DEGREE PROJECT

Sustainable supply logistics and inventory management

a case study at Axelent AB

Ebba Knutsson

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Luleå University of Technology
Department of Social Sciences, Technology and Arts

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Acknowledgement

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Ebba Knutsson

Abstract

The purpose of this study is to give an insight to operation and managerial possibilities and difficulties of sustainable inventory management. The objective is to give a general picture of what is available in terms of economic models as well as the implications from the current situation and eventual changes. The study uses an abductive approach with both qualitative and quantitative data. Quantitative data is composed of current available measurement at the case company, Axelent AB. While the qualitative is composed of interviews to establish the operational framework at the case company.

The study found that both the common Economic Lot-Scheduling and Economic Order Quantity models have been successfully proven to be adaptable to include emission. To measure emission's, the GHG Protocol is found to be useful and is recommended. Though monetisation of emission's are not consecutively required by the models, it is recommended with well selected prices. There is a need to establish the effects of a change in operations in order to avoid negative effects on the everyday operations. The current way of operation would most likely be changed if emission's would be introducing into the inventory management models.

The study only included the supply where the company was the order trigger, thereby excluding vendor-controlled inventory. The warehouse that was studied is in a shared building with production. There were two components taken as examples for calculations.

Key words:

Sustainable supply logistics, sustainable inventory management, carbon monetisation

Sammanfatting

Syftet med denna studie är att ge en inblick i operativa och ledningsmöjligheter samt visa på svårigheter med introducering av hållbar lagerhantering. Målet är att ge en allmän bild av vad som finns tillgängligt i form av ekonomiska modeller samt konsekvenserna av den nuvarande situationen och eventuella förändringar. Med ett abduktivt tillvägagångssätt samlades både kvalitativa och kvantitativa data in. Kvantitativa data sammanställda av aktuella tillgängliga mätetal. Medan den kvalitativa var sammansatt av intervjuer för att fastställa den operativa ramen på caseföretaget.

Resultaten av studien var att både de vanliga modellerna för Economic Lot-Scheduling och Economic Order Quantity har framgångsrikt visats vara anpassningsbara för att inkludera utsläpp. För att mäta utsläpp har GHG-protokollet visat sig vara användbart och är även rekommenderat. Modellerna visar inte på att monetarisering av utsläpp inte behövs, rekommenderas detta med väl utvalda priser. Det finns ett behov av att fastställa effekterna av en verksamhetsförändring för att undvika negativa effekter på verksamheten. Den nuvarande arbetsättet skulle med största sannolikhet ändras om utsläppen skulle införas i lagerhanteringsmodellerna.

Studien omfattade endast försörjningslogistiken där företaget lägger ordrar, alltså ingår inte leveratörsstyrda lager i studien. Laget som ingått i studien ligger i samband med produktionen. Det fanns bara två komponenter som togs som exempel i beräkningar.

Nyckelord:

Hållbar försörjningslogistik, hållbar lagerhantering, monetarisering av koldioxid

List of abbreviations

SC	Supply Chain
SSC	Sustainable Supply Chain
ELS	Economic Lot-Scheduling
GHG	Greenhouse Gas
ETS	Emission Trading System
GDP	Gross Domestic Product
ERP	Enterprise Resource Program
SEOQ	Sustainable Economic Order Quantity
LCA	Life Cycle Analysis
JIT	Just-in-time

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1 Introduction

The subject, problem formulation and background of this master thesis will be presented in this chapter. In addition with purpose, research questions, delimitations and a brief presentation of the case study company.

1.1 Problem Background

In the supply chain (SC) inventory and transport costs have conflicting relationships with each other, meaning that minimising one will lead to an increase in the other (Das & Tyagi, 1997; Nozick & Tumquist, 2001). Managing both inventory and transportation costs is crucial for overall cost management and profitability of a company (Tanaka & Respati, 2021). Additionally, the growing emphasis on environmental impact and sustainable practices is becoming increasingly important across all aspects of a company's operations. Where implementation of sustainable practices seems like the way forward in all of a company's areas of operations.

Internationally the efforts for increased sustainability have been sporadic. The EU has only set goals for reducing carbon emission's from road transport without implementing strict policies, resulting in varying business conditions across member states. Many countries have set their own mitigating strategies with national reduction targets. These are often quite generalised and can be misguided in directly affecting a specific sector, such as the logistics sector according to Rüdinger et al. (2016). A more widespread scheme such as the European Unions (EU) Emission Trading Scheme (ETS) have been implemented throughout sectors for more precisely targeting. For the logistics sector there were ETS implemented on airlines in 2012, maritime shipping in 2018 and road transport in 2023 (ICAP, 2022). The introduction of the EU ETS scheme adds upon the challenges of recent increase in global gas and oil prices, supply constraints, and the ongoing conflict in Ukraine (Stiglitz et al., 2017) that companies are facing.

With these challenges companies can take the general idea of monetisation of emission that schemes such as the EU ETS introduces. ETS's allows market forces to facilitate a reduction in emission's without causing significant negative effects on GDP (Parry, 2020). In other words, by placing a value on emitted carbon through a tax or cap-and-trade system, emission's are monetised. This, in turn, enables the inclusion of emission's into overall economic calculations (Benjaafar et al., 2012; Wahab et al., 2011; Elhedhil & Merrick, 2012; Pagell, 2014; He et al., 2015). Effectively enabling adaptation of economical calculations to incorporate emission's. These changes in core business functions ensures a smooth transition to a sustainable supply chain (SSC).

Studies have incorporated carbon emission's within a JIT system, such as the single and multistage economic lot-scheduling (ELS) and/or economic order quantity (EOQ) (Benjaafar et al., 2012; Bouchery et al., 2012; Bittini et al., 2014; Bazan et al., 2015; Hovelaque & Bionneau, 2015; Gurtu et al., 2015; Memari et al., 2016; Jaber et al., 2017; Taleizadeh et al., 2018; Wang & Ye, 2018).

1.2 Problem Formulation

Green and sustainable supply chain management is both available and most essential to be considered (Fang & Zhang; 2018). But in reality, not all companies have so far made efforts to have a supply chain that can be considered to be green or sustainable. Axelent AB is such a company that has of yet implanted green performance as a real parameter into their way of making business. With a more trying supply chain environment, which includes extended EU ETS schemes, recent increase in global gas and oil prices, supply constraints, and the ongoing conflict in Ukraine (Stiglitz et al., 2017), efforts to grow and stay profitable will most likely include a more sustainable focus.

The integration of emission management into supply and inventory management brings with it its own set of challenges and hinders. Often these are due to the unique circumstances that each company are in. By performing a case study, the collective understanding and knowledge of how companies can integrate a sustainable supply chain can be added to.

1.3 Purpose & Research Question

The purpose of this paper is to conduct a case study of a company that has of yet no direct emission or sustainable management of its supply chain. By scrutinize and analyse suitable sustainable inventory management tools proposed in academic literature in a case study at Axelent AB. By highlighting the correlation and application, or lack thereof, to a real-life case the analysis will answer the following research questions.

RQ1: To what extent can carbon reduction requirements be addressed by an inventory management tool?

RQ2: What insights and direction could a sustainable inventory management tool provide to a company's daily operations and managerial direction?

1.4 Case Study Company

Axelent started in 1990 in Hillerstorp, Småland. Their main products are safety systems for industries, such as safety nets for automatised robots and safety solutions in warehouses. The production plant is situated in Hillerstorp, in connection with the main office. The company is interested in evaluation of environmental impact of their supply logistics, since there is no such parameters that they use in decision making today. Currently most of the in-logistics and suppliers is situated in close proximity to the warehouse and main office. Production and the central warehouse are situated in Hillerstorp, Sweden, while their sales are international with sales offices and in some cases even warehouses in North America, Europe, and Asia.

1.5 Delimitations

This thesis will only include national truck transports inside of Sweden. These studied transports are triggered and paid for by the buyer. Delivery is at the sight in Hillerstorp where production and packing take place. There is no extra warehouse location that is taken into consideration in this study.

Two components is included as examples that represent supply logistics. The products are high volume components and are packed by the company. Further information is sparse since the suppliers are not a part of this thesis and the aim or this is not to act as an interlude between business partners. The restriction of information is simply to ensure the intellectual property and operational information of the case company.

2 Theoretical Frame of Reference

In this chapter a comprehensive presentation of previous research will be presented. It is including the basis of sustainable inventory management, along with a quick review of the Greenhouse Gas (GHG) Protocol and GHG quantification and monetarisation.

2.1 Emission Assessment

Based on the Intergovernmental Panel on Climate Change (IPCC) report, the transportation sector was the fourth largest emitter of greenhouse gases (GHG) globally in 2019, following power, industry, and agriculture, forest, and land use (AFOLU) sectors. Within this sector, road transport was responsible for the majority of emissions at 69%, primarily from combustion engines running on petroleum-based fuels that emit not only carbon dioxide, but also other GHG’s like methane (CH4) and nitrous oxide (NOx). Although carbon dioxide makes up 77% of total emissions, it has become the standard by which other GHG’s are measured, and efforts to reduce emission's have primarily focused on carbon reduction. However, accurately calculating carbon emissions can be challenging and prone to errors, making the use of simple methodologies based on distance (Gonzalez-Feliu, 2011; Leitner et al., 2011; Montoya-Torres et al., 2016; Makhloufi et al., 2015; Muñoz-Villamizar et al., 2020) or energy consumption (Chabot et al., 2018; Muñoz-Villamizar et al., 2020; Stellingwerf et al., 2019; 2018;; Soysal et al., 2018; Wang et al., 2018) more common in research.

Calculating emission's from buildings are also a complex task, with electricity and heating contributing to 57% of carbon emission's in the building and housing sector. Material usage during the construction or remodeling phase is the second-largest contributor. To accurately determine emission's from an unoccupied building such as a warehouse or an industry, a life cycle analysis (LCA) is often used (Cabeza et al., 2022). Tools such as the GHG Protocol can simplify the process of measuring carbon emission's associated with building usage (Naturvårdsverket, 2022). However, this approach does not account for emission's resulting from activities within the building, which can be controlled to reduce overall emission's.

Measuring GHG gases from warehousing is complex and will include a number of aspects. Rüdiger et al. (2016) argues that the validity of results is dependent on the accuracy of measurement. With electricity being the major source of emission's from logistics facilities, the measuring of this is essential. Different types of logistics facilities may focus on different areas of emission sources. Effectiveness of warehouses with ambient (non-refrigerated) goods with order-picking may be measured with the space occupies by the goods and packing factors, along with number of outgoing items and average storage times (Rüdiger et al., 2016). The space occupied can be related to the energy usage of the facility and emission's measured per square meter (m^2) or storage positions. Packing factors in such that automations may exists adds to emission's and waste may also occur in packing activities. The authors argued that these four areas may be used as emission performance indicators (EPI).

2.2.1 Greenhouse Gas Protocol

In 1998, two non-governmental organizations (NGOs), the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), collaborated to create the

GHG Protocol. This standardised framework was designed to assist organisations in measuring and managing their greenhouse gas (GHG) emission's by combining the research capabilities of WRI with the leadership of WBCSD (WBCSD, 2004). The GHG Protocol classifies emission's into three scopes based on the strategic and operational boundaries of the organisation. Scope 1 comprises emission's from an organisation's own operations, while Scope 2 encompasses emission's from purchased energy sources such as electricity, heating, and cooling. Scope 3 includes the indirect emission's associated with the products or services purchased by the organisation (Naturvårdsverket, 2022).

The GHG Protocol provides a structured approach for identifying and measuring emission's across the three scopes, which allows organisations to link their activities to their carbon footprint. According to Green (2010), the protocol makes it relatively straightforward for companies that are interested in self-reporting or preparing for future regulations to track and report their emission's accurately.

As of June 2022, the Swedish Environmental Protection Agency, Naturvårdsverket, recommends the GHG Protocol as one of two methods for measuring carbon emission's for reporting to the Swedish government. The other method is ISO 14064-1. By endorsing the GHG Protocol, the agency acknowledges the value of a standardised approach to measuring carbon emissions and the importance of accurate and transparent reporting.

There is an observed difficulty in obtaining accurate measurement from third-parties. The data is often a lump sum that is seen as a possible marketing advantage and direct data from production and delivery might be seen as a possible bargaining positions loss (Rüdiger et al., 2016). This increases the difficulty of accurate measuring of the emission's from scope 3. Both scope one and two are more connected with the main company and therefore more straightforward to measure (Rüdiger et al., 2016).

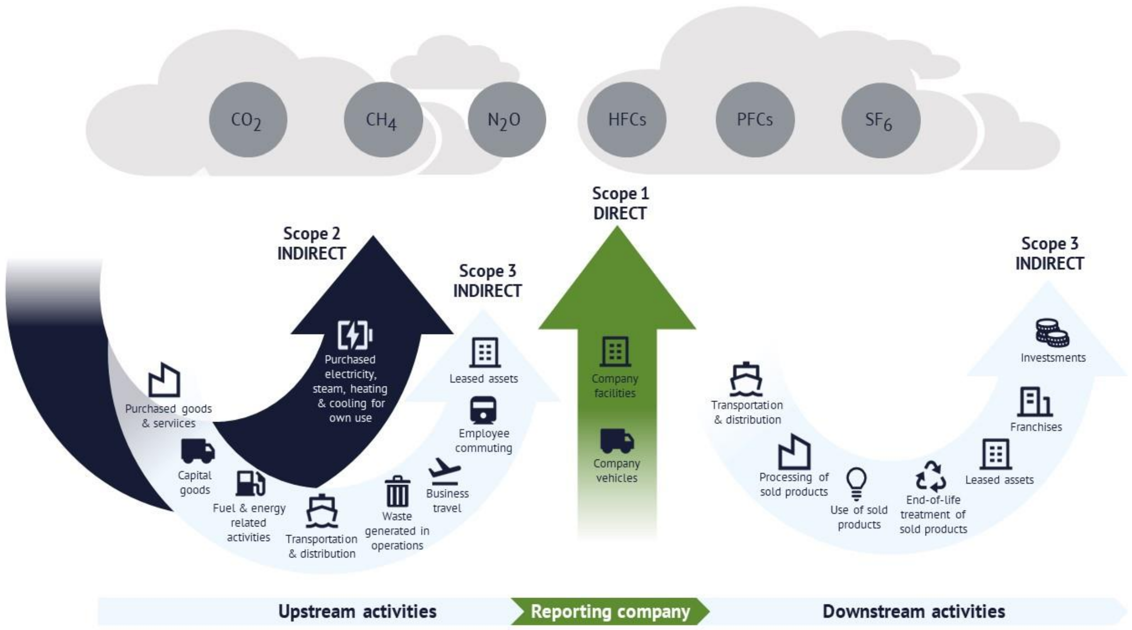

Figure 2.1. Depicting the three scopes as the occur in the value chain. From GHG protocol (https://ghgprotocol.org/blog/you-too-can-master-value-chain-emissions)

2.2.2 Carbon pricing

Setting a price on carbon emission's through a carbon tax, emission's trading system, or a hybrid scheme has long been recommended as integral and cost-efficient in reducing emission's and mitigating climate change impacts (Baumol & Oates, 1988; Metcalf, 2009; Cramton et al. 2017; Stiglitz et al., 2017). The social cost of carbon (SCC) is the optimal price that can be defined by monetising the damages associated with emitting an additional tonne of CO2, but the global SCC has a wide range due to uncertainty's in damage estimations, making it unhelpful for policymaker (Adler et al., 2017; Rafay et al., 2020). Instead, advanced target-based approaches have been suggested where appropriate pricing is chosen to minimise the cost of achieving a desired reduction in CO2 emission's over a given time period (Hepburn, 2017).

In the efforts of adding taxes and ETS schemes (cap-and-trade) in order to lower emission while avoiding economic disturbances the price of the commodity at the core is also important. Fuel prices are at its highest in a long time, affected by the post-COVID reopening and the war in Ukraine, the energy prices are as well historically high (Stiglitz et al., 2017). This is a trend already observed in 2014 when Gurut et al. (2014) wrote that companies and organisations must come to terms and accommodate to these changes of transport prices. Emission's from electricity in Sweden have had a downwards trend with more and more renewable energy sources being introduced. Sweden has one of the best electricity mixes in Europe and on average emits 28 grams of CO2/kWh (ENTSO-E, 2023; Nowtricity, 2023).

The EU Emissions Trading System (ETS) is a cap-and-trade scheme that covers about 38% of the European Union's greenhouse gas (GHG) emissions. It applies to the energy, industry, and domestic aviation sectors, and it is currently the world's largest ETS in terms of trading volume. The average auction price is EUR 78.91 per EUA (EU Allowance = 1 tonne CO2), with the secondary market price averaging at EUR 80.82 per EUA, according to ICAP (2023).

Companies can estimate the effectiveness of their sustainable investments by incorporating a shadow tax or cap on emission's, according to studies by Benjaafar et al. (2012) and Battini et al. (2014). This strategy not only improves a company's own efforts towards sustainability but also prepares them for future demands from customers and third parties. In 2023, the Gotland region adopted a similar approach, approving a shadow price of 902 SEK per tonne CO2 for suitable investments (Region Gotland, 2023). FI (Finansinspektionen) recommended Swedish companies to establish an internal carbon price to self-report carbon emission's. This would aid companies in mitigating risks and exploit possibilities when demand for emission reduction arises. There are different ways of utilising this method, one is to set a singular price whilst there are some companies connect their price with a market price and gets a difference that is either lost or gained. The price can either be added into all the decision-making processes of the company or as indicators for larger scale decisions to adhere to (FI, 2020).

2.2 Sustainable Inventory Management

Inventory management involves two key elements, inventory cost and transport cost (Das & Tyagi, 1997; Nozick & Tumquist, 2001). However, balancing only transportation and inventory holding costs is often not sufficient. To minimise the total cost of inventory, different aspects can be used as a variable while setting the rest as set parameters. The ELS method uses order quantity as the variable, where the minimisation of total cost incentivizing a moderate order quantity in stationary cases without capacity restraints (Axsäter, 1986). On the other hand, EOQ determines the order size by balancing demand, D, and inventory holding cost, H, with the order cost, F, according to the base model:

$$EOQ = \sqrt{\frac{2DF}{H}} \tag{1}$$

Therefore, the variable can be either the frequency of orders per time period (t = 1, ..., T) or the time period between orders, also known as the economic order period (EOP), which is given by TBO = (EOQ/D)*T (Krajewski et al., 2016). Both methods require knowledge of the demand (D) over the entire time period (T), which provides the separate demands for each period $\sum d_t = D$, as well as holding cost, h, for inventory at the end of each period (annual holding cost, $\sum h_t = H$) and an order cost, F. These models assume instant replenishment and no lead times (Axsäter, 1986; Staggemeier & Clark, 2001; Krajewski et al., 2016), but additional constraints may be necessary to adapt them to specific real-world situations.

2.2.1 Sustainable Economic Lot-scheduling

The single- or multistage lot-sizing (or -scheduling) model as originally proposed in 1958 by Wagner-Whitin lends itself for adaptations such as multistage production with capacity restraints. But in practice the method is often used as guidance and a last touch up of the result is needed before it is put into action (Axsäter, 1986). Single-stage lot-sizing applies when the lot size aligns with a single production or transportation step, while multiple stages are necessary if the lot size must conform to two or more processes. Adding several products to the model does not alter its single or multiple-stage characteristics (Staggemeier & Clark, 2001). When choosing between methods, the ELS model is preferable for stable, high-volume demand (Jaber et al., 2017).

The basic model aims to determine the optimal balance between ordering more within a specific time period and paying for inventory costs during that time period, in order to avoid incurring order costs (Axsäter, 1986; Staggemeier & Clark, 2001). The minimization problem can be expressed as follows:

$$Min \sum_{t=1}^{T}(Fy_t + hI_t) \tag{2}$$

Subject to

$$I_{t-1} + q_t - I_t = d_t \tag{3}$$

$$q_t \leq (\textstyle\sum_{t=1}^{T} d_t)y_t \tag{4}$$

$$I_t \geq 0 \;\; and \;\; q_t \;\geq 0 \qquad\qquad for\; t = 1, \ldots, T \tag{5}$$

$$y_t \in \{0,1\} \qquad\qquad for\; t = 1, \ldots, T \tag{6}$$

Where q_t is the amount to be produced or ordered and y_t is a binary variable that decides if a production or buy order is placed or not.

Additions such as capacity constraints are added as follows:

$$x_t \leq c \tag{7}$$

c is the max capacity in each period t for variable x (Staggemeier & Clark, 2001). These constrain modification can also be applied to emission constraints (Benjaafar et al., 2012; Memari et al., 2016). Benjaafara et al. (2012) proposed this as a modification of equation (7) where emission from storage, eH, transport, eF, and per unit produced or supplied, eC, as follows:

$$eFy_t + eHI_t + eCq_t \leq c \tag{8}$$

$$y_t \in \{0,1\} \qquad for\ t = 1, \dots, T \tag{9}$$

Benjaafara et al. (2012) discovered that capping emissions per time period, rather than for the entire planning period, could led to higher emission's, as there was no trade-off of emitting more in one period to significantly reduce it in the next. This underscores the need for companies to be able to bank unused emission quotas or borrow future ones. Memira et al. (2016) similarly found that periodically imposed emission caps resulted in higher inventory levels. Where Memira et al. (2016) examined cumulative emission caps or a global maximum and found that inventory levels were less affected by the introduction of a maximum for emission's. However, they cautioned that managers should anticipate higher holding costs when combining a lot-sizing scheme with an emission cap.

Benjaafar et al. (2012) provided further evidence to support this argument by introducing a carbon emission price in their study. The study emphasised the crucial relationship between holding and transport costs and their corresponding emission's, which determined the impact of a lowered emission cap on total cost. The authors concluded that operational adjustments were more cost-effective than emission reduction investments. However, Memira et al. (2016) did not reach this conclusion directly as when simulating a tax or cap-and-trade system.

According to Jaber et al. (2017), when considering additional sustainability costs, the JIT scheme, utilising the ELS model, is more sensitive compared to using an EOQ model. However, it is worth noting that the authors incorporated worker welfare costs into their analysis, which were not taken into account in other studies.

2.2.2 Sustainable Economic Order Quantity

In the EOQ model the cost of holding inventory for another time period is set against the costs of replenishment. The assumption is that orders are received in full and on time. However, due to complexity's in real-life operations, there are different variants of how reorder points are applied.

When using the Q system, the order frequency per time period, such as weeks or months, varies and the order quantity, Q, is set. This results in an inventory system that is practically a two-bin system, with the first bin representing the inventory above the R level, and the second bin representing the safety stock below R. This system enables easy establishment and modification of delivery reliability with the R level. The cost of transport is included in the cost of placing an order (Buxey, 2006), and if the supplier handles the transport, this cost is included in the unit price. The Q system is preferred for ordering truckloads, obtaining quantity discounts, and complying with capacity constraints (Krajewski et al., 2016).

Alternatively, there is a one-bin system, which aims to maintain a target maximum inventory level, S. This level represents the demand and the safety stock during the economic order period (EOP), designed to absorb random changes in expected demand (Buxey, 2006). This system is suitable when joint orders from common suppliers or full truckloads are preferred (Krajewski et al., 2016).

According to studies conducted by Bouchery et al. (2012), Gurut et al. (2015), He et al. (2015), and Daryanto et al. (2021), adding the cost of emission to the holding and order cost, by simulating a tax scheme, leads to an increase in the order quantity and the total cost. Daryanto et al. (2021) explains that this increase is expected due to the relationship between the order quantity and the number of deliveries required. Although the distance travelled is not explicitly declared in the emission cost, it is directly proportional to the amount of emission. Hence, Gurtu et al. (2015) argue that companies that source locally have an advantage in terms of sustainability. Battini et al. (2014) add to this subject by proposing the addition of space to encourage full loads and reduce emission's. In their study, the authors compared different transportation modes and found that modifying the order quantity did not significantly lower emission's, whereas changing the transport mode after evaluation did.

Additionally, Bouchery et al. (2012) suggested that imposing a fixed carbon price may not effectively achieve the goal of reducing emission's. Instead, the authors found that a cap-and-trade system was more effective in achieving this objective. He et al. (2015) further emphasised the significance of the ratio between holding and transport costs and their respective emission's. When the cost of emission's equals the holding and transport costs, there is no change in the order quantity, irrespective of whether a tax or cap-and-trade system is in place. Therefore, the ratio between holding cost and inventory emission cost (H/CeH) and the transportation cost and transportation emission cost (T/CeT) are crucial factors. Determining that the order quantity will rise if:

$$\frac{T}{Ce_T} > \frac{H}{Ce_H} \tag{10}$$

and fall if

$$\frac{T}{Ce_T} < \frac{H}{Ce_H} \tag{11}$$

when compared to the classic EOQ.

Hovelaque and Bironneau (2015) compared the transportation and holding costs with its related emission's to determine the effectiveness of a carbon tax. They found that if the quotas between these factors were equal, the original model would optimize profit and minimise emission's, rendering a carbon monetisation strategy ineffective.

$$\frac{H}{T} = \frac{e_H}{e_T} \tag{12}$$

If not, both cap-and-trade and tax schemes were found to lower emission's, but with differing effects on profit. It was found that a tax always had a negative effect, whereas He et al. (2015) found no decisive difference in emission between cap-and-trade and tax. However, the tax needs to be higher than the price of emission permits in the cap-and-trade to ensure that this does not increase emission's in comparison. If the price of emission is the same for holding and transportation, both schemes lower emission to the same extent. This was also proven by Hovelaque and Bironneau (2015). Therefore, it is urgent to estimate the environmental impact as correctly as possible to ensure that the result is viable and not misleading (Taleizadeh et al., 2018). The choice of emission to adhere to is also of great importance according to Bazan et al. (2015), where the authors balanced different emission types that can occur within a company's operations and found that different emissions could have conflicting objectives.

Table 2.1: The models presented and their content as it relates to this study.

Articels	Model(s)	Monetised carbon emission	Motetization scheme	Emission included
Benjaafar et al., 2012	ELS	Yes & no	Cap-and-trade, tax	Transportation, inventory and replenishment
Memari et al., 2016	ELS	Yes	Cap, internal tax	Transportation
Jaber et al., 2017	ELS and EOQ	Yes	Internal tax	Transportation, production, and energy consumption
Bouchery et al., 2012	EOQ	Yes	Cap, internal tax	Replenishment, inventory and transportation
Gurut er al., 2015	EOQ	Yes	Tax	Transportation and replenishment
Bazan et al., 2015	EOQ	Yes	Cap-and-trade, tax	Transportation
Hovelaque & Bironneau, 2015	EOQ	Yes & no	Cap-and-trade, tax	Replenishment and inventory
Battini et al., 2014	EOQ	Yes	Internal tax	Transportation, inventory
He et al., 2015	EOQ	Yes	Cap-and-trade	Replenishment, inventory and transportation
Continuation on next page				

Taleizadeh et al., 2018	EOQ	Yes	Internal tax	Transportation, production and inventory
Daryanto et al., 2021	EOQ	Yes	Internal tax	Transportation, inventory

3 Methodology

In this chapter the methodology and design used to fulfil the purpose and answer the research questions will be described. Firstly, a general research approach and its methodology will be presented. Followed by the research process along with the collection and analysis of data. Finally, reliability and validity of the report will be argued as well as the confidential aspects of the report.

3.1 Research Approach

The thesis is based on an abductive approach where theoretical concepts are compared and adjusted to reality. This in order to contribute new insights and understanding's through questioning various aspects. To endorse this the thesis was structured as an explanative study. Where the formulated research aim and research questions is designed to explain relations and differences between variables (Saunders et al, 2016). Such as the relationship between the reality provided by the case company and previous research on sustainable inventory management. Theoretical concepts where choose to communicate a basic understanding of the pivotal points of inventory management, emission assessment and monetisation. As these areas contribute and sets the stage for later stages of the thesis. Data was collected in cooperation with the case company though a small quantitative and a qualitative collection approach. Both these added to the general knowledge and description of the current situation. The similarities and gaps that was identified between the theoretical parts and collected data provided the basis for the sustainable inventory management methods.

3.2 Research Process

The explanatory nature of this thesis was added up on with a certain explorative element in order to minimize oversights. The explorative approach benefits the seeking of new insight through a flexibility and adaptability to new situations (Saunders et al. 2016). This was deployed in four phases that is show in figure 3.1. All four phases are connected in streamline but with inter connections that shows the explorative side. If one phase found a discrepancy or a needed addition was identified a redirection was done. This enabled the process to redirect to an earlier step and fill the gaps that was found as to avoid oversights and establish sharp explanatory research.

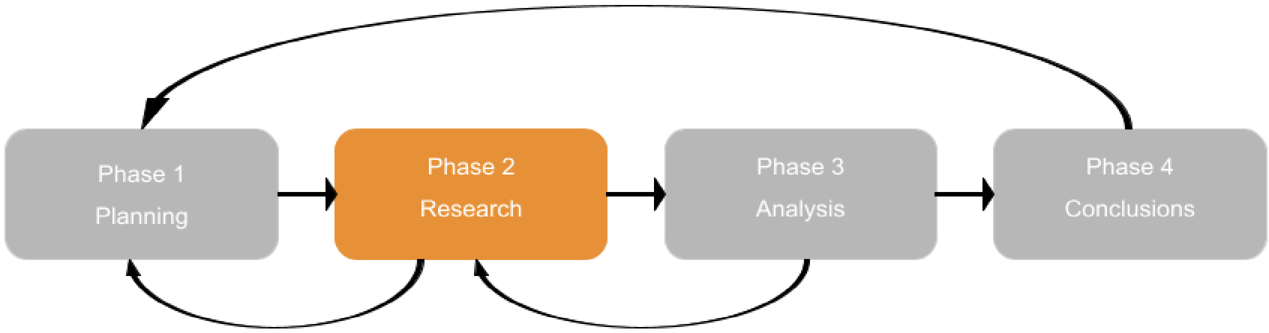

Figure 3.1; Model of the research process.

In phase one the research area was selected, and delimitations was established. Through a literature review understanding of the research previously was gained. This gave insight in choosing the area of sustainable supply logistics to continue with.

Moving to phase two, there was a focus on gaining deeper knowledge of the models presented by earlier works. By a thorough literature review and interviews information and understanding was gain of the complexity's of the thesis subject. The interviews added knowledge of business ecosystem that an inventory model would have to accommodate. Deeper literature review was performed to ascertain proposed models and the areas of carbon assessment. A focus on current demands on emission reporting and regulations was deemed appropriate for moving to step three.

The analysis in step three was performed in two steps where the first one is the thematic analysis. The first part was to fill in gaps of what emission assessment would be needed, and its implications as connected to the case study company. Second step was done in order to comprehensively compare the results with previous studies and findings. The focus was to connect to the research questions in order to express the insights that was found through this research.

The fourth phase evaluated and concluded the analysis with a discussion of the implications of the result and analysis. In this step there was focus on the greater picture and gaps that was found with in this research was filled in by returning to phase two and adding further information from the case company or further accounts from literature.

3.3 Data Collection and Analysis

Information and data used in this thesis are mostly primary data, collected in interviews. Secondary data was provided by research through reputable journals and books, with some presented by the company. While the data and business information are provided by the company along with informal interviews that was performed on sight. While using the research model presented in figure 3.1 the contact with the company was performed in stages as to ascertain if certain areas of inventory management applied or not. For example, where areas such as buyback and back orders not included since this was not occurring in the company's current operations. Though papers and research with these operations was included in the theoretical background. This added to the paper since the aim is to present theoretical models and tools that would be applicable to the case company. Furthermore, the decision was made to base the selection of papers and models on other factors, presented in 3.4.

3.3.1 Literature Review

Databases used to find scientific articles from relevant journals Google scholar and Scopus was used. Priority was focused on well-renowned journals, well-established institutions and scientific articles. There was preference for articles no older than 10 years in order to incorporate as much as possible of knowledge already established by other authors.

The literature review in phase one was widespread and aimed to garner basic information. Hence all of the key words used for this research is not presented. Instead, the keywords that furthered the research and promoted the work from phase one to two is presented.

For the in-depth research in phase two a multitude of articles were sources along with sources for current trends in economics and politics. The sources for these real time reports were choose for their reputation and their connection to science. The IPCC is connected to the United Nations and its aim is to assess science on climate change. While the ICAP is an international forum for governments that have implemented ETS trade.

Key words in the literature review: *Sustainable inventory management, GHG Protocol, Supply Logistics, carbon pricing, lot sizing/-scheduling model, SEOQ*

3.3.2 Interviews

Interviews were conducted with personnel of the company as to ascertain an understanding of the research area. Since there was no current direction or agenda for emission assessment or reduction in the exact SC are that was studied. Their input guided the research in giving insight in the current supply chain landscape of the company. The interviews were conducted in a semi structured way to attain deeper knowledge of the company’s supply chain operations, the guiding values and the specific situation that effect the operations. The semi structured format made it possible to gain a deeper description of the current situation at the company. Since the open questions could be discussed and descriptions of solutions of real situations gave unease to the data.

The selection of interviewees, further called R1 and R2, was made in order to cover the complete operational side of the replenishment part of the SC. This equates to two people in the company. Firstly, an order placer, R1, who have daily operationally work tasks. Secondly was the purchasing manager, R2, who are in charge of selecting and setting suppliers and transporters. By selecting to interview the purchasing manager there was insight into the strategical side of the replenishment. Whilst the operational day to day responsibility of managing orders enabled a good understanding of the internal values and views on transport and inventory. The questions are presented in appendix 1. The interviews were conducted over video link which enabled recording of the interview. During the interview notes were taken which then were compared to the recordings and additions were made, which where the basis of the thematic analysis.

3.3.3 Quantitative data

It became quite evident early on that there was significant data missing in order for it to garner the research much. Most prominently was the missing data or structure for collecting data of the emission's from inventory holding. The data that was gathered comes from the companies own system. The transport emission is a number (per km) given to Axelent by their transporter. They have not done any research of their own of the accuracy of this number. Though this number is expected to be used in future calculations of Axelent.

3.4 Credibility of Research Findings

Validity refers to the research methods quality of measurement (Saunders et al., 2016). This paper chose to use inventory management models based on traditional well researched and used models with addition of constraints, see table 3.1. In article search and selection, the following parts were used in discerning the credibility and value the article could bring to the study. Firstly, articles published in the last 10 years and well cited as this provided great credibility to the research published. Secondly newer or less cited articles was included dependent on the value they brought to this research. This encompassed articles with comparison of models, different approach to emission inclusion or newer research. To increase validity in terms of the literature review in general the articles found through Google scholar was critically examined, since the search engine can provide results with questionable credentials. In the case of the interview's validity was considered in that the interview questions were written in conjunction with the theoretical framework. These main questions where choose as to contain and direct the interviews in an appropriate direction to the study. Follow up questions were used as a means of gaining more and deeper information of the operations and perception of the interviewed.

The quantitative data is provided by the case company and the author finds no reason for the company to not give correct data.

Reliability refers to what extent the same outcome and conclusions can be drawn by reusing the same approach again (Creswell, 2013). There are several approaches to enhance the reliability of the research: reputational analysis, constant data comparison, inclusive of the deviant case and use of tables (Leung, 2015). In this study used information that was published by reputable sources. For information and analysis of current regulations and recommendations from governments and regulators this study opted for using information published by the regulators and governments. Since the study was aim at studying the current situation for the cases company. Furthermore, a table of the models presented was presented in order to visualise the differences of the models and the approaches.

Generalizability is to what extent it is possible to render the research unspecific, reducing it to something general and universally applicable (Creswell, 2013). The study is mainly focused on the circumstances of the case company with a localised supply network. The scalability is great as this thesis creates a general understanding of the circumstances that can affect a company's sustainable efforts.

Table 3.1. Articles of the examined models.

Article	Publisher	No. citations (as of 2023)
Benjaafar et al., 2012	IEEE transactions on automation science and engineering	1335
Bouchery et al., 2012	European Journal of Operational Research	399
Battini et al., 2014	International Journal of Production Economics	276
Gurut et al., 2015	Applied Mathematical Modelling	89
Bazan et al., 2015	Computers & Industrial Engineering	159
He et al., 2015	Journal of Cleaner Production	225
Hovelaque & Bironneau, 2015	International Journal of Production Economics	214
Memari et al., 2016	Nature communications	172
Jaber et al., 2017	Computers & Industrial Engineering	18
Taleizadeh et al., 2018	Journal of cleaner production	125
Daryanto et al., 2021	International Journal of Manufacturing Technology and Management	7

3.5 Confidentiality

In accordance with Axelent AB, sensitive information and data have been excluded from this report. Components names and exact size along with their respective supplier's names are not mentioned, due to the lack of importance and sensitivity for Axelent AB. Numbers and data have been altered as to show schematic results but not to leak sensitive information about Axelent ABs organisation. This has however not affected the credibility of the research since the data is distorted as to keep relations.

4 Case Study

This chapter will present the case study conducted at Axelent AB. With the project scope as the foundation for the case study. Followed by presentation of the thematic analysis of the two interviews.

4.1 Project Scope

Axelent is used to tackle new situations. This also extends to challenges as multifaceted as global warming. The company finds an accumulating focus on environmental from all stockholders. For example, more regulations and measuring demands concerning GHG emission are coming. It is because of these anticipated changes that Axelent wants to bring in emission's into their current and coming ways of measuring their operations. In the ever-ongoing aim to develop the organisation and its decision-making tools the supply chain is to them an important area of development. Though not directly associated with an acute need in order to uphold profitability.

With a wide range of materials and components that is sourced, they find the challenge to be intricate. Currently there are around 2500 articles of raw-materials and components that have at some point been sourced by the company. Due to Axelents ability and willingness to adapt and create specialised solutions for their customers the number of sources components are high. But a few of the components and raw materials are high volume. There is therefore a need to have an effective and sustainable flow of these. Depending on their ability to affect the companies profitability and the environment. In the range of components there are many ready to repack components. The demand of these are fully controlled by customer demand and their delivery from suppliers effects Axelents ability to deliver to customers. Changes in the delivery pattern of these are therefore considered a great risk, but also a great area for reducing costs and develop sustainable delivery chains.

The components that have been chosen as examples in this project are according to Axelent, good representatives for the challenges found with their ready to pack, high volume components. They are sourced from two different suppliers and are of very different size. One being delivered on pallets and the other one in small carton boxes. Which results in delivery of the larger sized components often being delivered in both a truck and trailer. On the other hand, the smaller sized components could hardly fill a whole trucks capacity in one delivery.

The smaller component is named S and the larger one L. In table 4.1 the quota of holding, H, and transport cost, T, is presented along with the transport emission, eT, for each component, the latter is the distance, l, times e which is the emission in kgCO_2/km which is reported by the transporter, presented in equation 13.

$$e_T = l * e \tag{13}$$

Table 4.1; Example components for analysis

Component	Characteristics	Determinants for supply logistics	H/T	eT
S	Small palm sized, packed in cardboard boxes, supplier is less than three kilometers away.	Has a minimum of delivery that does not fill the capacity of a truck. The transport is paid for by Axelent AB.	424,7	0,9612
L	Long beam, packaged on pallets, supplier is more than 160 kilometers away.	No minimum determined but there is dialog with the supplier. The transport is organized by the supplier and is included in the procurement prize.	131,1	58,68

There is no current value for holding emissions, eH. But by modifying equation (12) to back track eH the value would be as follows if the current operations where in full emission effectiveness as He et al. (2015) and Hovelaque and Bironneau (2015) disclosed.

$$\frac{H*e_T}{T} = e_H \qquad (14)$$

With the value from table 4.1 the two components would have to emit over 408 and 7695 kg CO_2 per component, se table 4.1.1, in order for the current operations to be the most emission effective way of operating.

Table 4.1.1; Results from equation 14, holding emissions for each component.

S (kg CO_2)	L (kg CO_2)
408,19	7695,74

4.2 Thematic analysis

There were four themes, nine under themes with 17 codes developed from the interviews. These are presented in figure 4.2. The respondents or the interviewees R1 and R2 are described in chapter 3.3.2.

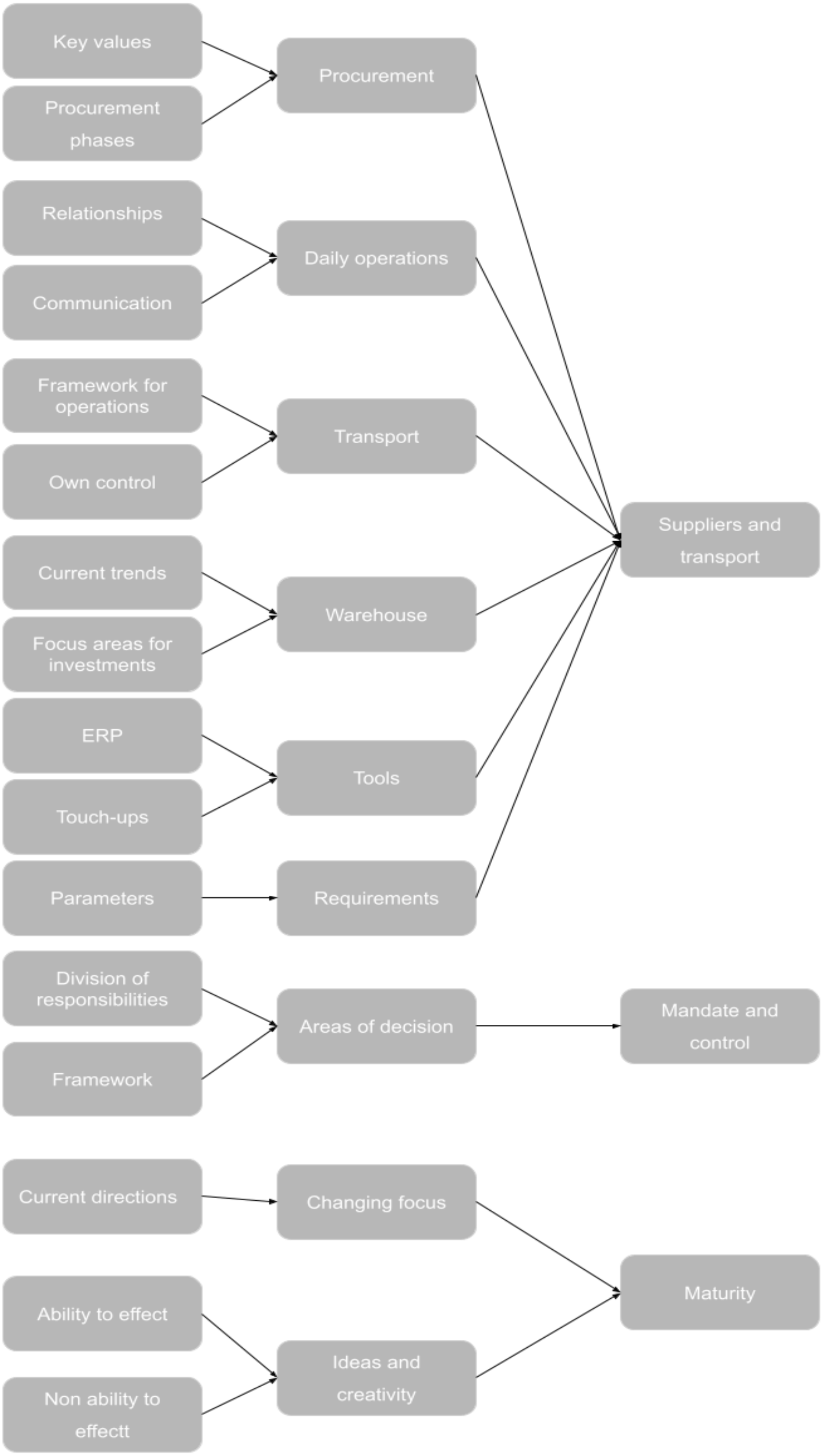

Figure 4.2 the thematic analysis, its themes, under themes and codes.

4.2.1 Procurement

The **procurement** efforts begin in new projects of new products. In the first phase the price is most often the predominant factor, from the point of view of the supply chain. Research and development, for example, might have additional requirement that they can add. In further establishing a more concurrent supply, in phase two, there are other **values** that become prevalent, such as availability and supply security. R2 explains that each of these phases have different people from the supply chain responsible, with the project buyer that are in charge in phase is quite detached from the rest of the phases. When a supplier or transporter is decided upon and the contract is finished and signed the operational part takes over, shown in figure 4.2.1. That is when R2 hands over to R1.

Figure 4.2.1; Schematic explanation of procurement phases and their key values.

In establishing contracts with transporters and suppliers R2 explained that beside price it was important to promote collaboration and communications. Form this the company can establish a good basis for delivery precision and supply security from suppliers. In the case of transporters this is due to the need for flexibility in tight situations. It is understood in the company that communication and collaboration are helped by having local suppliers and transporters. R2 further explained that due to expansion of their own business it is of great importance that their suppliers and transporters have potential for further growth. The **key values** for procurement of goods and services are collaboration and possibility for growth, beside beneficial prices.

4.2.2 Daily operations

R1 explains that collaboration goes both ways where R1 can ask for earlier or part deliveries of orders and the suppliers can ask for changes in delivery dates and quantity to favor of their own production planning. As long as Axelent are able to deliver on time, the approach is to further the **relations** to the suppliers. In terms of transporters, they oversee planning their own routes and packing. Which can end up in them asking for changes of delivery time as to benefit their planning as well as deliveries from the same supplier can be split into multiple trucks. R1 explains that with good **communications** in such situations there is possibility for aiding each other without risk of not covering demand.

R2 explains that the **relations** to suppliers are seen as a strength for Axelent. Although the sustainable efforts in connection with these have not yet been specified, R2 explains that their close work with suppliers results in both learning but also aiding each other. While

communication can lead to changes to aid suppliers it can also give insights which is used in enhancing the company's own operations.

4.2.3 Transport

The **framework of operations** in terms of transportation in the observed SC to or from Axelent is built up by contracted transporter. There is no indication from either R1 or R2 that this way of operating would change. In the flow of ordering, R1, explains that transports are booked by the supplier based on the delivery date on the order or other later agreement. Payment of the transport is at times taken on by the supplier and at times by Axelent. When Axelent is paying the transporter straight up they are procuring the contracts. R2 explains that these are set up as per loading meter (LDM) making this their way of **controlling** transportation cost. R1 explains this system does not make it possible for Axelent to **control** the number of trucks that will be used for one order. Because local transporters often uses set routes for their trucks as to cover several customers and bring the up the filling rate. R2 explained that this is seen as a strength for Axelent. As using such co-transportation brings down cost, promotes flexibility in order quantity and brings down emissions. Although the last one is not backed up by numbers, according to R2 it is quite a natural deduction. R1 explains that even if there is an effort made by joint ordering, adding there is no certainty for joint delivery.

4.2.4 Warehouse

The warehouse space is located in connection with both manufacturing and office area. Any larger rearrangements of the placement and location is not currently planned. Though R2 describes that warehousing is an area that are in focus for both investments and rearrangements. To meet the growth goals there is **investment** in automatization and turnover rate. The automatization initiations are especially aimed at dealing with bottlenecks in the warehouse and packing. These changes are mainly focused on the to customer supply chain. R1 describes that there are changes in order quantity due to lack of space in the warehouse. The **current investments** are to rearrange stock levels, automatizations, and expansion of the building enough to meet future demands, R2 explains. Which is echoed in that the stock levels can only rise at the same rate as sales.

R1 describes the warehouse as being very dependent on stacking and the height in the building is very much used. There are some very spacious and heavy components which takes up a lot more space. While other components fit inside the palm of ones had and those does not take any space or are of any concern, R1 explained in connection to space scarcity and order sizing.

4.2.5 Tools

There is a current **ERP** (enterprise resource program) in use and this uses an EOQ two bin system for aiding in ordering operations. Effectively setting that orders are made to fill-up stock levels. The optimal order size is not always followed but uses **touch-ups.** By R1, who describes the reasons for these as accommodations for various reasons, such as re-checking how long an order will last (done manually), space available and changing circumstances, such as new orders coming in. Safety stock levels are recalculated every month by the **ERP** and set by the manager but then **touched-up** by the order placer because of this person's knowledge level.

4.2.6 Requirements

R1 describes a great fluctuation in demand, since the company as a great growth goal, the sales department often hands in new orders quickly. R2 argues that a shift in expect delivery time to customers is possible and would benefit the current supply chain. It would mainly add more time to react, with a more stable demand and hence more ability to plan. There is no direct forecasting done today resulting in that new orders will very much directly affect the orders and the supply chain. Otherwise, both R1 and R2 agreed upon that the other classical **parameters** such as purchasing price and transportation costs, holding costs are as of now directly applicable for the order placer.

According to R1 there are two situations and/or **parameters** that needs to be taken into consideration when placing order. This is the available space in the warehouse, most this is not a problem but since components are of varying sizes, this needs to be taken into consideration. Secondly is the situation of the receiving department. R1 further explains that there is no current help with this from the ERP but it is important to take into consideration when setting order sizes and frequency.

4.2.7 Areas of decision

It is explained by R2 that **responsibility is divided** as such that anything money wise is handled and decide upon by the manager. This sentiment is also echoed by R1, since the goals for the order placers position is to make sure that delivery to customer is on time without building unreasonable stock levels. No real monetisation of these areas is introduced. R2 furthers this by emphasising that in order to measure someone's performance they need to be able to control this area. Monetisation of emission's are best placed in the level of manager, since this is where the person could affect this outcome. It is important that a person can control and affect what this person is measured on, otherwise measuring and evaluating is seen as effectless. Further mirrored by R1 where transports were taken as an example as a place where there is not enough direct control over the route nor packing of vehicles as to truly effect the emission's.

4.2.8 Changing focus

The changing times of more sustainability focus is very prevalent in Axelent according to R2. There are new board members that have a sustainable image which brings a clear **direction**. There is a new hiring of mangers in order to further develop the sustainability in the operations and decisions of the company. Another way of supporting sustainable work is ISO certifications which R2 explains will both give guidance in sustainability work and is a good communication tool internationally. Measuring of emission's are undergoing by using the GHG Protocol. R2 finds the protocol to be very substantial and covers everything, but there is still decisions to be made as to how some emission's should be measured.

R1 finds that the sustainability work have yet to reach the operational level. Though the order placer explains where in his role emission reduction is possible and that such changes in operations brings difficulties.

4.2.9 Ideas and creativity of workers

The **ability to effect** emissions is very dependent on position, R1 mentions that from an operational perspective several areas that cannot be affected. But an area that R1 currently found possibility to affect the number of transports was with co-ordering from the same supplier. Though even this effort might not have effect, since there are co-transports which are not controlled by the company. Hence even this cannot in the end be controlled, R1 analyses. R2 expresses the need for measuring of the benefit of changes and investments. The supply chain is a fickle thing, it works what we are doing right now, but it also needs improve for the future, R2 analyses.

5 Result & Analysis

The insights found in this research will be presented in this chapter. Each research question will be handled separately, in one part after another.

5.1 Sustainable Inventory Management Tool

Traditional inventory management tools like ELS and EOQ have undergone significant development to meet the sustainability requirements of modern SSCM. Extensive research has explored the effectiveness of these tools in reducing carbon emission's, as shown in Table 2.1. The studies reveal that it is not only feasible to incorporate emission's into the equations of EOQ and ELS, but also to assign a monetary value to them (Benjaafar et al., 2012; Memira et al., 2016; Bouchery et al., 2012; Gurut et al., 2015; He et al., 2015; Daryanto et al., 2021). This capability allows for effective and sustainable product flow management while also making it possible to the evaluation of future investments (Benjaafar et al., 2012; Memira et al., 2016; Bouchery et al., 2012; Gurut et al., 2015; He et al., 2015; Daryanto et al., 2021). Consequently, the management and reduction of emission's can be addressed both operationally and strategically.

Monetisation of carbon emission's where more prevalent, but there were examples of non-monetised versions of the models (Benjaafar et al., 2012; Hovelaque & Bironneau, 2015). The interviewees from the company were clear about the potential benefits of monetisation when aiming to reduce emission's. Though they both highlighted insecurities in introducing economic measurements in areas that are not typically assessed by this, see 4.2.6 and 4.2.7. Where the theme of **mandate and control**, see figure 4.2 showed insecurity in the new possible addition of monetised carbon, there still was clear cut in which position have which type of mandate, see 4.2.1. This resulted in each respondent arguing for their position and level of mandate. There is currently there are no direct monetary assessment at the operational level where this model would be utilised for managing emission's and order quantity. When focusing solely on operational tasks and manipulating order quantity to meet customer demand, there is expressed uncertainty whether the monetisation of carbon would prove advantageous for the process. There are both alternatives for this in the proposed models, there should hence be no hinders in addressing carbon reduction. Hence the insecurity of mandate and control could be diversified by the already exciting and presented model.

The models proved that investments in emission reduction can be evaluated (Benjaafar et al., 2012; Battini et al., 2014; Gurtu et al., 2015;). The need for measuring investments effectiveness was exclaimed by R2, see 4.2.9. The addition of emissions to the current EOQ model used the company can address the effectiveness of different alternatives. Both Battini et al. (2014) and Gurtu et al. (2015) made statements from evaluation using the SEOQ. Where Gurtu et al. (2015) established that location of suppliers is prominent in the ability to significantly effect emission's and Battini et al. (2014) proved that investment in greener transport had the most potential effect. Such effects is among what that Axelent is aiming to gain by focusing on **maturing** sustainably. The suggestion being that a SCM tool that incorporates emissions would further the company’s current trajectory. Effectively furthering the sustainable work into the operational part, which as of now is missing, see 4.2.8.

Jaber et al. (2016) identified the main difference between inventory models, which is their sensitivity to additional emission costs. The effectiveness of any calculation depends on the data input. Taleizadeh et al. (2018) emphasised the importance of data accuracy in estimating the environmental cost of a company's practices. As all the models presented increase the total cost in some capacity, caution must be exercised to avoid including a significant level of uncertainty and inaccuracy. There are two areas that are not covered by the calculations of the ERP as of now, but instead taken into consideration by the order placer, see 4.2.5. These are the LDM and the workload of at the arrival place, see 4.2.3. The suggestion from the **transporter and supplier** theme in considerations of models is that a wholistic inventory management tool would be beneficial.

5.2 Strategical and Operational Directions

The initial observation, in line with the findings of RQ1 discussed earlier, is that there is no immediate need to change the current usage of the EOQ model. This is because there are approaches available to incorporate emission costs into both the JIT and EOQ models. As a result, this research does not offer a definitive answer regarding which model would be more advantageous for the specific company under consideration. The differences between the models seems to be connected to the common characteristics of the basic models. Notably, Jaber et al. (2017) identified variations in sensitivity when sustainability and emission's costs were considered. Based on these findings, it can be inferred that the existing digital infrastructure, operational knowledge, and procedures associated with the current EOQ model are likely to be applicable going forward. This suggests that the main challenge for the company is to measure and gain a basis for their emission's and their sources. Which connects to the current works of implementing the GHG Protocol. This sentiment can also be found in 4.2.8 as reflected by R2 on the current sustainable work.

By continuing with the current approach and adapting it to a SEOQ model, there is an opportunity to evaluate operations by considering the quotas identified by He et al. (2015) and Hovelaque and Bironneau (2015), see equations 10, 11 and 12. Since the emission for inventory holding is currently not available can these quotas be used to estimate it. The numbers presented in table 4.1.1 represent the emission's per component if the current operations were environmentally optimized. However, the exceptionally high values indicate that the current operations and order quantity may not be emission efficient. Considering Rüdiger et al.'s (2016) presumption that the warehouse of Axelent primarily consumes energy, which contributes to emission's, comparing the average emission's per kWh in Sweden (28g) to the much larger values in table 4.1.1 suggests that there is likely room for improvement in terms of emission efficiency.

The quotas proposed by He et al. (2015) and Hovelaque and Bironneau (2015) provide valuable insights into the influence of various parameters on operational activities, including transportation and holding costs, as well as their duration's and mode's. By considering equations 10 and 11 suggested by He et al. (2015), it becomes possible to gain direct insights into the potential changes in operational activities, such as order quantity changes. These insights enable a deeper understanding of how different parameters impact the overall operational workflow. There are further areas, other than the cost and emission's parameters, that are affected by the operational decision, such as the work environment at the goods receiving. At Axelent a holistic view of decision-making even at the operational level is emphasised. Changes that might promote sustainability might give an adverse effect in some other area, see 4.2.9.

The quotas can have further implications and usefulness beyond the pure operational input. In the procurement process at Axelent, as depicted in Figure 4.2.1, the transportation parameters are established. The quotas enable a deeper understanding of potential changes in transportation mode and distance, which are strategic decisions for the company. These changes involve larger-scale adjustments of parameters to achieve larger emission's reduction. For example, this can be achieved by reducing eT (as it described in Equation 13) through alterations in transportation mode, as proposed by Battini et al. (2014), or by selecting suppliers located in closer proximity to the company, as suggested by Gurtu et al. (2015). Such insights would achieve the investments evaluations that Axelent actively seeks, see 4.2.9. These examples of beneficial investments presented by authors like Battini et al. (2014) and Gurtu et al. (2015) emphasise that a sustainable inventory management tool would not only facilitate the assessment of changes in order quantity but also prove valuable in evaluating green investments within the SC.

It is clear that significant strategic efforts are necessary before implementation. Axelent is presently in the phase of measuring all emission's for the first time. By adopting the GHG Protocol, they have the opportunity to conduct self-measurement, as explained by Green (2010). The interviews conducted emphasise the importance of determining which aspects to measure and the significance of utilising well-researched values to accurately estimate environmental impact, a point also emphasised by Taleizadeh et al. (2018). This demonstrates a meticulous approach and a recognition of the crucial role that reliable data and measurements play in evaluating environmental impact. By the data provided it can clearly be shown that the warehousing part of emission assessment is the more difficult aspect. Whether this depends on a lack of research or lack of time cannot be deducted. Though a clear understanding of the warehouse can be seen in 4.2.4.

A significant portion of inventory management operations at Axelent is outsourced to third parties, such as the production and transportation. This limits the operational control that Axelent can have over decisions that can effect the level of emission's. The current clump sum that is presented, se table 4.1; eT, connects with Rüdiger et al. (2016) findings. They highlighted that there is a degree of uncertainty associated with third parties and their reporting of emission's. Despite this, Axelent has already engaged in exchanges of ideas and operational changes that promote greener practices, indicating a contrary stance, see 4.2.1. Nevertheless, it is important to acknowledge that other parties may view emission's reporting as an opportunity to gain market shares, as noted by Rüdiger et al. (2016). Axelent's established practise of close partnerships may prove beneficial in this context. The company places strong emphasis on cultivating and maintaining relationships that foster growth, see 4.2.2. Although not explicitly stated by the company, it is evident that this focus is based in long-term sustainability. By incorporating emission's measurement into their management tool, Axelent would gain enhanced control over the environmental aspects. Though they do not directly control the emission's of suppliers they are responsible, according to the GHG Protocol. In order to control and reduce the emission of the replenishment activities, a thorough control over third party emission's is needed for this. The **supplier and transporter** theme have in general highlighted some areas of uncertainty that somewhat differ from the ones highlighted by academic authors. This might be due to that the company has of yet managed to bring sustainable practices to the operational level or the uncertainty's presented by authors such as Rüdiger et al. (2016) might not apply. From this study there is no way to precisely tell which one is correct.

Another strategic aspect to consider is the carbon price, which plays a crucial role in investment assessment. Determining the appropriate price levels and the type of monetisation scheme are important considerations. One option is a cap-and-trade system, which could be linked to the market price, as described by FI (2020). However, implementing such a scheme may pose challenges due to the motivation's expressed by the company. The motivation of emission reduction and sustainability efforts are coming from within which is expressed in the maturity theme. Axelent's shift towards sustainability thinking is not solely driven by being directly affected by an ETS or other cap-and-trade mechanisms. Instead, it is a response to a broader attitude shift among customers and other stakeholders. This means that Axelent would most likely introduce an internal tax. With the significance placed on the introduction of carbon prices, strategic decisions need to be made to determine the most suitable approach for Axelent. There are directions such as the internal tax needs to be set higher than the ETS price (He et al., 2015) and equal tax for both parameters (CeT and CeH) (Hovelaque & Bironneau, 2015).

6 Discussion & Conclusion

In this chapter an argumentation for the validity and reliability of the research's method and findings will be presented. Along with the studies contribution and recommendations for future research.

6.1 Study Contribution

This study has contributed to the understanding of the adoption of sustainable management tools, with a primary focus on the inventory management of a Swedish company. The study looked at the feasibility of constructing a sustainable inventory management tool given the current state of operations and motivation's for sustainability in the case company. Since the company did not have an established sustainable inventory management tool nor an emission's reduction goal, the research incorporates both JIT schemes and EOQ. The research is general in nature and examines the general idea of including emission's into the inventory management.

Future research could take one of these approaches and implement emission's into an organisation which has an emission reduction's goal. Additionally, research could explore the ability of companies in a value chain to collaborate with suppliers and transporter on sustainability and emission reduction efforts.

Further understanding of the research area could be added to through a general study of other companies. Where a broader understanding of companies experiences in adding sustainability markers into their inventory management could be garnered.

6.2 Validity and Reliability of Study

The explorative research method, presented in figure 3.1, garnered this research substantially. In terms of accuracy, the case company was interviewed and given the opportunity to review and edit the information presented about their organisation. To balance the company's interest in not declaring sensitive information with the author's need for accurate information, the research approach was redirected.

When choosing models to examine and introduce, there was no significant disagreement in between the results, which added validity to the arguments based on the literature research. However, to avoid potential discrepancies, the study utilised a method of choosing papers and models and presented them in a table, see table 2.1, to highlight differences. This demonstrated that despite similarities, the articles varied in their core components, such as monetisation and the inclusion of emission sources. This was seen as adding reliability to the analysis, conclusions, and recommendations.

6.3 Discussion and Recommendations

Coming from a perspective of no clear aims or goals of sustainability and emission reduction in inventory management makes it obsolete to currently add operation changes before strategy is set. There are parts of the emission pricing and measuring that makes and breaks these models. From FI, previous research, and the company itself comes the importance of establishing a solid pricing. Since the aim of these models are to change operations there are effects that would have to be evaluated. Such as the goods receiving end of the SC. When order quantity rises there might be challenges in pace and ability to handle larger quantities of arriving goods. Which sets a large responsibility for managerial direction in establishing further aims and goals. With the aid of quotas such as equation 10 and insights in general consequences such as higher total cost and increase in inventory there are more direction for the managers.

The first recommendation is to establish goals and a reason for emission reduction. It might be to hold market shares in a world where the sustainability of products is increasingly significant. Either way this will result in the appraisal of components in the inventory management tool since this will either grant the opportunity to evaluate investments or not. Operationally the reduction of carbon emission could do with only a cap-and-trade between time periods. Though with investments there would be a need for monetisation and a shadow tax on emissions. This could benefit from looking at industry standards. Many companies have come before Axelent and using their knowledge might help the company. Furthermore, there is a necessity to evaluate and establish all operation included in the supply chain. Clarifying where and who controls each and where possibilities for emission reductions are possible. This should be eased with the presence of the GHG Protocol measuring, though not completely. The differences in measuring emission's from warehousing is interesting. It brings a level of complexity of choosing how in depth the emission measuring should be executed at. Furthermore, can the automatization bring another level where the differentiation between inventory holding and packing for the customer needs to be separated.

It was made clear from the company point of view the importance of a holistic view when introducing suitability. Inventory management is only a part of a whole and how it functions will have effect far beyond its responsibility boarders. For Axelent the areas that were found was goods receiving and warehousing space. This should be seen as examples of effected areas and more could come from introducing emission's into traditional ways of operating. Especially for Axelent should the important relations to suppliers be evaluated and analysed for risks.

Moving forward the certain model should be established based on the organisation and the status of the supply chain. Including the mode of establishing transport emission's since the size of sourced components and materials are varying. This would have both operational implications as well as strategic sourcing significance. Since there is a need for control and oversight in all emission contributing operations to guarantee implantation one or more KPI’s could be introduced.

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Appendix

1 Intreview Questions

1. Beskriv hur hållbarhet och miljö påverkar Axelent ABs verksamhet idag
    a. Finns det miljömål?
    b. Vilka standarder följer man/ certifiering?
    c. Finns det ambitioner som har kommunicerats internt/externt?
    d. Vilka är intresserade?
    e. Finns det mål om att profilering?

2. Beskriv vilka steg som har tagits för att gynna hållbarhet.

3. Beskriv vilka investeringar som har sket inom lager, leverantörer och transport eller vilka faktorer som påverkade beslutet att utföra dessa.

4. Beskriv hur en sourcing kedja för en ny komponent ser ut för er
    a. Specificering
    b. Val av leverantör
    c. Val av transportör

5. Beskriv hur inköpsflödet ser ut hos er
    a. Hur stor är inköpsorganisationen?
    b. Vart kan olika beslut tas, vem har mandat för val av
        i. Leverantör
        ii. Transportör
        iii. Lägga inköpsordrar
6. Hur utvärderas lagerhantering och brister?

7. Hur utvärderas/väljs transporter och transportörer

8. I vilken mån ser ni att samarbeten med leverantörer och transportörer sker hos er?