Reasons and impacts of data deviations in a consolidation flow

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Abstract

The purpose for this study is to analyze and identify the reasons behind data deviations between different applications related to the consolidation flow at Volvo Cars Corporation. Furthermore, the purpose is also to calculate the packaging and transportation cost for articles where data deviations occur. In addition, the thesis also aims to come up with suggestions of solutions that can be implemented in the near future.

One of the data deviations that is identified in this thesis is *unit load* (set by packaging engineers and should be followed) and *shipping quantity* (set by supply chain controllers). This type of deviation has affected the company in terms of cost. Three different applications (IBL DC, PLUS & VSIM) are looked into, based on the provided data extracts from the applications' managers and information from interviews and meetings with Volvo Cars' employees.

One of the results shows that data deviations in the PLUS application occur for 85 out of 3623 articles (2.35 percent), where shipping quantity is less than unit load. The extra packaging and transportation costs are calculated to be approximately €235,000 annually for only 16 articles. The reason why unit load is not followed is because several articles have low demand and limited shelf-life. Unit load is simply set too high for these articles according to supply chain controllers. However, the manager of packaging engineering states that these decreases of demands are only temporary and therefore it is not ideal to redefine unit load. There is a dilemma of whether supply chain controllers should follow unit load or not during these decreases of demands. In any case, active communication and collaboration between packaging engineers and supply chain controllers should be improved in order to find an appropriate solution for this dilemma.

Keywords: *data deviations, unit load, shipping quantity, consolidator, consolidation center, cross dock*, *data quality, Volvo Cars Corporation*

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List of Abbreviations

Abbreviations	Full description
ASN	*Advanced Shipping Notice* - An electronic notification that provides detailed information about a pending delivery.
CMR	*Cargo Movement Requirement* - Document used to convey information about cargo that is being transported via road trucks.
CC	*Consolidation Center*
CC-ASN	*Consolidated ASN* - A new ASN is made based on the ASN received from the suppliers.
FDP	*Final Delivery Point* – A factory has different ports and FDP clarifies which port should be delivered to.
FIFO	*First-In-First-Out* - A method where goods are handled in the order they entered into the system.
LC	*Load Carrier* - A pallet or a plastic box for transporting or storing products.
M&L	Manufacturing and Logistics department of Volvo Cars.
PPAP	*Production Part Approval Process*
SCC	*Supply Chain Controller*
SCM	*Supply Chain Management*
SQ	*Shipping quantity* - Quantity of an article that is set by SCC.
UL	*Unit load* - Quantity of an article that is set by packaging engineers
VCCD	*Volvo Cars Chengdu* - Factory in Chengdu, China
VCCH	*Volvo Cars Charleston* - Factory in Charleston, USA
VGM	*Verified Gross Mass* - The weight of cargo including dunnage and bracing plus the tare weight of the container carrying this cargo.
X-Dock / XD	*Cross Dock*

1. Introduction

The following chapter includes the thesis' background, purpose, research questions, limitations and the report's structure.

1.1. Background

In the last few years, the fourth industrial revolution, also known as Industry 4.0, has been a new wave of automation and data exchange in the manufacturing industry. The concept of Industry 4.0 includes smart products, data-driven services, smart factories which everything is connected together (Rojko, 2017). According to Rojko (2017), Industry 4.0 is a bright solution that could reduce the costs of: production by 10-30%; logistic costs by 10-30% and quality management cost by 10-20%. Anna-Karin Arvidsson, IT-management at Volvo Cars, argues that Industry 4.0 means that the company can use the new technology to become even better in their industrial processes (Hedström, 2018). It also means having the right information to make decisions (Hedström, 2018). In other words, the development of the industrial revolution pushes Volvo Cars to become more data-driven in order to get better data quality and therefore better decision making.

Implementation of Industry 4.0 requires the improvement in production, design, exploitation and distribution. Therefore, it will have an impact on logistics (Marinko, Svetlana & Dejan, 2016). Logistics has been evolving in the last 30 years. In its beginning phases, logistics was fairly straight forward. Back then, it was about controlling internal flows and external transport. Today, supply chains are longer and networks between companies are more complex (Abrahamsson, 2013). Logistics has become one of the most important aspects in many companies' profitability and competitive strategy (Oskarsson, Ekdahl & Aronsson, 2013).

In a world where companies choose to place manufacturing, inventory and planning in different geographical locations, the link between IT and logistics has become increasingly important; both as control and communication purposes (Fredholm, 2013). Logistics data quality plays a big role here. High-quality data provides several benefits for the company, such as informed decision-making, lower costs and improved customer satisfaction (Redman, 2012). Data quality can make serious impacts on a company's efficiency and effectiveness, regarding its organization and business (Batini & Scannapieco, 2016).

Volvo Cars, where the thesis is performed at, is a big company with many complex logistics processes. However, the main focus in this thesis is the cross-dock flow in the company, specifically the consolidation flow. Consolidation takes place in distribution docking terminals or logistic centers. One of Volvo Cars' main logistic centers is located in Bulycke, Gothenburg. At the terminals, products from inbound trucks are unloaded, screened, sorted and reloaded into outbound trucks, which in turn, distribute directly to customers. This requires little or no storage and the main purpose is to reduce cost and time (Vogt, 2010). Since the purpose of having a consolidation center is to be able to directly distribute to Volvo Cars' other factories located in different countries, it is important to have accurate data of the packages that are coming in and out of the center. In order to obtain this data, Volvo Cars is using a concept that is called *system integration.* System integration means that several different standalone systems, in this case, software applications are linked to work together. The systems send data to each other automatically without having a person sitting and manually entering data (Hasselbring, 2000).

At this moment, Volvo Cars is using many different applications in which they are integrated with each other. However, it has been shown that the data that are transferred throughout these applications appear to be different in several cases. This is one of the main problems that Volvo Cars is dealing with and has affected the company, in terms of logistic costs. By identifying and analyzing the reasons behind these data deviations, it will help the company to see a clearer picture of the impact that data deviations have the company.

1.2. Purpose

The purpose of this thesis is to identify and analyze the reason behind data deviations between different applications and how it affects Volvo Cars, in terms of transportation and packaging cost. Furthermore, the purpose is also to come up with suggestions of solutions that can be implemented within the near future.

1.3. Clarification of research questions

1. How much and why does the data differ between different applications?
2. In what way does data deviations affect the company, in terms of transportation and packaging cost?
3. How can this be solved? What are the actions that can be implemented within the near future?

1.4. Limitations

There are several main areas within the inbound logistics of Volvo Cars. To begin with, the thesis specifically covers the consolidation area, i.e. Volvo Cars' consolidator at Bulycke and Ghent cross dock. Furthermore, the company's applications, i.e. IBL DC, PLUS and VSIM, are looked into in order to find out where and how much the data differ and why they occur. Data extracts of the applications are provided by employees of Volvo Cars, specifically the applications' managers, through personal communication.

The data that is analyzed is defined as *unit load*, *shipping quantity* and *amount* (actual quantity that is sent to the factory). The focus is mainly on articles that are sent to the factory located in Chengdu (China) via consolidation centers in Europe, specifically Bulycke (Gothenburg) and Ghent (Belgium). Furthermore, the impact that data deviations has on Volvo Cars are defined in terms of logistics cost, i.e. *transportation and packaging cost.* However, the impact of cost on the Chengdu factory is not taken into account and therefore not calculated.

1.5. Report's structure

The purpose of this chapter is to guide the reader through the different parts of the report. The report consists of seven chapters and each chapter and its contents are presented below.

The introductory chapter gives a background to the thesis where a short description of the problem is formulated and where the thesis is performed. Furthermore, the purpose of the thesis is presented and a clarification of research questions that this thesis raises and seeks to answer. Chapter one also gives a brief description of the thesis' limitations.

Chapter two discusses the theoretical basis that are related to the thesis and are based on literature research. The chapter presents the theory of system integration, data quality and its dimensions, definition of cross dock, logistics and logistics costs, the importance of packaging in logistics, order quantity, supply chain management and demand management. The concepts presented in this chapter should be seen as a theoretical framework supporting the conclusions and discussions of the results presented in chapter five.

Chapter three presents the different methods that are used for this thesis. The chapter covers a description of how information is collected. In addition, it presents facts about the interviewees, interview situation and the approach in conducting the interviews.

Chapter four covers a broad description about Volvo Cars Corporation. The chapter also presents brief descriptions of the different applications and how the consolidation flow works in the company. Furthermore, a more detailed description of the problem is lifted in this chapter as well.

Chapter five presents the results of the comparisons and analysis of the data deviations between different applications. Calculation of volume and cost is also presented in chapter five.

Chapter six lifts up different discussions based on the results that are presented in chapter five. Suggestions of solutions to the problem are also included in this chapter.

Finally, chapter seven contains a conclusion and summary of the results.

2. Theoretical basis

The following chapter covers the theoretical framework of the thesis, including system integration, data quality, logistics, logistic costs, definition of cross dock, the importance of packaging in logistics, etc.

2.1. Effect of system integration

System integration is more and more important especially for global organisations with complex manufacturing processes considering that the world of smart technology is changing. As reported by Daft and Lengel (1986), system integration enables close communication and allows sharing of information as well as determining appropriate performance improvement actions. It is essential because information sharing makes it possible for a global company working together toward common goals. This is because information sharing provides a coordination mechanism that supports task completion and lower coordination costs (Wong, Lai & Cheng, 2012). Furthermore, the costs in activities like distribution, order management, inventory and administrative processes will be reduced by the implementation of system integration (Lai, Ngai & Cheng, 2002).

2.2. Definition of data quality and its dimensions

In this era of digitalisation, it has become more evident how important data is and how important it is to be able to access, process and build on data that can be combined from the various systems of a business. The new economy is based on data and the significance of data will only increase. For many companies, high quality data is required in order to be profitable. According to the Data Warehousing Quality Institute's report on data quality, low data quality cost US companies more than 600 billion dollars a year (Batini & Scannapieco, 2016).

The definition of data quality is not fixed but varies depending on different fields and periods. According to quality management, data quality is "*quality of data to meet customer needs"*. Another definition of data quality is "*fitness for use"* (Fatimah et al., 2013). The Data Doc and President of Navesink Consulting Group, Thomas C. Redman (2013), states that data quality is high if it is "*fit for its intended uses in operations, decision making and planning.*"

According to the International Organization for Standardization (ISO, 2008), the definition of data quality is "*the degree to which the characteristics of data satisfy stated and implied needs when used under specific conditions*". The data quality characteristics are defined in several dimensions and is presented in the table below (see Table 2. 1).

Data Quality Characteristics	**Definition (all definition except for completeness and accessibility begin with: "the degree to which data has attributes that…")**
Correctness	correctly represent the true value of the intended attribute of

	a concept or event in a specific context of use
Completeness	subject data associated with an entity has values for all expected attributes and related entity instances in a specific context of use
Consistency	are free from contradiction and are coherent with other data in a specific context of use
Credibility	are regarded as true and believable by users in specific context of use
Currentness	are of the right age in a specific context of use
Accessibility	data can be accessed in a specific context of use, particularly by people who need supporting technology or special configuration because of some disability
Compliance	adhere to standards, conventions or regulations in force and similar rules relating to data quality in a specific context of use
Confidentiality	ensure that it is only accessible and interpretable by authorized users in a specific context of use
Efficiency	can be processed and provide the expected levels of performance by using the appropriate amounts and types of resources in a specific context of use
Precision	are exact or that provide discrimination in a specific context of use
Traceability	provide an audit trail of access to the data and of any changes made to the data in a specific context of use
Understandability	enable it to be read and interpreted by users, and are expressed in appropriate languages, symbols and units in specific context of use
Availability	enable it to be read and interpreted by users, and are expressed in appropriate languages, symbols and units in specific context of use
Portability	enable it to be installed, replaced or moved from one system to another preserving the existing quality in a specific context of use
Recoverability	enable it to maintain and preserve a specified level of operations and quality, even in the event of failure, in a specific context of use

Table 2. 1. ISO standard data quality dimensions (ISO, 2008).

2.3. Definition of cross dock

Cross docking is a logistic activity that is based on the just-in-time strategy and is used with the main purpose to reduce distribution lead time and inventory levels, which in turn reduce logistics cost. According to Ray Kulwiec (2004, p. 28), a broad definition of cross dock is "*the transfer of goods and materials from an inbound carrier to an outbound carrier, without goods or products actually entering the warehouse or put away into storage.*". The cross-docking activity usually takes place at a logistic center where the inbound freights are unloaded then inspected, sorted and finally reloaded to send off to its destinations.

As mentioned above, one of the main advantages of a cross dock is the decrease in cost of the supply chain. Cross dock also reduces storage space and also shortens delivery times and makes the supply chain more agile, which in turn leads to improvement of customer service (Panousopoulou, Panoudopoulou & Manthou, 2012). In addition, it also reduces a supply chain's carbon footprint.

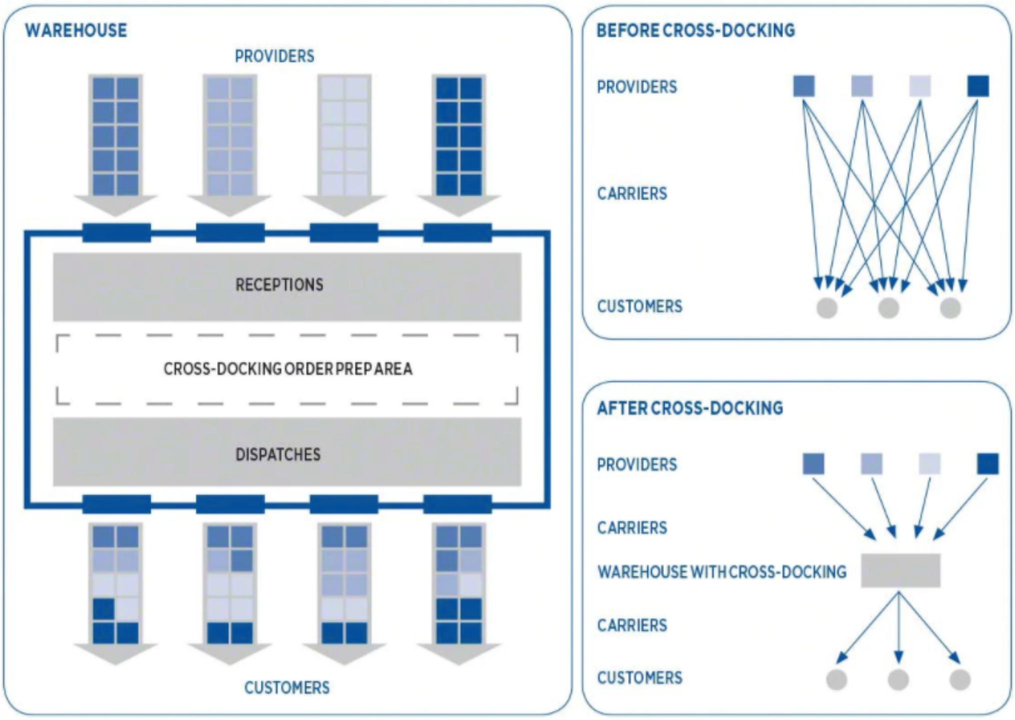

Figure 2. 1 Before and after using cross-docking (Interlake Mecalux, 2019)

Despite the many advantages of cross dock, there are also disadvantages and risks that come with the use of this strategy. The first disadvantage is that cross-docking is an expensive concept and strategy (Panousopoulou et al., 2012). In order to implement cross-docking, the warehouse would need to be appropriately redesigned to assist with the strategy. It also requires a lot of time and planning to maximize its effectiveness.

2.4. Logistics and logistics costs

"Logistics refers to the overall process of managing how resources are acquired, stored, and transported to their final destination" (Kenton, 2020). Management of logistics is significant because of their 4R- tasks which are providing "the *required* quantities of goods most efficiently at the *right place* in the *right order* at the *right time"* (Gudehus & Kotzab, 2009, p. 3).

Based on Jonsson and Mattsson (2017), logistic costs and capital tied up together with customer service have a direct impact on the corporation's profitability. Therefore, in addition to maximizing financial gain, companies need to minimize the logistic costs as much as possible. There are seven types of logistic costs that Jonsson and Mattsoon (2017) have identified as below:

- Transport and handling costs
- Packaging costs
- Inventory costs
- Administrative costs
- Order costs
- Capacity-related costs
- Deficiency and delay costs

The logistics costs can be defined differently to different corporations depending on in which industry and which country the company is operating (Jonsson & Mattsson, 2017).

2.5. The importance of packaging and unit load efficiency

One of the fundamental elements in the logistics performance and supply chain is packaging because it has a significant impact on both supply chain cost and furthermore on the environment (Pålsson, 2018). In order to improve the supply chain flow and at the same time reduce cost, choosing the right way of packing and the suitable number of articles is significant. However, it is not easy to create packaging efficiency that fulfil requirements from various areas such as logistics and production and at the same time have a minimal environmental impact because these different requirements may be in conflict (Pålsson, 2018).

The efficiency of unit load plays an important role in this case. Unit load is defined as "*a single item, a number of items or bulk material which is arranged and restrained so that the load can be stored, and picked up and moved between two locations as a single mass"* (Tompkins, White, Bozer & Tanchoco, 2010, p. 186) and plays a key role across the supply chain and is described as key cost driver (ECR Europe, 1997). When using larger unit loads, it reduces the frequency of the transportation and therefore the total move distance and handling cost decreases (Tompkins et al., 2010). Large packaging that holds a large amount of articles/parts minimizes the number of transports necessary. However, larger unit loads also increases the levels of work-in-process and it also requires more space at the points of loading and use (Hanson & Finnsgård, 2014).

Packaging plays an important role when it comes to environmental impacts that are unsustainable because of consumption of non-renewable resources and air pollution due to unnecessary transports (Verghese & Lewis, 2007). Due to that, packaging waste should be eliminated to ensure efficiency in the supply chain, reducing costs and minimizing impact on the environment.

2.6. Economic Order Quantity (EOQ)

According to Zuniga, Angel Piera and Narciso (2011), by having an optimal filling of a pallet the shipment costs are decreased and at the same time the stability and support of the load will be increased. Furthermore, optimal utilization of available space in packaging as well as in transport vehicles reduces the amount of carbon footprint per unit on the environment which is one of the most challenges of humanity and the planet.

In addition to maximizing utilization of packaging, many companies also consider the Economic Order Quantity (EOQ) - the ideal order quantity a company should purchase in order to minimize holding costs, shortage costs and order costs (Kenton, 2020). The formula for EOQ is:

$$Q = \sqrt{\frac{2 \times D \times S}{H}}$$

Where,
$Q =$ EOQ units
$D =$ Demand in units (typically on an annual basis)
$S =$ Order cost (per purchase order)
$H =$ Holding costs (per unit, per year)

2.7. Minimum Order Quantity (MOQ)

Aside from economic order quantity, minimum order quantity also needs to be considered when determining order quantity. MOQ is a requirement made by suppliers which means that the order quantity must equal or more than a specified level if an order is placed (Zhu, Liu & Chen, 2015). From the supplier's perspective, MOQ is required in order to reduce the risk of uncertainty and reach economies of scale. However, it can have a negative impact on buyer’s inventory control and therefore it causes higher holding cost, ordering cost and backordering cost when MOQ is relatively greater than their demand (Zhu, Liu & Chen, 2015).

Obviously, there are many factors that should be considered in order to determine the appropriate order quantity. Corporation’s profit is one of the most important aspects. Although, it is important that all companies consider environmental aspects when making decisions regarding order quantity.

2.8. Supply Chain Management

A *supply chain* consists of all parties involved in fulfilling a customer's request, including not only manufacturers and retailers, but also transporters, warehouses and even the customers themselves. A supply chain refers to the flow of funds, goods or information from the manufacturer to the final customer through all stages of production. Each stage includes all the parts needed to receive and satisfy the customer's request. Examples of such functions are product development, marketing and distribution (Chopra & Meindl, 2013).

Supply Chain Management (SCM) is also closely linked to logistics functions from an organization's point of view. The chain also includes the organizations and processes that are needed to create and deliver products and services to customers (Chopra & Meindl, 2013).

The goal of SCM is to satisfy the customer's request while at the same time generating value for the involved companies, such as profit. The profit should also be maximized, because otherwise the chain will be replaced by another better chain. Another objective of every supply chain is to maximize the overall *value* generated. The *value* that a supply chain generates is defined as "*the difference between what the value of the final product is to the customer and the costs of the supply chain incurs in filling the customer's request"* (Chopra & Meindl, 2013, p. 15).

2.9. Demand management

Demand management is one of the eight key business processes that need to be implemented within and across organizations in the supply chain (Croxton et al., 2002). According to Thomas W. Rodney, professor at University of Arkansas, a definition of demand management is "*focused efforts to estimate and manage customer demand with the intention of using this information to shape operating decisions.".* Another definition of demand management is that it is "*the supply chain management process that balances the customers' requirements with the capabilities of the supply chain"* (Croxton, Douglas, Garcia-Dastugue & Rogers, 2002, p. 51).

Demand management is much more than just forecasting. It is an integration of demand and supply which improves communication, coordination, and collaboration. It also improves the basic supply chain flows. According to Chase, author of *Next Generation Demand Management* (2016), by better predicting the impact of demand on supply chain, revenue can increase by at least 3-7%.

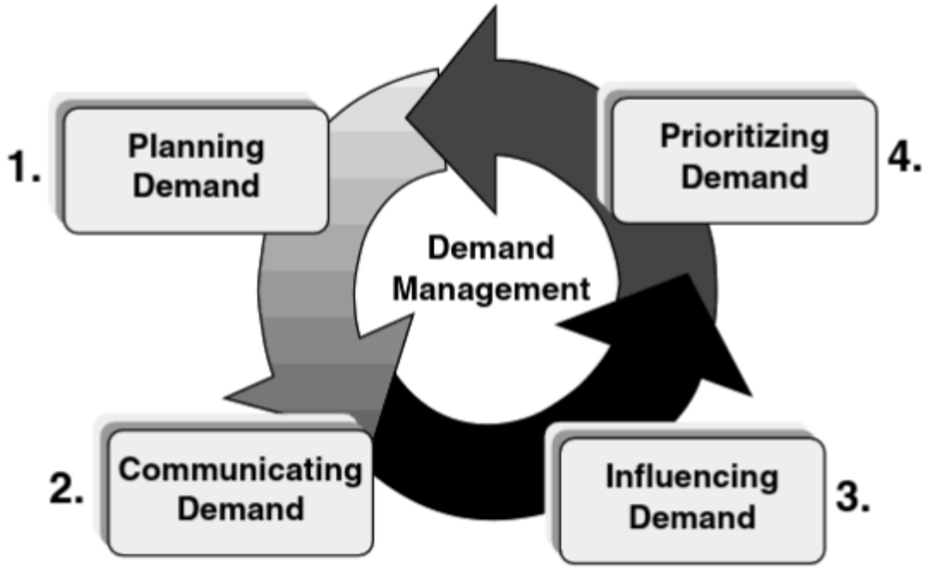

Figure 2. 2 Demand Management Process Model (Crum & Palmatier, 2003)

Figure 2. 2 illustrates a model of the demand management process. The process includes four different elements; *planning demand, communicating demand, influencing demand* and *prioritizing demand,* where each of the elements influences each other. In order to improve the accuracy of the demand forecast, the four elements have to integrate with each other with supporting processes and information. Brief descriptions of each elements are presented as following (Crum & Palmatier, 2003):

1. Planning demand - a process of planning all demands for products and services to support the marketplace.
2. Communicating demand - communicating the demand plan to the supply and finance organizations and, increasingly, to supply chain partners.
3. Influencing demand - includes marketing and selling tactics, product positioning, pricing, promotions, and other marketing and sales efforts.
4. Prioritizing demand - includes managing customer orders to match available supply.

3. Methodology

The following chapter describes the different methods that are used to collect data, including interviews, data extracts and literature study.

3.1. Data collection

This is a case study relying on quantitative data from different applications from Volvo Cars. During the thesis, primary data are collected mainly through qualitative research, such as interviews and meetings with different employees of Volvo Cars, where data and information about consolidation and data quality are collected. Information about different application systems are gathered through Volvo Cars' intranet, which is the company's internal network. Quantitative research is used where data from different applications are compared.

Furthermore, a visit at Volvo Cars Bulycke is performed, where the company's consolidation center is located. The purpose is to learn how the company's consolidation system works in practice.

3.1.1. Interviews

The interviews are performed mainly through personal communication, i.e. online meetings and via emails. Information gathered from the interviewees are referenced under their names and titles with their permissions. The interviews are conducted in the form of open discussions and the main purpose of the interviews is to gather information about data deviation, including the application that is used in the consolidation center and its connection with other applications. Furthermore, the purpose is also to collect data on how to generate the different logistics costs that are required in order to calculate the cost impact of data deviation has on the company. Another purpose is to gain more knowledge and understanding how the consolidation flow works at Volvo Cars Bulycke and get an overall understanding of the company's data management, in particular about data deviations and their impacts. With the help of the interviews, reasons and impacts of data deviations can be identified and analyzed.

3.1.2. Data extracts

Data extracts from different applications are needed in order to identify and analyze data deviation between these applications. The extracts are obtained through personal communication with the applications' managers, specifically through emails. Furthermore, basic information about the applications are also gathered through the managers. The data extracts are all provided in the form of Excel files. For some applications, only relevant data are provided in the Excel file while for others all data from the application are given. The data extract where all data are given are manually filtered with Excel to facilitate the comparison and analysis work. More details about data extracts and its relevant data are described in chapter 5.

3.2. Literature study

The main keywords that are used when searching for literature are; *inbound logistics*, *cross docking*, *consolidation, information integration, data quality management, supply chain management, demand management* and *logistics costs*. The types of literature that are mainly used as references are course literature, academic articles and journals. Furthermore, literature is mainly used for theoretical purposes and for describing and understanding the phenomenon that is studied, which is the impacts of data deviations in a cross-docking phase of a supply chain. Information regarding Volvo Cars Corporation is obtained through interviews and personal communication with Volvo Cars employees, as mentioned in chapter 3.1.1.

4. Volvo Cars Corporation

The following chapter begins with a brief description of Volvo Cars. Furthermore, the chapter includes an explanation of the difference between cross dock and consolidator and what roles they have in the company. The chapter continues with descriptions of the different applications and their connections and ends with an account of different package types and the importance of unit load.

4.1. About Volvo Cars

Volvo was founded and the first Volvo car rolled off the production line in 1927 in Gothenburg, Sweden (Volvo Cars Corporation, n.d). Since 2010, Volvo Cars has been a subsidiary of the Chinese automotive company, Zhejiang Geely Holding (Volvo Car Corporation, n.d). The company's roots are decidedly Scandinavian, but Volvo Cars is headquartered in Europe: Sweden, Belgium and Denmark; America and Asia: China, India and Malaysia which makes the company a truly global organisation (Volvo Car Corporation, n.d)

Located in the Chengdu Economic and Technological Development Zone, Chengdu is Volvo Cars's first complete manufacturing plant outside Europe (Volvo Cars, 2013). The plant's annual production capacity is 120 000 cars and the first car model to be produced here is the Volvo S60L (Volvo Cars, 2013). Five years later, on September 25, 2015 Volvo Cars started to build another plant in another continent which is Charleston Plant. It is located in Ridgeville Berkeley County, South Carolina and has the capacity to produce up to 150 000 cars annually. The plant is officially opened in June 2018 and produces all new S60 midsize sports sedan and around 2022 the plant is planned to produce the next generation XC90 sport utility vehicle (Volvo Cars, n.d.)

Today, Volvo Cars is one of the most well-known and respected premium car brands with sales of 534 332 cars in about 100 countries in 2016 which the company recorded sales and operating profit of 11 014 MSEK (Volvo Car Corporation, 2018).

4.2. Difference between cross docking and consolidation at Volvo Cars

Generally, cross docking and consolidation are of the same concept. However, at Volvo Cars there is a slight difference between the two (Logistic Engineer, Volvo Cars Corporation). There are many different methods of cross docking, depending on the types of product. *Truck/rails consolidation* is one of them. In this method, products from inbound trucks or rails need to be consolidated in a *consolidation center* (CC) in order to complete an order. Goods that arrive at the center are combined and sorted for outbound shipment within 24 to 48 hours compared to a *cross docking center* (XD) where the flow is almost uninterrupted and goods that arrive are regrouped and leave the same day. It also requires more administrative work in a consolidation center compared to a cross docking center (Logistic Engineer, Volvo Cars Corporation).

4.3. The role of consolidation center and cross dock at Volvo Cars

The aim of this thesis is to analyze data deviations between different applications related to the consolidation flow. Hence, it is important to know the role of consolidation center/cross dock at Volvo Cars. This subchapter describes the purpose of consolidation center and includes a brief description of the consolidation flow at Volvo Cars Bulycke.

Due to the fact that Volvo Cars is a global company and has many suppliers from different countries, the consolidator centers where Inbound and Outbound Logistics meet, plays a significant role. Volvo Cars has several consolidators and cross docks in Europe, i.e. Bulycke in Gothenburg, Ghent in Belgium, Herne and Maintal in Germany, etc. However, articles sent via Herne, Maintal and other cross-docks in Europe except for Bulycke will eventually go through Ghent (Logistics Engineer, Volvo Cars Corporation).

Based on Volvo Cars (n.d) “The Inbound Logistics (IBL) scope starts at parts suppliers and ends at the production facilities, the central parts distribution warehouse and via various consolidation centres to overseas production locations and for Outbound Logistics (OBL) the span starts at assembly factories and ends at the dealers”. In other words, a consolidator center is where materials from different suppliers are gathered and therefore, they will be forwarded to manufacturing plants such as Chengdu and Charleston plants.

Volvo Cars’ consolidation center’s flow is illustrated in the figure below (see Figure 4. 1).

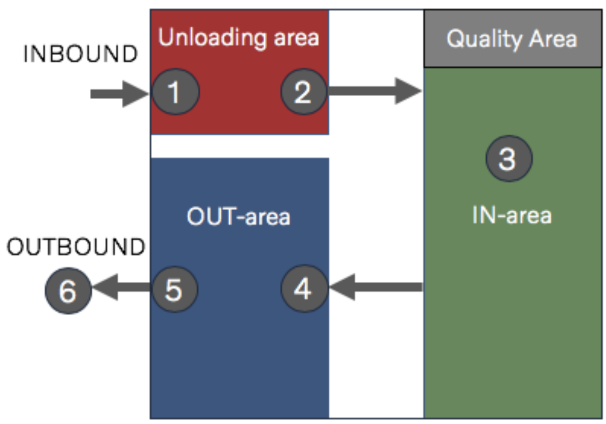

Figure 4. 1 Flow of Volvo Cars’ consolidation center in Bulycke, Gothenburg (Logistics Engineer, Volvo Cars Corporation)

In the unloading area is the incoming of transport orders (TOs). Visual inspection and signing of CMR (shipping note) are then performed. After that, scanning of barcodes and verifying of ASN sent from suppliers is performed. Moving on to the IN-area, which is where the materials per FDP is sorted into separated areas while documentation is verified by the administration. When the verification is completed, the TOs are moved to preloading lanes, in the OUT-area, according to FIFO based on the first scan in the LC. Goods are then loaded to containers when the preloading lane is full. Finally, the last step is to finalize documentation per container, weigh the container (VGM) and send CC-ASN to the receiving plant (Logistics Engineer, Volvo Cars Corporation).

4.4. Volvo Cars' applications

Due to the fact that Volvo Cars is a global organisation, there are hundreds of applications that are used at Volvo Cars to ensure that information flows correctly from the beginning to the end of a process. Figure 4. 2 below shows one of the company's departments which is Manufacturing and Logistics cluster and products from order to delivery.

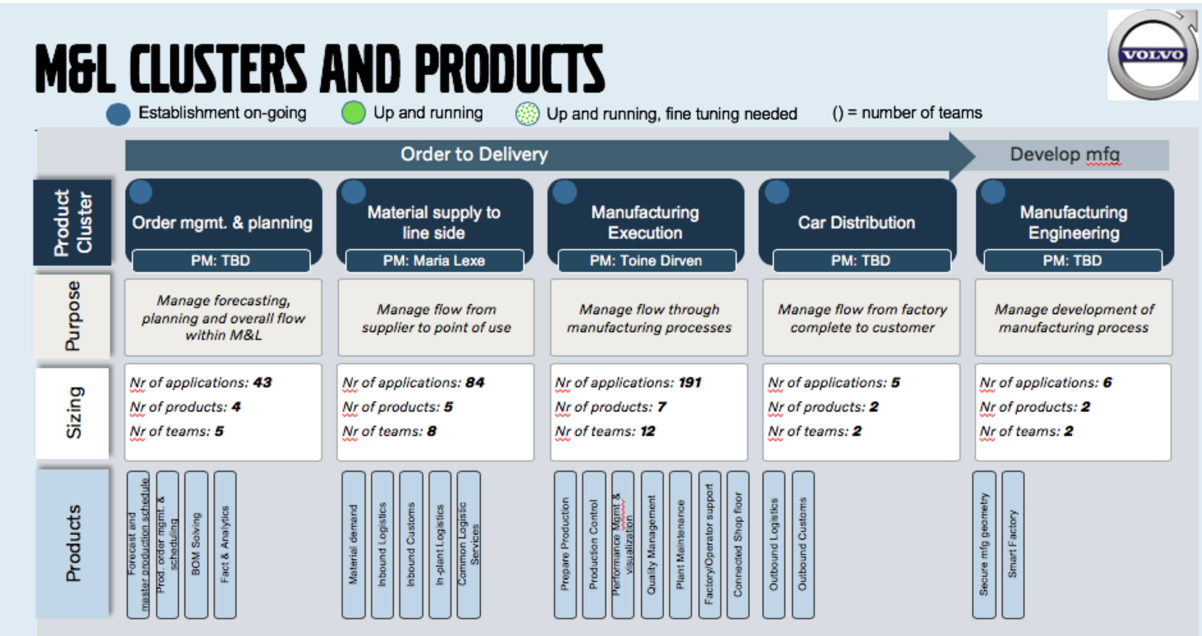

Figure 4. 2 M&L Cluster and Products (Volvo Cars Intranet)

In this department, Manufacturing and Logistics, there are already over 300 applications. As a result, many system integrations are created where data is received and sent to each other automatically. However, like mentioned before, this study will focus on Volvo Cars' consolidation center, also known as Newcast and some of other applications that are connected to Newcast which are PLUS, IBL Data Consolidator (IBL DC) and VSIM. According to Solution Architect of Volvo Cars, all of these applications except VSIM, belong to the Manufacturing and Logistics department's second product cluster "Material supply to line side". The following subchapters describe more about these four applications.

4.4.1. Newcast system

According to Alfabet (2020), Newcast has three main functions which are:

- Provides MP&L Overseas with systems that break down car specifications from MP&L Overseas markets to part requirements.
- Calculate the requirements to calls from suppliers.
- To do warehouse management when the goods are delivered.

As stated by Logistic Engineer of Volvo Cars, the consolidator (Newcast) system collects the shipments from EU suppliers and does the repacking and ship parts to both China and USA. However, consolidator will now also be used to trigger the message for the services and freight invoices (Infosys Team, 2018).

Based on a project documentation of Navami Hiremath (2018), Newcast receives 14 different types of information from 10 systems and sends out 13 different types of information to 8 other systems. For instance, Newcast receives Call-off information and shipper supplier ID, Lead time & other information from PLUS. On the other hand, Newcast sends PLUS call off and dispatch advice information (Hiremath, 2018).

Since Newcast gets data directly from IBL DC via LOGDAT and from PLUS (see chapter 4.4.6), it is not necessary to compare the data from Newcast but the focus is instead on the other applications.

4.4.2. PLUS system

PLUS is a system that is used for material ordering for Volvo Cars Torslanda, Volvo Cars Chengdu, Volvo Cars Daqing, Volvo Cars Pilot Plant Gothenburg and Volvo Cars Pilot Plant Shanghai (Khan, 2017). Because of that, PLUS is one of the most important systems to assure that materials are available when they are needed. If PLUS is unavailable for more than 24 hours will make it hard for the SCC to follow material flow. Therefore, information about when goods will arrive is lost and this can cause production disturbances (Khan, 2017).

PLUS communicates with various systems in different factories to get several base data files from other systems every night. Therefore, a job is run and the new data is noticeable in the system. Consequently, the SCC can work with parameter settings to tune the deliveries during daytime (Khan, 2017). Figure 4. 3 below illustrates the connections of PLUS with other systems where Newcast is one of them.

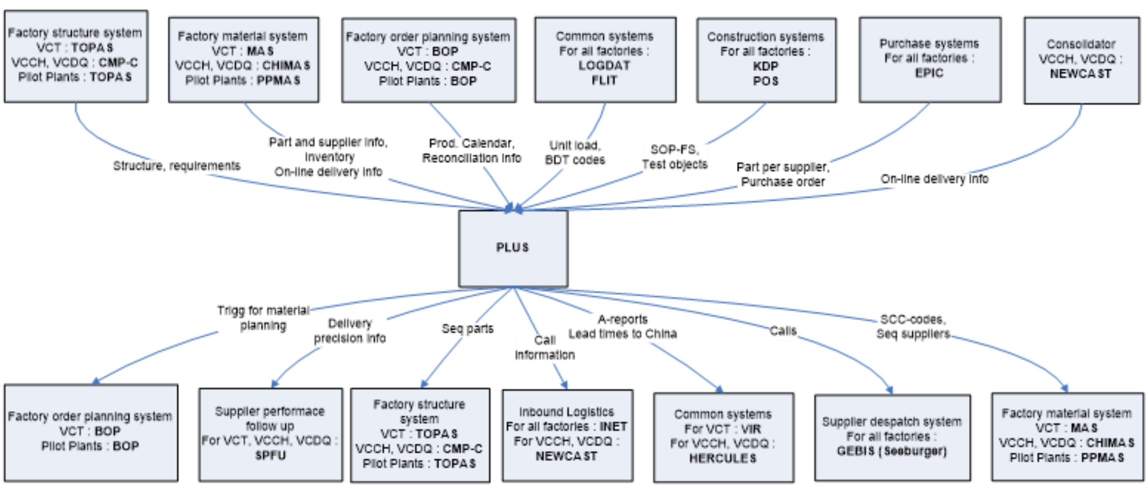

Figure 4. 3 PLUS connections for factories and Pilot Plants (Volvo Cars, 2015)

4.4.3. IBL Data Consolidator system (IBL DC)

"IBL Data Consolidator is a small utility that has been created inhouse to enable the inbound team to create Masterdata that is consumed by inet TMS CMS as well as 4flow Vista…" (Alfabet, 2020). In the IBL DC application, information of the container details for the part numbers are presented. This kind of data is called packaging instructions and is used by the inbound team of Volvo Cars.

4.4.4. VolvoSupplierImprovementMetrics (VSIM)

"*The VSIM scope is to update and maintain information about the suppliers' quality metrics and award status such as Delivery Performance, PPM, Certificates, Endorsements from within VCC etc. and enable external access for VCC suppliers. Furthermore, the 8D process, i.e the supplier's formal response to the customer's quality rejects (QRs) is handled in VSIM. The majority of the basic data comes from other VCC systems such as VIR, SPFU and PARMA*" (Alfabet, 2020). In other words, VSIM provides the fundamentals information on managing packaging instructions to suppliers (Claesson, 2019).

To ensure the optimal utilization of packaging, there are packaging engineers that work with maximizing the pallet's space at Volvo Cars. They decide *unit load* which is the quantity of an article in each pallet (see subchapter 4.4) and enter this information in the VSIM system. Therefore, this data should be followed (Logistics Engineer, Volvo Cars Corporation).

4.4.5. Logistics Data system (LOGDAT)

Like PLUS, Newcast and IBL DC, LOGDAT is also one of the Manufacturing & Logistics applications. These four systems belong to cluster 2 - Material supply to line side (Volvo Car Corporation, 2019). LOGDAT is an application that supports the logistic purchase preparation by putting together information on prenumber level for the plants VCT, VCG, PFS, VCOM, VCPP, VCCH and PP Shanghai (Volvo Car Corporation, n.d)

4.4.6. Connection between the applications

When it comes to *unit load*, VSIM sends this data to Newcast via IBL DC (Logistics Engineer, Volvo Cars Corporation). According to Volvo Cars' Manager of PLUS application, the PLUS application should get unit load data from VSIM. However, at this moment PLUS gets it from an old application system that is called LOGDAT. Because unit load is a parameter in PLUS, Supply Chain Controllers (SCC) can change this data and utilize their own value instead. Otherwise, PLUS does not have any connection with other applications regarding unit load.

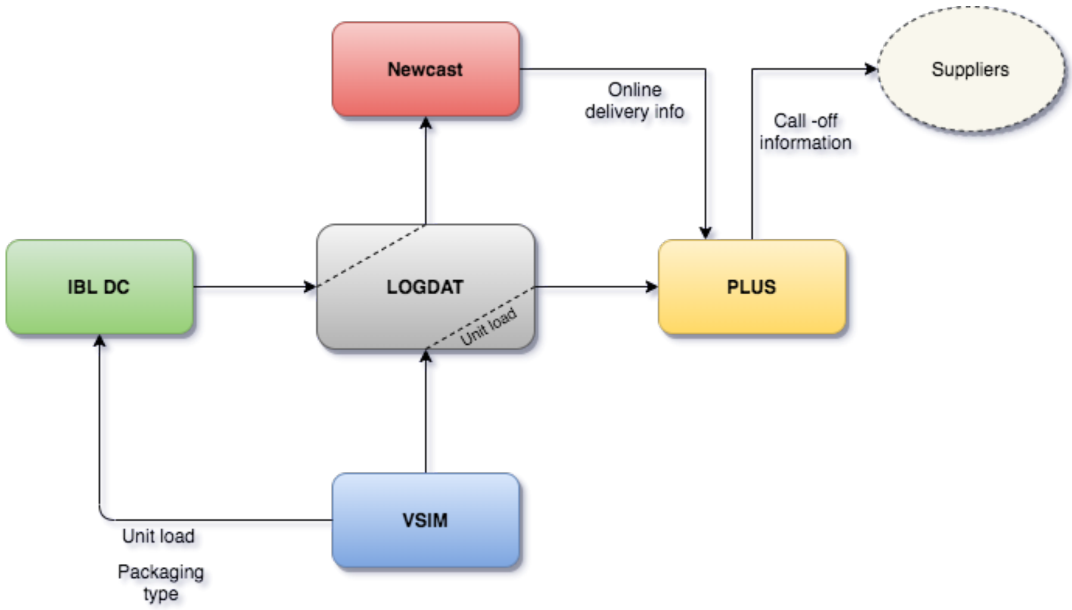

Figure 4. 4 Map of connection between different applications

As shown in Figure 4. 4 above, LOGDAT is a center application where information is gathered and is forwarded to other systems. In this case, LOGDAT's only job is to forward data to Newcast and PLUS. Therefore, data in the five above mentioned applications should be the same, including unit load.

4.5. Package types

Every article has their own package type where it determines how a package should be packaged. Normally, a package includes one pallet and one box. However, there are special types where a package contains several layers with one pallet and a specific number of boxes. The package types and their dimensions that are given are described in the table below (see Table 4. 1). Based on these dimensions of package types, their volumes can be calculated which in turn is necessary in order to calculate packaging costs of the articles (see subchapter 5.4).

Package type	Amount of pallet	Amount of boxes per layer	Maximum layers	Width (mm)	Height (mm)	Length (mm)
V81	1	1	1	790	351	1140
V82	1	1	1	790	546	1140
V83	1	1	1	790	741	1140
V84	1	1	1	790	936	1140
V10	1	8	4	284	192	367
V11	1	4	4	377	192	556

V12	1	2	4	554	192	762

Table 4. 1 Different package types and its dimensions (Logistics Engineer, Volvo Cars Corporation)

4.6. The importance of unit load

At Volvo Cars, the quantity of an article in each pallet, also called *unit load* (UL)*,* is decided by packaging engineers and it should be followed because it optimizes the packaging (Logistics Engineer, Volvo Cars Corporation). Furthermore, packaging engineers is working together with the production team and suppliers to determine UL and it is also based on the articles' consumption rate (Manager of packaging engineering, Volvo Cars Corporation). However, there are some cases where this quantity is changed by the Supply Chain Controllers (SCC), the changed UL is called *shipping quantity* (SQ). In addition, UL is changed by SCC in the PLUS application since it works as a parameter. In cases where SQ is less than UL, the pallets for the order would not be full and this in turns, will result in extra cost for the company. The calculation for transportation and packaging cost is presented in subchapter 5.4.

As an example, a full pallet of an article according to its UL should contain 10 units. The most effective way is to order 10, 20, 30, etc. units because it optimizes the space of the pallet. If the SCC changes this quantity to 5 then the pallet would be half full for every order. This would be extra costly since the article must now be ordered twice as much, instead of filling the pallet with 10 units for each order. The pictures below illustrate examples of a full pallet and an unfilled pallet of the same article, where UL and SQ is 10,000 and 2,000 respectively (see Figure 4. 5).

In addition, UL is set to prevent article damage and facilitate transportation. If UL is not followed which leads to empty boxes, there is a high risk for articles' damage due to the instability of the pallet and this in turn might also lead to human injury (Manager of packaging engineering, Volvo Cars Corporation).

Figure 4. 5 Example of a full pallet (left) and unfilled pallet (right) (Logistics Engineer, Volvo Cars Corporation)

5. Results

The following chapter is divided into four subchapters. The first subchapter presents the result of comparison of data from the PLUS application. The second subchapter describes the result from comparison of data from the IBL DC application. The third subchapter covers data comparison between PLUS, IBL DC and VSIM application. Finally, the last subchapter presents calculations of different logistics costs when data deviations occur.

5.1. Comparison of unit load and shipping quantity from PLUS application

In this subchapter, unit load (UL) and shipping quantity (SQ) are compared in the PLUS data extract. Initially, factories from Chengdu (VCCD) and Charleston (VCCH) were looked into. From the PLUS application data extract, UL and SQ are compared for both of these factories. The goal is to find the amount of cases where SQ is less than UL since these articles results in extra cost for the company. However, there are cases where SQ is set to 1. These articles are yet to be approved by the PPAP (Senior Manager Supply Chain, Volvo Cars Corporation) and therefore are seen as exceptions and are not included in our analysis.

Table 5. 1 presents the result of comparison of UL and SQ from PLUS data extract. For VCCD, there are 85 out of 3623 articles where SQ is smaller than UL. Meanwhile for VCCH, there are only 4 articles out of 3870 where SQ is smaller than UL.

Factory	**Total articles**	**Articles where SQ < UL (*)**	**Percentage difference**
VCCD (Chengdu)	3623	85	2.35 %
VCCH (Charleston)	3870	4	0.10 %

(*) excluding cases where SQ = 1

Table 5. 1 Unit load versus shipping quantity from PLUS data extract

It is clear to see that there are more data deviations in VCCD than VCCH, the reason behind this is discussed in chapter 6. To narrow down the amount of total data that needs to be analyzed, it is logical to disregard VCCH and look more into the VCCD factory instead.

5.2. Comparison of shipping quantity and actual quantity from IBL DC

From the IBL DC data extract, a list of all orders to suppliers is also given. In this list, actual quantities that are sent from the suppliers to Chengdu via consolidation center are listed. Shipping quantity (SQ) and the actual quantity (amount) are compared in this subchapter (see Table 5. 2). Since ‘amount’ is the actual quantity that is sent to Chengdu, it should be equal to SQ which is set by SCC in Chengdu. An example of the list is presented in appendix A. The most relevant data from this list are:

- *Area* - the factory that the articles are sent to, in this case CHD (Chengdu).
- *Article* - the article number / article ID
- *Amount* - the actual amount of quantity that is sent for every article to Chengdu, this data should be equivalent to SQ and UL. Ideally, SQ and Amount should be equivalent to UL or more.
- *PickUpEarliest* - indicates the earliest date where the order should be picked up, the relevant year in this case is 2020.

Total articles	**Total orders (*)**	**Orders where *amount* < SQ**	**Orders where *amount* < UL (%)**
85	3998	28 (corresponding 0.07 % of all orders)	70 (corresponding 1.75 % of all orders)

(*) This is the total amount of orders for each article that are sent to Chengdu. Each article has multiple orders.

Table 5. 2 Comparison of unit load, shipping quantity and amount

As mentioned in the previous subchapter, the total amount of articles that are analyzed is narrowed down to 85 since cases where SQ = 1 are excluded. As Table 5. 2 presents, the articles where *Amount* is less than SQ is considered to be extra problematic since they are much less than UL, which in turn leads to extra cost (see subchapter 5.4). When comparing these data, the total orders for each article are taken into account. For example, an article could have up to 30 orders listed and one of these orders happens to have an ‘*amount*’ that is less than SQ. One thing that is worth mentioning is that for articles where ‘*amount’* is less than SQ, this kind of deviation only occur for one order and never more.

5.3. Comparison of unit load between IBL DC, PLUS and VSIM

In this subchapter, unit load (UL) is compared between three applications: IBL DC, PLUS and VSIM. As mentioned in chapter 4.4.4, VSIM is the application that has the basic information of an article, such as its package type, unit load (UL), plant, destination, etc. The UL data from IBL DC and PLUS should therefore be equal to the UL data from VSIM since it is the original data where the packaging engineers have set.

All of data from the VSIM application are provided in the data extract. To simplify the comparison and analysis, relevant data (columns) and variables are filtered in the Excel file as Table 5. 3 presents. For example, ‘PLANT’ is one of the relevant columns in the VSIM data extract. In this column, there are two different variables, i.e. Chengdu plant

(CHN03) or Charleston plant (CHA03). In this case, CHN03 is the relevant variable and is therefore filtered for the analysis and comparison. An example of the VSIM data extract is presented in Appendix C.

Relevant data	Variables	Relevant/filtered variable
PLANT	▪ CHN03 (Chengdu) ▪ CHA03 (Charleston)	CHN03 (Chengdu)
ORDER (*)	▪ MO (Material Order) ▪ PP (Preseries)	MO (*)
STATE	▪ New Part ▪ New Version ▪ Estimated ▪ Awaiting Approval ▪ Partly Approved ▪ Approved ▪ Incomplete ▪ Rejected	Approved

(*) A short explanation for why MO is relevant is because PP stands for "Preseries" which means a test series that runs before normal production starts. MO which stands for "Material Order" is materials used in production.

Table 5. 3 Filtered data from VSIM data extract

When comparing data from these applications, several unexpected errors are discovered. As an example, two articles are picked out to present the errors (see Table 5. 4 & Table 5. 5).

VSIM

Article	Plant	ORD	STATE	UL
31424426	CHN03	PP	Partly_Approved	450
31424426	CHN03	MO	Approved	18
31424426	CHN03	PP	Incomplete	144

IBLDC

ARTICLE	DESTINATION_NUMBER	CAPACITY (UL)	STATUS	
31424426	CHN03_RDC	450	complete	

PLUS

Factory	Planning point	Part nr (article no.)	UL	SQ
VCCD	CHN03	31424426	450	144

Table 5. 4 Data for article 31424426 from VSIM, IBL DC and PLUS (filtered version)

As Table 5. 4 presents, UL for article 31424426 is 450 in both the PLUS and IBL DC application (red marked). However, in VSIM application UL is 450 for PP but 18 for MO. Furthermore, for PP the 'STATE' of the article is only partly approved, meanwhile for MO it is approved.

VSIM

Article	Plant	ORD	STATE	UL
974687	CHN03	MO	Awaiting_Approval	200
974687	CHN03	PP	Approved	19200

IBL DC

ARTICLE	DESTINATION_NUMBER	CAPACITY (UL)	STATUS	
974687	CHN03_RDC	200	complete	

PLUS

Factory	Planning point	Part nr (article no.)	UL	SQ
VCCD	CHN03	974687	19200	14400

Table 5. 5 Data for article 974687 from VSIM, IBL DC and PLUS (filtered version)

As for article 974687, the UL from PLUS and IBL DC are different. PLUS has gotten the UL from PP in the VSIM application while IBL DC got the UL from MO.

The reason why these types of errors occur is unclear as it is unexpected errors that have not been discovered before. Further discussion about these errors is covered in subchapter 6.2.

5.4. Calculation of logistics costs

One of the purposes of this thesis is to identify the impact of data deviation has on Volvo Cars, in terms of logistics costs, for articles where unit load is not followed. In this subchapter, calculations of logistics costs are presented and explained.

Logistics costs in this case are defined as *pre-carriage cost, handling cost, sea transport cost, total transport cost, total packaging cost* and *annual cost.* Pre-carriage cost is the freight cost from the supplier to the consolidation center and handling cost includes wages, fixed cost such as rent and etc. Table 5. 6 presents the mentioned cost for Bulycke and Ghent.

Consolidation center / X-dock	**Pre-carriage cost (€/m^3) (*)**	**Handling cost (€/m^3)**	**Sea transport cost (€/m^3)**
Bulycke (Gothenburg)	8	24	28.2
Ghent (Belgium)	28	15	28.2

(*) Most of the suppliers are in Sweden, which means shorter mileages to Bulycke compared to Gent.

Table 5. 6 Costs for Bulycke and Ghent (Logistics Engineer, Volvo Cars Corporation)

The calculation of the packages' volumes is straight-forward since the dimensions of the different package types are given (see subchapter 4.5). From the 85 articles mentioned in subchapter 5.2, articles with relevant package types are picked out in order to calculate their volumes and costs. Furthermore, only articles sent via the Bulycke or Gent CC are looked into (see appendix B). Table 5. 7 below presents the volumes of each package type.

Package type	**Volume (width ×height ×length) (m^3)**
V81	0.316
V82	0.491
V83	0.667
V84	0.843
V10 (*)	0.144
V11 (*)	0.165
V12 (*)	0.205

(*) The volume for the pallet is not included for V10 - V12's dimensions, but only for V81-V84. Therefore, the volume of the pallet has to be added to the total volume of packages V10-V12. Pallet's volume is 0.124 m^3

Table 5. 7 Volumes of different package types

5.4.1. Total transportation cost and packaging cost

The total transportation cost is the sum of pre-carriage, handling and sea transport cost that are calculated in the previous subchapter. The total transportation cost for each package type are presented in Table 5. 8 & Table 5. 9, presenting for Bulycke and Ghent respectively.

Packaging type	Pre-carriage cost (€ / pallet)	Handling cost (€ / pallet)	Sea transport cost (€ / pallet)	Total transportation cost (€ / pallet)
V81	2.529	7.587	8.914	19.030
V82	3.934	11.801	13.867	29.602
V83	5.339	16.016	18.819	40.174
V84	6.744	20.231	23.772	50.746
V10	1.154	3.463	4.069	8.687
V11	1.316	3.949	4.640	9.905
V12	1.643	4.928	5.790	12.361

Table 5. 8 Pre-carriage, handling and sea transport costs for each package type in Bulycke

Packaging type	Pre-carriage cost (€ / pallet)	Handling cost (€ / pallet)	Sea transport cost (€ / pallet)	Total transportation cost (€ / pallet)
V81	8.851	4.742	8.914	22.507
V82	13.768	7.376	13.867	35.011
V83	18.686	10.010	18.819	47.515
V84	23.603	12.644	23.772	60.019
V10	4.040	2.164	4.069	10.274
V11	4.607	2.468	4.640	11.714
V12	5.749	3.080	5.790	14.620

Table 5. 9 Pre-carriage, handling and sea transport costs for each package type in Ghent

Calculation of total packaging cost is based on cost of a pallet and one box, i.e. 7 euro and 1.5 euro respectively. The number of pallets and boxes for specific package types are presented in Table 4. 1 in subchapter 4.5. Table 5. 10 below presents the total packaging cost per unit for each type of package.

Package type	Total packaging cost per pallet (€)
V81 - V84	8.5
V10	19
V11	13
V12	10

Table 5. 10 Total packaging cost per unit

The total cost per unit can now be calculated by adding the total transportation cost to the total packaging cost (see Table 5. 11 & Table 5. 12).

Package type	Total cost per pallet (€)
V81	27.530
V82	38.102
V83	48.674
V84	59.246
V10	27.687
V11	22.905
V12	22.361

Table 5. 11 Total cost per unit for packages sent to Chengdu via Bulycke

Package type	Total cost per pallet (€)
V81	31.007
V82	43.511
V83	56.015
V84	68.519
V10	29.274
V11	24.714

V12	24.620

Table 5. 12 Total cost per unit for packages sent to Chengdu via Ghent

5.4.2. Annual cost and annual saving potential

From the VSIM data extract, the annual volume is provided for each article. Based on the annual volume, the number of pallets for each article can be calculated for both unit load (UL) and shipping quantity (SQ). The annual cost for each article is then calculated based on the number of pallets. The goal of calculating annual cost is to see how much money the company can save by setting SQ accordingly to UL. As an example, table Table 5. 13 presents the annual cost and saving potential for article 8640202. Formulas for each calculation is explained as following:

- Number of pallets according to UL = Annual volume ÷UL
- Number of pallets according to SQ = Annual volume ÷SQ
- Annual cost according to UL = Number of pallets (acc. UL) ×Total cost per pallet (Bulycke or Ghent)
- Annual cost according to SQ = Number of pallets (acc. SQ) ×Total cost per pallet (Bulycke or Ghent)
- Annual saving potential = Annual cost (acc. SQ) - Annual cost (acc. UL)

Article	8648202
Package type	V81
UL	72,000
SQ	24,000
X-dock/Consolidator	Volvo Consolidator Bulycke
Annual Volume	273,290
Pallets (acc. UL)	273,290÷72,000 = 3.796
Pallets (acc. SQ)	273,290÷24,000 = 11.387
Annual cost (acc. UL)	3.796 ×27.530 ≈ €104.50
Annual cost (acc. SQ)	11.387 ×27.530 ≈ €323.48
Annual saving potential	€323.48 - €104.50 = €208.99

Table 5. 13 Annual cost and saving potential for article 8648202

As Table 5. 13 presents, Volvo Cars can save €208.99 annually, for transportation and packaging costs, for article 8648202 if UL is followed. When SQ is set smaller than UL, it will always lead to extra transportation and packaging cost for the company. Another example is presented in Table 5. 14 below. In this example, article 32291569 with package type V10 and sent via Ghent.

Article	32291569
Package type	V10
UL	150
SQ	8
X-dock/Consolidator	X-dock West Ghent
Annual Volume	6,584
Pallets (acc. UL)	6,584÷150 = 43.893
Pallets (acc. SQ)	6,584÷8 = 823
Annual cost (acc. UL)	43.893 ×29.274 ≈ €1,284.92
Annual cost (acc. SQ)	823 ×29.274 ≈ €24,092.32
Annual saving potential	€24,092.32 - €1,284.92 = €22,807.39

Table 5. 14 Annual cost and saving potential for article 32291569

.

For article 32291569, SQ is set to be much smaller than UL which naturally leads to more cost. As presented in table 16, saving potential for this article is €22,807 per year.

The annual cost and saving potential for other articles with relevant package types and sent to Chengdu via European XD and CC are presented in appendix D. The sum of annual saving potential for these articles is €234,688 in total. Note that this is a calculation of only 16 articles.

5.5. Reasons to why unit load is not followed

As presented in the previous subchapter 5.4, articles where shipping quantity (SQ) is less than unit load (UL) results in extra transportation and packaging cost for Volvo Cars. The question that remains is: if UL is set to optimize packaging and prevent articles damage, how come it is not followed for specific articles?

According to Supply Chain Controller of Volvo Cars in Chengdu, current demand is one of the factors that is relied on when setting SQ. Some articles have shelf life and have a UL that is too high. SCC suggests that packaging engineers should check the forecasts of the articles and lower UL for those that have lower demands.

As for articles where SQ is set higher than UL, Volvo Cars' senior manager of supply chain, believes that these articles are purchased with an MOQ or they are simply articles with high volume and therefore are frequently sent with full pallets. As mentioned in 2.6.2, MOQ is a requirement made by suppliers that means the order quantity must equal or more than a specified level if an order is placed. In addition, EOQ which is the ideal order quantity a company should order to minimize holding costs, shortage costs and order costs, is also considered. Due to both MOQ and EOQ, UL is set to optimize packaging but also to satisfy supplier's requirements and minimize the costs.

6. Discussion

The following chapter brings up various discussions regarding the results that are presented in chapter 5.

6.1. Chengdu factory vs. Charleston factory

As mentioned in subchapter 5.1, both Chengdu and Charleston factories were looked into in the beginning of this thesis work. At Charleston, the percentage of articles where shipping quantity is less than unit load is only 0.10 percent, while at Chengdu it is at 2.35 percent. According to Logistics Engineer of Volvo Cars, one of the reasons for this can be that the Chengdu plant is older than the Charleston plant. As mentioned in subchapter 4.1, Chengdu is Volvo Cars' first complete manufacturing factory outside Europe which can lead to this kind of problem due to the lack of experiences. Meanwhile, Charleston Plant started being built after Chengdu and Daqing Plants. Volvo Cars has possibly learned from previous experiences and because of that, Charleston factory had a better starting condition than Chengdu factory.

There are five years between when Chengdu and Charleston factories were built. However, under these five years many actions are performed in order to improve work methods as well as IT systems. Furthermore, it is usually easier to build something from ground up than repairing. Due to that, it is comprehensible that data deviations of unit load and shipping quantity occur more at Chengdu than Charleston.

6.2. Data deviation between VSIM och IBL DC

When it comes to *unit load*, VSIM sends this data to Newcast via IBL DC as mentioned earlier in subchapter 4.4.6 It means that data regarding unit load should be the same between VSIM and IBL DC applications. However, there are still some cases where the information differs as presented in subchapter 5.3.

The possible explanation is because of the system failures. In the VSIM extract there are different amounts of articles depending on the status of this article such as: New part, Incomplete, Partly approved, Approved, Estimated or Rejected (see Appendix C). Furthermore, the material's state can be MO or PP. MO means "Material Order" which is ordinary production (Logistics Engineer, Volvo Cars Corporation). PP means "Preseries" which is a test series that is run before ordinary production starts (Logistics Engineer, Volvo Cars Corporation). For instance, if Vovo Cars have a new variant of a car model and there may be only a few cars to be manufactured. Therefore, a special packaging may be needed just for those. In other words, PP is the state that is before MO. Because MO is the final packaging instruction, it should be followed.

In conclusion, when IBL DC retrieves information from VSIM regarding unit load, it should extract the data where its status is MO and 'Approved' if there are more than one option to choose from. Because of the different status of articles, data deviation can occur due to confusion of the system when extracting data. Since the exact reason behind this type of deviations is very unclear as it is an error that is unexpected and recently discovered during this thesis, it is difficult to discuss the impact it has on the company and come up with appropriate solution for this problem.

6.3. The dilemma of unit load vs. shipping quantity

There is a clear dilemma as to whether to set unit load (UL) to optimize packaging and safety or to set it according to the articles' demands. Unfortunately, there is no direct answer nor solution to this dilemma. Obviously, the data deviation occurs because of interest conflicts between different departments, in this case between packaging engineers and SCC. Demand is the main focus from SCC's side when it comes to setting shipping quantity (SQ), meanwhile packaging engineers set UL based on optimization of packaging and the safeness of the articles. As presented in chapter 2.5, it is difficult to fulfill requirements from various departments. However, the corporation's total costs and the environmental impacts should be considered anyway.

According to Manager of packaging engineering of Volvo Cars, cases where SQ is lower than UL is only temporary, and demand may increase again for these articles and therefore it is not ideal to redefine UL for these articles. The question is, should SCC follow unit load or not during these temporary decreases of demands? If SCC doesn't follow UL, then it will lead to extra cost as calculated in subchapter 5.4. However, if SCC follows UL, then it may lead to other costs such as inventory cost at the factory or articles with expired shelf life might be discarded.

Furthermore, it also depends on what type of articles we are looking at and how long these temporary decreases of demands last. It is difficult to apply a single solution to this dilemma since it appears to be different depending on the type of articles. Suggestions of appropriate solutions is presented in chapter 7.

6.4. Impact of data deviation on Volvo Cars and environment

As calculated in chapter 5.4.2, Volvo Cars can potentially save €208.99 annually for article 8648202 and €22,807 for article 32291569, if UL is followed. In other words, the difference between UL and SQ has a significant impact on Volvo Cars in terms of saving costs. However, the company also needs to consider the potential logistics costs such as inventory costs and administrative costs that can arise when ordering more than needed. This thesis is only focusing on the potential saving by following UL and due to that, the big picture of the problem is missing. Although, it is obviously a great amount of money that this is about. Therefore, the company should consider this identified problem and should implement some actions to fix it.

When it comes to the environment's aspect, unfilled and empty boxes is not a sustainable way of packing. In this case, articles are transported first from suppliers, in Europe, to consolidation centers/cross docks and thereafter forwarded to other factories in different continents. It is about long distances and because of that the carbon footprint is huge due to transportation. However, from the SCC's point of view, it is also not environmentally friendly to order more than needed since articles with expired shelf life are discarded. As a car manufacturing and global company, Volvo Cars can have a major impact on the environment. In consequence, every little thing should be considered to minimize the negative effects on the environment. Therefore, UL can be one of the things that the company may have to redefine to ensure that wastes are reduced.

7. Conclusions

The main purpose of this thesis is to identify and analyze the reasons behind data deviations regarding unit load between different applications at Volvo Cars. For some deviations, no exact reasons were identified as it has not been discovered before. Therefore, it is difficult to estimate the impact this type of deviation has on Volvo Cars and come up with an appropriate solution.

Regarding the issue with unit load and shipping quantity, the result indicates that data deviations occur more at Chengdu than Charleston factory. The possible explanation is that because Charleston is a newer factory than Chengdu. It has also been shown that data deviation takes place because of the different interests between different departments at Volvo Cars. On the one hand, SCC determines shipping quantity based on the current demand of the articles. On the other hand, unit load is set by packaging engineers in order to optimize packaging and to improve transport efficiency and safety. Furthermore, the minimum order quantity requirement from suppliers also plays a significant role when deciding unit load. However, it is understandable that this kind of requirement exists with the idea of long-distance transportation. Regarding the environmental aspect, it is neither environmentally friendly to send empty boxes or order more than needed due to the articles' shelf life. This conflict of interests is not uncommon today, especially in a big and global company such as Volvo Cars. Both departments have their strong arguments that should be considered.

When unit load is not followed, it affects the efficiency and safety of transportation, optimizing packaging and the environment. Moreover, it will also have an impact on Volvo Cars in terms of transportation, packaging and handling costs. Totally, the sum of annual saving potential for 16 articles is calculated to be around €235,000. The aim of this calculation is to display the potential costs due to this problem. However, these identified costs represent only the costs that arise because of ordering less than unit load which leads to empty boxes and unnecessary handling costs.

Even though packaging engineers have taken consumption rate into consideration when setting unit load, it still happens that sometimes the actual demand is different from the estimated demand. Therefore, the question that remains is if unit load is followed, how would it affect Volvo Cars, specifically the Chengdu factory? Ordering more than demand can lead to other problems and costs such as inventory costs and even worse throwing away some materials due to the ending of the produced car model or their limited shelf life. Therefore, it is important to evaluate and compare advantages and disadvantages of following and not following unit load. However, costs that occur at the Chengdu factory are not taken into account in this thesis and therefore not calculated. Therefore, it is difficult to know if following unit load is more cost beneficial for Volvo Cars. It is also difficult to draw a conclusion about whether following unit load will benefit the company or not in other aspects.

In conclusion, there are hundreds to thousands of euros for each order of articles that can be saved annually if unit load is followed. However, cases where unit load is set much higher than demand will lead to other problems instead. A proposal for the solution is that the company should take an extra look at those articles where unit load and shipping quantity differs a lot. Each article is unique with different demands and lifecycle. Therefore, it is more profitable to order more than demand (following unit load) in some occasions, but in other cases it may be better to order as much as needed. Another solution is to identify if the decreases of articles' demands are actually temporary by analyzing the order history or demand history of these articles and redefine unit load if needed. In any case, active communication and cooperation between packaging engineers and SCC should be greatly improved. Instead of focusing on each department's interests, the company's total profit should be the main focus when ordering materials.

Regarding other types of deviations that were identified, it is suggested that the company should research this type of error further to see if it affects the company negatively in any way. This could also be an interesting subject for future study and research.

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Appendices

Appendix A: Example of list of all orders to supplier

Example for article 32315091

Timestamp	System	Area	ValidFrom	Article	Plant	Dock	MFG	ShipFrom	Amount	PickupEarliest
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	268	2020-04-06 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	170	2020-04-20 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	296	2020-04-27 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	202	2020-05-04 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	226	2020-05-11 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	225	2020-05-18 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	449	2020-05-25 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	220	2020-06-08 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	279	2020-06-15 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	194	2020-06-22 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	245	2020-06-29 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	214	2020-07-06 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	89	2020-07-13 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	98	2020-07-20 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	144	2020-07-27 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	289	2020-08-03 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	257	2020-08-10 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	257	2020-08-17 08:00
2020-03-23	PLUS	CHD	2020-03-	3231509	CHN03	764-	A426C	A426C	197	2020-08-24

05:00			23	1		2DGV				08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	193	2020-08-31 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	232	2020-09-07 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	253	2020-09-14 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	238	2020-09-21 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	223	2020-09-28 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	240	2020-10-05 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	206	2020-10-12 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	213	2020-10-19 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	155	2020-10-26 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	196	2020-11-02 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	178	2020-11-09 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	106	2020-11-16 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	125	2020-11-23 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	116	2020-11-30 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	108	2020-12-07 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	242	2020-12-14 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	239	2020-12-21 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	268	2020-12-28 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	231	2021-01-04 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	176	2021-01-11 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	198	2021-01-18 08:00
2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	260	2021-01-25 08:00

2020-03-23 05:00	PLUS	CHD	2020-03-23	32315091	CHN03	764-2DGV	A426C	A426C	205	2021-02-01 08:00

Appendix B: Articles with relevant package types and via Europe CC

Articles sent to VCCD via Bulycke

Article no.	UL	SQ	Package type	Consolidator
8648202	72,000.00	24,000.00	V81	Volvo Consolidator Bulycke
981743	48,000.00	12,000.00	V84	Volvo Consolidator Bulycke
31333045	32,000.00	2,000.00	V81	Volvo Consolidator Bulycke
31349218	1,600.00	100.00	V10	Volvo Consolidator Bulycke
32262812	1,000.00	500.00	V10	Volvo Consolidator Bulycke
8672278	1800	1500	V10	Volvo Consolidator Bulycke
32234409	10,000.00	2,000.00	V11	Volvo Consolidator Bulycke

Articles sent to VCCD via Ghent

Article no.	UL	SQ	Package type	X-dock / Consolidator
31469769	384.00	100.00	V84	Volvo Cars XD EAST CZ c/o DHL (*)
31430937	1,760.00	264.00	V84	Volvo Cars XD MAINTAL c/o DHL (*)
31430015	960	320	V83	Volvo Cars XD HERNE c/o Duvenbeck (*)
31417623	12	10	V82	Volvo Cars XD EAST CZ c/o DHL (*)
31109041	800.00	400.00	V10	EU X-Dock West GENT
32291569	150.00	8.00	V10	EU X-Dock West GENT
32279964	42.00	8.00	V10	EU X-Dock West GENT
32279976	42	8	V10	EU X-Dock West GENT
31417621	12	10	V11	Volvo Cars XD EAST CZ c/o DHL (*)
32298336	11.00	4.00	V12	EU X-Dock West GENT
32279982	42.00	32.00	V10	EU X-Dock West GENT

(*) Articles sent via these cross-docks are eventually going through Ghent.

Appendix C: Example of VSIM data extract

* Note that not every column is included in this example due to lack of space. The relevant columns are marked with red color, i.e. PLANT, ORD and STATE.

NUMBER	NEWIN	INTRW	NAME	PSS	PLANT	ORD	REQ	PE RESP	ID	S	STATE	SUPPLIER	LC	UL
81000			-		CHN03	EE	TBD	TBD	TBD	N	New Part	FIKTI		
191391	7089	198928	SPRING NUT-ST4,8*1	600	CHN03	MO	YES	yluo19	PI-A25F	P	Approved	B4V0A	K11	50400
192248					CHA03	PP	NO	NA	PI-B4M7	T	Incomplete	FIKTI		1
590037	Y413	200846	WASHPRIMER-TYPE 2	280	CHN03	PP	NO	yluo19	PI-A2BK	I	Partly_Approved	FIKTI	V2	16
590037	Y413	200846	WASHPRIMER-TYPE 2	280	CHA03	PP	NO	NA	NA	E	Estimated	FIKTI		
598041	V331	202007	GLYCERINE-	830	CHN03	PP	NO	yluo19	PI-A22C	I	Partly_Approved	FIKTI	V2	4
945626	7089	198928	SPRING NUT-ST4,8*3	660	CHA03	MO	YES	cstaweck	PI-A27C	P	Approved	B4V0A	V10	7000
945626	7089	198928	SPRING NUT-ST4,8*3	660	CHN03	MO	YES	yluo19	PI-A29X	P	Approved	B4V0A	V10	7000
948211	7089	198928	CABLE TIE-73	0	CHA03	MO	NO	NA	NA	N	New Part	AEKIX		
948555	E191	199140	EARTH CABLE-280	0	CHN03	PP	YES	yluo19	PI-A27E	P	Approved	BK6LB	V10	600
949386	313C	201346	CLAMP-17	330	CHN03	PP	YES	yluo19	PI-A2DF	T	Rejected	AD6DO	T65	6000
949921	P066	199713	SPRING NUT-M6	50	CHN03	PP	YES	yluo19	PI-A29V	P	Approved	B4V0A	K11	18000
949937	7089	198928	SPRING NUT-M5	0	CHN03	PP	NO	yluo19	NA	N	New Part	B4V0A		
952626	7089	198928	CLAMP-11,1	0	CHN03	PP	NO	yluo19	PI-A2BT	I	Partly_Approved	AD6DO	T62	18000
952635	7089	198928	CLAMP-25,4	0	CHN03	PP	NO	yluo19	PI-A22H	P	Approved	FIKTI	B1	1
961613	ANNU	198928	WELD NUT-M6*5	0	CHN03	PP	YES	yluo19	PI-A28S	P	Approved	C84HA	T3	60000
966883	7089	198928	WELD NUT-UT6*5	0	CHN03	PP	NO	yluo19	PI-A2A7	P	Approved	C84HA	K12	120000
966883	7089	198928	WELD NUT-UT6*5	0	CHN03	MO	YES	yluo19	PI-C4GV	P	Approved	AEAL8	K11	45000

Appendix D: Examples of annual cost and annual potential saving

Note: Articles sent via XD EAST CZ, XD MAINTAL and XD HERNE are going through Ghent before going to Chengdu.

Article nr	UL	SQ	PT	x-dock / consolidator	Annual volume	Pallets (UL)	Pallets (SQ)	Annual cost (UL) (€)	Annual cost (SQ) (€)	Annual saving (€)
8648202	72,000	24,000	V81	Volvo Consolidator Bulycke	273290	3.796	11.387	104.49	313.48	£208.99
981743	48,000	12,000	V84	Volvo Consolidator Bulycke	123305	2.569	10.275	152.20	608.78	456.59
31469769	384	100	V84	Volvo Cars XD EAST CZ c/o DHL	4251	11.070	42.510	758.53	2,912.74	2,154.21
31430937	1,760	264	V84	Volvo Cars XD MAINTAL c/o DHL	7916	4.498	29.985	308.18	2,054.53	1,746.35
31333045	32,000	2,000	V81	Volvo Consolidator Bulycke	67939	2.123	33.970	58.45	935.18	876.73
31430015	960	320	V83	Volvo Cars XD HERNE c/o Duvenbeck	7916	8.246	24.738	461.89	1,694.99	1,233.10
31417623	12	10	V82	Volvo Cars XD EAST CZ c/o DHL	3464	288.667	346.400	12,560.18	15,072.21	2,512.04
31109041	800	400	V10	EU X-Dock West GENT	273290	341.613	683.225	10,000.29	20,000.57	10,000.29
31349218	1,600	100	V10	Volvo Consolidator Bulycke	40635	25.397	406.350	703.15	11,250.42	10,547.27
32291569	150	8	V10	EU X-Dock West GENT	6584	43.893	823.000	1,284.92	24,092.32	22,807.39
32279964	42	8	V10	EU X-Dock West GENT	34431	819.786	4303.875	23,998.22	125,990.66	101,992.44
32262812	1,000	500	V10	Volvo Consolidator Bulycke	34683	34.683	69.366	960.25	1,920.50	960.25
32279976	42	8	V10	EU X-Dock West GENT	13616	324.190	1702.000	9,490.28	49,823.96	40,333.68
32234409	10,000	2,000	V11	Volvo Consolidator Bulycke	136645	13.665	68.323	312.98	1,564.90	1,251.92
32298336	11	4	V12	EU X-Dock West GENT	6544	594.909	1636.000	14,646.58	40,278.10	25,631.52
32279982	43	32	V10	EU X-Dock West GENT	54983	1309.119	1718.219	38,322.85	50,298.75	11,975.89

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