regarding the costs linked to international purchasing of batteries was the sustainability cost. This cost carries a substantial role for Volvo Trucks. The continuous demands from customers for sustainable goods have pushed many OEMs such as Volvo Trucks to adjust their strategies and procurement procedure to be sustainable and socially responsible.

Fulfilling and adopting sustainability is not an expense-free. Every development occurred by moving the traditional process/product to the phase of sustainability incur a cost. According to the empirical findings, the cost of sustainability is on the expenses of a buying or a supplying company — depending on the negotiation between the two parties. According to empirical findings, it is feasible that Volvo Trucks bears sustainability cost when it demands a supplying company to designate a specific sustainable property for its products. This means that the cost of a component will rise compared to the status when there is no change in the hallmark of that component. Nonetheless, a supplying company might be compelled by itself to act sustainably to keep its competitive position in the market, particularly, if a large proportion of its competitors have already become sustainable in their activities. Samsung Chemical, which has turned to be sustainable in its production and even in the phase of pre-production: from the raw material extraction to inbound logistics, would be a leading example for other suppliers to act sustainably. Moreover, being sustainable would save some costs, for example, for the buying companies such as Volvo Trucks, since there is less costs related to visiting and investigating whether a supplying company follow sustainability in their activities.

Sustainability cost has not been seen and observed to be covered by researchers in the literature of TCO. Nevertheless, we believe that sustainability cost could be placed under the umbrella of pre-transaction costs in Ellram's study (1993) since it involves activities that takes place in the pre-stage of ordering a product, such as, visiting, investigating and inspecting whether a supplying firm fulfils the sustainability requirements. Moreover, our belief is in alignment with Degraeve, et. al (2000), since the cost generated by on-site visiting is considered pre-transaction cost. Furthermore, the miscellaneous category of costs in the Ferrin and Plank (2002) study - covering all costs that have not been placed on their thirteen categories - could implicitly include the sustainability cost as well.

5.5 Usages of TCO

There is a scepticism in the Electromobility purchasing at Volvo Trucks of adopting a TCO model. However, still, there are some supporters for this tool in the same department. This was found during the interviews where some employees were with the idea of using TCO as an efficient tool, while others couldn't believe totally in its efficiency. TCO has been used by some managers since it assists them by not only selecting a proper supplying company but also by renegotiating the price with the suppliers as well. This was completely consistent with the results of the studies of Dogan and Aydin (2011), and Caniato et. al (2015).

In the findings, we realized that the benefits of adopting TCO in purchasing batteries were not sufficiently known among most managers in the department of Electromobility purchasing. This is consistent with Wouters et al., (2005) since they show that many purchasing managers have little experience regarding applying TCO. Lack of knowledge of this tool makes some interviewees believe that TCO is not apt enough for tackling all costs and assisting them in selecting a proper supplier. This finding is in line with the study of Caniato et. al (2015), who found that lack of experience of TCO is one of the limitations of using it.

The Electromobility purchasing department uses other tools and methods in its decisions regarding choosing a proper supplier for its batteries, such as Cost Breakdown. This tool tackles costs regarding processes, materials, logistics, and packaging among others. This means that the Cost Breakdown is similar to TCO. Moreover, Cost Breakdown was found to have a similar goal like TCO: finding a proper supplier. Therefore, based on the similarity of tackling costs and setting a common goal, we believe that Volvo Trucks uses indirectly TCO tool.

The literature and the findings emphasized that TCO and Cost Breakdown, respectively, are efficient tools for identifying overall costs regarding a purchase situation, though they have some limitations. For example, it has been found that the open-page information between a supplier and the buying company is limited regarding using the Cost Breakdown method. According to our findings, a supplying company does not reveal the overall cost in the Cost Breakdown document, the one that is sent to a supplier to be filled out about his actual costs regarding producing a particular product, in order to conceal the margin. If there is a case of a lack of open-page information, this means that the Cost Breakdown is inefficient in assisting

Electromobility purchasing in choosing the right supplier for the batteries. Thus, the possibility of lack of open-page information is considered the main limitation for Cost Breakdown, which is the same limitation for TCO as well. This strengthens our belief that Volvo Trucks has used indirectly TCO in its purchasing decisions since the Cost Breakdown is significantly similar to the purpose and limitation of TCO. Therefore, by keeping in mind that Volvo Trucks uses indirectly TCO (dollar-based approach: monetary costs), the lack of open-page information mentioned in the findings is consistent with the studies of Ellram (1994) and Nyaga et al. (2010), who emphasize on such delimitations.

5.6 Revised conceptual framework

The analysis has shown that the international purchasing of batteries by an OEM operating in the Electromobility sector of the commercial vehicle industry involves eight major costs. These costs should be considered during the supplier selection and also in the decision to make or buy batteries. The conceptual framework has been revised and altered in accordance with the findings of the analysis. The five main conventional costs of TCO identified during the literature review, can be considered valid for the battery purchasing except for the *operation cost*. This is because Volvo Trucks does not involve any operation activities such as manufacturing or assembly in the procurement of batteries. Therefore, this cost was not included in the new conceptual framework. The new “*costs bubbles*” emerged during the analysis, have been included in the revised conceptual framework (see Figure 6). It is important to highlight that some of these costs, such as the learning costs and development costs are recently very significant, however, in the long run, it is anticipated that their influence will decrease in the TCO calculation. Regarding the cost drivers in case of international purchasing of batteries, we could identify the followings: 1.) the supply-demand disequilibrium influences the purchase price, 2.) the sensitivity, the weight of batteries and the remote location of suppliers influence the logistics cost, 3.) the raw material scarcity and the need to secure the capacity influence the investment cost, 4.) the new technology influences the learning cost, 5.) the improvement of cross-functional cooperation influences the administrative cost, and 6.) the sensitiveness of the supply chain influences the sustainability cost. Moreover, in the procurement of batteries it was found that the purchase price and costs such as administrative, investments, and developments have been directly impacted by the de-liberalizing trade environment as well.

The attributes of TCO as a decision influencer on the structure of Volvo Trucks regarding the battery supply chain has been semi-proven during this case study. The value of the TCO cannot be the only factor that influences how a company organizes a new and emerging supply chain, even though the literature of TCO suggests this. We could identify other factors that besides TCO can determine the decision about the setup of the battery supply at Volvo Trucks. First, the lack of knowledge about the production of battery cell hampers in the short-run the internal production of batteries. Second, the recently geographically concentrated setup of battery suppliers determines the global supply chain setup of the batteries. Third, the lack of economies of scale that Volvo Trucks would have in case of internal production of battery cells, raises the question if it would worth to not purchase them but instead to internally produce. The last additional influencing factor that we could identify is the fact that Volvo Trucks is more interested in the acquisition of the best battery technology.

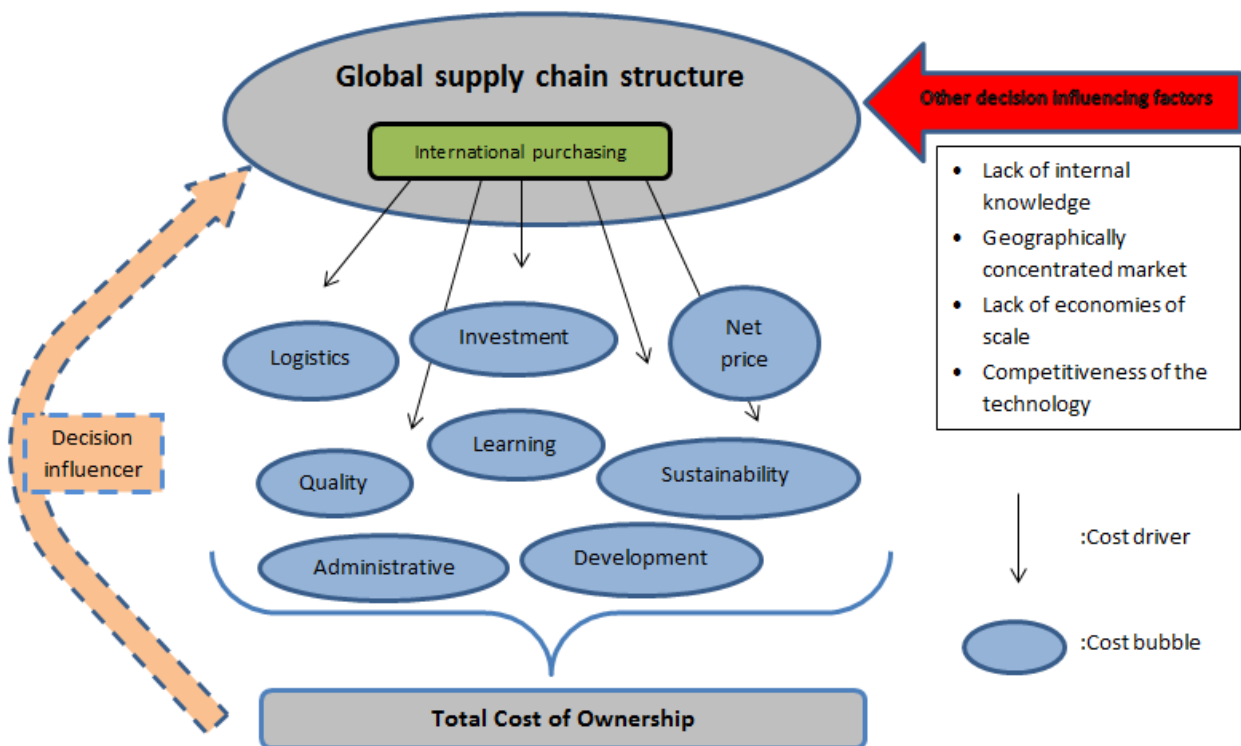


Figure 6: Revised conceptual framework. Compelled by us.

6. Conclusion and outlook

This chapter presents the conclusion of the derived findings in the analysis and answers this study's research question: "What cost factors are essential in an OEM's purchasing decision to source energy storage systems in a de-liberalizing international trade environment?" After presenting the conclusions and contributions, managerial implications are posted. Lastly, the study's limitations and suggestions for future research are outlined.

6.1 Findings and theoretical contribution

This case study focuses on identifying the costs generated when an OEM operating in the commercial vehicle industry purchases batteries from international supplying companies under turbulent international trade environment. The academic literature lacks detailed insight on specific costs for each industry since it is believed that every component and purchase situation has its own "cost bubble" structure, which might differ from case to case. We applied a case study approach to find an answer to our research question. The results show that in the Electromobility sector, an OEM has eight different cost factors (four direct and four indirect costs) that are incurred when it internationally purchases energy storage systems (batteries). Moreover, in the procurement of batteries it was found that the purchase price and costs such as the administrative costs, investments costs, and developments costs have been directly impacted by the de-liberalizing trade environment. Recently the observed OEM is vulnerable to the effects of the international turbulent trade environment because of two reasons. The studied OEM is unable to source the batteries from the North American region because of the lacking local suppliers, and it is also unable to offshore the battery cell production in the North American region because of the lack of internal knowledge about battery cell production. However, it has been observed that there is a strong intention from Volvo Trucks to overcome the negative effects of the turbulent international trade environment on the long run by creating a battery supply chain structure that can act more locally than globally, thus eliminating the negative effects of the emerging de-liberalizing international trade environment.

The findings show that there are many costs that have been generated from an international purchase of batteries. These costs start from a time when a buying company has an idea of purchasing a battery to, but not limited, the stage of receiving that component. This includes logistics, investment, learning, sustainability, development, quality, and administrative costs

in addition to the purchase price. These costs have been generated mainly either through governmental regulations, market characteristics or/and customer preferences. These costs should be taking into consideration by a buying company when it needs to make a decision between internally make or externally buy. Compared to the five conventional “cost bubbles” that the literature of the TCO outlines, the eight battery purchasing specific cost factors confirm the argument of previous studies which outline that different type of cost factors emerge for each purchase situation. Further, in contrast to the previous TCO studies, we observed an industry sector that is currently emerging and its related supply chain is immature. These facts could provide a unique subject and perspective, and allow us to shed light on purchasing related costs such as learning or part of administrative costs that, according to our presumption, will disappear when the Electromobility sector in the automotive industry becomes mature in the coming decades. We believe that we are among the first observers who applied the concept of TCO on a currently emerging industry sector with an immature supply chain. With this study, we think that we could prove that the theory of TCO is an efficient concept to identify major costs and can be utilized not just in case of a mature but in case of an immature supply chain as well. However, we have also drawn up the attention that in case of an immature supply chain the decision about the future supply chain setup cannot be based only on TCO but there are other decision influencer factors as well.

Moreover, the study shows that buyers at an OEM in the Electromobility sector use some tools and methods to assist its decision making regarding a purchasing situation. Cost Breakdown and Net Present Value were among the tools used by the studied company to make a proper decision regarding the purchasing. The findings have not confirmed completely and comprehensively the usage of TCO in the Electromobility purchasing team in Volvo Trucks. Further, this case study shows that an open-page information from the supplying company is still crucial for the buyers in order to be able to make an efficient decision regarding the supplier selection. The result, therefore, confirms with the statements of previous studies that argued for a need for transparency between the trade parties in order to achieve cost efficiency.

6.2 Managerial Implications

The results suggest that it is not possible in the short term to mitigate the negative effects of international turbulent trade environment on the battery sourcing. The reason for this is twofold. First, the internal production of the battery cells is not reachable in the near future thus the internal production [localization] through offshoring is not a possible way. This is

because the lack of knowledge and economies of scale are the hampering factors. The second reason originates from the fact that the Electromobility sector, and more precisely, the battery supply chain is immature. The recently geographically heavily concentrated battery cell producers are mainly in Asia. Thus, currently, the sourcing of battery cells from other continents other than Asia is severely limited.

Even though the Cost Breakdown method has been found to have a similarity to the TCO concept, and it is considered as a reliable tool to select a proper supplier, we can say that TCO can shed more lights on costs that cannot be identified by using only the Cost Breakdown method, such as, learning costs and part of the administrative costs. We assume that the combination of TCO and Cost Breakdown analysis would be the most feasible way to grasp reliably all the costs occurring during the battery purchasing.

As stressed in this study, since batteries are new and complex products and have a fast rate of technical development, the consideration of all the purchasing related costs is necessary. This study gives a complete and comprehensive overview of the costs incurring all the way from the creation of an idea of purchasing a battery up to the point where it is delivered to the added-value-process (application on the trucks). Taking these costs into consideration will assist battery buyers to evaluate and select the proper suppliers. Not to overlook the fact that some of these costs do not have a direct effect in selecting suppliers since they relate to the costs that are generated mainly from the industry. A key implication is that OEMs can tackle all these costs efficiently when applying a TCO model in their purchasing activities since all these costs are “*cost bubbles*” of such a model.

6.3 Limitations and future outlook

We suppose that since this study is among the first that reveals a more comprehensive picture of TCO of battery purchasing, it has only scratched its surface. We consider the single case study approach of this study is a currently unavoidable limitation. We believe that a study that can be conducted on more researched units can provide more reliable findings. However, the opportunity to conduct multiple case studies or even a quantitative research method on the field of Electromobility sector in the commercial vehicle industry is limited today. The players on this market are currently restricted to only 4-5 huge MNCs and even the number of specialists who operates in the procurement of Electromobility is considerably low. Companies, involved in the Electromobility of commercial vehicles, are situated in different countries or even

continents and are usually reluctant to participate in multiple case studies. These factors limited our research opportunities to involve more companies in our study. In order to utilize the real advantage of the TCO concept and build a model with the real purchase price of e.g. batteries, a multiple case study or a quantitative approach is inevitable. Thus, we would recommend further studies involving multiple cases in the field of TCO for Electromobility purchasing, since it is relatively new and unexplored. Furthermore, the recently establishing BEV sector is such a paradigm change in the automotive industry both in technology and in business wise as well, which is, according to our opinion, can provide a very interesting study field that can challenge or ensure the findings of many other academic business studies written in the field e.g. supply chain management, global sourcing or transnational production networks.

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Appendix 1

-Interview-

Introduction

- Can you tell us a little about e-mobility (purchasing) division?
- When did you start working at Volvo Truck?
- What is your role at the company?
- For how long have you been working at the E-mob purchasing department?
- What is your professional background/education?
- How different is BEV truck purchasing compared to ICE truck?

Characteristic of battery supply chain of Volvo Truck

- Can you please describe your battery supply chain characteristic at e-mob?
 - What type of supply chain does the company have regarding to the batteries?
 - Where are the battery suppliers situated in the world?
 - What size of suppliers do you operate with? (SME, MNC)
- What is the reason that the Volvo is not involved more in the value chain of the batteries?
- How deep is the vertical integration of Volvo Truck? Meaning that, how many suppliers are owned partly or entirely by the Volvo?
- What are the characteristics of a “good” supply chain?
- What characterizes a ‘bad` supply chain?

Characteristics of choosing a supplier of a battery

- What kind of factors influence the e-mob purchasing process?
- What is the KPI of the e-mob purchasing department?
- What are the challenges to source the batteries from suppliers?
- How long does it usually take to select a supplier? (assuming that the cooperation reaches the delivering status)

Cost factors that influence TCO Value

- Have you already heard about the TCO concept? If yes, please elaborate!

- What kind of costs are being considered when purchasing a product? (//hint: administrative, logistic, quality, operation, and purchasing price)
- Are there any indirect costs being taking into consideration when the product's cost is evaluated? (//hint: downtime costs: repair of a machine)
- Do you think that there are other costs or activities that are more specific for e-mobility purchasing than conventional truck purchasing?
- How does the fact influence the e-mob purchasing that this is a relatively new industry sector? (learning, missing supplier base, more time, energy and cost is necessary to find the right partners)
- Do you think the changing trade environment in the world would create some other costs regarding the international supply chain?
- What is the process of purchasing a battery starting from the stage of generating an idea to the stage of delivering it?
 - What kind of activities does the purchasing process involve?
 - What kind of costs could incurred during this process?
- Do you think that the company supplier selection method miss out any important cost factor that could be important?
 - Do you think that the sustainability movement in the world would have some impact in case of e-mob in supplier evaluation and selection further on the cost of the supply?