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Data-Driven Analysis and Evaluation of Regional Warehouse Operations for an Automotive Spare Parts Wholesaler

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Abstract

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The objective of this thesis was to analyse and improve the operations of regional warehouses belonging to a Finnish automotive spare parts wholesaler. The study focused on inventory control, product range, and the processes of the regional warehouses. The study is based on data from the company's ERP systems, including sales, internal transfers, and replenishment records. The theoretical foundation was formed by studying literature on supply chain management, inventory control, warehousing, lean practices, and spare parts logistics.

The results show that there are inconsistent warehouse processes and issues with data that reduce the reliability of analysis and decision-making. To improve operations, the thesis recommends improving and standardising item group structures, collecting stock and product range data more systematically, and applying advanced classification methods to support the replenishment processes. Standardised processes for all regional warehouses are also proposed to improve comparability. Further analysis of the best-performing warehouse is suggested to identify transferable best practices.

Keywords: Automotive Spare Parts

The originality of this thesis has been checked using Turnitin Originality Check service. Grammarly has been used to finalise the language. As the author of this thesis, I am responsible for all of the content.

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1 Introduction

Automotive spare parts logistics is complex and costly. Companies manage many products with unpredictable demand, as parts are only needed when something breaks. Customers expect fast deliveries even for rare items. Regional warehouses help improve availability, but they also add complexity and costs.

1.1 Objective

The objective of this thesis is to evaluate and improve the efficiency of regional warehouse operations within a Finnish automotive spare parts wholesaler. The goal is to identify key issues related to inventory levels, product range, and order fulfilment and to propose practical improvements that balance service level and inventory costs across the warehouse network.

1.2 Scope

This thesis focuses on the company's ten-warehouse distribution network, consisting of one central warehouse and nine regional warehouses. The analysis is limited to spare parts that are physically handled and stored in the regional warehouses, excluding direct supplier orders.

1.3 Methodology

The study combines theoretical research on supply chain management, inventory control, and warehouse strategies with empirical data analysis. Weekly sales and replenishment data were collected and pre-processed to enable comparisons across regions. Demand classification techniques (ABC, volume-based, urgency-based) were used to analyse product range effectiveness. Customer input was gathered through a questionnaire to understand which product groups are urgently needed.

2 State of the Art

2.1 Supply Chain Management

A supply chain is a network of organisations that connect the original material suppliers to the customer purchasing the final product or service. In addition to the movement of products or services, the supply chain includes the flow of finances and information both upstream and downstream. (Sople, 2011)

Supply Chain Management (SCM) is the coordinated management of all activities involved in the supply chain. Its focus is improving the supply chain's competitiveness. SCM integrates business functions both within a company and across organisations to improve efficiency and achieve competitive advantages. (Stadtler and Kilger, 2007)

SCM involves close collaboration with stakeholders, including suppliers, distributors, third-party service providers, and customers. SCM ensures that everyone works together to run operations well, share risks, and keep good, long-term relationships. Good SCM improves the movement of goods and also helps with communication and coordination across the supply chain.

2.1.1 Key Components of SCM

The SCM of a single company can be split into three parts: procurement, production, and distribution. In addition, a key component of the supply chain is logistics. It connects all the different parts of the supply chain. (Sople, 2011)

2.1.1.1 Procurement

Procurement is the process of managing the flow of inbound materials by creating a connection between the company and its suppliers. It involves planning and coordinating schedules between the buyer and suppliers to keep and develop better and more optimised material flow. Modern procurement often uses co-

makership, where suppliers and buyers work together to cut costs instead of passing them along. This approach usually means partnering with a smaller group of suppliers, allowing companies to form stronger relationships. With fewer suppliers, managing and improving quality and efficiency is easier. (Sople, 2011)

Also, integrating systems like materials requirement planning (MRP) and electronic data interchange (EDI) can help companies streamline operations, reduce lead times, and cut costs in the supply chain. This approach views suppliers as part of the customer's own work, building long-term, collaborative relationships. (Sople, 2011)

2.1.1.2 Production

Production is generally seen as the process of manufacturing goods; this is correct for manufacturing companies. In an importing and distributing company, the focus shifts towards coordinating with suppliers to maintain flexibility and responsiveness to changing market demands. Flexibility here involves securing various products from manufacturers in quantities that match demand without costing too much. Demand forecasting and order planning are essential; they allow the company to balance stock levels to optimise responsiveness and cost. (Sople, 2011)

2.1.1.3 Distribution

Distribution in supply chain management (SCM) is more than transportation and warehousing; it is about managing demand effectively. Successful distribution relies on the flow of information, which includes medium-term forecasts, customer usage data, production schedules, inventory status, and marketing activities. Instead of relying on forecasts that can be wrong, companies should aim to reduce this dependence by improving demand information and creating supply chains that can respond quickly. This quick response approach helps cut costs and improves customer service by matching supply with up-to-date consumption data. (Sople, 2011)

2.1.1.4 Transportation and Logistics

Logistics is considered a critical enabler of supply chain management, effectively bridging the gap from sources of supply to the market demand. It ensures a smooth flow of products and information by properly coordinating important parts of the supply chain, such as warehousing, transportation, inventory control, and information systems. Logistics aims to deliver the right product at the right time, at the right place, and at the lowest possible cost, balancing the demands of customer service with cost efficiency. (Sople, 2011)

Effective logistics management reduces inventory levels and accelerates the movement of inventory while providing reliability and consistency for product delivery. Logistics is important in integrating supply chain operations and aligning them with customer needs for cost reduction and higher customer satisfaction. Logistics innovations, coupled with tight coordination with suppliers and advanced information technology, provide faster replenishment cycles, flexible manufacturing, and better asset utilisation. (Sople, 2011)

With globalisation, logistics becomes even more important since companies are sourcing products from across the globe and trying to meet growing customer demand while minimising costs and wasting less time. Logistical operations are, therefore, essential for supply chain success and a determining factor in the capability to stay competitive in global markets. (Sople, 2011)

2.1.2 KPI

Key Performance Indicators (KPIs) are important tools that help managers understand how their business is performing. With the right KPIs, managers can get a clear picture of the areas that are performing well and those that need improvement. Good managers can split their business into essential KPIs to make better decisions. Without a good understanding of these metrics, managers may feel uncertain and make poor decisions. (Marr, 2012)

2.1.2.1 SMART KPIs

The SMART framework, introduced by Doran in 1981, is a structured approach used for setting effective goals and objectives. According to the SMART framework, objectives should be Specific, Measurable, Assignable, Realistic, and Time-related. Doran highlights the importance of clarity in goal setting, and he also states that all objectives do not need and will not have every SMART criteria. Since the 1980s, the SMART framework has gained popularity and has been used across many different industries (Ashford and Mercer, 2013).

While the SMART framework was originally introduced as a way to write goals and objectives, its principles also work for KPIs. The modern meaning of SMART has shifted to Specific, Measurable, Achievable, Relevant, and Time-sensitive. Table 1 provides an explanation and an example for each of the modern criteria. (Parmenter, 2007)

Criteria	Explanation	Example
Specific	A clear KPI states what needs to be achieved in simple terms.	Process all orders within 2 hours.
Measurable	A KPI must be quantifiable. If a measure is not obvious, it is not a strong KPI.	Deliver 98% of the orders on time.
Achievable	A KPI should be realistic and actionable for staff.	Improve inventory accuracy from 90% to 95%.
Relevant	The KPI must be directly tied to key operations.	Fill outbound shipping containers at least 85% to cut costs.
Time-sensitive	A KPI should focus on immediate and ongoing priorities.	Fix 95% of picking errors within 24 hours.

Table 1. SMART framework. (Parmenter, 2007)

Only using the SMART framework is not enough for good KPIs. A KPI can be specific, measurable, achievable, relevant, and time-sensitive, but it may be useless or even harmful if it does not link to critical business success factors. Some KPIs drive the wrong behaviours, making employees focus on hitting numbers instead of real improvements. (Parmenter, 2007)

Breaking down KPIs into smaller parts for different teams often creates disconnected goals that do not support the big picture. Expecting teams to create KPIs without training leads to poor measures, and a top-down KPI setting by a few specialists often fails because it ignores real operational needs. Tying KPIs to pay encourages people to game the system instead of working toward real progress. Instead of just being SMART, KPIs should be well-connected to business priorities and used for improvement and not just as targets. (Parmenter, 2007)

2.1.2.2 Common Supply Chain KPIs

There are countless supply chain KPIs to choose from, making it challenging to select the right ones. Businesses should select a small set of the most important KPIs and focus on implementing them in the best way. Table 2 covers some of the most important KPIs and their descriptions. (Chae, 2009)

Category	KPI	Description
Planning	Forecast Accuracy	Measures the accuracy of demand forecasting.
	Planning Cycle Time	Tracks how often planning processes happen.
	Total Inventory Days of Supply	The number of days inventory is expected to last.
	Cash to Cash Cycle Time	Time taken to recover cash from inventory investments.
Sourcing	Supplier Fill Rate	Supplier reliability to deliver on time and in full.
Manufacturing	Order Fill Rate	Percentage of orders that are fulfilled with stock on hand.
Transportation	Freight Cost per Unit	Transportation cost relative to the number of units.
Inventory	Inventory Turnover Ratio	How often inventory is sold and replaced.
	Stockout Rate	The percentage of demand not fulfilled due to stock unavailability.
	Inventory Accuracy	Recorded inventory compared to actual inventory.
	Obsolete Inventory Rate	The percentage of obsolete or unsellable inventory.
	Order-to-delivery Time	Time taken from order placement to delivery.
	Safety Stock Level	Additional inventory held as a buffer.
	Carrying Cost of Inventory	Total cost of holding inventory.

Table 2. Common Supply Chain KPIs. (Chae, 2009; Putra, Sriwana and Amani, 2024)

There are five main categories for different SC KPIs: planning, sourcing, manufacturing, transportation and inventory. For example, for a company that wants to keep a low inventory level, Forecast Accuracy and Supplier Fill Rate would be suitable KPIs alongside inventory KPIs such as stockout rate. These KPIs help the organisation measure demand forecasting accuracy and supplier delivery reliability. (Chae, 2009)

2.2 Inventory Management

Inventory management is about tracking, controlling, and optimising inventory to ensure availability while minimising costs and avoiding overstock or stockouts. It involves demand forecasting, ordering, storage, and distribution. The primary goal of inventory management is to reduce the average cost of the inventory system while keeping at least the minimum level of service. It ensures that a company always has the correct inventory in the right quantities, at the right time, and at the correct cost. Inventory can be categorised into different types, using many different classifications. (Kordic, 2008)

Inventory is held for three primary reasons: time, uncertainty, and economies of scale. Moving goods along a supply chain requires time. Once an order is placed, there is usually a lead time before the goods are received. Excess inventory can be used during these delays. For example, demand and supply fluctuations can cause uncertainty in the supply chain. Maintaining inventory acts as a safeguard against these uncertainties. By purchasing, transporting, and storing goods in bulk, businesses can lower unit costs, this strategy requires maintaining higher inventory levels as a trade-off. (Rossi, 2021)

Inventory is a current asset on the balance sheet because it can be sold and converted into cash. Holding inventory ties up the acquiring cost of the inventory, also storing the inventory has costs. This money could be used more efficiently somewhere else in the company. Figure 1 shows a basic inventory system presented in a simplified way with three elements: supplier, warehouse and customer. (Rossi, 2021)



Figure 1. Simple inventory system (Rossi, 2021).

The warehouse fulfils customer demand by issuing items from the inventory. This is only possible if there is sufficient inventory at hand. The warehouse maintains its inventory levels by placing orders for the supplier. The process where inventory quantities are assessed on hand by managers is called an inventory review. (Rossi, 2021)

2.2.1 ABC Analysis

ABC analysis is an inventory categorisation method that classifies items into three categories based on their value and frequency of use. The ABC inventory control technique operates on the principle that a small percentage of items often account for most of the revenue, while many of the items contribute minimally to the revenue. Category A consists of the most valuable items, these items are around 20% of the product selection and they make around 80% of the revenue. Category B has the middle section, making around 15% of the revenue with around 30% of the selection. C Category has the lowest sales but the most products, around 50% selection, making only 5% of the revenue. This classification helps to apply the correct control measures to each category and optimise inventory management. (Kavitha, Kandeepan and Narmadha, 2016)

High-value A-items require tight control and should be managed by experienced personnel, whereas low-value C-items can be managed with less oversight, as their lower value and high quantity make strict oversight unnecessary. This method directs management's focus toward the most critical inventory items rather than the less significant ones. ABC analysis also helps maintain inventory

turnover rate, reduces storage and carrying costs by lowering overall inventory levels. (Kavitha, Kandeepan and Narmadha, 2016)

ABC analysis accuracy in predicting inventory needs can be affected by product demand and price fluctuations since it does not account for this. XYZ analysis can be used to extend ABC analysis by evaluating demand fluctuations. Each ABC category is split into X, Y, and Z, based on a 20%:30%:50% ratio. X-category consists of materials with stable or rarely fluctuating demand, making scheduling and forecasting highly accurate. Y-category includes materials with moderate fluctuations in demand, often due to seasonality or product trends, making scheduling and forecasting moderately reliable. Z-category contains materials with highly irregular demand, making forecasting and scheduling difficult. The ABC-XYZ field matrix enhances inventory control and is useful when demand fluctuations are significant, and consumption is high. This combined method results in improved inventory management and better decision-making. (Pandya and Thakkar, 2016)

2.2.2 Push vs. Pull Inventory

A push system controls production and inventory movement based on a set schedule rather than responding to real-time demand. Materials are supplied to a department or location as scheduled by the source rather than being requested by the receiving location. (Sople, 2011)

In a strict push system, goods are sent directly to distribution points without waiting for specific demand signals, which are typically based on predetermined distribution rules. When supply cycles are long and transportation times are short, it can be better to keep some reserve stock centrally. A modified push system may involve storing safety stock at a central warehouse to address potential shortages at distribution centres. Management of a push system requires access to comprehensive data on demand and inventory levels across the network. (Stadtler and Kilger, 2007)

A pull system initiates production or inventory movement only when required by the downstream location. Unlike a push system, inventory movement does not follow a preset schedule but real-time consumption or demand signals. When stock at the source is sufficient, orders are fulfilled accordingly. If supply is limited, inventory is allocated based on demand and existing stock levels. (Stadtler and Kilger, 2007)

Distributing the stock this way across locations helps maintain service levels until the next replenishment. Some locations may receive less products than their actual needed amount, and there might be a need for transfers between distribution points. In a pull system, transportation is initiated only when inventory at a location drops to a predefined reorder point. (Stadtler and Kilger, 2007)

A push-pull strategy uses both push and pull systems at different points in the supply chain. The reorder strategy at any given stock point within the distribution network can follow either a push or pull model. For instance, a supplier may push inventory to a distribution centre, which then supplies retailers based on either a push or pull approach. (Kordic, 2008)

2.2.3 Just-in-Time

Just-in-Time (JIT) is a production and inventory management philosophy that aims to make sure that items and resources arrive precisely when they are needed. Its goals are to eliminate waste, lower the cost of keeping inventory, and increase operational efficiency. JIT was originally developed at Toyota in the 1950s and popularised in the 1980s, nowadays JIT is in use in many industries, including automotive, manufacturing, and logistics. JIT is traditionally seen as a philosophy for production, but it can and should be applied to the whole supply chain. (Alcaraz and Macías, 2015)

2.2.3.1 Benefits of JIT

The Just-In-Time philosophy has a lot of important advantages that improve financial performance and operational effectiveness. One major advantage is lower inventory costs. Reduced stock levels lead to smaller storage expenses, decreased risk of inventory obsolescence, and free up capital tied in inventory. With less capital tied in inventory, the company has more cash flow to invest in other areas. (Alcaraz and Macías, 2015)

JIT also helps with quality control, using smaller frequent deliveries allows quality issues to be identified and corrected quicker. JIT allows for faster response to market changes, making it possible for the company to quickly shift its supply based on current demand and customer preferences. (Alcaraz and Macías, 2015)

2.2.3.2 Challenges and Limitations of JIT

While Just-In-Time has a lot of great benefits, it also comes with some challenges that businesses need to be aware of. One of the biggest challenges is supplier reliability. Since JIT depends on materials arriving exactly when they are needed, any delay can bring everything to a standstill. If suppliers are not dependable, the whole system falls apart. (Alcaraz and Macías, 2015)

Another limitation is the lack of buffer stock. Because JIT keeps inventory levels low, there is very little room for error. If demand suddenly spikes or a shipment is delayed, companies do not have extra stock to fall back on. JIT is also vulnerable to more significant external risks. Natural disasters, geopolitical instability, and global supply chain disruptions can all impact the availability of materials, causing delays. These unexpected events can cause serious problems for a company using JIT that does not have backup suppliers and plans in place. (Alcaraz and Macías, 2015)

2.2.4 Total Cost of Ownership

Total Cost of Ownership (TCO) is a structured approach for evaluating all costs linked to acquiring and using a product or service from a supplier (LaLonde and Pohlen, 1996). It goes beyond the initial purchase price, offering a more comprehensive view of expenses, including freight, inventory, tooling, tariffs, currency exchange fees, maintenance, and potential costs from supplier underperformance. TCO is not a new concept, and many companies use it to focus on strategic cost management and to stay competitive. (Wisner, Tan and Leong, 2012; Cavinato, 2006)

TCO also helps companies assess how inter-firm relationships impact costs within the purchasing firm, providing valuable insights for decision-making (LaLonde and Pohlen, 1996). Firms can also use total cost analysis as a negotiation tool to highlight areas where suppliers need to improve. One of the biggest challenges with TCO is identifying the cost drivers that truly determine the total cost of ownership. (Wisner, Tan and Leong, 2012)

TCO can be grouped into three categories: pre-transaction, transaction, and post-transaction costs. Pre-transaction costs occur before an order is placed and received, including expenses for supplier certification, training, and evaluating alternative suppliers and delivery options. Transaction costs cover the direct costs of purchasing and receiving goods or services, such as the purchase price, order processing, and delivery costs. Post-transaction costs arise after the goods have been delivered, including warranty claims, maintenance costs, reputational damage from product failures, and service expenses. (Wisner, Tan and Leong, 2012; Cavinato, 2006)

TCO can also be grouped into explicit and hidden costs. Explicit costs include purchasing, installation, maintenance, spare parts, energy consumption, transportation, and disposal. Hidden costs can significantly impact total expenses. These include labour costs for dispensing and refilling, floor space

usage, lost sales due to service delays, and the cost of training and maintenance throughout the product's lifecycle. (Caniato et al., 2015)

2.2.5 Economic Order Quantity

Economic Order Quantity (EOQ) is the order quantity that minimises the balance between inventory holding costs and reorder costs. It is necessary to make some assumptions to easily calculate EOQ, the demand must be uniform and continuous over time. Orders must have a constant lead time, and there can be no capacity restrictions on order size. The order size does not affect the cost of placing an order, and holding costs remain unaffected by stock quantity. EOQ is good for maintaining an optimal inventory level and ensuring cost efficiency in stock management. (Agarwal, 2014)

$$EOQ = \sqrt{\frac{(2 \times D \times S)}{H}} \quad (1)$$

D = Demand (units per year)

S = Ordering cost per order

H = Holding cost per unit per year

The probabilistic EOQ model can be used in situations where both demand and lead time are fluctuating. Using the probabilistic EOQ model requires calculating safety stock. By accounting for uncertainty, the model is more accurate than the basic EOQ model, this improves order planning and helps prevent stockouts. (Istiningrum and Munandar, 2021)

2.2.6 Reorder Point and Safety Stock

The reorder point (ROP) is a stock level of an item, where an order must be placed to replenish stock. It represents the stock level required to cover demand during the lead time of replenishment. The reorder point is calculated by multiplying the daily usage (d) with the lead time (TL). (Senthilnathan, 2019)

$$ROP = d \times T_L \quad (2)$$

If the inventory falls at or below the reorder point, a replenishment order is made to restore stock to the order-up-to level. If demand stays steady and an order is placed only after the stock goes under the reorder point, a shortage occurs. Inventory control helps mitigate the risk of a stockout by ensuring enough stock is available for the demand during the lead time. (Silver, Naseraldin and Bischak, 2009) Safety stock is used as a buffer against fluctuations in demand and delays in lead times. The safety stock level depends on demand variability, lead time uncertainty, and the wanted service level, and it can be calculated using different models. Safety stock (S) can be factored into the reorder point calculation by simply adding the safety stock after multiplying the daily usage and lead time. (Senthilnathan, 2019)

$$ROP = d \times T_L + S \quad (3)$$

Figure 2 shows the stock level over time.

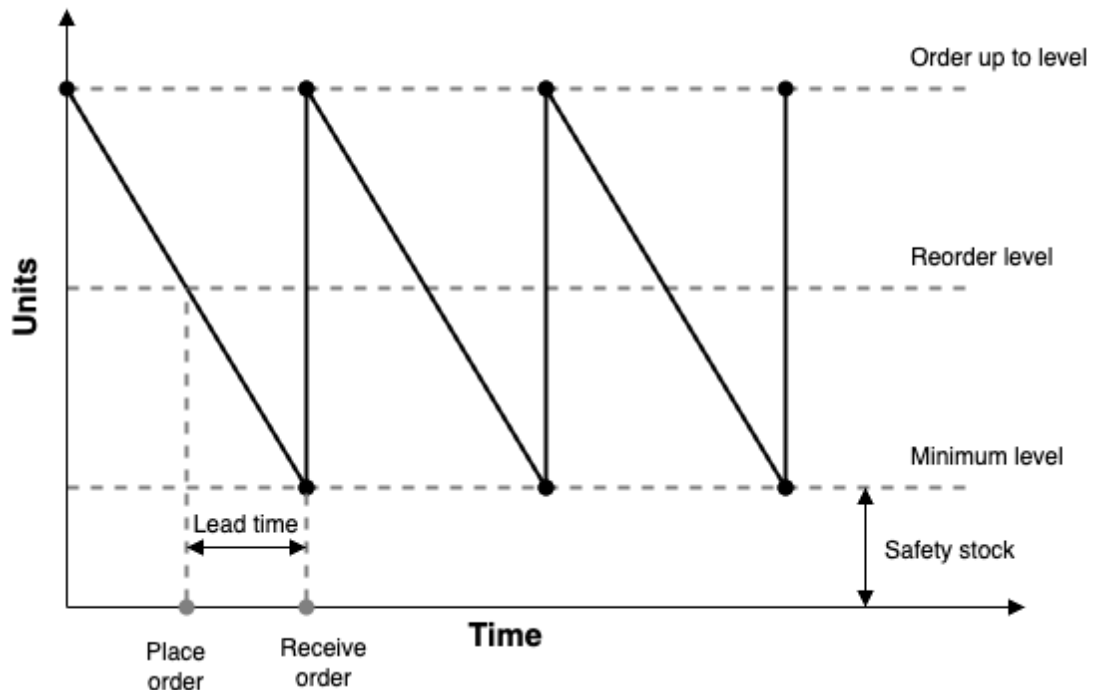


Figure 2. Stock level over time (Senthilnathan, 2019).

The maximum stock level is the sum of the safety stock and the order quantity. When inventory reaches the reorder point, a new purchase order is placed. The safety stock ensures that orders can still be fulfilled while waiting for the replenishment to arrive. Once the new stock is received at the warehouse, the inventory level rises to the order up to level, and the cycle repeats. (Senthilnathan, 2019)

2.2.7 Demand Forecasting

A demand forecast is a prediction of the future demand for products. The main benefit of demand forecasting is improved inventory planning. The forecast is often done by analysing historical sales data using statistical models. Many other factors also influence a product's demand, market trends, economic conditions, and other external factors. Some of these external factors can be used as dependencies in the forecast, for example the demand for ice cream is heavily linked to the weather. Other factors can be accounted for by market research and expert judgment. (Axsäter, 2015)

Since predicting the future is still only guessing, there are many mistakes to be made. It is important to determine how uncertain the forecast is and adjust planning accordingly. One systematic error in demand forecasting is that the previous sales do not necessarily reflect the actual demand. It is hard to measure actual demand, so sales data is used. If there is a previous lost sale because of a lack of inventory, the sales are not equal to the demand. Machine learning, advanced analytics, and real-time data tracking can be used to help make demand forecasting more accurate. (Axsäter, 2015)

2.3 Warehousing

Warehousing is one of the most essential and critical logistics activities in both industrial and service sectors. It is essential in many industries, from automotive and tile manufacturing to food production, healthcare, and service sectors like

banking, universities, and hospitals. Warehousing has the same mission as logistics: to ensure products are delivered to the right place, at the right time, and in the correct quantity without damaging the goods. (Manzini, 2012)

Warehousing is often associated with high costs and inefficiencies, but in reality, most industries have to rely on warehousing in some capacity to function at all. Customers expect their orders to be fulfilled immediately. Since it is impossible to predict exactly when and how much of a product will be needed, businesses must keep stock to be ready for sudden demand. Warehousing is also need for enabling access to distant markets. As the variety of goods increases, businesses face a growing demand for smaller, more frequent orders with faster delivery times, this can be made possible with local warehouses. These customer demands make logistic service levels an important part of supplier selection. (Hompel and Schmidt, 2006)

As globalization and offshore sourcing have become the standard, efficient supply chain management is more critical than ever. A global supply chain needs a strong logistics system to ensure goods move efficiently across borders. Warehousing is a key strategic factor in global operations, directly influencing costs, supply chain performance, and overall competitiveness. (Manzini, 2012) Warehouse location and design are an important part of optimising operations and performance. (Sople, 2011)

2.3.1 Functions in Warehouses

The main functions of a warehouse are to store products, to assemble customer orders, to add value to the orders by customisation, to organise transport to the customers and to ship orders to the customer. In a typical warehouse, material flows through the functions of receiving, put-away, storage, order picking, and shipping. These functions are pictured in Figure 3 and explained in greater detail in the following sections. (Manzini, 2012)

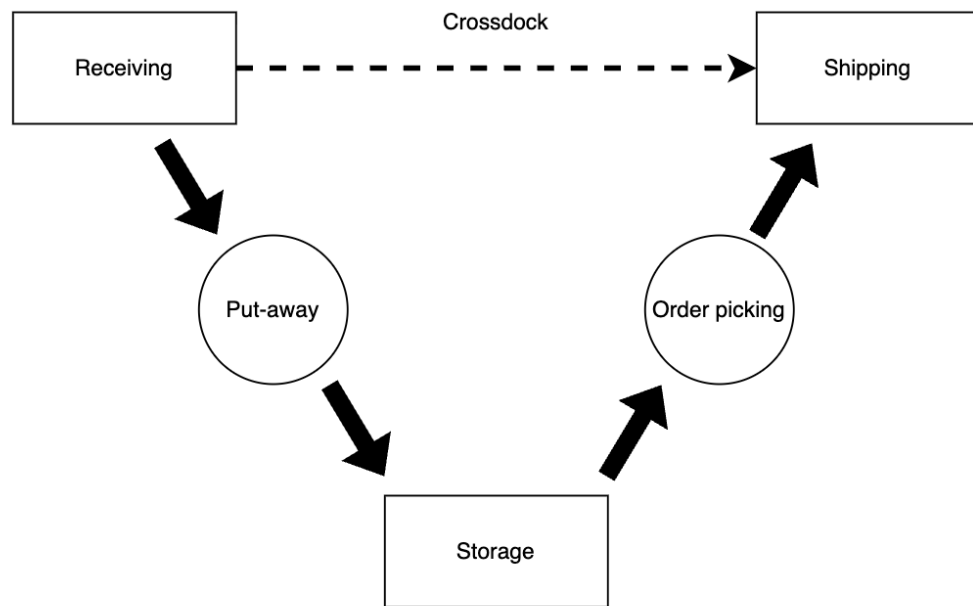


Figure 3. Warehouse functions (Hompel and Schmidt, 2006).

2.3.1.1 Receiving

Receiving is the process of handling materials as they first arrive at the warehouse. The process begins with verifying that the delivered goods are the correct goods. This check is done by comparing the delivery note to the original order and by a physical inspection. During the initial physical check, the unloading staff inspects the type, quantity, and quality of the delivered goods. (Hompel and Schmidt, 2006)

After the initial inspection some of the items can go to further quality control done by quality assurance personnel according to company guidelines. These inspections can range from a simple visual check to laboratory testing of samples or even a full-scale quality control process. Any faulty goods found are marked and handled depending on the company's policies and agreements with suppliers. (Hompel and Schmidt, 2006)

2.3.1.2 Put-Away

Once all the required inspections are passed, the goods are ready for storage. Put-away is the process of moving and placing these materials into their designated storage locations within the warehouse. (Manzini, 2012)

Before putting the goods to storage, back orders must be checked since if certain items are needed immediately, they can be transported directly to the point of consumption or the shipping area instead of being stored. This process is often called split-lot storage, where only a portion of the received goods is stored while the rest is directly used or shipped. (Hompel and Schmidt, 2006)

A related concept is cross-docking, it describes a broader and more extensive logistics strategy. In cross-docking, goods receipts and dispatches are synchronised so that incoming shipments do not go to storage at all and are transferred directly to the shipping department. (Hompel and Schmidt, 2006)

2.3.1.3 Storage

Storage is the act of physically housing materials until they are needed. Unit load systems and small load systems are the two primary warehouse storage system classifications. Unit load systems are designed for large items like full pallets and oversized boxes. On the other hand, small load storage systems are used for smaller items like plastic bins, cartons, or individual product components. Each system is chosen based on the size and handling requirements of the stored materials. (Hompel and Schmidt, 2006)

The storage location of an item determines where it is placed within the warehouse. Factors such as item size, demand frequency, and handling requirements influence storage placement. A well-organised storage system minimises retrieval time, uses less space, and improves warehouse efficiency. (Hompel and Schmidt, 2006)

2.3.1.4 Order picking

Order picking is the process of retrieving items from storage to collect a specific customer order. Order picking includes collecting specific items from larger storage units, combining them, and preparing them for shipment. This process might include packaging items together to match order requirements. (Manzini, 2012)

Order picking is one of the most expensive functions in a warehouse. In a typical warehouse, it accounts for 55% of costs (Tompkins, 2010) because of its labour intensity. It should be seen as one of the most important functions to improve efficiency on. A picker's productivity is influenced by four key factors: basic time (order acceptance, document sorting, and preparation), gripping time (retrieving and handling items), idle time (searching, verifying, and processing), and way time (moving between pick-up and transfer points). The total of these is called picking time, which depends on order complexity, system structure, and storage organisation. (Hompel and Schmidt, 2006)

Order picking can be categorised based on the type of retrieval units. Pallet picking is typically performed in unit load storage systems, case picking can be done from pallet storage, bulk storage, or case storage systems. Broken case picking, is done in small load storage systems, by selecting individual items from cartons or bins. (Manzini, 2012) Order-picking systems can also be split into two categories based on whether the picker moves to the product or the other way around. In a picker-to-stock system, the picker goes to the storage location for each item to retrieve them. In a stock-to-picker, the item or the storage location is mechanically brought to the picker. Stock-to-picker is often faster and increases efficiency. However, it requires automation, which often comes with a bigger initial investment. (Hompel and Schmidt, 2006)

2.3.1.5 Shipping

The shipping function can be seen as the final steps before the orders leave the warehouse. The picked orders are grouped, checked for completeness, and packed, after which they are loaded onto transport vehicles. Before departure, shipping documents are prepared, and loaded units are scanned to confirm order completion. (Manzini, 2012)

Both inbound and outbound loading often happen within a short time window due to delivery schedules. This creates peaks in receiving and dispatching, requiring temporary storage in shipping zones. This is often handled by grouping the shipping units together for each load near the loading bays, either by using floor storage for pallets and other big loads and shelves for smaller shipments. (Hompel and Schmidt, 2006)

2.3.2 Centralised vs. Decentralised Warehousing

There are storage points at every step of a supply network. These storage points range from simple waiting areas before a specific step in a manufacturing facility to massive warehouses to shelves in retail stores. The locations and methods used for storing products in the network have a significant impact on companies' operations, agility, service levels, and total costs. This does not mean that simply gathering extensive inventories is good. Companies can gain a competitive advantage by strategically maintaining the correct quantity and type of stock in the right locations. Optimal warehouse locations also work as points for collecting critical data to help with forecasting and replenishment planning. (Manzini, 2012)

An important part of supply network design is choosing between centralised and decentralised distribution systems. A larger central distribution centre can act as a single facility for supplying a large area. This can lead to reduced costs by enabling better inventory control and by using economies of scale. A decentralised system with multiple warehouses doing the distribution allows better and faster customer service. Customers also prefer smaller and more

frequent deliveries, this can be achieved by placing distribution centres closer to the customer. The option for more frequent deliveries and increased product availability can lead to better customer trust. (Sople, 2011)

When planning a warehouse network, management must perform a cost-benefit analysis considering market size, demand patterns (seasonal or continuous), product type, desired customer service levels, competitive intensity, and set-up and operating costs (Sople, 2011). Warehousing and transportation are some of the most significant logistics costs (Tompkins, 2010). These costs are linked to each other, the warehousing costs increase proportionally with the number of warehouses, and transportation costs decrease as the number of warehouses increases. Figure 4 shows this relation. (Sople, 2011)

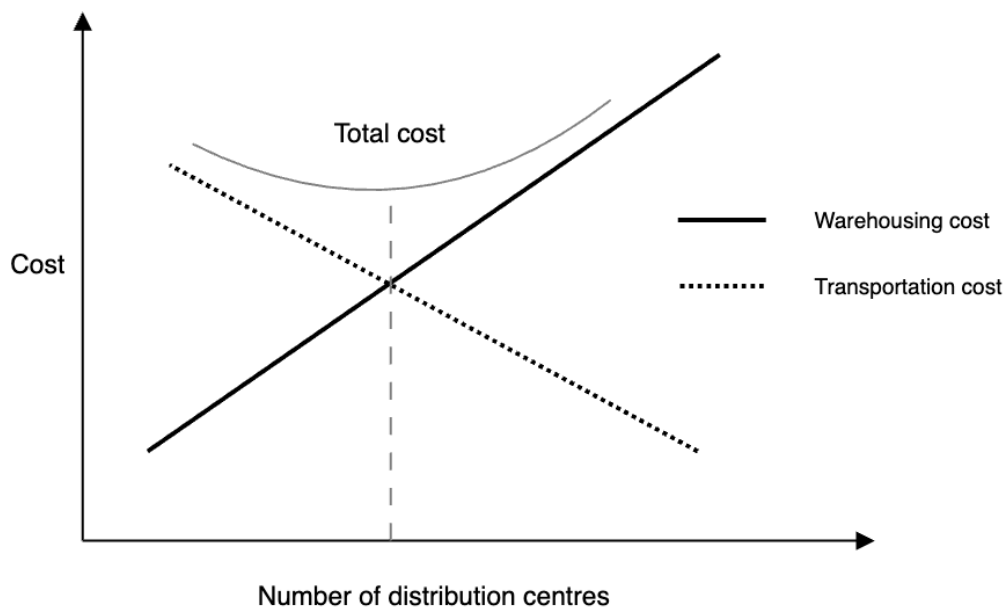


Figure 4. Costs related to the number of warehouses. (Sople, 2011)

The number of stocking points and, thus, the warehousing and inventory costs can be reduced by only having a single centralised warehouse. However, this raises the transportation costs. To find the optimal number of distribution centres,

both inventory and warehousing costs must be considered to minimise total costs. (Sople, 2011)

A decentralised distribution system where decisions about inventory are handled locally can take into account local needs. This relies heavily on the competence and inventory management skills of the local personnel. They might act subjectively without considering all of the information available in a centralised system. Local management might overreact to temporary events, and they often prefer having high inventories at their warehouse. High inventory levels help react to sudden demands and enable better customer service, but it is costly. If local management is competent, decentralised inventory decisions can lead to high customer service levels with optimal inventory holding costs. (Sople, 2011)

A centralised distribution system allows the company to employ more competent purchasing and inventory management specialists who can better evaluate strategic buying opportunities and economic trade-offs. Reducing the number of warehouses increases the need for transparent processes, clear inventory visibility, and order management. Effective centralised inventory control from a primary warehouse can significantly lower stock levels and reduce costs by minimising the number of regional distribution warehouses. (Hompel and Schmidt, 2006)

Distribution centre location selection involves determining the optimal location for a single depot to achieve wider area coverage and ensure product availability for customers. The location of a distribution warehouse for a specific geographical area can be chosen by using different methods. Some of these methods are the centre of gravity of area model, the centre of gravity of load model, and centre of gravity of tonnes-kilometres model. (Sople, 2011)

The centre of gravity of area model determines warehouse location by using a physical representation of the area. A map of customer locations is drawn, this map is then balanced to find the optimal warehouse location. This method minimises the overall distance to all customer locations within the area. The

centre of gravity of load model considers the demand distribution across the area, this gives a more ideal location for the warehouse. This can be physically represented by creating a map of the area with holes for the customer locations. Each of these holes should be weighted proportionally to that location's demand. Again, when the sheet balances, the optimal location is found. The centre of gravity of tonnes-kilometres model identifies the optimal warehouse location by factoring in the shipment loads and the transportation distances. The goal of this is to keep transportation costs as low as possible by considering shipment volumes and travel distances. Finding the optimal solution using a physical map can be difficult and involves extensive trial and error. However, it can be made easier by data analysis and algorithmic optimisation. (Sople, 2011)

2.4 Lean Supply Chains

The concept of lean was first introduced at Toyota as a way to make manufacturing more efficient, and it is based on JIT principles. Lean is a series of activities and solutions that reduce non-value-added (NVA) operations, optimise the value-added process, and improve overall efficiency. A key aspect of lean supply chains is addressing the seven causes of waste: overproduction, Drwaiting, transportation, over-processing, unnecessary inventory, unnecessary motion, and defects. Lean has become one of the most used manufacturing systems because it can reduce waste and variability while adding performance and customer value. (Paksoy, Weber and Huber, 2018; Arif-Uz-Zaman and Ahsan, 2014)

A lean supply chain (LSC) aims to be a streamlined, highly efficient system that identifies and eliminates all types of waste within the value stream to reduce lead times. It does this by removing non-value-adding activities related to excess time, labour, equipment, space, and inventory while ensuring the product is available to the customer. Lean supply chain management extends this by linking the flows of products, services, information, and funds in upstream and downstream organisations. (Tortorella, Miorando and Marodin, 2017)

2.4.1 Lean tools

Lean manufacturing uses many different tools and techniques to help supply chain performance across all parts of the supply chain, including planning, sourcing, production, delivery, and returns. (Arif-Uz-Zaman and Ahsan, 2014) The Toyota Production System provided a foundation for lean tools, focusing on workplace organisation, uninterrupted flow, minimising changeover times, and error-free processing. Table 3 categorises these tools based on their focus areas. (Davis, 2011)

Focus Area	Tools
Workplace Organisation	5S, Visual Controls, Standardised Work, U-Cell
Uninterrupted Flow	Pull Production, Point-of-Use Manufacturing, Kanban
Insignificant Changeover	SMED, 5S, Visual Controls, Standardised Work
Error-Free Processing	Poka-Yoke, Total Productive Maintenance (TPM)

Table 3. Toyota Production System Tools. (Davis, 2011)

These tools help reduce waste, improve efficiency, and enhance overall supply chain performance. By using the right combination of lean tools, organisations can create better workflows, lower costs, and increase customer value. (Davis, 2011)

2.4.2 Kaizen

Kaizen is a continuous improvement practice that works by making small, incremental improvements to quality, productivity, safety, and workplace culture. Kaizen is not limited to manufacturing, it applies to any business process,

improving teamwork, standardisation, and problem-solving. Successful Kaizen implementation depends on strong management, production engineering, and business process improvements. (Davis, 2011)

The Kaizen cycle starts by clarifying the ideal state of the process, the next step is to analyse the actual state and identify inefficiencies. This allows businesses to see the difference between the current state and the ideal state. Next, a plan for getting to the ideal state is made, and then the plan is implemented, and the results are measured. When an improvement is made, the process is standardised. The cycle is repeated, continuously improving efficiency, reducing waste, and enhancing performance. (Stewart, 2018)

2.5 Quality Management

Simply thinking the quality of a product or service is just how good or bad it is, in reality it is subjective, based on the observer's perception and perspective. Producers often measure quality by how well a product or service meets the set specifications, while customers often focus on comparing specifications between alternative options. Companies can achieve competitive advantages through quality, so it is important to focus on. (Kim-Soon, 2012) Quality in warehousing refers to the ability to consistently meet or exceed customer expectations, which can be achieved by using well-defined processes, accurate inventory management, and efficient operations. (Sople, 2011)

Effective quality management systems help organisations meet customer expectations while improving processes and maintaining records. Quality management systems should be strategic and comprehensive, because of this, they need long-term commitment to improve products, services, and processes. To keep a quality plan relevant and adaptable, organisations should develop an annual Quality Action Plan that sets clear priorities for the following year. A good quality plan should include short-, medium-, and long-term goals, addressing customer experience, safety, risk management, and regulatory compliance.

Businesses should focus on the most impactful changes by, for example, using the 80:20 principle. (Savsar, 2012)

Quality management has been consistently linked to both financial and non-financial aspects of organisational performance. (Kim-Soon, 2012) However, once high quality is achieved, making it a regular part of daily work is one of the biggest challenges in a quality system and makes good management important. Keeping changes in place is often more complicated than it seems, causing wasted work when changes fail. Both systems and people need to change for improvements to last. (Savsar, 2012)

Total Quality Management (TQM) is a management philosophy that involves all employees of the organisation, focusing on long-term success through customer satisfaction. Unlike traditional inspection-based quality control, TQM builds quality into processes to prevent defects rather than detecting them after they happen. Common TQM practices include cross-functional product design, process management, supplier quality management, customer involvement, strategic planning, and employee engagement. For TQM to succeed, companies need a good quality culture, an innovative environment, good leadership, and proper support. (Aized, 2012)

ISO 9000 is an international standard developed by the International Organisation for Standardisation (ISO) for implementing a quality management system (QMS). The standard does not define specific product or service quality levels, it focuses on standardising process management. By keeping a structured and documented quality management system, organisations can get a certification from an accredited firm, ensuring that the interpretation and application of the standard are done correctly. The purpose of the ISO 9000 series is to prove to customers that the supplier uses standardised quality management practices. (Dale, Bamford and van der Wiele, 2016)

Six Sigma is a data-driven quality control system developed by Motorola in the 1980s. Six Sigma uses statistical analysis to measure deviations from the

expected quality, making it possible to eliminate defects in any process. The name comes from the representation of standard deviation being sigma (σ). Six Sigma reduces errors to an extremely low percentage while improving efficiency across all processes, from manufacturing to services. (Aized, 2012)

2.6 Spare Parts Supply Chains

Spare parts orders are often irregular, and demand rises and falls based on repair schedules and unexpected maintenance. The varying mix of vehicles in each region, a wide range of spare parts, and complex supply networks create unpredictable demand. The ability to fulfil orders directly from stock is a key performance indicator in the automotive spare parts industry. Delays in delivering spare parts can cause longer vehicle repair times, and having no stock for a specific part can lead to losing that sale and the other sales the customer might have made. Good inventory management and demand forecasting ensure that customer demands are met without spending too much on inventory. (Ramos et al., 2020; Achetoui, Mabrouki and Mousrij, 2022)

One of the biggest challenges in the automotive spare parts industry is long-tail products, these items have slow and irregular demand. They are needed to avoid losing potential sales when customers require them, so it is necessary to have a lot of different slow-moving parts in inventory. Long tail products often make up a substantial portion of a distributor's inventory, they tie up capital in inventory and use warehouse space. The sales for these products are often a big part of the total revenue, so they are necessary. These slow-moving spare parts can also easily become obsolete since there is zero demand if a part in use does not break. (Bi, He and Teo, 2023; Mehdizadeh, 2019)

Choosing between centralised and regional warehousing for spare parts is about choosing the better and cheaper inventory control of centralised warehousing or the shorter customer lead times and reduced shipping costs of regional warehousing. Managing multiple warehouses makes it harder to avoid overstocking and stockouts but being closer to customers can provide better

service levels. An automotive spare parts company must balance service and inventory levels to control costs, this requires ongoing data analysis and planning. (Mehdizadeh, 2019)

2.6.1 Spare Parts Inventory Management

Traditional inventory control methods are often unsuitable for automotive spare parts, as they rely on demand patterns that do not exist with spare parts. It is important to know which items matter the most when managing spare parts. Categorisation through ABC analysis groups spare parts into three levels based on their value. When combined with XYZ analysis, which considers demand variability, the resulting ABC-XYZ matrix provides a better way to manage spare parts with unpredictable demand. ABC-XYZ analysis can be improved by using different categorisation criteria, such as vehicle mileage, fleet size, lead time, criticality, and the availability of substitute parts. (Mehdizadeh, 2019; Ramos et al., 2020)

Achetoui, Mabrouki and Mousrij (2022) provide a system for evaluating the performance of the supply chain for automotive spare parts. This system has a total of ten key performance areas with different categories and KPIs. The area focusing on inventory management is stock and procurement performance. This area has three categories: service quality, activity level, and control and tracking. Service quality has KPIs such as stock-out rate, stock-out frequency, and achievement level of the procurement plans. Activity level includes inventory turnover, stock coverage, and stock levels of safety, minimum, maximum and alert stock. Control and tracking KPIs are the error rate of inventory transactions, inventory discrepancy rate, and the average time required to perform stocktaking.

Warehouse performance focuses on three categories: capacity, service quality, and operational productivity. Capacity KPIs include number of warehouses, equipment, and utilisation rates. The service quality KPIs include the order processing time as well as the error rate of goods preparation and storage delay rate. Operational productivity includes the number of orders, items picked or

shipped, and cross-docking operations. Delivery performance is split into the same categories: capacity, service quality, and operational productivity. Capacity is tracked with number of vehicles, carrying capacity, and vehicle utilisation. Service quality tracks delivery time, the rate of non-compliant deliveries, and on-time delivery. Operational productivity includes the number of deliveries, total mileage, and average driving time. (Achetoui, Mabrouki and Mousrij, 2022)

2.6.2 Demand for Spare Parts

Forecasting demand for spare parts can be challenging due to their highly irregular and uneven consumption patterns. Demand patterns are often unpredictable and include items with long periods of little or no activity. This is particularly problematic in decentralized supply chains, where forecasting demand across multiple warehouses adds complexity. The automotive industry faces significant uncertainty in spare parts demand, often relying on vague, inconsistent, or incomplete data. These data quality issues limit forecasting accuracy, and even the most advanced analytical tools cannot fully compensate for poor input data. Traditional forecasting systems and inventory management solutions are often unsuitable for handling products with such unpredictable behaviour. (Mehdizadeh, 2019; Chien, Ku & Lu, 2023; Leeuw and Beekman, 2008)

Specialised methods have been developed to address these forecasting difficulties. Croston's method is one of the earliest and most widely used techniques for forecasting intermittent demand, which separates demand size and frequency into distinct components. However, Croston's original approach was later found to be biased, and several refinements have been proposed. (Chien, Ku & Lu, 2023) Still, some researchers say that improving the accuracy of the demand rate alone may not significantly benefit inventory control, as it does not provide reliable insight into when the next order will occur. This limitation is particularly relevant with long-tail products. (Bi, He and Teo, 2023)

In response to the limitations of classical models, recent research has focused on data-driven forecasting approaches using machine learning. These methods can identify complex demand patterns and improve forecasting accuracy. Techniques such as neural networks, support vector machines, and ensemble models like random forests and XGBoost have all been successfully applied to spare parts forecasting. However, despite their potential, these models rely heavily on high-quality historical data and are most effective when stable, product-specific demand history is available. (Chien, Ku & Lu, 2023) In reality, missing or unreliable data often remain a significant problem in spare parts management. Additionally, the complexity of these models, limited user expertise, and a lack of supporting software have restricted their widespread adoption in practice. (Mehdizadeh, 2019)

To address the challenges of intermittent demand better, newer forecasting frameworks are shifting from constant base stock models to models that link demand forecasting with replenishment strategies. These new frameworks consider both the demand size and timing, offering a more comprehensive picture of the demand behaviour. This enables companies to estimate the probability of demand arriving in each time period based on the elapsed time since the last order. One of the newer policies is the staggered base stock (SBS) policy, which gradually rebuilds inventory for slow-moving items over time. Unlike traditional reorder policies, SBS does not rely on immediate replenishment. (Bi, He and Teo, 2023)

Flexible stocking policies must be applied because spare parts are required on an unpredictable and intermittent basis. For instance, the staggered base stock (SBS) policy can reduce average inventory without impacting the fill rate. This allows better space utilisation and cost savings, particularly in companies managing large portfolios of slow-moving items. (Bi, He and Teo, 2023)

3 Case Company

3.1 Background

The Case company is a subsidiary of Parent Company Sweden, which is a subsidiary of Group Company. Both the Case company and the parent company are automotive spare parts wholesalers. Group Company also owns an automotive repair service provider in Finland. The company operates 18 service centres for passenger vehicles, one for trucks, and one specialized in transmission maintenance.

3.2 Warehouses

The Case company operates 10 warehouses across Finland, one central warehouse and nine regional warehouses. The central warehouse is the main office for the company, and most of the sales and order picking is done there. The company's product range is managed by five product managers, each responsible for a specific group of products. A single regional warehouse coordinator working at the central warehouse manages the product ranges and the logistics for the regional warehouses. Each regional warehouse only has a small number of staff who handle the sales, warehousing and logistics of each region. The company uses a demand forecasting software for demand forecasting both to the central warehouse and to the regional warehouses.

4 Current State of Regional Warehousing

4.1 Data

The analysis is based primarily on sales data collected at the item, area, and weekly levels. Data on regional replenishments and transfers between warehouses is available. Both the regional inventory levels and the regional product range are available, but they are not stored historically, which makes it difficult to assess the stock situation at the time of each sale. This limits the ability

to determine whether low sales were caused by low demand or product unavailability due to stockouts.

The sales data does not explicitly tell if an order is picked at the central or the regional warehouse. Order-picking location is only available by manually inspecting a single order at a time. The sales type gives an idea of the picking location of the item; however, this is not always entirely accurate. There are differences in how each region and employee operates. In some regions, items that are not in stock locally are sold from the central warehouse. In other regions, the same situation is handled by making the sale from the regional warehouse despite no stock being available, which results in a negative balance, and then a transfer order is made for the central warehouse.

Products that are ordered directly from suppliers or competitors and only pass through the warehouse via cross-docking, without being stored or picked, were excluded from the analysis. Since these items are not handled through the standard warehouse picking process, they were removed from the dataset during preprocessing to ensure the analysis focuses only on items that are part of the warehouse operations and relevant for inventory-related decisions. The share of these items varies per region and is visualised in Figure 5.

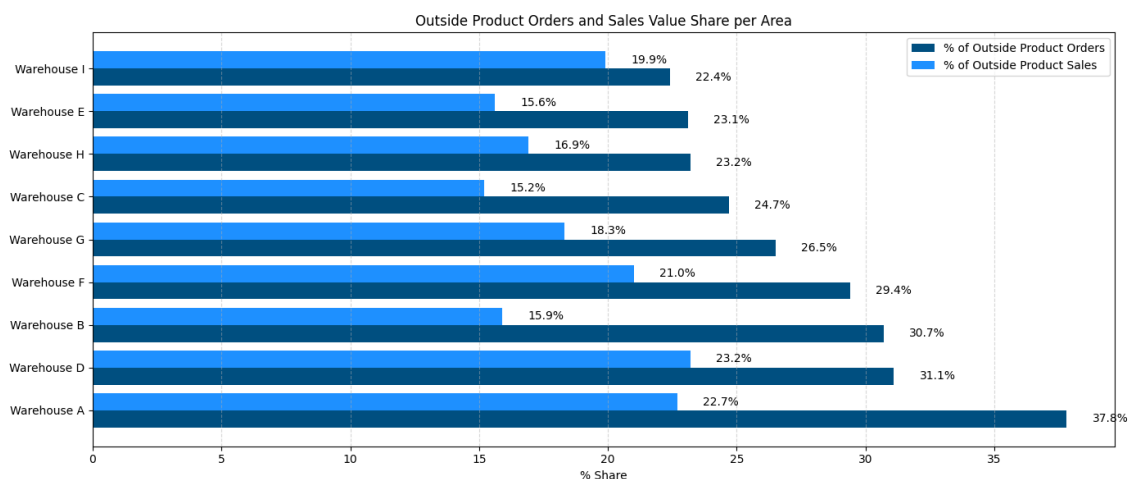


Figure 5. Outside product orders and sales shares per area.

Table 4 presents a general overview of the regional warehouses based on the sales data. The table summarises the share of total regional sales, the share of total regional orders, and the share of orders picked at the regional warehouse for the different regions.

Area	Share of Total Regional Sales (%)	Share of Total Regional Orders (%)
Warehouse A	19,54 %	18,11 %
Warehouse B	18,93 %	20,56 %
Warehouse C	13,90 %	13,66 %
Warehouse D	9,49 %	8,96 %
Warehouse E	8,91 %	10,14 %
Warehouse F	8,44 %	8,57 %
Warehouse G	7,48 %	7,10 %
Warehouse H	6,97 %	6,87 %
Warehouse I	6,34 %	6,03 %

Table 4. Regional warehouse overview.

There are currently around 600 different item groups. Many of these groups are very similar or even identical, with only slight differences, for example, a different manufacturer. In some cases, item groups also partially overlap, for example, group A may include item X and item Y, while group B includes item Y and item Z. For the analysis, the item groups were manually compressed down to 55 broader groups, based on the current groupings and, in some cases, the item names. Figure 6 shows the top 20 item groups by sales value.

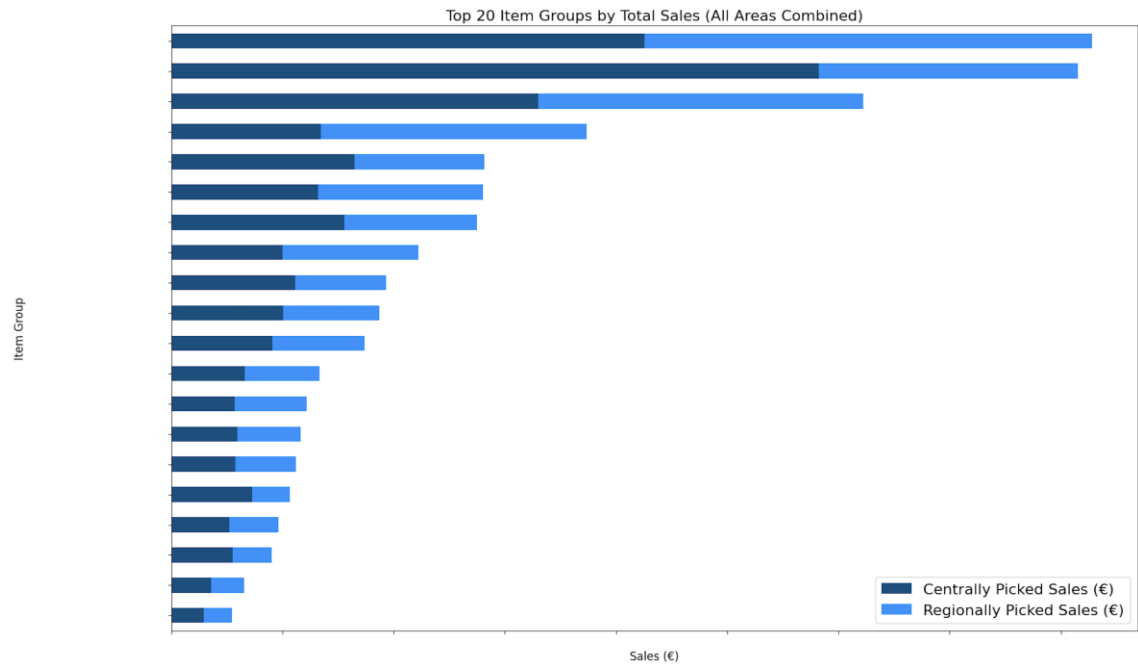


Figure 6. Top 20 item groups.

The product groups are unevenly distributed in terms of sales value. A few top groups dominate the sales, while many smaller ones contribute less. For example, the three largest product groups account for approximately 40 % of total sales, the following seven item groups make up around 32 %, and the rest comprise 45 different item groups.

Weekly reporting about the regional warehouses is done by the regional warehouse coordinator, who monitors key performance indicators related to inventory and product availability. These reports cover the total inventory value as well as the inventory value for products that are currently in range. Additionally, the report shows the availability of in-range products as a percentage that reflects how much of the product range is in stock at each of the regional warehouses at the time of reporting. Turnover for the in-range products is also tracked weekly. The demand forecasting software automatically calculates the turnover rates for each regional warehouse based on historical sales data.

4.2 Order Fulfilment

Customer orders can be placed through multiple channels depending on the customer type and their preferences. Customers can place orders directly through the company's online platform, which provides product availability and estimated delivery times. Customers can only see the stock of their regional warehouse and the main warehouse. They can leave a request for a missing product, and the sales staff will handle the orders. Orders can also be placed by contacting the company's sales representatives directly by phone or email.

Depending on the product and the regional warehouse stock, the order is either picked at the regional warehouse or the central warehouse. If the order cannot be fulfilled from the regional warehouse but there is central stock, it is either made directly to the central warehouse or a transfer request is made. If there is no stock at any of the warehouses, the item is procured from a supplier or a competitor, depending on the urgency of the order.

Products picked at the central warehouse are transferred to the regional warehouses with third-party logistics (TPL) providers. After a shipment is received at the regional warehouse, it is either delivered directly to the customer or shelved as stock. The company's sales representatives make customer deliveries from the regional warehouse as a part of their daily tasks. The order fulfilment process is described in Figure 7.

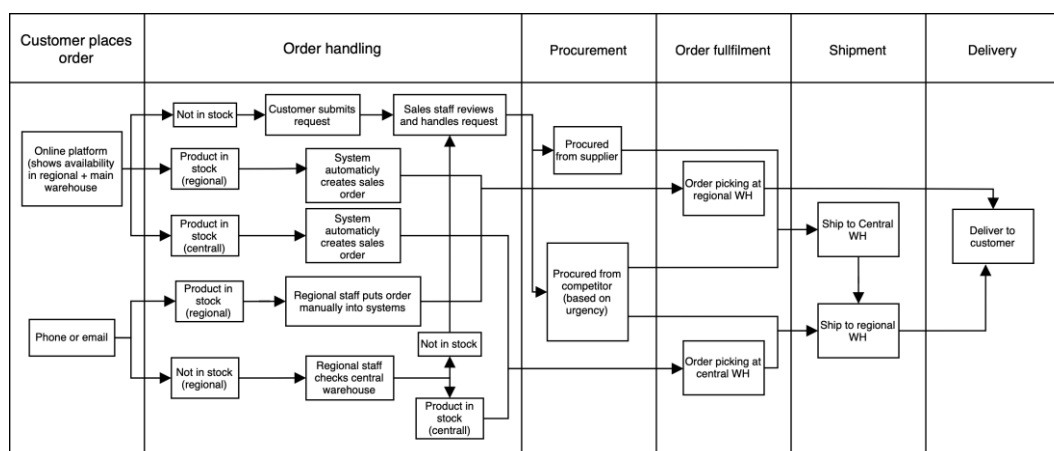


Figure 7. Order fulfilment process.

4.2.1 Return Handling

Product returns from customers are typically handled through the company's regular delivery routes. Returned items are first sent to the regional warehouse along with the standard regional delivery vehicle. If the returned product is part of the regional warehouse's product range, it is returned to shelf stock. If the item is not included in the regional warehouse's product range, it is forwarded to the central warehouse as part of the regular return shipments.

4.2.2 Transfers Between Regional Warehouses

Sales staff at regional warehouses have access to the balances of other warehouses, making it possible to check product availability and order from another warehouse. If a transfer between regional warehouses is needed, it can be made with a direct transfer using TPL providers or routed through the central warehouse combined with the scheduled return logistics. This adds an extra day to the transfer timeline compared to direct regional warehouse-to-warehouse transfers.

4.3 Product Range in Regional Warehouses

The product range is determined based on sales history, product turnover, and the regional vehicle fleet. The products can be split into three different categories: Standard Stock Products, Contingency Products, and Centralised Products. Standard Stock Products are products that are regularly used for routine maintenance, like filters and brake pads. Contingency Products include parts like brake callipers; these parts may be needed unexpectedly while the car is being repaired for a related issue. The third class of products, Centralised Stock Products, are only stored in the centralised warehouse. These are parts that are difficult to store, have low turnover, or are only needed for preplanned repairs.

4.3.1 Product Range Screening

The product range screening is done on a three-week cycle by the regional warehouse coordinator, three regional warehouses per week. In addition to this, each regional warehouse has the possibility to request for a specific product to be added to their product range. The categorisation of products into Standard Stock, Contingency, and Centralised Stock is based on automotive expertise, internal company agreements, and customer input.

The product range screening starts with the regional warehouse coordinator using a search template in the demand forecasting software that searches for products not currently in the assortment but that have had at least one sale in the past year. This data is processed individually for each regional warehouse and exported to Excel. Each product is then reviewed to check if a replacement item is already in the assortment, assuming product data is properly maintained. Only products in the Standard and Contingency stock categories are considered for the product range. Sales volumes are looked at both in the region and at the central warehouse. If the sales rise, the product can be added to the range. The criteria for adding a product to the product range varies a lot. Products in the Standard stock category are often added even with low sales due to higher possible demand and lower holding costs. Additionally, the regional car fleet, including vehicle counts and ages, is taken into consideration. If a product is added, it is assigned a minimum fill level of one, and the demand forecasting software calculates the rest. Maximum fill levels are defined in specific cases, and the demand forecasting software will automatically limit the quantity accordingly.

The process for removing items from the regional assortment is essentially the reverse of the addition process. The regional warehouse coordinator uses a search template in the demand forecasting software to look for products that are currently in the regional range but have had no regional sales activity within the past year. This search is run individually for each regional warehouse, and the results are exported to Excel for further review. Each product is checked to

confirm there is no demand or special reason to keep it. Once confirmed, the item is removed from the range in the demand forecasting software, and the system automatically adjusts forecasts and stock levels.

4.3.2 Handling of New and End-of-Life Products

New products are held in the central warehouse until the demand is known. If a new product gets significant central sales and has sales through a specific regional warehouse, it is added to that region's product range.

End-of-life products are handled by removing them from the product range. If a substitute product exists, it is added to the product range if it has a good sales history with the product being phased out.

The regional warehouses have extensive inventories of products that are not in the regional product range but still are stored at the regional warehouses. Some of these products have been acquired with the warehouse from a bought-out company and have just remained there since no decision was made to transfer or dispose of them. Some are just built-up inventories of products that have been removed from the product range and have not yet been sold.

4.4 Replenishment Process for Regional Warehouses

Replenishments to regional warehouses are made from Tuesday to Friday. The demand forecasting software suggests replenishments from the regional product range based on the regional inventory, past sales, and forecasted demand. The regional warehouse coordinator checks if there is enough central stock to make the replenishment. If not, or if there is another limiting factor, such as regional warehouse shelf space, the replenishments are rejected.

Approximately 1000–2000 product replenishment lines are sent weekly to all regional warehouses in total. In addition to the normal replenishments, roughly 700 to 1000 product lines are sent weekly as transfers because a sale has

already been made. The replenishment quantities of individual warehouses vary depending on the size and are better shown in Table 5.

Area	Average Replenishment/ Total	Average Transfers/ Total	Replenishment/ Transfers Ratio	Transfers/ Orders Share (%)
Warehouse A	13,07 %	11,27 %	1,82	8,37 %
Warehouse B	16,69 %	10,45 %	2,51	6,88 %
Warehouse C	8,00 %	6,22 %	2,02	6,07 %
Warehouse D	11,92 %	14,82 %	1,26	22,29 %
Warehouse E	12,18 %	16,74 %	1,14	22,19 %
Warehouse F	11,19 %	11,36 %	1,55	17,88 %
Warehouse G	9,62 %	8,58 %	1,76	16,38 %
Warehouse H	12,08 %	13,29 %	1,43	26,01 %
Warehouse I	5,25 %	7,27 %	1,14	16,32 %
Total	100,00 %	100,00 %	1,57	13,47 %

Table 5. Average replenishments and transfers per area.

Table 5 also shows the transfers to orders share, and the replenishment to transfers ratio. The transfers to orders share can indicate how customer orders for out-of-stock items are handled in a specific region. If the share is high, that area might more often log the sale to the region and then ask for a transfer for the negative stock. Notably, there is a lot of variation in the replenishment-to-transfer ratio, which could point to insufficient regional product ranges and regional differences in customer orders.

There is also suspicion that some of the regional warehouses are making replenishment requests even though they have the needed stock at the regional warehouse. This was investigated by analysing the daily product replenishments, sales made from the regional warehouse, and the requested transfers. Each one

of these was looked at in relation to one another. The logic was that if a replenishment had been made for a specific item to a specific area, and the next regional sale for that same item in that area included a transfer request within the same week, it was marked as a possible case. The cases where the sale quantity was larger than the previous replenishment were excluded. The remaining values are shown in Figure 8.

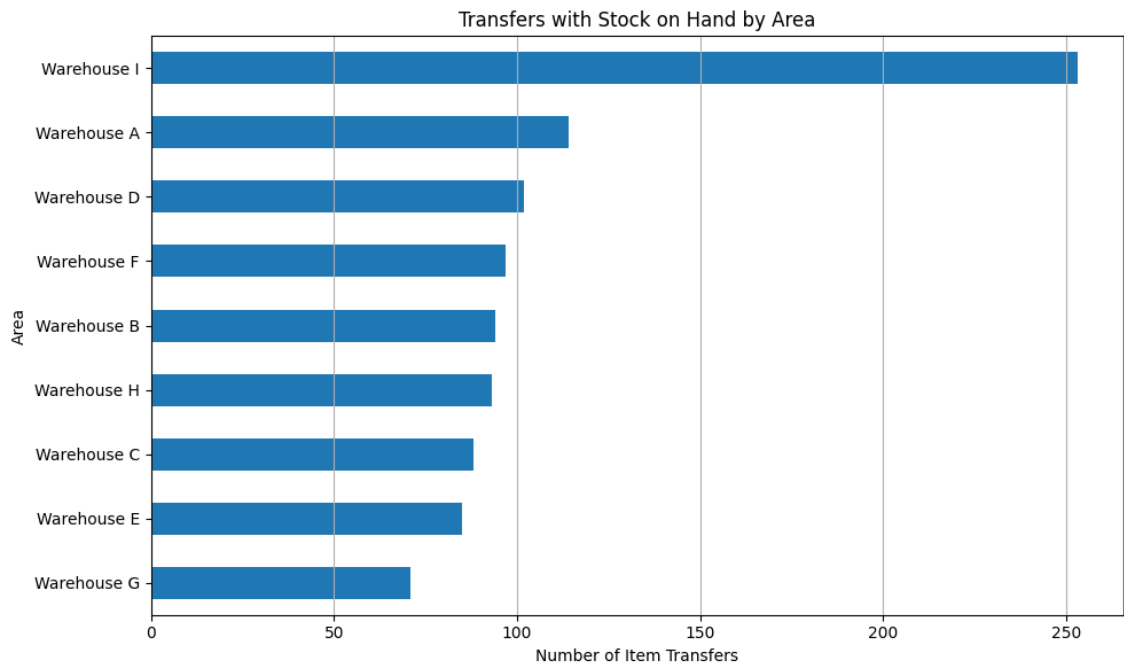


Figure 8. Requested transfers with stock on hand.

The results in Table 5 and Figure 8 may indicate that the regional Warehouse I is potentially requesting replenishments despite having stock available. This is notable, especially in the context of the region showing a high number of transfers with stock on hand while having a comparatively small sales volume. However, these findings should not be interpreted as definitive; each individual case would require separate verification to draw conclusions.

4.5 Customer Needs

A questionnaire about the regional warehouses was conducted for the repair shop managers of the sister company. The general satisfaction of the regional

warehouses and the item groups which were most often missing were identified. Item groups where the need for the part is known while scheduling the service were also identified. The questionnaire asked to identify item groups that could experience sudden immediate demand during a vehicle repair and item groups in which the part would not be needed immediately. These results were used to create an urgency class for the different item groups. Figure 9 shows the urgency class for each of the product types.

Product Group	Classification	Same %	Next %	5 day %
Group A	Same day	66,67 %	26,67 %	6,67 %
Group B	Same day	60,00 %	30,00 %	10,00 %
Group C	Same day	60,00 %	30,00 %	10,00 %
Group D	Same day	54,55 %	36,36 %	9,09 %
Group E	Same day	53,85 %	38,46 %	7,69 %
Group F	Same day	52,94 %	35,29 %	11,76 %
Group G	Same day	52,38 %	38,10 %	9,52 %
Group H	Same day	50,00 %	41,67 %	8,33 %
Group I	Same day	47,37 %	42,11 %	10,53 %
Group J	Same day	47,06 %	41,18 %	11,76 %
Group K	Same day	43,75 %	43,75 %	12,50 %
Group L	Same day	42,31 %	34,62 %	23,08 %
Group M	Next day	38,46 %	46,15 %	15,38 %
Group N	Next day	36,84 %	42,11 %	21,05 %
Group O	Next day	35,00 %	45,00 %	20,00 %
Group P	Next day	33,33 %	44,44 %	22,22 %
Group Q	Next day	29,41 %	47,06 %	23,53 %
Group R	Next day	28,57 %	42,86 %	28,57 %
Group S	Next day	26,67 %	40,00 %	33,33 %
Group T	Next day	25,00 %	37,50 %	37,50 %
Group U	Next day	21,43 %	42,86 %	35,71 %
Group V	Next day	21,43 %	42,86 %	35,71 %
Group W	Next day	18,75 %	43,75 %	37,50 %
Group X	Next day	18,75 %	43,75 %	37,50 %
Group Y	Next day	18,18 %	45,45 %	36,36 %
Group Z	Next day	14,29 %	42,86 %	42,86 %
Group AA	Later	27,78 %	33,33 %	38,89 %
Group AB	Later	21,43 %	35,71 %	42,86 %
Group AC	Later	15,38 %	38,46 %	46,15 %
Group AD	Later	13,33 %	40,00 %	46,67 %
Group AE	Later	11,11 %	33,33 %	55,56 %
Group AF	Later	9,09 %	36,36 %	54,55 %
Group AG	Later	9,09 %	27,27 %	63,64 %
Group AH	Later	9,09 %	27,27 %	63,64 %

Figure 9. Urgency classification per product type.

The urgency classes were used to create two figures: Figure 10 shows the distribution of item urgency classes in relation to the number of orders in the

region, and Figure 11 shows the distribution based on regional sales value. These charts show how the different urgency classes are represented in actual demand and sales activity. A fourth group, “Not in Questionnaire”, was added for the remaining groups that were not included in the repair shop manager questionnaire.

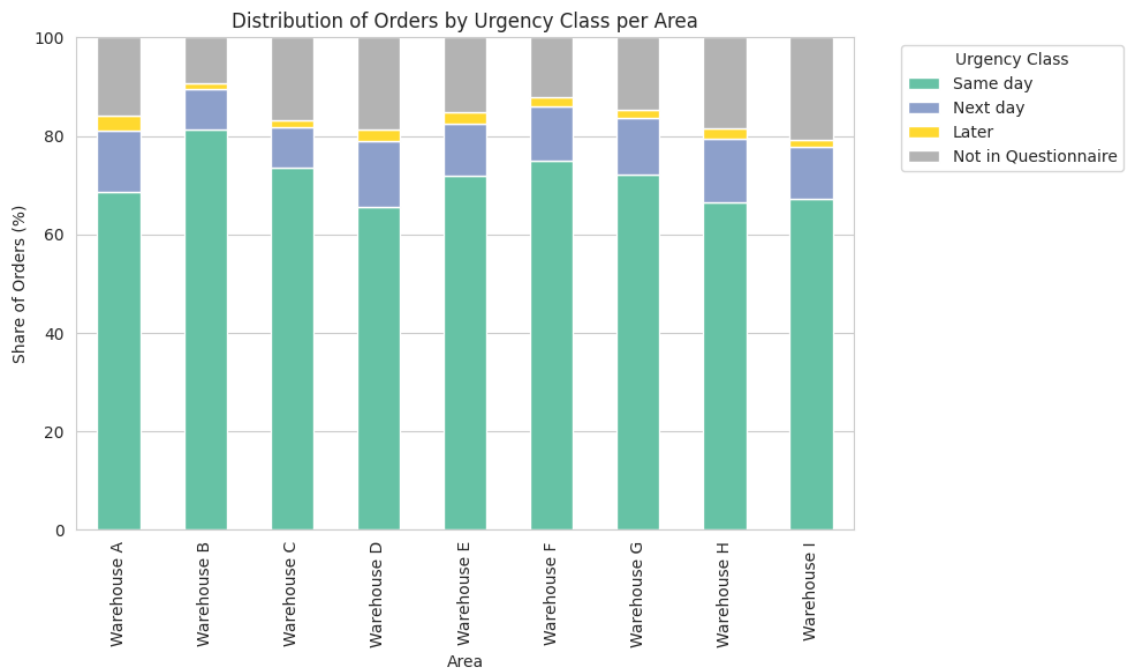


Figure 10. Distribution of Orders by Urgency Class per Area

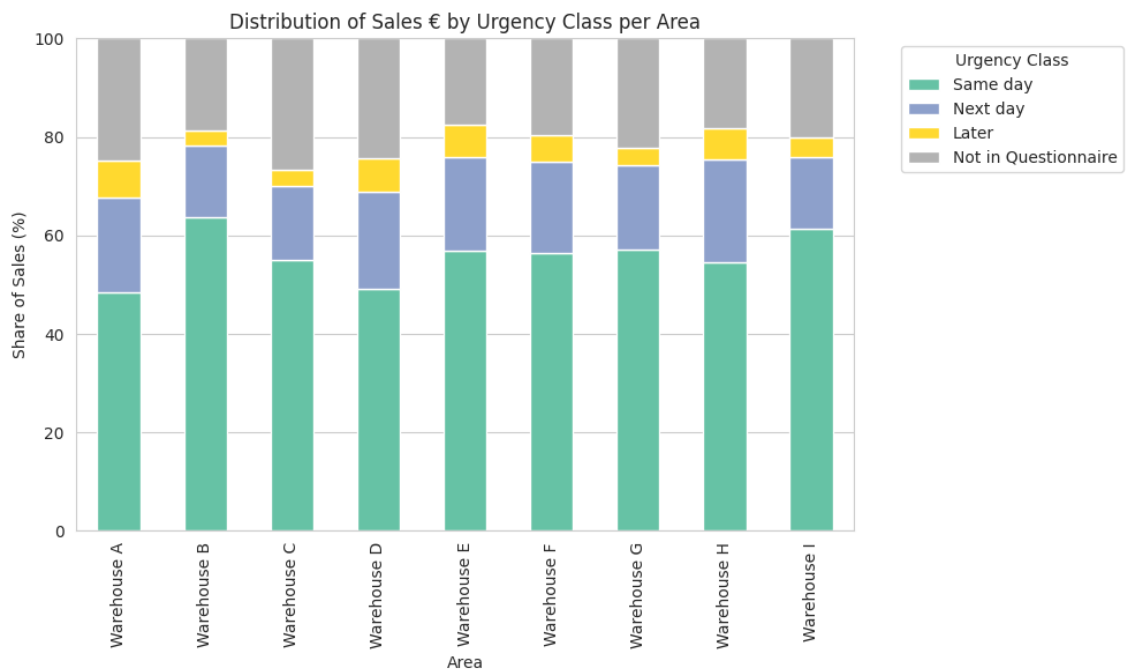


Figure 11. Distribution of Sales by Urgency Class per Area

Both figures show that items in the "Same Day" urgency class make up a significant portion of the total orders and sales values, while the other urgency classes account for smaller shares. This could suggest that the repair shop managers base urgency not only on how fast a part might be needed but also on how important it is for daily repair work. Repair shop managers might classify items that they rely on regularly as high urgency, even if the demand for them can be known in advance. However, from a business perspective, it still makes sense that fast delivery is prioritised for items that generate the most orders and sales value.

4.6 Regional Warehouses

For the analysis, each different item sold in a specific region was split into a regional ABC value class and a regional Item Volume class. Each item's total annual sales were calculated, and the items were then ranked in descending order based on value. A-items account for the top 80% of the total sales value, B-items for the next 15%, and C-items for the remaining 5%. Figure 12 displays the share of products in each ABC category.

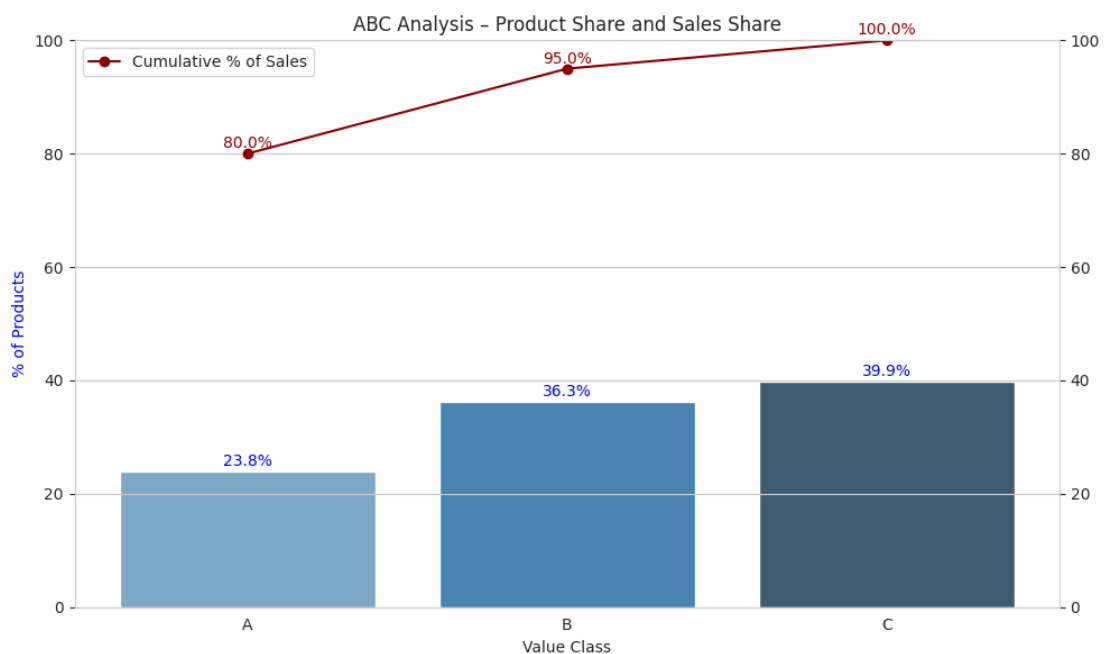


Figure 12. Product share per ABC class.

Items were also grouped by volume class based on the total number of specific items sold over the year. Items were ranked in descending order by sales volume and then categorised into three classes: High, Medium, and Low volume. Items with eight or more orders in the specific area were classified as High volume, Items with 2 to 7 orders as Medium volume, and items with only a single order as Low volume. Figure 13 shows the number of items in each volume class by area.

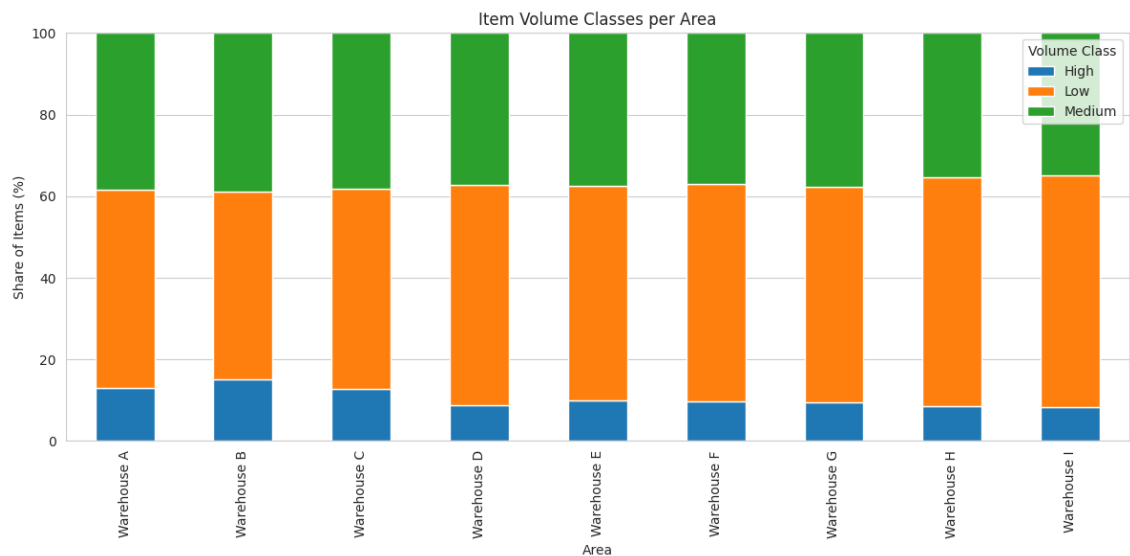


Figure 13. Volume classes per area.

These value and volume classifications and the urgency classification were used to evaluate the performance of each regional warehouse. The analysis focused on how well each warehouse served its local demand by looking at where the ordered products were delivered. The share of orders picked at the regional warehouse versus the central warehouse shows the effectiveness of the product range of each location. Approximately 52 % of the total regional sales are collected at the central warehouse. Heatmaps were created to visualise how order picking is distributed across different product categories to support the analysis. Generally, a higher regional picking share for high-value, high-volume, and high-urgency items might mean that the regional warehouse supports local demand well. However, low-volume, high-value items ideally should not be stored at the regional warehouse since they are expensive and are not needed often.

4.6.1 Warehouse A

The regional Warehouse A contributes approximately 20 % of the total regional sales. Roughly 42 % of orders placed in this area are picked at the regional warehouse. The ABC classification for this warehouse closely matches the overall distribution across all regions shown in Figure 12. Figure 14 shows that C-value items outside the high-volume category have the highest regional picking share in this area.



Figure 14. Regional order picking, volume and value, Warehouse A.

Additionally, the urgency value Figure 15 and the urgency volume Figure 16 show that products in the non-urgent urgency classes sometimes have higher regional order picking shares than the products in the same-day class.

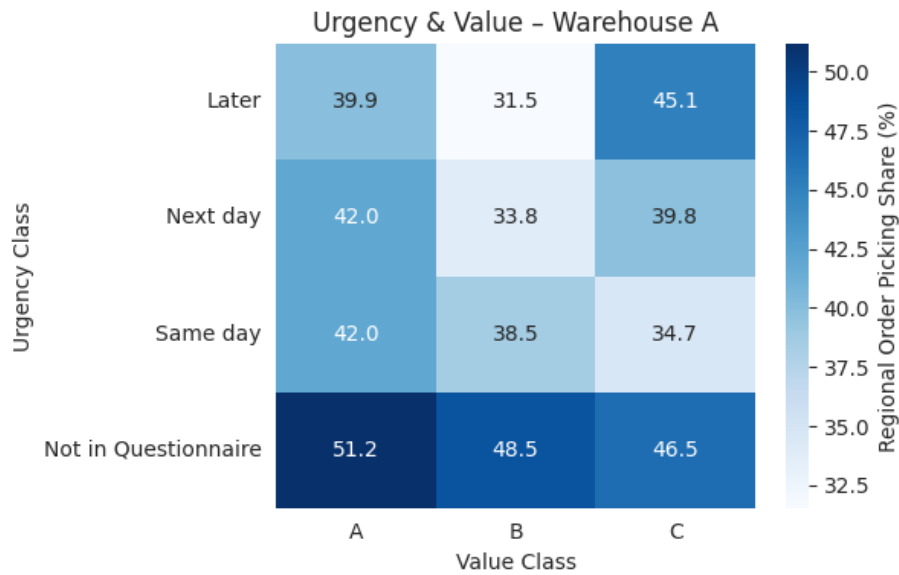


Figure 15. Regional order picking, urgency and value, Warehouse A.

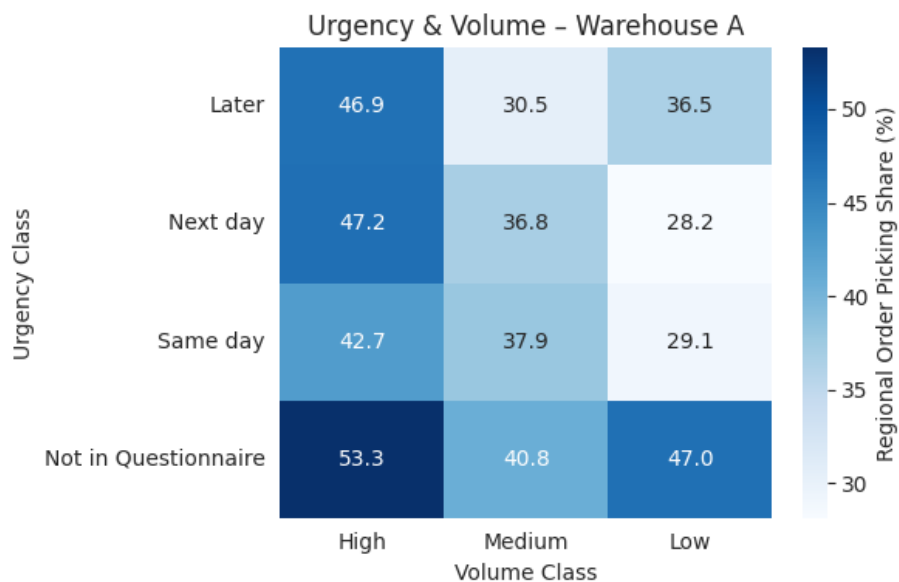


Figure 16. Regional order picking, urgency and volume, Warehouse A.

4.6.2 Warehouse B

The regional Warehouse B contributes approximately 19 % of the total regional sales. Around 47 % of orders placed in this area are picked at the regional warehouse. The ABC classification for this warehouse closely matches the overall distribution across all regions shown in Figure 12. Figure 17 shows a clear gradient in the volume classes, with the share of regional order picking highest

for high-volume items and lowest for low-volume items. The value classes have the opposite pattern, with C-class items having a higher share of regional picking than A-class items.

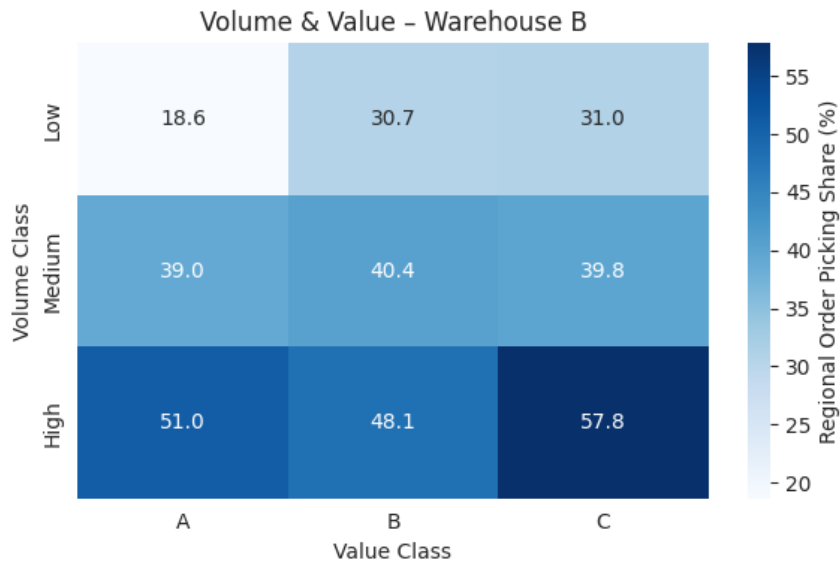


Figure 17. Regional order picking, volume and value, Warehouse B.

Figures 18 and 19 show the regional picking share across urgency-value and urgency-volume combinations. Both heatmaps display a clear gradient, with the highest regional picking share in the Same Day–A and Same Day–High categories and the lowest in the Later–C and Later–Low categories.

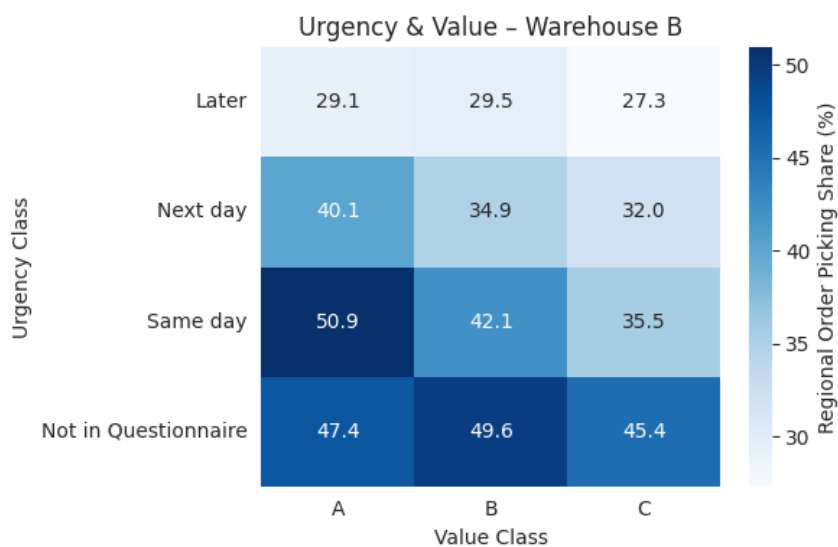


Figure 18. Regional order picking, urgency and value, Warehouse B.

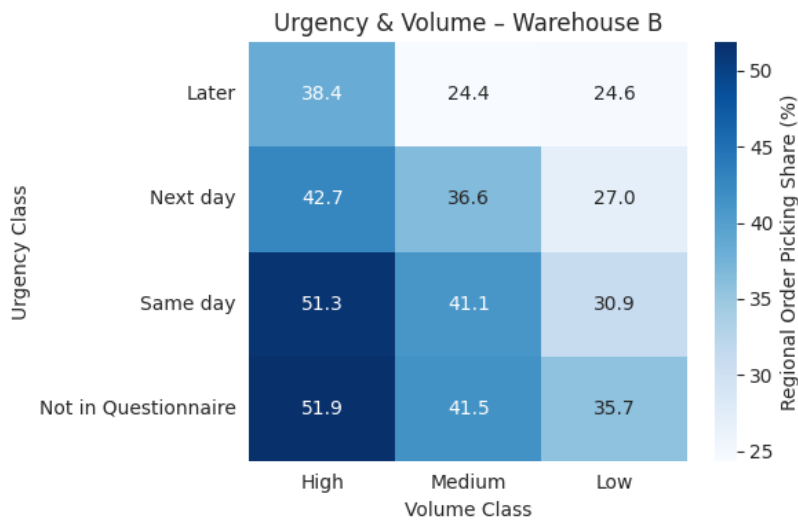


Figure 19. Regional order picking, urgency and volume, Warehouse B.

4.6.3 Warehouse C

The regional Warehouse C contributes approximately 14 % of the total regional sales. Warehouse C is the area with the smallest share of orders picked at the regional warehouse, accounting for only 23 % of its total orders. The share of products in each ABC class is similar to that of the two largest regional warehouses. The value-volume heatmap for this region shown in Figure 20 shows no clear pattern in regional picking share.

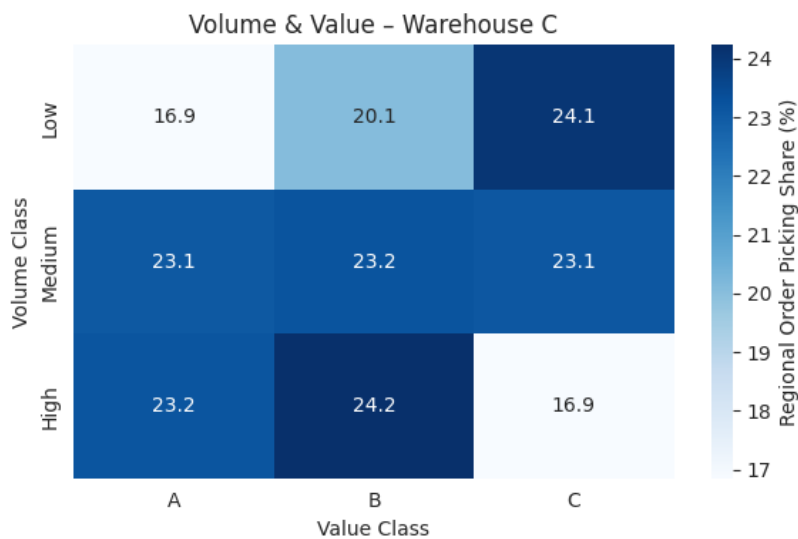


Figure 20. Regional order picking, volume and value, Warehouse C.

Figures 21 and 22 present the urgency–value and urgency–volume heatmaps for this region. Both figures show no clear pattern in regional picking share.

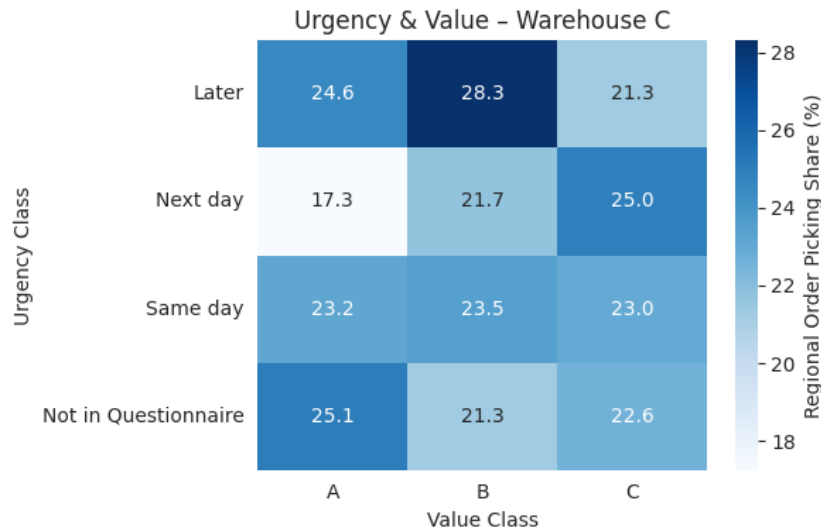


Figure 21. Regional order picking, urgency and value, Warehouse C.

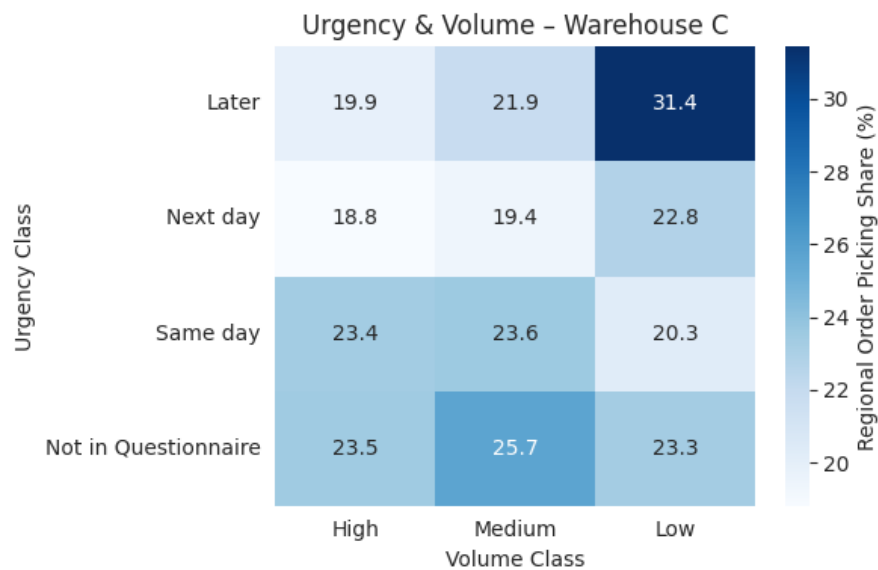


Figure 22. Regional order picking, urgency and volume, Warehouse C.

The overall low share of regional order picking and the low variation between the order picking share within different classifications show that there are possible problems with the region. The results limit the possibility of evaluating the region

but are at least an indicator of inventory issues and problems in the regional processes.

4.6.4 Warehouse D

The regional Warehouse D contributes approximately 9,5 % of the total regional sales. Around 70 % of orders placed in this area are picked at the regional warehouse. Figure 23 shows that this region has a higher share of A-class products, and a lower share of C-class products compared to all areas combined.

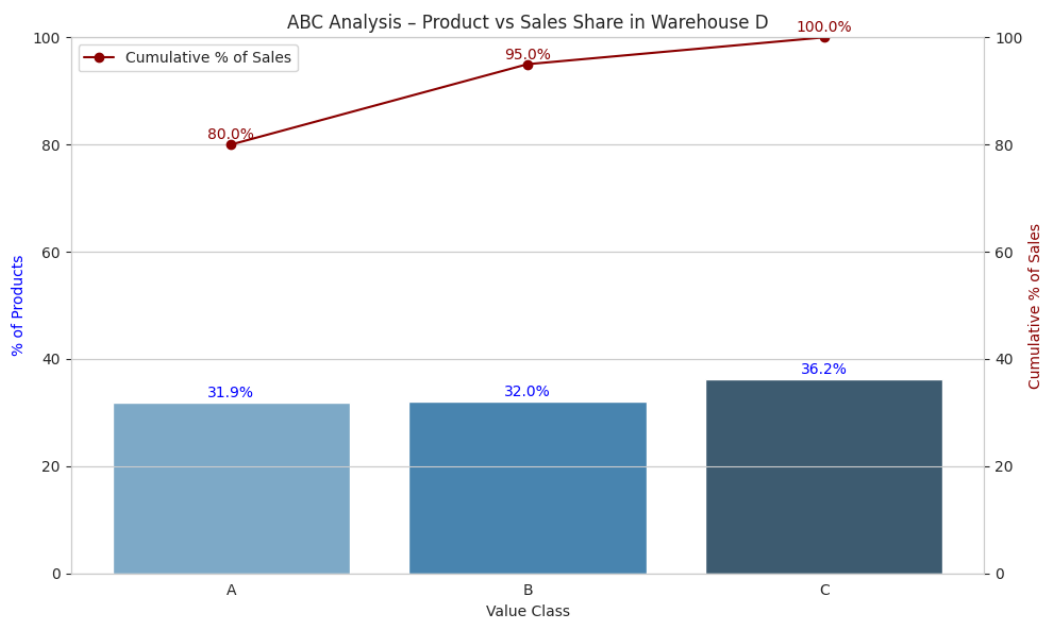


Figure 23. Product share between regional ABC classes, Warehouse D.

Figure 24 shows that C-class items have a higher share of regional picking compared to the other classes.

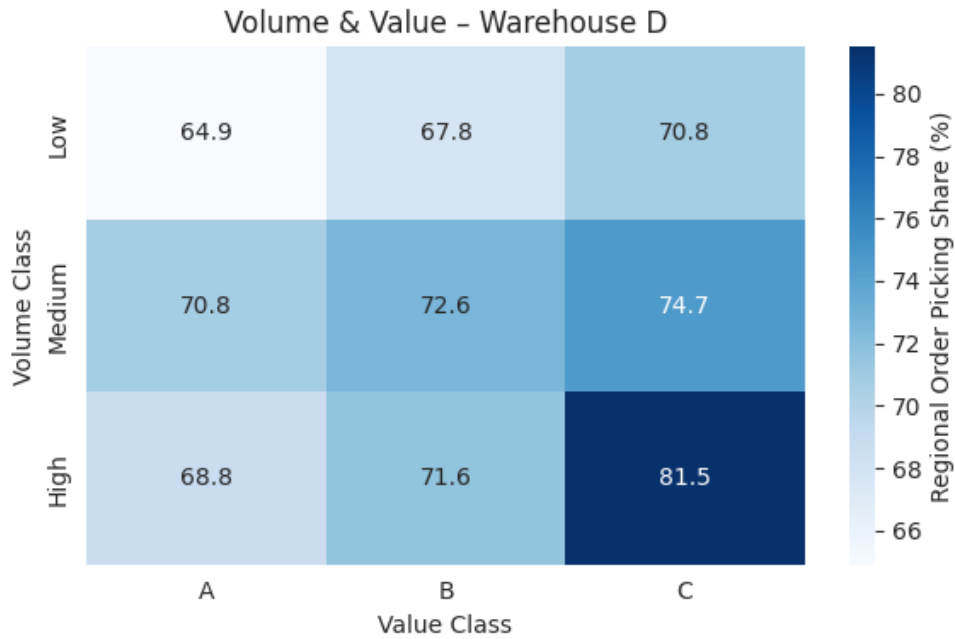


Figure 24. Regional order picking, volume and value, Warehouse D.

The urgency volume Figure 25 shows that products in the non-urgent urgency classes have a higher regional order picking share than the products in the same-day class. This is also true with the urgency-value heatmap. However, the variation between the order picking share within different classifications is low, making it difficult to identify clear patterns.

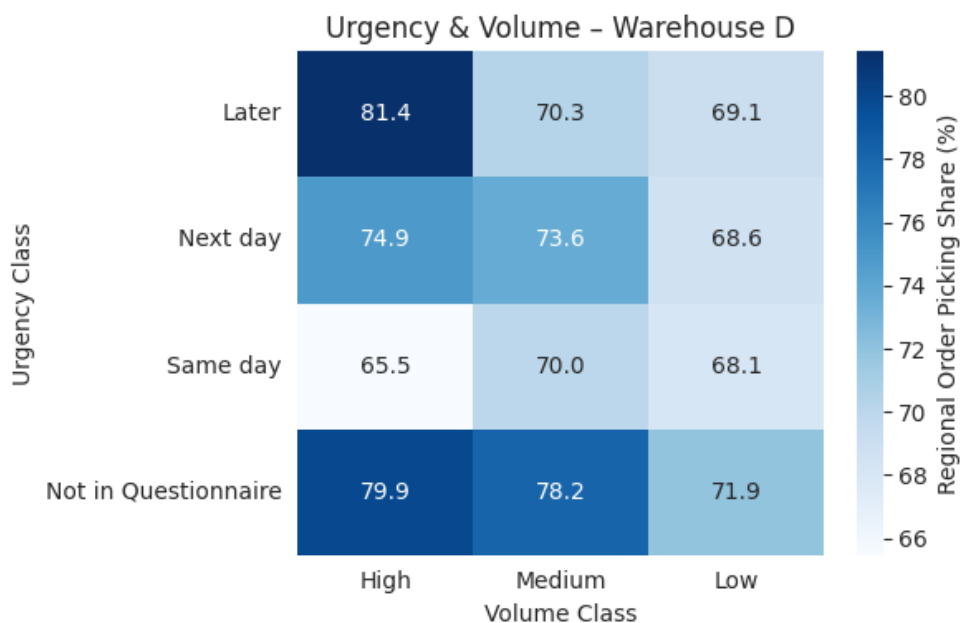


Figure 25. Regional order picking, urgency and volume, Warehouse D.

4.6.5 Warehouse E

The regional Warehouse E contributes approximately 9 % of the total regional sales. Around 68 % of orders placed in this area are picked at the regional warehouse. The share of products in each ABC class is similar to those in Warehouse D. The value-volume heatmap in Figure 26 shows almost even picking share across the volume classes. However, the lower-value class items have a higher regional picking share. The urgency-value Figure 27 shows that products in the same day and next day urgency classes have similar regional order picking share while the products in the later class have smaller shares. This is also true with the urgency-volume heatmap.

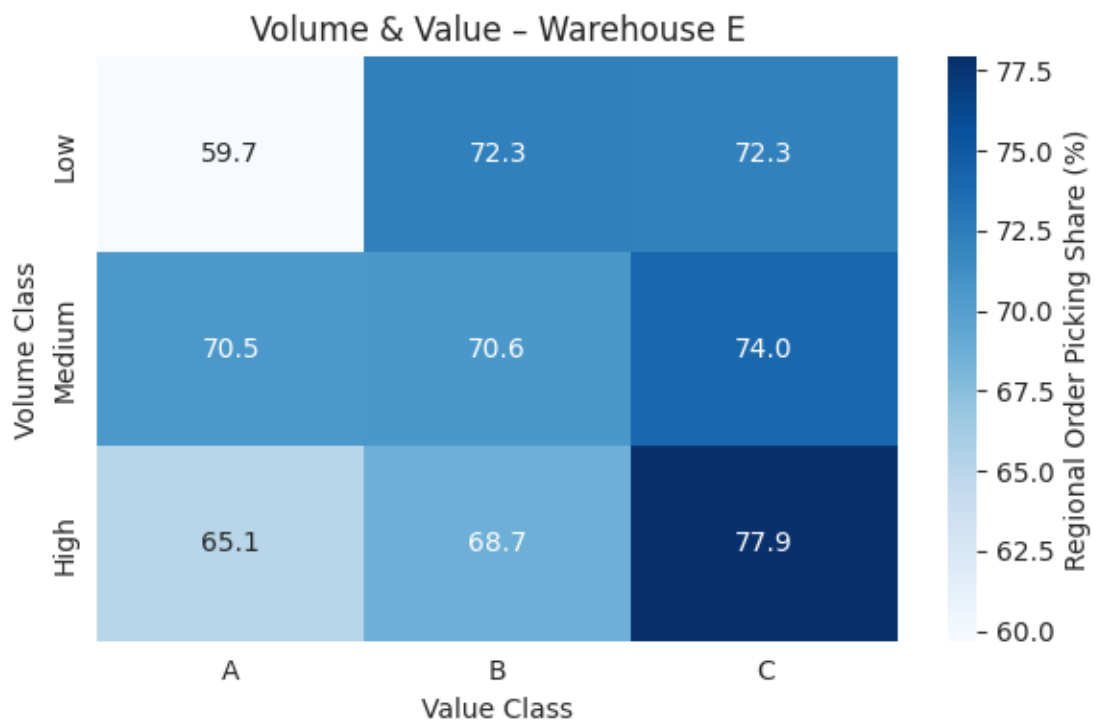


Figure 26. Regional order picking, volume and value, Warehouse E.

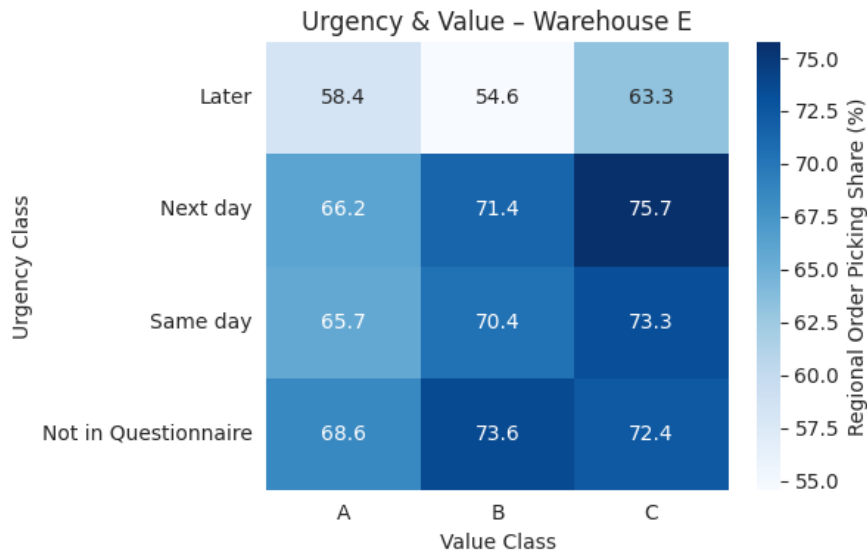


Figure 27. Regional order picking, urgency and value, Warehouse E.

4.6.6 Warehouse F

The regional Warehouse F contributes approximately 8,5 % of the total regional sales. Around 70 % of orders placed in this area are picked at the regional warehouse. The share of products in each ABC class is similar to the shares in Warehouse D. The volume-value Figure 28 shows that lower value and lower volume items have a higher share of regional picking compared to the higher classes.

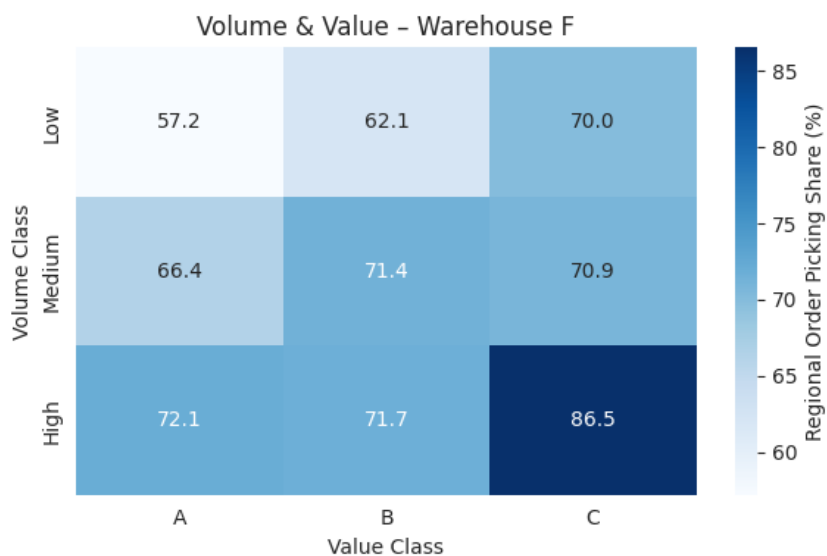


Figure 28. Regional order picking, volume and value, Warehouse F.

The urgency–value Figure 29 and urgency–volume Figure 43 show that there is a higher share of regional order picking in the next-day urgency class.

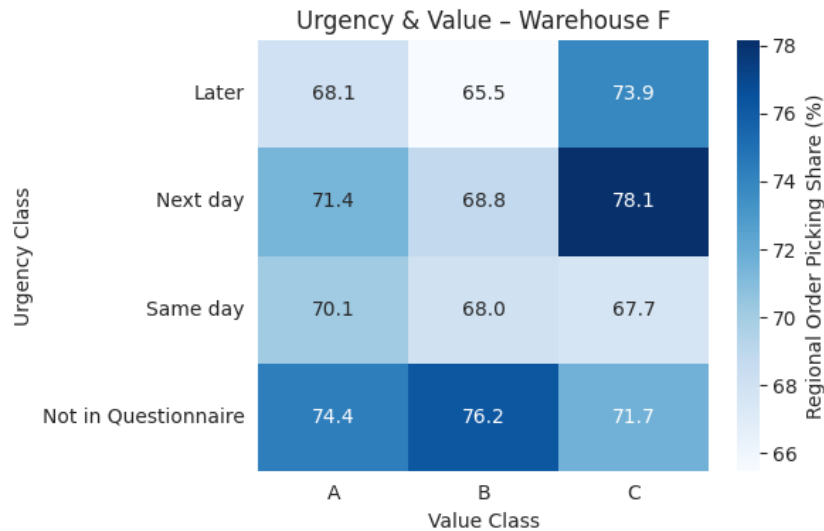


Figure 29. Regional order picking, urgency and value, Warehouse F.

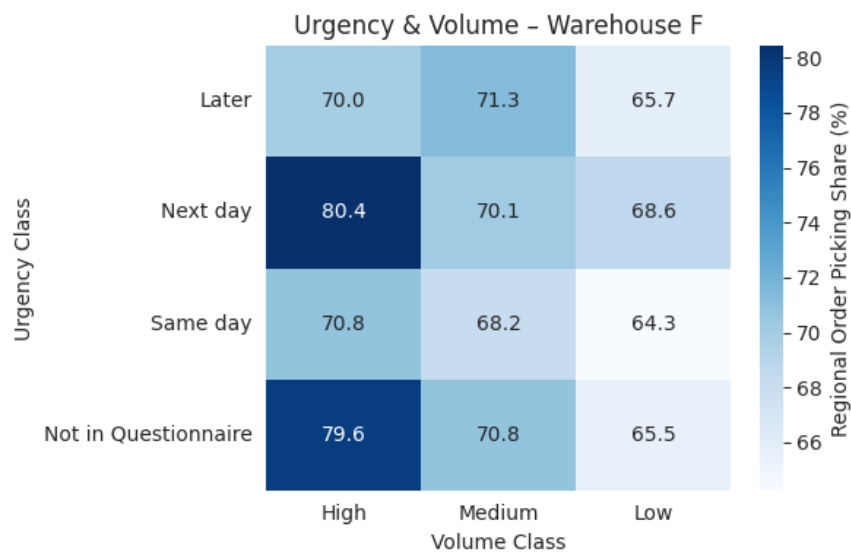


Figure 30. Regional order picking, urgency and volume, Warehouse F.

4.6.7 Warehouse G

The regional Warehouse G contributes approximately 7,5 % of the total regional sales. Around 56 % of orders placed in this area are picked at the regional

warehouse. The share of products in each ABC class is similar to those in Warehouse D. The volume-value order picking shares in Figure 31 show that low-volume items have a lower regional order picking share. On the value axis, the share remains almost even between the classes. The urgency-value in Figure 32 and urgency-volume in Figure 33 show that items with higher urgency have larger order picking shares.

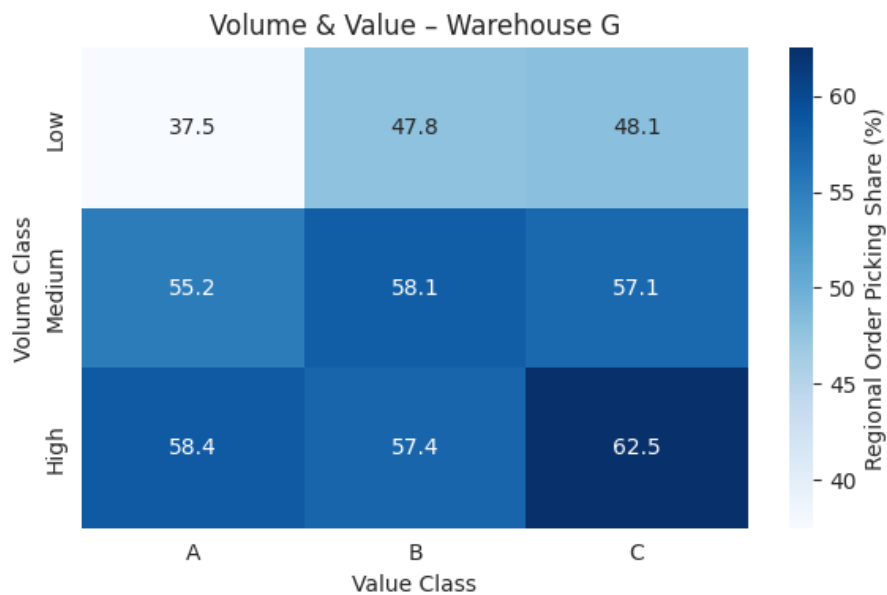


Figure 31. Regional order picking, volume and value, Warehouse G.

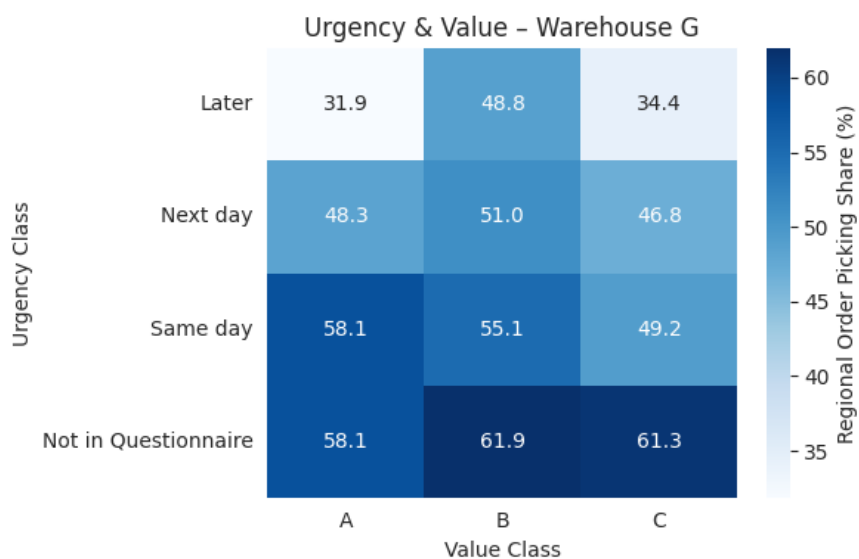


Figure 32. Regional order picking, urgency and value, Warehouse G.

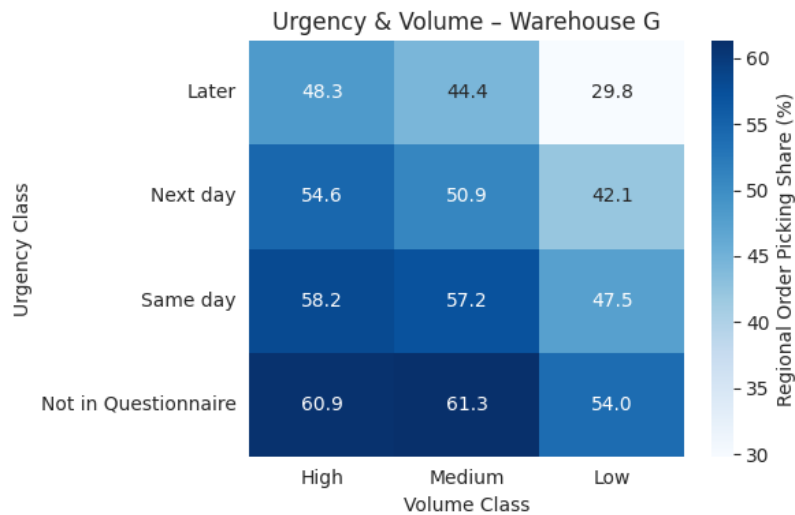


Figure 33. Regional order picking, urgency and volume, Warehouse G.

4.6.8 Warehouse H

The regional Warehouse H contributes approximately 7 % of the total regional sales. Around 83,5 % of orders placed in this area are picked at the regional warehouse. The share of products in each ABC class is similar to the shares in Warehouse D. The regional order picking shares vary very little between the different classifications, and no clear patterns can be seen from the urgency-volume or urgency-value heatmaps. Figure 34 shows the volume-value order picking shares.

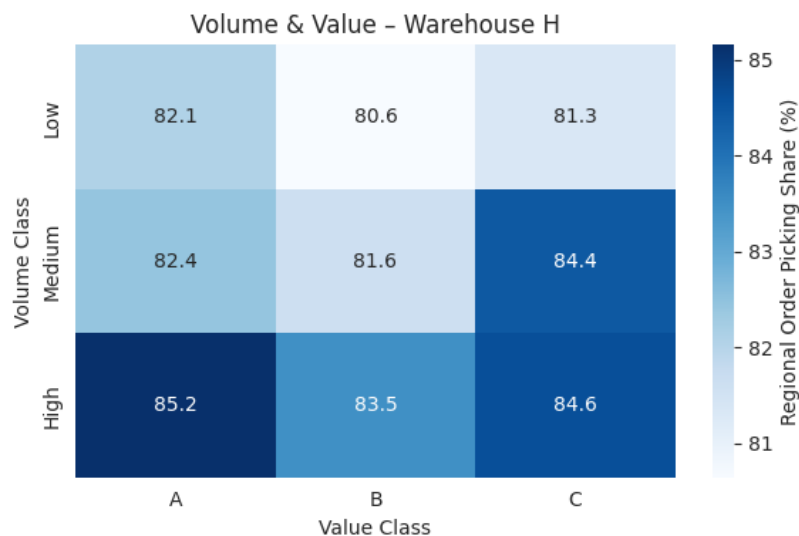


Figure 34. Regional order picking, volume and value, Warehouse H.

4.6.9 Warehouse I

The regional Warehouse I contributes approximately 6,5 % of the total regional sales. Around 38 % of orders placed in this area are picked at the regional warehouse. The share of products in each ABC class is similar to those in Warehouse D. Figure 35 shows that the lower volume items have a lower regional order picking share. The urgency-value in Figure 36 shows that the same-day products, and especially same-day A-value products, have a higher regional order picking share.

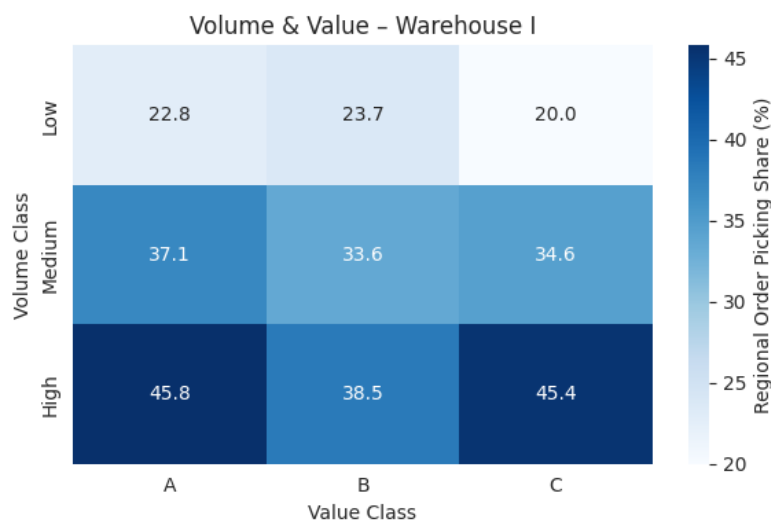


Figure 35. Regional order picking, volume and value, Warehouse I.

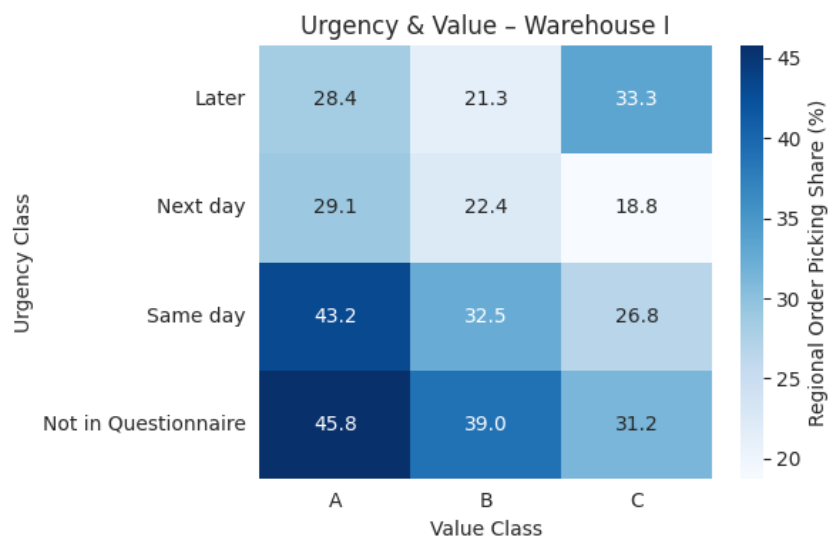


Figure 36. Regional order picking, urgency and value, Warehouse I.

4.6.10 Comparison of Regional Warehouses

The performance of the three largest regional warehouses differs noticeably. All of them handle a large number of orders, but the regional order-picking patterns vary a lot. The transfers to orders share were very similar in all three regions, and Warehouse A and Warehouse B had similar shares of regional order picking. Warehouse C had a noticeably smaller share of regional order picking. This could mean that there are problems with the local inventory or that a decision has been made to handle most orders through the central warehouse. Warehouse B shows the clearest pattern and has a higher regional focus on high volume, high value, and high urgency orders. Additionally, the low-volume, high-value items have the smallest regional order-picking share. Warehouse A shows some pattern, especially with the high-volume orders having more regional share.

Warehouse D, Warehouse E, Warehouse F, and Warehouse G all have similar sales values and similar regional order-picking shares. Warehouse H and Warehouse I are the two smallest regions, but their regional order-picking shares vary significantly.

Warehouse H and Warehouse C are also a great comparison, just looking at the order picking share and the value of the warehouses, it seems like they are completely different. However, neither of them shows clear patterns in the classification figures. This could mean that both areas have sub-optimal product ranges. Warehouse G and Warehouse B show very similar patterns, both with a focus on the higher urgency, volume, and value classes, this points to good regional product ranges.

The regions can also be grouped based on how much their regional order picking share varied across the different classifications. Warehouse B, Warehouse G, and Warehouse I had high variance, meaning that order picking rates clearly differed between different product classifications. Warehouse A and Warehouse E had medium variation, showing some differences, but not as clearly. Warehouse C, Warehouse D, Warehouse F, and Warehouse H had low variance,

meaning that the picking rates did not change significantly between different product classifications.

4.7 Summary of Issues in the Current State of Regional Warehousing

Issues with data quality are one of the most significant challenges in the current state analysis. Incomplete, inconsistent, or inaccurate data makes analysing the performance of regional warehouses difficult and distorts the results. Most notably, the problems with the large number of item groups with many unclear overlaps make analysis and management more difficult. The lack of historical stock data and unclear sales location and order-picking information complicate the analysis. These data limitations reduce the reliability of key metrics and limit the possibility of a more detailed analysis. Improving data accuracy and standardisation across systems is needed for more meaningful evaluations and better decision-making.

There is clearly variation in the effectiveness of the regional warehouses. This may be due to differences in the effectiveness of product ranges and the lack of standardised processes between regional warehouses. There are clear inconsistencies in how regional warehouses operate, particularly in how orders and inventory are managed. Without shared criteria and clear guidelines, each region's performance appears differently in the data.

The product range relies heavily on the regional warehouse coordinator, there is a lack of standardised processes, and many decisions are made with personal judgement. While the current setup works well, it is unclear how well the current system would continue to work if the coordinator changes or is unavailable. The problems with data also affect the product range screening, missing equivalent part data can cause the product range to have two interchangeable parts.

Items with only a single yearly sale staying in the regional product range can cause the inventory value to rise a lot. This is especially relevant for more expensive items that tie up more capital without significantly increasing service

levels. In many cases, it may be more efficient to centralise these items in the central warehouse and deliver them when needed. A clear strategy is needed to define when low-frequency items justify local storage and when they do not.

Even with the demand forecasting software in use for forecasting and managing product range, the process for approving replenishment suggestions and screening the product range is still very manual. This leads to a risk of delays, as approvals depend on individual availability and prioritisation. Manual steps also increase the chance of human error.

5 Propositions to Improve Regional Warehousing

To improve the current situation, several development actions are proposed. The overall quality of the data should be improved. This includes cleaning up the item group structure, eliminating overlaps, and ensuring that the grouping is meaningful for analysis and inventory management. Stock level and product range data should also be collected and archived on a daily basis to make it easier to evaluate historical performance and support future planning.

More advanced classification methods could be introduced to help the replenishment and monitoring processes. This could also be used to create more automation in the demand forecasting software. More advanced analytical models could also be developed with better data to evaluate the costs and benefits of stocking certain products locally. These models could incorporate more detailed variables and even use machine learning methods to improve over time. The goal would be to support more precise decisions about which items belong in regional warehouses and which do not.

There is a clear need to establish standardised and transparent processes for regional warehouses. This includes standardising how orders are placed and fulfilled, along with clear guidelines explaining how the processes work and why specific procedures should be used. Consistent practices across the different

regions would help improve efficiency and allow for more reliable data comparisons.

Further analysis should be done on the best-performing regional warehouse, Warehouse B, to identify the reasons for its strong performance. This could include reviewing its product range, ordering practices, and processes. By identifying what works well in that location, the best practices could be shared with other warehouses to improve regional performance and develop more consistent processes.

6 Conclusions

The objective of this thesis was to analyse and improve the operations of regional warehouses of a Finnish automotive spare parts wholesaler. The focus was evaluating inventory management practices, warehouse performance, and demand fulfilment efficiency. The goal was to identify ways to improve the regional warehouses, their product ranges, and operational processes. This study aimed to find inefficiencies and inconsistencies in regional warehouse operations, especially regarding inventory levels, product ranges, and regional processes.

Theory about supply chain management, inventory planning, warehouse optimisation, and spare parts supply chains was studied to understand the field. Sales, replenishment, and internal transfer data from the company's ERP system were used to understand demand behaviour, analyse current warehouse performance, and identify problems. Product classification was done using ABC, volume, and urgency-based methods. The urgency classification was derived from repair shop manager questionnaires. The classifications were used to analyse regional product range and stock management.

The results show challenges in the current warehouse operations. One notable issue is the quality of data. There are unclear item groups, no stock history, and problems accessing order-picking location data. These problems make it difficult

to perform accurate analysis and reduce the reliability and possibility of creating key performance indicators. Another substantial issue is the inconsistency between regional warehouses. Processes for handling orders vary across regions. Some regions operate efficiently, and others clearly show problems with product range and regional processes.

Suggested improvements include refining product range criteria using urgency and demand classification, improving data quality and consistency for better analysis and forecasting, establishing standardised, transparent processes for the regional warehouses, and analysing high-performing warehouses in more detail to identify best practices that could be applied across the network.

More research should be done to identify which spare parts are most likely to be needed on short notice by repair shops. Understanding which items are urgent and typically create same-day demand could be done through a broader survey of repair shop managers and mechanics, and possibly by analysing repair shop data, the data analysis depends on the availability and quality of that data. With a more comprehensive understanding of the demand urgency, only the products that require same day delivery could be stored at the regional warehouses.

In conclusion, this thesis provides a comprehensive view of how the regional warehouses function, where there are problems, and what can be done to improve the operations and service levels through data analysis and process improvements.

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I hereby declare that I have written this bachelor's thesis independently and that I have only used the resources specified in my paper. I have not submitted this paper or a paper with the same or similar topic elsewhere.

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