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Warehousing Process Improvement: The Case of an Airline Company

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Master in, Management of Services and Technology

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BUSINESS
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ABSTRACT

With the intensification of competitiveness between airlines, there is a need to reflect on the management of airline operations. Logistics is not an exception, as it has a direct impact on operations and consequently the numbers of passengers that the airline will serve. Research suggests that the warehouse is one of the key elements of a supply chain (Frazelle, 2002; Gu, Goetschalckx, & McGinnis, 2007). Of the various activities taking place in the warehouse, order picking is the most costly, representing around 55% of the total costs of the warehouse (De Koster, Le-Duc, & Roodbergen, 2007). The present study investigates how the picking process in inflight catering services warehouse in the company X can be improved to become more efficient.

Based on the literature review on strategies to improve the picking process, interviews with warehouse employees, and direct observation and archival records of company X, it was possible to conclude that the adoption of an SKU allocation policy would contribute to a reduction in the distances covered during the picking. Centred on a case study approach, the Storage Location Assignment Problem was solved by formulating a mathematical programming model and subsequently tested for two scenarios.

The analysis of the study results allows the conclusion that the adoption of either of the proposed scenarios represents significant improvements compared to the current scenario concerning distances covered. Along with the study elaborated and together with the proposed recommendations, the picking process can be improved to become more efficient.

Keywords: Inflight Services, Optimization, Picking, Warehouse Management, Storage Location Assignment Problem
JEL Classification System: M11; L62; C61

RESUMO

Com a intensificação da competitividade entre as linhas aéreas surge a necessidade de refletir sobre a gestão das operações. A logística não é exceção, uma vez que impacta diretamente na operação e consequentemente no número de passageiros. Pesquisas sugerem que o armazém é um dos elementos-chave de uma cadeia de abastecimento (Frazelle, 2002; Gu, Goetschalckx, & McGinnis, 2007) e que de entre as diversas atividades nele existentes, o processo de *picking* é a mais cara, representando cerca de 55% do custos totais do armazém (De Koster, Le-Duc, & Roodbergen, 2007). O presente estudo investiga como o processo de *picking* no armazém de *inflight catering* da Empresa X pode ser melhorado para se tornar mais eficiente.

Com base na revisão da literatura sobre estratégias para melhorar o processo *picking*, entrevistas com funcionários do armazém, observação direta e registos em arquivo, foi possível concluir que a adoção de uma política de alocação de SKUs contribuiria para a redução das distâncias percorridas durante o picking. Centrado numa abordagem de estudo de caso, o Storage Location Assignment Problem foi resolvido com a formulação de um modelo de programação matemática e posteriormente testado para dois cenários.

A análise dos resultados permite concluir que a adoção de qualquer um dos cenários propostos representa melhorias significativas face ao cenário atual em relação às distâncias percorridas. Com o estudo elaborado e em conjunto com as recomendações propostas, o processo de *picking* pode ser melhorado para se tornar mais eficiente.

Palavras-chave: *Inflight Services*, Otimização, *Picking*, Gestão de Armazéns, *Storage Location Assignment Problem*

JEL Classification System: M11; L62; C61

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GLOSSARY

COI – Cube-per-Order Index

ERP – Enterprise Resource Planning

HUD – Head-Up Display

KPI – Key Performance Indicator

MILP – Mixed Integer Linear Programming

RFID – Radio Frequency Identification

SKU – Stock Keeping Unit

SLAP – Storage Location Assignment Problem

WMS – Warehouse Management System

1. INTRODUCTION

This chapter presents the research theme by exploring the context of the airline industry in Portugal – and the challenges in it. The growth of the industry and the competition imply a need for adaptation and consequently the revision of some methods used. Firstly, a brief explanation of the airline industry in Portugal and its supply chain is provided, highlighting the importance of logistical processes for the company studied – Company X –, focusing on storage and picking processes.

Based on this context and identified challenges, the research question and objectives are presented to respond to it as a short presentation of the methodology used, and the structure of the dissertation is made.

1.1. CONTEXT

In 2018, the airline industry was contributing to the growth and development of the global economy. In Portugal, 15 airports and 9 airlines were registered, with 56 286 907 passengers transported, 6,3% more than the previous year (Pordata, s.d.). Contributing indirectly to the growth of the economy through job creation, according to the IATA report (2019), it created about 322 000 jobs and contribute to the Portuguese economy at the equivalent of 6,6% of GDP, representing 12,3 billion euros.

According to KPMG (2019), big changes in the aviation industry have been noticed in the last decades and airlines are the lifeblood of this market. The number of passengers has increased with the desire to travel and experience the world between millennials and Generation Z, and the older generation spending their retirement travelling. In this way, the necessity arises for the market to fit the needs of these new passengers and to satisfy them. Together with the intensification of competitiveness between the different airlines, there is a need to reflect on operations management and adjustment to new trends, and consequently to improve the service provided, by getting all processes more efficient by minimizing or eliminating waste throughout the processes, and also by reducing costs and maximizing profits.

An airline company is associated with a complex chain, since the relationships between suppliers can be considered a complex network, due to the international nature of the industry with several partners across the globe (Jones, 2004). It is necessary to guarantee the delivery of a service as efficiently as possible to the final customer, in this case, the passenger. The airline must assess different services that could have an impact on the service provided to the final customer. According to Ivanovic & Vujic (2007), the impact of logistics and certain services for the final customer is indirect, however, for airlines, the impact of logistics on their operations is direct and can impact on the number of passengers and consequently on profit and loss.

One logistics area that needs to be considered corresponds to the inflight services, which even indirectly adds value to the customer experience offered. Inflight services include catering, entertainment, duty-free shopping, onboard amenities, and other services that are available to the passenger.

The supply chain of inflight catering can be considered as an integrated network of physical products flowing from suppliers to producers and with some challenges in controlling performance related to ordering products from suppliers, associated logistical activities, and building relationships across a network (Jones, 2004).

Inflight catering products are critical to the core business of airlines since they can directly affect aircraft operational efficiency.

One of the key cornerstones of the inflight catering supply chain is the warehouse (Frazelle, 2002; Gu, Goetschalckx, & McGinnis, 2007). This investigation will be focused on the inflight catering warehouse, which is considered an important process station, as it can represent the efficiency or inefficiency of the entire supply chain. The inflight catering warehouse storage part of the material for the caterer and outstations supplied by the company, as well as material for cleaning and dress the aircraft, as blankets, pillows, backrests, etc.

The warehouse serves all other logistical activities and its main role is the storage of products (Frazelle, 2002). Among the warehouse's various operations, order picking is one of the most expensive, representing about 55% of the warehouse's total operating expenses (De Koster, Le-Duc, & Roodbergen, 2007), being considered as one of the main areas for improvement. This is the case for airline companies operating all over the world, including Company X, where the study will be conducted. The significant contribution to the warehouse management costs of the order picking process in the warehouse devoted to the inflight catering services in Company X makes it essential to explore the picking process and evaluate how it can be improved to make it more efficient and, consequently, reduce underlying costs.

Within this setting, and since according to Frazelle (2002) the picking process mainly involves travelling, searching, and extracting, with travelling representing around 50% of the time spent at the warehouse. Reducing the travelling distances across the warehouse to make the searching and extracting functions as fast as possible could be a way to improve the picking process. These improvements are thus the focus of this project.

1.2. Research Question

Based on the context previously presented, the question that will be researched in this dissertation will be:

"*How can the picking process in the warehouse of the inflight catering service in Company X be improved to become more efficient?*".

1.3. Objectives

Associated with the research question, the main objective of the dissertation is the improvement of the picking process in the warehouse of the inflight catering service in Company X both by reducing the distances travelled in the warehouse and by making the searching and extracting functions faster.

To answer the research problem, the following specific objectives were created:

a. Mapping the "*as is*" process in the warehouse – picking process.
b. Characterize the "*as is"* process in terms of the travelling, searching, and extracting times.
c. Propose alternative solutions to improve the picking process.
d. Evaluate the alternative solutions based on different key performance indicators – travelling distance and other relevant KPIs.
e. Compare the "*as is"* process in the warehouse with the "*to be"* process characterizing each of the proposed alternative solutions.

1.4. Methodology

This dissertation is based on the Case Study approach since according to Yin (2014) this approach is the preferred strategy when "*how*" or "*why*" questions are being posed, when the researcher does not control events, and when the focus of the research is a contemporary phenomenon with a certain real context.

The steps developed to carry out the investigation will be the following:

- Step I – Characterizing the picking process in the warehouse.
- Step II – Proposing alternative scenarios for improving the picking process.
- Step III – Evaluating scenarios
- Step IV – Recommendations for future improvements.

1.5. Structure

Aiming to complete the objectives and respond to the research question the dissertation will be structured in the following way:

Chapter 1 – Introduction: This chapter will present the context of the investigation, the formulation of the research question, and the objectives. Concluding with the adopted methodology and the structure of the dissertation.

Chapter 2 – Literature Review: The literature review supports research in theoretical terms, containing concepts and tools used to answer the objectives and research question. The chapter begins with the description of warehouse management and warehouse management for inflight services, moving on to the focus of the research question, picking process. The concept of picking process is covered and described, and strategies to improve the process is clarified. At the end of the chapter, the Storage Location Assignment Problem is covered and some conclusions of the literature review.

Chapter 3 – Methodology: This chapter describes in detail how the investigation was conducted, in this case through a case study and its justification.

Chapter 4 – Problem Modelling: This chapter provides the formulation of the mathematical programming model used to solve the problem under study.

Chapter 5 – Case Study: In this chapter, there is going to be a brief overview of the company and the problem under study and then the implementation of each of the research stages.

Chapter 6 – Conclusion: In the final chapter the main conclusions of the investigation are presented, with the objectives and research question answered. Following are the recommendations for future improvements.

2. Literature Review

This chapter aims to present the theoretical background that will support the investigation. The literature review has been based on the following keywords: warehouse management, inflight catering, order picking, SLAP. Databases that have been used were ScienceDirect, SAGE journals, and Emerald.

To answer the research question in a first phase, the management of warehouses is, especially relating to inflight catering and the activities of the warehouse focusing on order picking. Later, the strategies for improving the process are explained, and finally, the most used methods to solve the storage location assignment problem are clarified.

2.1. Warehouse Management

Warehousing is an integral part of the supply chain, somewhat defining business success though cost and customer service (Gu, Goetschalckx, & McGinnis, 2007; Phogat, 2013; Stock, Lambert, & Ellram, 1998; Rushton, Croucher, & Baker, 2014), being involved in several phases from sourcing, distribution, production of goods from raw materials to finished goods (Rushton, Croucher, & Baker, 2014).

Frazelle (2002) suggests the warehouse as the last of the logistical activities, since the good planning of the logistical activities that precede storage can eliminate this need, but also because the warehouse must meet all the requirements of the customer service and hold all the inventory necessary for order fulfilment (Bowersox, Closs, & Cooper, 2002). Which is to say, it must be consistent with all previous activities, warehousing constitutes a service for all logistics areas.

Storage was always a key point in the development of the economy (Bowersox, Closs, & Cooper, 2002) and represents an important link between the producer and the consumer (Stock, Lambert, & Ellram, 1998). Production and consumption take place in different locations and there is no reliable and reasonably costly transport for the product to be produced to go directly to the customer. Storage reduces the costs of the logistics system and puts the product more efficiently close to the market, thereby improving customer service (Carvalho, et al., 2012). By acting as a buffer between supply and demand variability, warehouses become a necessary element in the supply chain (Phogat, 2013; Rushton, Croucher, & Baker, 2014).

Storage alone does not add any value to the product for the customer, but it contributes to the whole logistics system and can fulfil the value proposition (Carvalho, et al., 2012). Ballou (2004) believes that storage is an economic convenience, more than a need.

According to Bowersox, Closs, & Cooper (2002), a warehouse provides economic benefits when logistical costs are reduced and thus the warehouse can be economically justified. In literature, the reasons for storage are reasonable in different ways by several authors. The decrease in transport costs, the increase in economies of scale both in the shipment of items and in their purchase, seasonality and safety stocks (Coyle, Bardi, & Langley, 1988; Stock, Lambert, & Ellram, 1998; Ballou, 2004; Bowersox, Closs, & Cooper, 2002; Rushton, Croucher, & Baker, 2014) are reasons to maintain stocks. Coyle, Bardi & Langley (1988) and Stock, Lambert & Ellram (1998) also added customer service, since an "effective customer service plan can relieve the pressures of delays in production or transportation". All warehouses should be designed with the specifics of the supply chain to which they belong, however there are a set of activities in common (Frazelle, 2002; Rushton, Croucher, & Baker, 2014). For an inventory holding warehouse, the typical operations and material flows are; receiving, reserve storage, order picking, collation, added value services and packing, marshalling and dispatch.

The research focus will be the picking process which is going to be studied in detail in section 2.1.2.

2.1.1. Warehouse Management for Inflight Catering Services

According to Hovora (2001), a huge number of products are placed on board, the type of service and passengers influences the number of products, and for example, a short flight implies a smaller load of products and quantities while a long-haul flight requires a greater number of articles and greater complexity.

Hovora (2001) also states that food is normally carried by the caterer and that the logistics of the remaining products are the responsibility of the airlines, however some companies have decided to outsource these services to specialized supply chain companies. However, even when airlines outsource catering, they still receive inflight products or beverages. From this perspective, Jones (2004), considers the logistics inflight supply chain as an integrated network of physical goods from suppliers to flight production units.

According to Ivanovic & Vujic (2007) comparing to other industries, for example, retail, the flight service warehouse has a different orientation and some differences can be noted: these warehouses tend to stock raw materials to be assembled and load by the service providers instead of goods available for final consumption, the stock holding of equipment that is important as products or material, and the location of these warehouses are usually close to an airport.

High quantities of materials are constantly being moved around the globe and for that reason, while some SKUs may have little stock in some places, in others they may be overstocked (Hovora, 2001).

2.1.2. Order Picking Process

Order picking (and sorting) is a key activity in most warehouses, which consists of removing a product required by the customer and its delivery, in good time, and good condition. It is considered the costliest warehouse activity (Gu, Goetschalckx, & McGinnis, 2007), about 50-55% of warehouse operating costs. Order picking is a very labour- and capital-intensive activity following De Koster, Le-Duc, & Roodbergen (2007) and Frazelle (2002) and therefore is considered the highest-priority area for improvements in productivity.

It is in picking, in accordance with Carvalho, et al., (2012), that customer service begins, by declaring that this activity will have an impact on the "time-cost-quality" logistics triangle.

"The faster the picking, the faster you can deliver to the customer (time); the more efficient the picking, the lower the cost to the customer (cost); the more effective the picking, without errors, the higher the delivery quality." (Carvalho, et al., 2012, p. 308)

According to Frazelle (2002), picking consists of travelling (55%), searching (15%), extracting (10%) and others (20%).

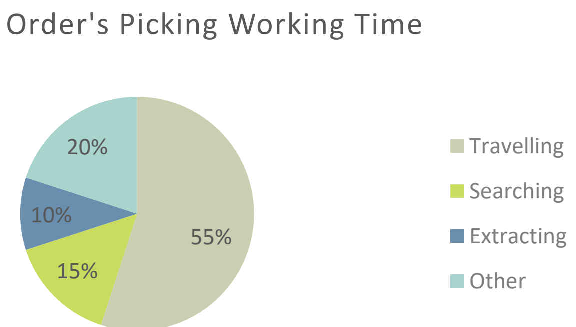

Figure 2.1 Order's Picking Working Time (Frazelle, 2002)

Most of the time is spent on travelling and searching, Frazelle (2002) suggests that storage be moved close to the picker, thus making the whole process more efficient. The efficiency in the picking process will be a consequence of the efficiency in these tasks. In order to obtain the best performance, different strategies can be followed:

i. Redefinition of the Layout – Henn, Koch, Gerking, & Wascher (2013); Štefančić, Bede-Jakovinac, Bajor, & Ivaković (2018); Diefenbach & Glock (2019).
ii. Redefinition of Picking Routes – Elbert, Franzke, Glock, & Grosse (2016); Franzke, Grosse, Glock, & Elbert (2017).
iii. Redefinition of Picking Types – Dukic & Oluic (2007).
iv. Redefinition of Assignment Policies of SKUs – Tarczyński (2017); Wang, Zhang, & Fan (2020).
v. Implementation of Information Technologies – Hanson, Falkenström, & Miettinen (2017); Dujmešić, Bajor, & Rožić (2018); Fager, Hanson, Medbo, & Johansson (2019).

2.1.2.1. WAREHOUSE LAYOUT

The layout of a storage facility has as its main goal to ease the flow of products inside the warehouse and to minimize the distances travelled (Bowersox, Closs, & Cooper, 2002; Carvalho, et al., 2012).

The layout classification relies on the flow of goods and can be a directional flow or through-flow and broken flow or U-flow (Carvalho, et al., 2012).

In broken flow (Figure 2.2 – right side), the receiving and shipment take place on the same side of the warehouse (Rushton, Croucher, & Baker, 2014). The major advantage of this layout is the reduction of picking and stockpiling distances (Carvalho, et al., 2012), and it is also beneficial when receiving and shipping takes place at different times of the day (Rushton, Croucher, & Baker, 2014).

The directional flow (Figure 2.2 – left side) is advantageous for reducing congestion inside and outside the warehouse since receiving and shipping operations occur on opposite sides of the warehouse (Carvalho, et al., 2012).

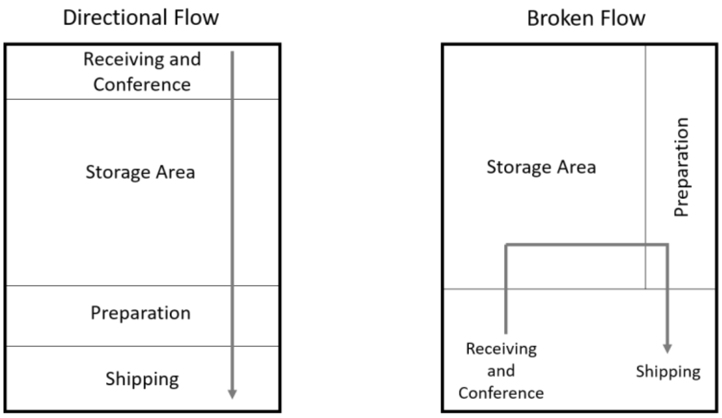

Figure 2.2 Warehouse Layout (Adapted from Carvalho, et al., 2012)

According to Rushton, Croucher & Baker (2014), other layouts may be considered, as is the case of L-flow, where the receiving and shipping area is not located on opposite sides but neither are side by side or even a mix of different types of layout.

For example, Diefenbach & Glock (2019) applied the U-shaped layout when storing pallets in the order picking zone of the warehouse, decreasing between 13 to 18% of the total distances. Štefančić, Bede-Jakovinac, Bajor, & Ivaković (2018) compared three different layouts and concluded that the U-flow is the most suitable for an average number of picks (Henn, Koch, Gerking, & Wascher, 2013), and compared to a classic layout, the flying V has a 10% improvement and the fishbone reduces the distances covered in 20%.

2.1.2.2. Picking Routes

Using a specific route policy that defines the sequence and routes of travelling is one of the problem-solving ideas given by some authors in the scientific literature as a way to reduce traveling distances (Dukic & Oluic, 2007; De Koster, Le-Duc, & Roodbergen, 2007).

Dukic & Oluic (2007) affirm that, nevertheless, the performance of a method will depend on the storage assignment policy adopted, and vice versa. Most of the problems related to routes are solved by heuristic algorithms since optimal routing has some disadvantages. De Koster, Le-Duc, & Roodbergen (2007), additionally advise that it is necessary to take into consideration that an optimal algorithm may not be available for all layouts and that an optimal standard algorithm does not take into account the congestion of the aisles, which with heuristics can be avoided.

Dukic & Oluic (2007) and De Koster, Le-Duc, & Roodbergen (2007) introduce six different route policies:

- S-shape or Transversal – It is the simplest heuristic routing. In this method, the picker goes through all the aisles where there are items to pick, until the end. If there is no item in that aisle, it is skipped, unless the number of aisles is odd.
- Return – The picker enters and exits the front of the aisle whenever there is an article to be picked.
- Midpoint – This policy imaginatively divides the warehouse into two parts, only the first and last aisles are completed in their entirety. The picks in the front half are accessed by the front cross aisle and the picks in the back half are accessed by the back cross-aisle. When the number of picks per aisle is small, Hall (1993) argues that the adoption of this method is better than the S-shape.
- Largest Gap – Similar to the midpoint heuristic, the aisles will be crossed with items to be picked, only the last and the first aisles will be fully covered. The gap represents the separation between two adjacent picks. The picker enters and exits on the same side of the corridor running past the midpoint. This heuristic is more complex than those previously mentioned.
- Composite/Combined – Represents a combination of two heuristics, the s-shaped and the return, reducing the distance travelled between the farthest picks in two adjacent aisles.
- Optimal – Results in the shortest route to travel. Combining graph theory and dynamic programming.

Franzke, Grosse, Glock, & Elbert (2017) studied the effects of picking routes on the picker blocking and concluded that only the optimal policy “led to shortest mean throughput times” when a route is assumed by all order pickers. It was also concluded that the combined policy minimizes mean throughput time without blockings when compared to other policies, but when blocking is considered the mean throughput time increases.

Elbert, Franzke, Glock, & Grosse (2016) also studied the picker's behaviour during picking and concluded that the use of an optimal route is advised even if an effort is required in its implementation and a high risk exists of the picker deviating from the route. Heuristic algorithms are advantageous for a high number of picks and have a low probability of deviation from the route.

2.1.2.3. Types of Picking

Productivity depends on the technique used for picking by considering the profile/type of orders. Carvalho, et al. (2012) and Rushton, Croucher, & Baker (2014) defend the following methods:

- Picking by Order – Picker travels the warehouse to gather all the items in an order. Utilization of this method reduces errors; however, productivity is lower due to the time spent travelling.
- Picking by Line – A specific product collection sequence is defined, and the picker follows this route collecting in each location the quantity of each SKU needed to satisfy various orders. The route is defined so that the distance travelled is as small as possible, in this case, productivity is high, but the frequency of errors may be higher.
- Zone Picking – In this type of picking, each picker is responsible for one zone and goes to picking in that same zone, collecting the SKUs for each order located in its area. In the end, the order is consolidated in one zone. Chance of errors occurring is lower and productivity is higher since each picker only works on one order at a time.
- Batch Picking – This method is similar to picking by line, but for a set of orders and not with the total of orders. The picker collects the quantity of SKUs for the total of this set and separates them by orders, the greater the number of orders, the greater the productivity but the greater the possibility of errors.

Dukic & Oluic (2007) reveals that order batching demonstrated the best performance in reducing the distance travelled, mainly with small orders.

2.1.2.4. Storage Assignment Policies

Gu, Goetschalckx, & McGinnis (2007) argue that different warehouses can use different SLAP (Storage Location Assignment Problem) policies considering the specificities of SKUs and storage technologies. The efficiency of handling and moving products in the warehouse can be impacted by the method used to define their location (Carvalho, et al., 2012).

Carvalho, et al. (2012) aggregate them into three: random location, fixed location, and class-based location.

In random location, each pallet or amount of similar products goes into the warehouse and is randomly assigned to a location, depending on the empty spaces in the warehouse. The same reference may have several locations in the warehouse (Carvalho, et al., 2012), requiring the maintenance of a detailed position record and stocks, requiring constant updating. The main advantage of this method is the high profitability of the space available in the warehouse, easily adapting to variations in stock quantities, however it leads to an increase in the distances travelled in a warehouse during picking (De Koster, Le-Duc, & Roodbergen, 2007; Carvalho, et al., 2012). De Koster, Le-Duc, & Roodbergen (2007) completes this strategy by referring to the closest open location storage in which if the picker could choose where to place the products, they would be placed closer to the entrance/exit. There would be very full racks near the entrance and as the picker moves, they become emptier. This method is only used for products moved on full pallets.

In the fixed location or dedicated storage (De Koster, Le-Duc, & Roodbergen, 2007) there is a location previously defined based on the rotation, the number of movements of entry and exit, the volume, and on the ratio volume/number of movements of entry and exit, among others. The disadvantage of this method is the underutilization of space that can be created. The space required for each reference is calculated based on the maximum stock, but it is not always the case in the warehouse that you have the maximum stock, therefore there will be some empty spaces (De Koster, Le-Duc, & Roodbergen, 2007; Carvalho, et al., 2012).

A class-based location (Carvalho, et al., 2012) or class-based storage (De Koster, Le-Duc, & Roodbergen, 2007) is the combination of the two methods mentioned above. Thus, there is a storage space subdivided into zones with fixed locations and within those zones the references are stored in any location (Carvalho, et al., 2012).

For the different types of storage, Gu, Goetschalckx, & McGinnis (2007) present the three most used criteria when choosing the location:

- By Popularity – defining the number of storage or shipments per unit of time. For this policy, the product classes are ranked in decreasing order of popularity and the most popular classes will be stored in the most desired locations.
- Maximum Inventory – defining the maximum space for each SKU in the warehouse. In this criterion, product classes are ranked by increasing maximum inventory and classes with the lowest maximum inventory are allocated to the most desired locations.
- Cube-Per-Order Index – defined as the ratio of the maximum number of allocated storage space to the number of storages by the number of shipments in the time unit. This policy considers the popularity of SKUs and the required storage space, classes are ranked in ascending order of COI value and classes with a lower COI are arranged in the most desired locations.

Gu, Goetschalckx, & McGinnis (2007) conclude that COI policy has been extensively studied in the literature and it is more effective than the other two.

One of the most well-known and most commonly used methods in the industry is ABC analysis (Millstein, Yang, & Li, 2014). According to Carvalho, et al. (2012), not all articles have the same importance and for that reason should have different procedures. Present analysis categorizes articles, normally, by their value or volume of consumption in each period, based on the Pareto rule, 80/20. (Millstein, Yang, & Li, 2014; Carvalho, et al., 2012).

The top 20% are classified as A, the next 30% as B and articles C the following 50%, so articles A are more important, having storage in a more desirable position in the warehouse.

Instead of using a traditional "data→concept→assign" product allocation method, Wang, Zhang, & Fan (2020) proposed the data-based-approach in which decisions follow data and products are allocated. They conclude that it is an easy-to-use method although more suitable for warehouses with few aisles.

Tarczyński (2017) researched the impact of COI-based storage on order picking times and concluded that using class-based storage leads to considerable improvements in picking activity. Research indicates that in warehouses where the picker collects many items in one trip, storage based on picking frequency is superior to storage based on COI.

2.1.2.5. Information Technologies

Bowersox, Closs, & Cooper (2002) argue that one way to improve order processing and order picking is through technology.

The four most used technologies in order picking are: paper picking, pick by light, pick by voice, and radio frequency identification, according to Zivanic, Vladic, & Dokic (2011). In addition to the first four previously mentioned, Fager, Hanson, Medbo, & Johansson (2019) present the pick by HUD (head-up display), and Hanson, Falkenström, & Miettinen, (2017) explored augmented reality.

- Paper Picking – Utilized in order picking for a long time, and appropriate for small order picking operations. It consists of printing a paper with the picking list and the picker confirms with a pen when he collects the products.
- Pick by Light – Is the technology that has the highest productivity and accuracy compared to other technologies (Zivanic, Vladic, & Dokic, 2011). This is a system with a light that indicates the next location and the quantity that satisfies the order, combining "get information" and "search" activities.
- Pick by HUD – System which uses a head-up display and computer visualizations to orient the picker. In comparison with other technologies, it demonstrates the potential in aspects such as quality and time efficiency (Guo, Wu, Shen, & Starner, 2015; Hanson, Falkenström,

& Miettinen, 2017). The picker gets information through a graphical interface.

- Pick by Voice – The benefit of this technology lies in the fact that it is hands-free, enabling the picker to focus on the product and its location. The location and quantity are indicated to the picker via headset and confirmed with the picker's voice recognition. Picking time can be reduced with this technology, as the picker listens to while moving to the next location.
- RFID – This technology is used with radio and wireless waves to obtain information without or reduced human intervention. One of the advantages is that RFID tags can be read from a great distance and simultaneously.
- Augmented Reality – Hanson, Falkenström, & Miettinen (2017) define AR as the combination of the real and the virtual worlds using 3D technology and being interactive in real-time. The pick by AR was developed only for the study of Hanson, Falkenström, & Miettinen (2017), who conclude that the choice of this method must be analysed and can be applied in the options mentioned above.

Fager, Hanson, Medbo, & Johansson (2019) studied four different picking system types in single kit and batch preparation and concluded that pick by light has advantages in single kit preparation. In batch preparation, a system that presents little or no time to separately confirm each order, as paper picking is beneficial in terms of time efficiency.

Dujmešić, Bajor, & Rožić (2018) applied pick by voice in different types of warehouses in Croatian markets and the positive results were evident, improving the efficiency of the process – 20% – and the reduction of control points in the first phase.

To get a better performance in order picking, several strategies can be followed. Among them is the redefinition of the assignment policies of SKUs (Gu, Goetschalckx, & McGinnis, 2007) already mentioned in subchapter 2.1.2.4, referring to the SLAP, one of the most important problems at a warehouse.

Accorded the impositions of the company this shall be the strategy to use and therefore the following subchapter refers to the presentation of methodologies used to support the issue.

2.2. Storage Location Assignment Problem

"The warehouse management problem and, more specifically, the storage location assignment problem (SLAP) has represented a critical issue in Operations Management and Operations Research since 1976 (…)" (Battista, Fumi, Giordano, & Schiraldi, 2011, p. 1).

SLAP is an operational problem that is related to the allocation of products in the storage area and to the optimization of material handling costs and storage space utilization. The definition of this issue depends on the parameters such as “storage area design, storage space availability, warehouse storage capacity, physical characteristics of the products, arrival times, and demand behaviour (Reyes, Solano-Charris, & Montoya-Torres, 2019, p. 200).

Reyes, Solano-Charris, & Montoya-Torres (2019) present a chart with the most used methods in the literature to solve this type of problem, with the exact methods being the most frequent, followed by the heuristic and metaheuristic methods.

Regarding exact methods, branch-and-bound is one of the methods that is used and consists of dividing the problem into subproblems. The optimal solution to the subproblem may or may not be the global solution of the problem. Each time a solution is found, it is checked to see if the solution is better than the previous one (Hoffman & Ralphs, 2012), thus making the branch-and-bound method slower and inefficient. However, it presents an exact and optimal solution. Muppani & Adil (2008) applied the branch and bound algorithm to solve a product allocation problem with class-based storage.

Another widely used method is mixed-integer linear programming (MILP) (Reyes, Solano-Charris, & Montoya-Torres, 2019). Ene & Öztürk (2012) used MILP with class-based storage and proposed the use of a genetic algorithm to minimize the time travelled for storage and recovery in the automotive industry and Chen & Lu (2012) studied an exact model to solve a storage problem in a marine terminal.

Heuristic algorithms are tremendously efficient for large problems, but the optimal solution is not ensured to be achieved. These methods tend to be more effective in finding feasible solutions within an acceptable time-frame (Hillier & Lieberman, 2005). According to Reyes, Solano-Charris, & Montoya-Torres (2019), the methods most applied in the literature are algorithms and procedures (SA&P), multi-stages procedures (MS) and hierarchical procedures (HH). To minimize the distance covered in order preparation, Wutthisirisart, Noble & Chang (2015) proposed a heuristic model in two phases, sequencing, and location.

Concerning metaheuristics, the best-known methods are taboo search, simulated annealing and genetic algorithms, all of which use innovative concepts that guide a search procedure to move toward the optimal solution (Hillier & Lieberman, 2005; Reyes, Solano-Charris, & Montoya-Torres, 2019).

Although these are the most used approaches, it is important to note that late in the literature other methods like simulation have started to be used more frequently. Gagliardi (2014), in order to compare distances taking into account different allocation policies, presupposed the use of discrete event-based simulation in the automated environment.

2.3. CONCLUSIONS

In this chapter, the theoretical concepts that support the investigation were defined and developed.

First, the management of warehouses and their activities have been clarified, with a focus on the order picking process as well as the strategies to improve it.

To reduce the distance travelled by the picker during the picking process is to take the locations to the picker. This means, the closer the locations are to the picker the better – this is supported by literature in the area since travelling during the picking process is recognized to represent 50% of the time spent at the warehouse (Frazelle, 2002). Items with the highest turnover nearest to the preparation area will consequently reduce the picking time.

The reduction in picking time and distance travelled in this activity could be reduced through the adoption of different strategies presented in the literature review, namely:

1. Redefinition of the Layout.
2. Redefinition of Picking Routes.
3. Redefinition of Picking Types.
4. Redefinition of Assignment Policies of SKUs – SLAP.
5. Implementation of Information Technologies.

The research will focus on the improvement of order picking in the warehouse of Company X. Since company X does not want to change the layout or modify the picking process or even the information systems used. In this way, the only possible solution to improve the performance in order picking process is the redefinition of the assignment policies of the SKUs. The Storage Location Assignment Problem plays a significant role in the investigation since the distribution of the SKUs at the warehouse, distances, and picking times should be improved. The methodology to be used for the formulation of the mathematical model will be the exact method, more specifically the MILP, due to the fact that it indicates an optimal solution for the problem presented.

To conclude, all the studies done and analysed in this chapter created a strong theoretical foundation for the orientation of this research, which makes it possible to present a solution to the proposed problem, making the picking process more efficient by optimizing the allocation of SKUs.

3. METHODOLOGY

3.1. INVESTIGATION METHODOLOGY

This dissertation is written as a case study.

According to Yin (2014), case studies are the preferred strategy when "*how*" or "*why*" questions are being posed, when the researcher has very little or no control over events, and when the focus of the study is contemporary phenomena with some real context. Explanatory cases can be complemented by two other types: exploratory and descriptive (Yin, 2014).

This investigation is a descriptive and exploratory study and categorized as a single case since the investigation is only one business situation without the influence of other companies. It is descriptive because it describes the various procedures of the department under study, using qualitative data obtained descriptively through observation, which allows a detailed description of all existing processes. Quantitative data will also be obtained through archival records. It is also considered exploratory because, as the name implies, it explores the research question that could be applied in other studies and where enhancements will be proposed and their evaluation. It is characterized by being flexible and versatile and often the front end of the total research design. Qualitative data is obtained directly through interviews and quantitative data via participant observation.

3.2. CASE STUDY STEPS

There should be a research design for all investigations. According to Yin (2014), a research design is used to guide the investigator into the process of collecting, analysing, and interpreting its observations. More than a work plan, the design aims to prevent the researcher from deviating from the focus of the research question.

Below is an outline of the steps to follow:

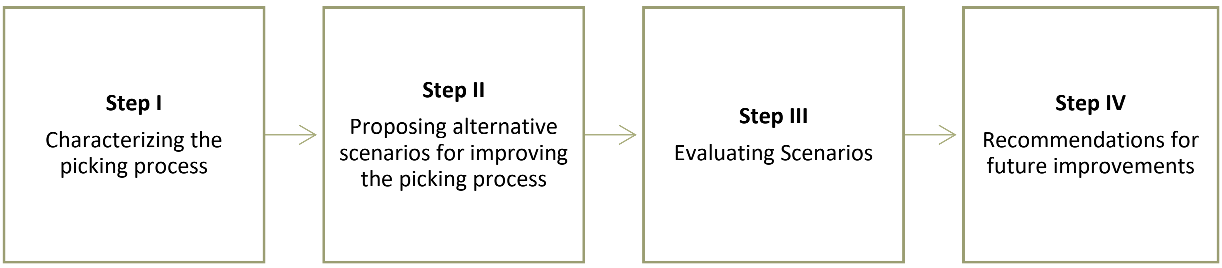

Figure 3.1 Research Steps

3.2.1. STEP I – CHARACTERIZING THE PICKING PROCESS

Initially, the picking process in the warehouse will be characterized and then the current layout and allocation of products, which is, the way the products are disposed in the warehouse.

To obtain this information, some tools should be used (Yin, 2014), namely semi-structured interviews, a focus group, archival records, direct observation and participant observation.

The semi-structured interviews are the first step in data collection. Interviews will be conducted with the warehouse manager and two warehouse pickers to better understand all the steps of the picking process and some other important details such as the layout decisions. A guide must be created to support interviews with some general questions (Annexe A), and, with the direction of the interviews, other questions will be raised.

After the interview, a picker will demonstrate the picking process to map all the steps in the process. This will be done through direct observation since the case study takes place in a real-world situation (Yin, 2014). Based on a picking list extracted from ERP – SAP – it is possible to observe how the picker works and the picker's movements in the warehouse. To find the distances between the different points of the warehouse, measurements should be made in meters through participant observation. Additionally, measurements will be taken of the different storage spaces and certain volumes of articles, given that the "archival records" (Yin, 2014) only had certain measures and stocks available by the end of each month. Through the archive records, it will also be possible to obtain part of the warehouse plants.

According to Yin (2014) and Voss, Tsikriktsis, & Frohlich (2002), reliability and validity may be better achieved when the same environment is explored by different sources. Ultimately and to validate all the information, a focus group with the warehouse manager and the supply chain manager will be conducted.

To complete this first step, the "*as is*" picking process will be mapped by using the Bizagi software.

3.2.2. Step II – Proposing Alternative Scenarios for Improving the Picking Process

According to the data collected on the allocation of SKUs and the picking routes, different scenarios with alternative options to allocate the SKUs are proposed (see Figure 3.2). First, the average stock for every SKU and the available space will be defined, and then, through an ABC analysis, the analysis of two different scenarios will be performed: (A) general ABC analysis and (B) ABC analysis by product families.

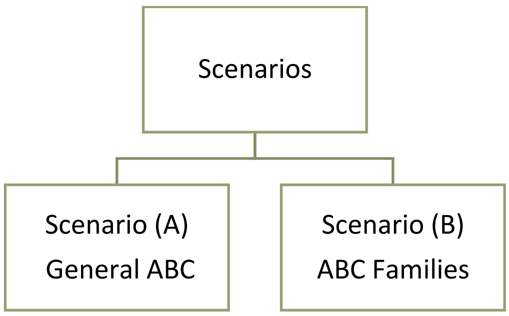

Figure 3.2 Scenarios

In case any of the SKUs stored in the warehouse belong to a family (i.e., similar products for example wine is one family or cutlery and plates or cups is another), it is relevant to consider two different scenarios. The first scenario (Scenario (A)) relies on a general ABC analysis based on the movements of each SKU, not taking into account its family – according to this scenario any SKU can be stored anywhere in the warehouse, i.e., different SKUs belonging to the same family can be stored in distant location of the warehouse. The second scenario (Scenario (B)) differs from the first scenario by forcing SKUs belonging to the same family to be stored in the same area of the warehouse. This is achieved following a two stage-procedure: i) first, ABC analysis is used to classify each family as A, B or C based on the associated number of movements, and this classification will inform the decision on where to locate each family in the warehouse; and ii) in a second stage, the SKUs of each family are also classified using the ABC analysis to be assigned somewhere in the area that has been previously allocated to the family in the warehouse.

A mathematical programming model shall be formulated to identify the optimal allocation of SKUs, i.e., the allocation that allows minimizing the distances travelled in the picking process (details can be found in Chapter 4). This model will be applied to these two different scenarios.

3.2.3. Step III – Evaluating Scenarios

The optimal allocation obtained for the two scenarios are compared with the current scenario and between them. Through a picking list with 11 SKUs (Annexe L), previously observed for the characterization of the picking process, the distances covered in the different scenarios will be compared, to understand the best one.

The proposed scenarios will be evaluated based principally in one KPI: distance travelled during the order picking process, and with the aid of a multifactorial analysis.

3.2.4. Step IV – Recommendations for Future Improvements

Based on the results achieved and the analysis conducted, a report will be shared with the company including recommendations for future enhancements.

4. Building the Mathematical Programming Model for Optimization the Allocation of SKUs in the Warehouse

According to the findings drawn from the literature review, the reduction of picking time in the warehouse could be achieved through several strategies, namely the reallocation of SKUs to the optimal locations – SLAP.

This chapter aims to present the modelling of the problem under study using a MILP model, which will support the decision of the optimal location.

All formulation steps will be explained in detail and the associated notation (including indexes and sets, parameters, and variables) will be detailed followed by the formulation of the objective function and constraints.

4.1. Model Assumptions

To evaluate the solutions proposed within the scope of this project, there is a need to compare the current allocation of SKUs in the warehouse with the allocation proposed for all the scenarios explored in the project. Accordingly, a set of assumptions will be assumed for building the model, and then the current situation and the proposed scenarios will be compared considering the same assumptions, making the results comparable.

The model is thus based on the following assumptions:

a. In each location, only one SKU can be allocated since they will be arranged on pallets. However, an SKU may be allocated in more than one location.
b. All of the routes used by the pickers will be carried out between the preparation area and the SKU location, returning to the preparation area after collecting each SKU. Therefore, for each SKU collected, two routes will be counted.
c. The model considers the SKUs' outflow movements over the studied period with an ABC analysis meaning that SKUs with more movements should be allocated to locations closer to the preparation area. Nevertheless, outflow movements will be compared against the average stock, allowing a balance between both. This is essential because an SKU with a higher number of outflow movements is not necessarily an SKU with the largest volume and vice versa. This ratio will be included in the objective function thus allowing movements to be distributed among the locations to the corresponding SKU. This is significant in situations where the proportionality between stock dimensions and demand does not exist. In order to gain a better understanding, if SKU A occupies one location and half of another and presents a total of 15 movements, 10 movements will be allocated to the first location and 5 to the second. If the objective function only contemplates the stock,

this SKU is going to be wrongly placed close to the preparation area since there are SKUs with much higher demand. On the other hand, if only movements have been contemplated, it would be assumed that the two locations have 15 movements each and would be counted twice.

4.2. MATHEMATICAL FORMULATION OF THE MODEL

The formulation of the mathematical model will be described presenting the indexes and sets, the parameters, the decision variables, the objective function as well as the constraints to which it is subject.

4.2.1. INDEXES AND SETS

The indexes and sets defined for the model are:

- $s \in S,\ S = (s_1, s_2, \dots, s_N)$ – Set of N SKUs
- $l \in L, L = (l_1, l_2, \dots, l_P)$ - Set of *P* storage locations
- $f \in F, F = (f_1, f_2, \dots, f_K)$ - Set of *K* families

4.2.2. PARAMETERS

The parameters used in the model are as follows:

- $Movements_{sf}$ – outflow movements of SKU $s \in S$ belonging to family $f \in F$
- $LocF_{lf}$ – equal to 1 if location $l \in L$ can store SKUs belonging to family $f \in F$; 0 otherwise
- $Stock_{sf}$ –average stock (in dm^3) of SKU $s \in S$ belonging to family $f \in F$
- $Distance_l$ – distance (in meters) travelled between the storage location $l \in L$ and preparation area
- $Capacity_l$ – volume (in dm^3) that the storage location $l \in L$ holds
- SKU_f – number of SKUs belonging to family $f \in F$
- *T* – storage location occupancy rate

4.2.3. VARIABLES

In the model three types of variables are used: integer, binary, and continuous. Variables that are used are as follows:

INTEGER VARIABLE:

- X_{sfl} – volume (in dm^3) that SKU $s \in S$ belonging to family $f \in F$ occupies in storage location *l*

BINARY VARIABLE:

- $Y_{s\,f\,l}$ – 1 if SKU $s \in S$ belonging to family $f \in F$ is stored in the storage location *l*; 0 otherwise

CONTINUOUS VARIABLE:

- *M* – total distance (in meters) travelled during picking operation

4.2.4. OBJECTIVE FUNCTION

The objective function aims at minimizing the total distance travelled by the picker inside the warehouse, considering that the picker moves from the preparation area to the location of the product and again to the preparation area. The ratio between the volume of SKU $s \in S$ belonging to family $f \in F$ and allocated to location *l* (X_{sfl}) and the total stock SKU $s \in S$ belonging to family $f \in F$ ($Stock_{s\,f}$) ensures that SKUs are reallocated to minimize the distance travelled during the picking process and ensures that movements are distributed across the different locations that the SKU $s \in S$ belonging to family $f \in F$ occupies.

$$Min\ M = \sum_{s \in S} \sum_{l \in L} \sum_{f \in F} 2 \times Distance_l \times Movements_{sf} \times \frac{X_{sfl}}{Stock_{s\,f}} \qquad (1)$$

4.2.5. CONSTRAINTS

The objective function is subject to the following restrictions:

$$\sum_{f \in F} \sum_{s \in S} Y_{sfl} \leq 1\ \forall\ l \in L \qquad (2)$$

$$\sum_{l \in L} X_{sfl} = stock_{sf}\ \forall\ s \in S, f \in F \qquad (3)$$

$$X_{sfl} \leq Capacity_l \times Y_{sfl} \times T\ \forall\ s \in S, f \in F, l \in L \qquad (4)$$

$$Y_{sfl} \leq LocF_{fl}\ \forall\ s \in S, f \in F, l \in L \qquad (5)$$

$$\sum_{s \in S} \sum_{l \in L} Y_{sfl} \geq SKU_f\ \forall\ f \in F \qquad (6)$$

$$X_{sfl} \geq 0\ \forall\ s \in S, l \in L, f \in F \qquad (7)$$

$$Y_{sfl} \in \{0,1\} \qquad (8)$$

Equation (2) guarantees that only one type of SKU is allowed per location regardless of the volume.

Equation (3) ensures that all stock is stored.

Equation (4) is defined to ensure that the stored volume of SKU $s \in S$ do not exceed the capacity of the location $l \in L$. The parameter T indicates the desired occupancy rate for the locations, ensuring that only one type of SKU is stored per location.

Equation (5) guarantees that SKU $s \in S$ is only stored in the locations assigned to its family. This constraint is only valid when there are locations fixed for a given family, according to the guidelines of the company.

Equation (6) ensures that all the SKUs belonging to the family $f \in F$ should have at least one location.

Equation (7) ensures that variable X is non-negative and equation (8) guarantees that variable Y is binary.

5. CASE STUDY

This chapter presents the details related to the application of the methodology presented above to the proposed case study. Firstly, the company and the storage activity for inflight catering products will be described, highlighting the picking process and the warehouse plan.

The data used in the investigation will be examined in detail, to propose alternative scenarios. Then, the scenarios that have been proposed are evaluated and compared.

Finally, the findings will be further discussed in this chapter and final recommendations will be made.

5.1. COMPANY X

Company X is an airline responsible for the transport of passengers and cargo on a global scale.

Airplanes that carry passengers carry, for each flight, a certain amount of products to provide service to passengers during the flight, such as food items, beverages (soft drinks, beer, wine, and liquors), cutlery, chinaware and textile items (tablecloths, blankets, etc), re-usable (routable) plastic items (trays, dishes, etc.), disposable items (paper napkins, plastic cups, etc) and onboard kitchen (galley) items including boxes and carts used for the service in the cabin.

Company X operates 5 warehouses in the system with more than 5 physical spaces accountable for the service on board and also on land whose objective is the timely supply of all items necessary for the activity.

The focus of the investigation is the inflight catering warehouse, the biggest one and which stores some articles that go onboard and the articles that supply the outstations. The outstations are the destinations where the company flies and therefore it is necessary to have locally stored material for the return flight.

5.2. STEP I: CHARACTERIZING THE PICKING PROCESS

In this subchapter, the picking process in the warehouse will be characterized. The inflight catering warehouse is represented in the system by one warehouse but physically split by two spaces with three rooms with 155 racks to store products distributed by the warehouses, it can also be observed in the following image and detail in Annexe B.

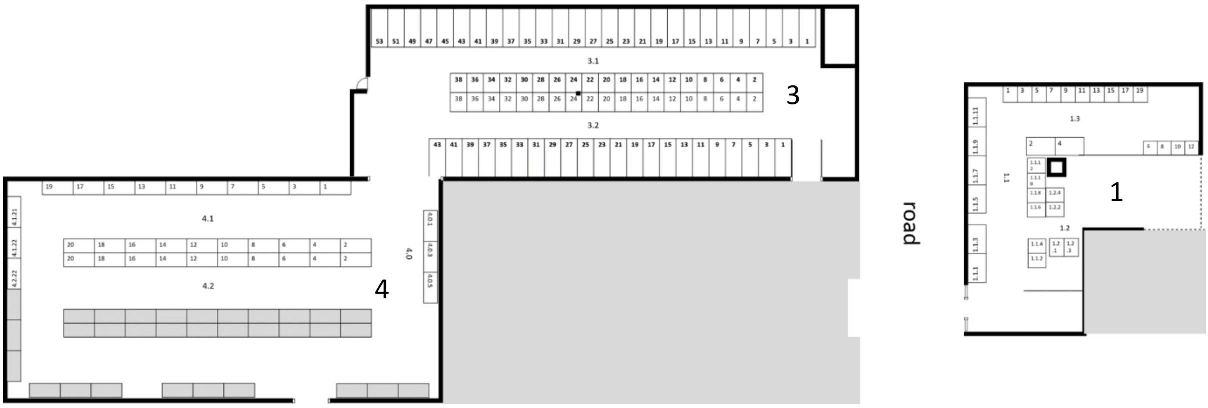

Figure 5.1 Warehouses

Racks are identified according to the warehouse they belong to according to the corridor, the rack number, level and side, left or right. As shown in the illustrative example below, the identification of the rack of warehouse 4, aisle 1, rack number 2, third level and left side (1) or right side (2).

4.1.2.3.1

Figure 5.2 Rack ID

Based on figure 5.3 process picking in the warehouse will be described.

The picking activity begins after the warehouse manager prints the picking list and assigns it to a picker. Each picking list has only one order assigned, this means that the picking method used is picking by order.

The order picker receives and analyses the picking list, and then goes to the warehouse. The analysis of the picking list is necessary because it is not organized according to a specific criteria and for this reason, it is required to understand which products are closest to each other and their quantities.

The picker moves to the product location with the forklift and picks the product in the right quantity. If space allows, the picker moves to another location and picks another product, this process is repeated until it is not possible to add more products. When it is not possible to add more products, the picker transports it to the makeshift preparation area. This process repeats until the order is complete.

After the order is complete, labels are all glued to the boxes for orders that will be sent by plane and all pallets are filmed regardless of whether they are going to be sent by plane. After this, pallets are transported to the shipping area, and the picking process finishes.

The route selected by pickers is random and decided by the picker after analysing the picking list.

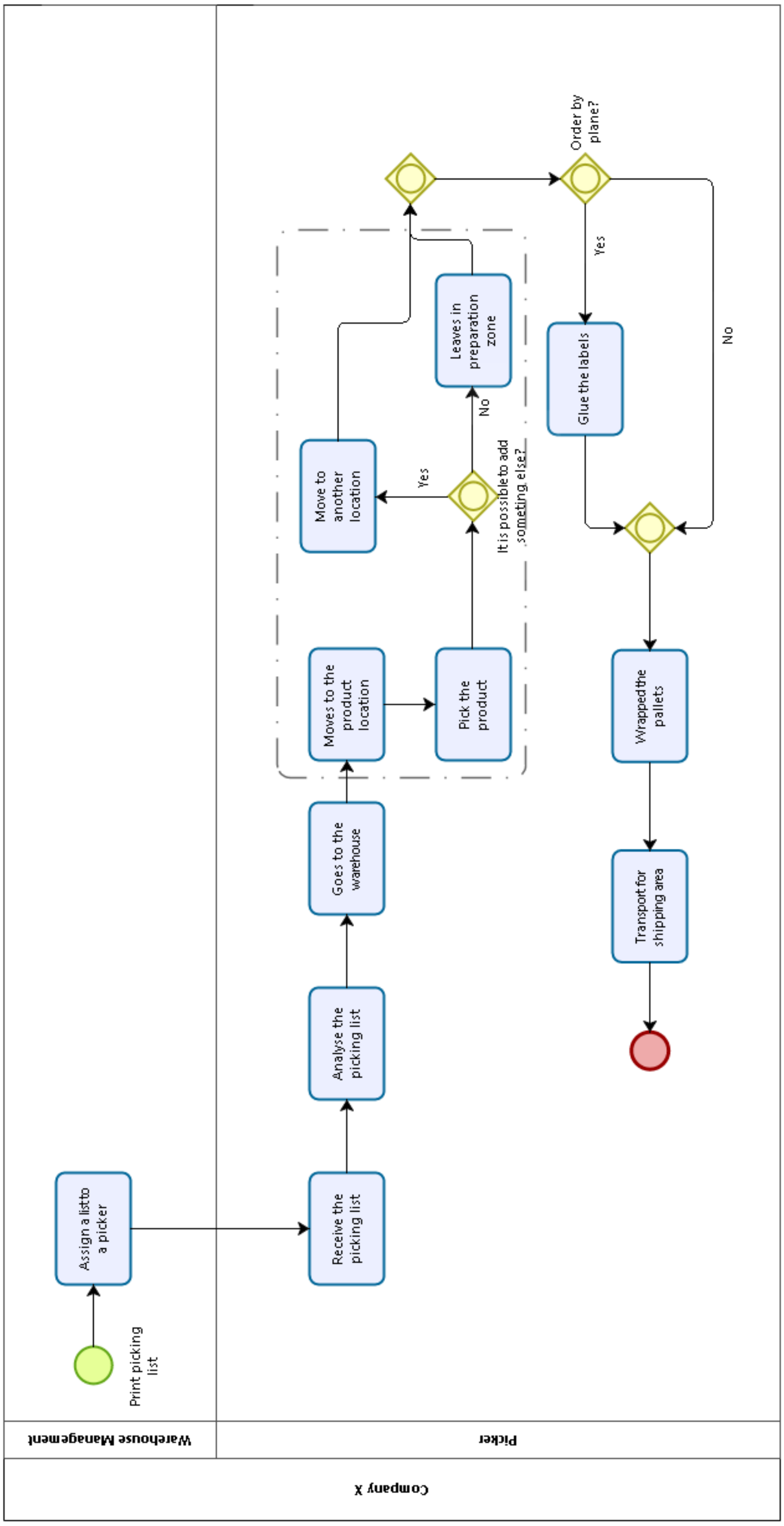

Figure 5.3 Order Picking Process

5.2.1. DATA COLLECTION

For the appliance of the two alternative scenarios – General ABC and ABC by families – some important data were collected.

Some data collected has been provided by the company, others have been collected through direct observation. All of these data are particularly relevant for obtaining the best solution for the problem in question, and after collecting the data, contributed to its treatment.

5.2.1.1. CAPACITY

As mentioned above there are 155 racks with 518 storage locations to store the SKUs. There are five different types of racks in the warehouse, each with different dimensions. The capacity of each storage location was collected through direct observation during visits to the warehouse.

Table 5.1 Rack Type

Type	Description
Type 1	Rack with three levels – two pallets per level
Type 2	Rack with two levels – two pallets per level
Type 3	Rack with three levels – one pallet per level
Type 4	Rack with two levels – one pallet per level
Type 5	Rack for boxes, four levels and four columns

The dimensions of each location can be found in Annexe C and drawings of the racks can be found in Annexe D.

5.2.1.2. DISTANCES

The distances in meters from the preparation area to each of the 518 storage locations have been collected on-site through direct observation. Due to the high number of locations, it has not been possible to measure all the distances, however, some distances and racks were measured and so it was possible to do an approximation calculation for all the others (Annexe C).

5.2.1.3. STOCK

The data related to the stock was obtained through the ERP, and an average stock was calculated for the end of each month in the year 2019. Referring to the volume of each SKU, some measures were obtained through the ERP as well and others were measured on-site visits to the warehouse. Based on this data the total volume of each SKU to be stored was calculated in dm^3. For some SKUs, the stock has been adapted to a greater understanding of the model.

SKUs that were not consumed in 2019 were removed as well as those that, for internal reasons of the Company X, are no longer allocated in this warehouse. The final list presents 240 SKUs. After some adjustments, some SKUs were grouped due to their physical similarities and because they have similar dimensions, reducing the total to 185 SKUs.

The high number of SKUs makes the use of the model complex to solve and the need arises to reduce it again, this time according to the number of movements, thus assuming the existence of 93 SKUs (Annexe F). However, since two scenarios are going to be compared and for comparison as real as possible it is appropriate to take as many SKUs as possible into consideration, therefore, scenario B will take into consideration 185 SKUs (Annexe G).

After reviewing the data mentioned above, the SKUs belonging to each family were analysed. In Company X there are 15 families of SKUs, however, since one family already possesses its specific location at the warehouse it should be considered only 14 for this analysis. Families were then also grouped by their similarities, reducing further from 14 to 9 families. The information related to these families was compiled: the number of SKUs and the total volume of the family (Annexe E).

5.2.1.4. Movements

Through the company's ERP system, it was possible to obtain the data related to the outflow movements of each SKU during 2019 and after analysing, these were added according to their family. In the end, it was likely to get the movements per family.

The following table presents a summary of all the data collected and the methodology used in its collection.

Table 5.2 Data Collection and Methodology

Inputs	ERP	On-Site Observations
Number of locations		X
Dimensions of Locations		X
Distances between location and preparation area		X
Volume of SKUs	X	X
List of SKUs	X	
List of families	X	
Movements of SKUs	X	

5.3. Step II: Proposing Alternative Scenarios for Improving the Picking Process

In Step II, the proposed scenarios, and data collection for the resolution of the mathematical model will be explained.

Currently, no storage criteria are used in the inflight catering products warehouse, therefore, and as stated above, two storage scenarios will be proposed – general ABC and ABC by families.

5.3.1. Scenario A – General ABC

In scenario A it is intended that the SKUs are allocated to get the shortest distance covered during the picking process. This scenario considers the outflow movements of each SKU for the ABC analysis and its average stock, in addition to the distances to each location and its capacity.

In this scenario, the family of each SKU is not relevant, it will be assumed that every SKU belongs to family 1.

The generated solution will take into consideration not only the movements but also the volume, thereby allowing better profitability of the available space and the placement of the most active SKUs in locations close to the preparation area.

For this scenario, the 93 SKUs $s \in S,\ S = (s_1, s_2, \dots, s_{93})$ belonging to family 1 $f \in F, F = (f_1)$ will be considered. For the successful implementation of this model, the restrictions to be used will be:

$$\sum_{f \in F} \sum_{s \in S} Y_{sfl} \leq 1 \;\forall\; l \in L \tag{9}$$

$$\sum_{l \in L} X_{sfl} = stock_{sf} \;\forall\; s \in S, f \in F \tag{10}$$

$$X_{sfl} \leq Capacity_l \times Y_{sfl} \times T \;\forall\; s \in S, f \in F, l \in L \tag{11}$$

$$\sum_{s \in S} \sum_{l \in L} Y_{sfl} \geq SKU_f \;\forall\; f \in F \tag{12}$$

Due to the existence of 185 SKUs, it is necessary to make the individual allocation after the reorganization according to movement to 93SKUs.

5.3.2. Scenario B – ABC by Families

In scenario B, it is intended that the SKUs are organized by families, which means that SKUs belonging to the same family will be stored in the same area of the warehouse. Storage will be organized under the same criteria referred to in scenario A: movements and stock.

The implementation of this scenario is then divided into two parts, stage I – allocation by families and stage II – allocation within each family. The figure below illustrates the scenario. First, the model identifies the allocation by families and through the obtained output, locations of each SKU are identified.

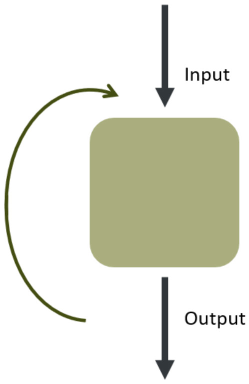

Figure 5.4 Scenario Illustration

In the first stage will be clarified through an ABC analysis which family is A, B or C and then is second stage an ABC analysis of the SKUs of each family based on movements.

9 families will be considered for the implementation of the model $f \in F, F = (f_1, f_2, \dots, f_9)$ and the 185 SKUs $s \in S,\ S = (s_1, s_2, \dots, s_{185})$.

The constraints to consider for the application of the model include:

$$\sum_{f \in F} \sum_{s \in S} Y_{sfl} \leq 1 \ \forall \ l \in L \tag{13}$$

$$\sum_{l \in L} X_{sfl} = stock_{sf} \ \forall \ s \in S, f \in F \tag{14}$$

$$X_{sfl} \leq Capacity_l \times Y_{sfl} \times T \ \forall \ s \in S, f \in F, l \in L \tag{15}$$

$$\sum_{s \in S} \sum_{l \in L} Y_{sfl} \geq SKU_f \ \forall \ f \in F \tag{16}$$

One of the outputs of this first model will be a table referring to the *LocF* parameter that guarantees that a specific SKU is only allocated in locations belonging to its family.

In a second phase of the model – allocation within the family – the constraints to be used will be:

$$\sum_{f \in F} \sum_{s \in S} Y_{sfl} \leq 1 \ \forall \ l \in L \tag{17}$$

$$\sum_{l \in L} X_{sfl} = stock_{sf} \ \forall \ s \in S, f \in F \tag{18}$$

$$X_{sfl} \leq Capacity_l \times Y_{sfl} \times T \; \forall \, s \in S, f \in F, l \in L \quad (19)$$

$$Y_{sfl} \leq LocF_{fl} \; \forall \, s \in S, f \in F, l \in L \quad (20)$$

5.4. Step III: Evaluating Scenarios

In step III, the results obtained in both scenarios will be presented and performance will be evaluated and compared later.

5.4.1. Results Obtained

After applying the problem data to the mathematical model, it is imperative to analyse the results.

Results were obtained through the General Algebraic Modelling System (GAMS) 30.3 using CPLEX (an optimization software).

One of the outputs of the model remains the total distance travelled in meters if all SKUs at the warehouse were collected during the year of 2019, although the optimal location for each SKU (Annexe Hand Annexe I).

Also, will be evaluated the picking list already mentioned.

5.4.1.1. Scenario A – General ABC

As previously mentioned, one of the outputs obtained is the total distance travelled, verifying that for this scenario 287 184 meters are covered in the picking process.

Analysing the results obtained in detail, considering the locations of each SKU, it was possible to calculate the average distances covered considering their class, as it can be seen in Figure 5.5.

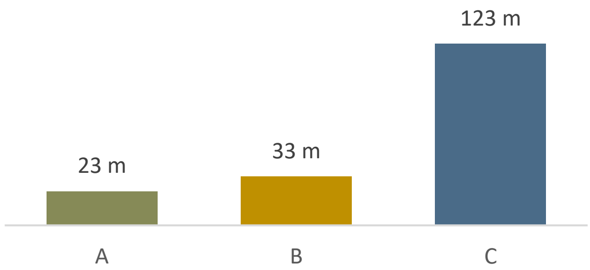

Figure 5.5 Average distance (meters) travelled between each SKU class and the preparation area

Through the analysis of the results, it is possible to conclude that the SKUs with more movements are the ones that are closest to the preparation area. This result is in line with what was expected. SKUs with more movements, that is, are consumed more frequently and are located at a shorter distance from the preparation area, travelled 23 meters (on average). Consequently, it turned out to be also expected that the SKUs least consumed would be located further away from the preparation area, travelling 123 meters (on average).

Based on the analysis it remained possible to check that the smaller SKUs, considering their class, are allocated to a shorter distance from the preparation area.

Table 5.3 ABC Analysis Results

Class	Number of locations	Number of SKUs	Volume
A	282	76	334 411 dm^3
B	77	40	90 097 dm^3
C	116	69	103 973 dm^3
Total	**475**	**185**	**528 481 dm^3**

Table 5.3 refers to the locations occupied by each class and the corresponding number of SKUs and volume. Since SKUs have variable volumes, and locations have variable capacities, these values are not proportional.

The output may be explained by class B, even though fewer SKUs than class C having a higher volume per SKU, while at the same time occupying locations with the highest capacity in the warehouse.

Regarding the allocation of SKUs, it was additionally possible to assess that not all locations have been occupied. This is owing to the fact that the total volume of SKUs, and respecting the restriction that an SKU can only be allocated in one location, was not more than the total capacity of the warehouse. Of the 518 available locations, only 475 have been occupied, leaving 43 storage locations empty, mostly those furthest from the preparation area on warehouse 1.

5.4.1.2. Scenario B – ABC by Families

In the scenario by families, it would have been possible to obtain a total distance travelled of 863 136,82 meters if all products from the warehouse have been collected in a single trip.

As in the earlier scenario, it might be possible to confirm that families with more movements were positioned closer to the preparation area and families with fewer movements further away. Figure 5.6 illustrates the average distance between the location of each class and the preparation area.

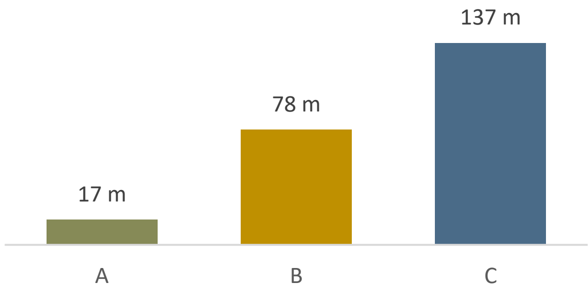

Figure 5.6 Average distance (meters) travelled between each family class and the preparation area

Class A is the nearest one an average distance of 17 meters, at the same time as the class B at 78 meters (average) and class C at 137 meters (average). These are the results anticipated.

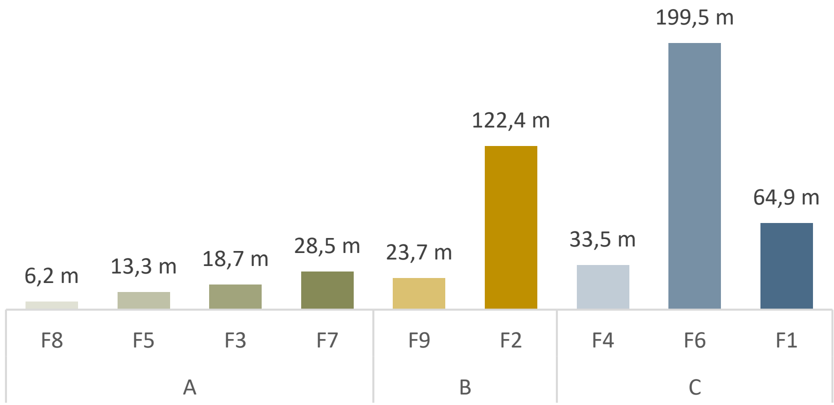

Figure 5.7 Average distance (meters) between each family and preparation area

Figure 5.7 displays the average distance per family to the preparation area. Beginning from left to right, families are ranked from the most consumed to the least consumed. The representative families of class A are placed in terms of the average distance between the preparation area and the location of each family, thus family 8, the most consumed, presents an average distance to the preparation area of 6,2 meters. While family 7, the one with the lowest total number of movements belonging to class A, is allocated an average distance of 28,5 meters.

Class B families are also rated according to their movements. However, family 9 is at a smaller average distance than family 7 – class A –, 23,7 meters and 28,5 respectively. Clarified by the fact that it possesses more total volume and by SKU, that is to say, when an SKU occupies more than one location, the first one manages to be closer to the preparation area whereas the other or the others are further away.

In class C, the distances from the families' locations are not sorted by their movements since family 1, although not as consumed as families 4 and 6, presents a smaller volume in addition to a smaller number of SKUs and for that reason, it is closer to the preparation area.

Table 5.4 ABC families Analysis Results

Class	Number of locations	Number of SKUs	Volume
A	236	122	263 042 dm^3
B	143	28	185 649 dm^3
C	117	35	79 790 dm^3
Total	**496**	**185**	**528 481 dm^3**

As previously stated, the volumes of the SKUs and the capacities of the storage locations are variable and for this reason, the values referred above are not proportional. Once more, the total volume of SKUs is less than the total capacity of the warehouse and, therefore, 22 locations have still not been occupied.

5.4.2. COMPARISON OF SCENARIOS

The results of both scenarios are shown in Table 5.5, showing that the allocation of scenario A is more advantageous since the total number of meters covered is 287 184 meters compared to the 863 136,82 meters of the scenario B – allocation by families.

Table 5.5 Comparison between scenarios

Scenario A – General 93 SKUs	Scenario B – Families 185 SKUs
287 184,00 meters	863 136,82 meters

Even though in scenario B class A is closer to the preparation area than in scenario A, the other two classes – B and C – are closer in scenario A than in scenario B. The total average of distances involved is lesser in scenario A, presenting a value of 49 meters in comparison to the 63 meters in scenario B.

The picking of 11 SKUs a comparison was made among the two proposed scenarios and the current scenario of Company X, the list of SKUs, in addition to their distances and locations can be found in the Annexe L.

Table 5.6 Comparison between picking list scenarios

Current Scenario	Scenario A	Scenario B
1 207,52 meters	285,1 meters	327,72 meters

Presently, the picker travels around 1 207,52 meters to collect the 11 SKUs, once adopting scenario A, he might be able to go on to travel 285,1 meters in collecting the same 11 SKUs, with a reduction of 922,42 meters in the total distance travelled. Scenario B possesses a distance of 327,72 meters to collect the 11 SKUs, a reduction of 879,8 meters concerning the scenario currently used by Company X, however an increase of 42,62 meters in relation to scenario A.

To conclude, it is possible to verify that scenario A is better than scenario B, bearing in mind the total distance travelled as well as the picking list.

However, for Company X, this model is not viable, since the same SKU must be stored in locations as near as possible of the same SKU. In the illustration below (Figure 5.8) it is possible to observe the allocation of three different SKUs using the first scenario proposed.

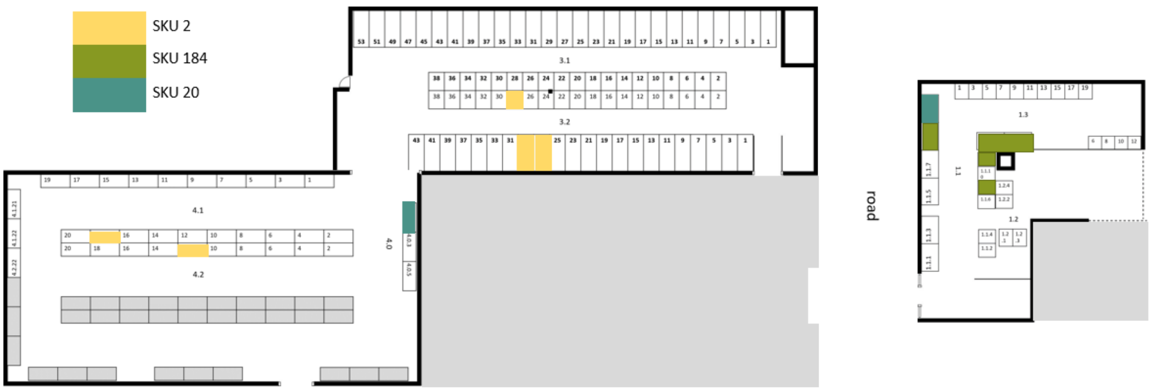

Figure 5.8 Allocation of three different SKUs - Scenario A

An alternative solution is thus explored below.

5.4.3. Alternative Solution

An alternative objective function has been created, that will only consider movements of the SKU s of the family f.

$$Min\ M = \sum_{s\in S}\sum_{l\in L}\sum_{f\in F} 2 \times Distance_l \times Movements_{sf} \times Y_{sfl} \tag{21}$$

The objective function (21) is also going to be tested for both scenarios stated above and the constraints that will be used in the application of the model will be consistent with those that have already been referred to in chapter 4.2.5 and the outputs will be the same. Whereas function (1) takes into account the ratio between the stock and the movements of each SKU, function (21) only considers movements. For a clearer understanding, an example follows: there are two SKUs, SKU A and SKU B, the first occupies a location and a half and has 15 movements, while the second occupies only one location and has 13 movements. If both SKUs only occupied one location, it would make sense that the first one would have to be positioned closer to the preparation area, regardless of the function used.

Using the first function (1), it is possible to state that the order of allocation of the SKUs relative to the proximity of the preparation area would be something like A – B – A. Since not only the movements but also the stock is considered, in the first location of A 10 movements are allocated, and in the second there are 5. Using function (21), which only considers movements, storage will be A – A – B, and in both locations of A, the 15 movements are allocated.

Performance Evaluation

After applying the model with the new objective function (21), the results of both scenarios were studied (Annexe J and Annexe K).

The total distance covered in scenario A is 473 200,56 meters.

Similar to the results already obtained, class A is always at a lower average distance, compared with the other classes, to the preparation area. The average distance between class A and B are close, with only a difference of two meters, but it is evident that class C is positioned a great distance from the preparation area.

Results that have been achieved concerning the volume by class and number of SKUs are similar to the results already analysed for scenario A. Only the occupied locations are changed; of the 518 locations, only 465 will be occupied. All empty locations are located in warehouse 1.

In scenario B the total distance travelled proved to be 1 005 686,40 meters and once again the results obtained about the average distance per class to the preparation area were expected.

When analysing each family of SKUs individually, it was also possible to see that the most consumed families are also the families that are the shortest distance from the preparation area. In this scenario, it was possible to obtain an occupation of 493 locations.

Table 5.7 Comparison between alternative scenarios

Scenario A – General **93 SKUs**	**Scenario B – Families** **185 SKUs**
473 200,56 meters	1 005 686,40 meters

Through the analysis of those two scenarios, it is possible to verify that, similar to what occurred previously, the scenario with allocation by families is unfavourable in relation to the general allocation scenario, exposing a difference of 532 485,84 meters. The average distance to the preparation area in scenario A is 46 meters and 58 meters in scenario B.

Meant for the alternative solution the collection of the picking list with 11 SKUs was also compared for both scenarios and the current scenario to come up with a more realistic situation.

Table 5.8 Comparison between picking list alternative scenarios

Current Scenario	Scenario A	Scenario B
1 207,52 meters	372,28 meters	250,2 meters

Better outcomes have been achieved again than the one that is currently being used by the company. Scenario A displays an improvement of 835,24 meters and 957,32 meters in relation to scenario B. In this case, in particular of the picking list, a better solution through the scenario B, however, it is important to take into consideration that it is a certain combination of SKUs and does not reveal a pattern.

Contemplating all the data, it is clear that scenario A presents superior overall results than scenario B.

5.4.4. CONCLUSION

As mentioned before, the objective function (1) minimizes distances, together in the general scenario and by families, however, if an SKU fills more than one location, they will be removed from each other, consequently presenting an advanced and indented stock model. The objective function takes into consideration movements and stock simultaneously, distributing movements across the locations assigned to a specific SKU or family.

For Company X it was required that the same SKU to be in close locations and for this reason that it was essential to establish a new objective function (21).

Along with function (1), it concluded that the most feasible scenario, the one that would decrease the distances in the picking process and consequently the time, would be the scenario A – general ABC. Introducing the smallest total distance covered, the smallest distance considering the picking list and even a smaller average distance between the preparation area and the locations. Scenario A additionally occupies fewer locations than scenario B, therefore revealing a better optimization of the warehouse's capacity.

Through function (21) it was possible to conclude that scenario A – AS (Alternative Solution) is more beneficial than scenario B – AS (Alternative Solution), even though the distance in the picking scenario was greater. Nevertheless, the total distance travelled, and the average distance between the preparation area and the different locations, above and beyond the occupied locations, are smaller in scenario A – AS than in scenario B – AS.

In all situations, class C is always at a longer distance, because of the distance from warehouse 1 to the preparation area.

The following table outlines the comparison between the four scenarios studied, the table with the detailed comparison can be found in the Annexe M.

Table 5.9 Summary of scenarios

SCENARIO	TOTAL DISTANCE	PICKING DISTANCE	AVERAGE DISTANCE	OCCUPIED LOCATIONS
SCENARIO A	287 184 m	285,1 m	49 m	475
SCENARIO B	863 136,82 m	327,72 m	63 m	496
SCENARIO A – AS	473 200,56 m	372,28 m	46 m	465
SCENARIO B – AS	1 0005 686,4 m	205,2 m	58 m	493

It is concluded that all the scenarios studied present advantages over the system currently used, and the scenario that most minimizes the distances covered during the picking process is scenario A, though it is important to consider the other data. Since there is no scenario where all the KPIs presented are better than the others, a multifactorial method (Annexe N) has been used to determine the best scenario.

Not all criteria have the same level of importance, therefore the following score was defined:

Table 5.10 Multifactorial Method

SCENARIO	TOTAL DISTANCE 50%	PICKING DISTANCE 5%	AVERAGE DISTANCE 15%	OCCUPIED LOCATIONS 30%	TOTAL SCORE
SCENARIO A	0,5	0,1	0,3	0,6	**1,5**
SCENARIO B	1,5	0,15	0,6	1,2	**3,45**
SCENARIO A – AS	1	0,2	0,15	0,3	**1,65**
SCENARIO B – AS	2	0,05	0,45	0,9	**3,4**

Analysing Table 5.10, it is possible to see that scenario A is effectively the best solution since it has the lowest total score, 1,5.

Since this solution is not the most suitable for the company, it can be said that scenario A – AS is the best solution under the conditions of the company, with the second-lowest score, 1,65.

5.5. Step IV: Recommendations for Future Improvements

It is important to note that Company X ensures all conditions for the implementation of any of the four proposed scenarios, guaranteeing the allocation of all SKUs and respective stock.

Nevertheless, it is pertinent to be taken into consideration some recommendations to the company, which can make this process even more efficient.

A more regular review of the stock could bring advantages in the allocation of the products, also avoiding the excess of stock for SKUs with little movement, thereby preventing that they become obsolete or that ruptures occur. Given the complexity of the supply chain, it is important to guarantee, in this way, the very best and most efficient service to the final customer.

The adoption of a Warehouse Management System (WMS) that contemplates the location of each SKU and respective distance from the preparation area will assist the picker in this task, and considered a more efficient route during the process. With the adoption of this system, the picker will save time in the analysis of the picking list, this task is performed by the WMS.

Ultimately, there is a possibility of placing more than one SKU per location or the introduction of smaller locations. There are several SKUs of smaller dimensions and/or with little stock, and so the acceptance of this recommendation may further optimize the storage space in use and, in a way, further decrease the distances travelled during the picking process.

6. Conclusions

This investigation has been focused on the inflight catering warehouse of Company X, which is considered an important process station – it represents the efficiency or inefficiency of the entire supply chain.

The study was intended to answer the research question: *"How can the picking process in the warehouse of the inflight catering service in Company X be improved to become more efficient?".* To accomplish the main goal of finding the picking process more efficient, it was first necessary to characterize the entire picking process in the warehouse, to suggest alternative scenarios and then finally compare the main distance travelled as the principal KPI.

Under the existing literature, it would be possible to comprehend the importance of the warehouse in the supply chain and its activities, concentrating on order picking in addition to the strategies that are linked to it to improve its efficiency.

For Company X, the strategy of enhancing efficiency to be used required the allocation of SKUs. Therefore, from the different methods presented, it was decided that a mathematical programming model would be used to find a solution to the case study.

Once formulated, the model has been applied to the two initial scenarios - general ABC and ABC by families.

The main output of the model is the optimal allocation of SKUs, resulting in the SLAP solution.

Through the analysis of the results and considering the current situation both scenarios reveal better outcomes than the current one, however, scenario A presented better results than B. Following the analysis of the outputs, it was possible to verify the impracticality of any of the scenarios for Company X and an alternative objective function was established, which was intended to allocate the same SKU in nearby locations and applied to the same two scenarios.

Once again, both scenarios got better results than the existing one and scenario A – Alternative Solution presents a superior solution than scenario B – Alternative Solution. Though, it is relevant to mention that when compared to the scenarios first tested, scenario A – Alternative Solution presents weaknesses concerning scenario A although scenario B – Alternative Solution has advantages when compared to scenario B.

Through the analysis of scenarios, it is possible to conclude that any of the tested scenarios presents benefits compared to the present scenario. The scenario that minimizes the distances covered by the picking process is scenario A, that is, the very best scenario to be implemented. Due to the conditions of the company, the scenario that must be implemented is scenario A – AS. Though it is not the one that minimizes the total distances travelled, it is the one that assigns the SKUs according to the requirements of the company.

The focus of the mathematical model is the allocation of SKUs by locations, however, and responding to the research question, other procedures may be considered by the company. To make the process more efficient, procedures may also include a more frequent review of stocks, the adoption of a WMS for the establishment of routes, and the possibility to allocate more than one SKU per location, thus optimizing the total storage space.

The investigation had been carried out in the specific context of Company X, though the steps followed could be adapted and generalized to other warehouses to make them more efficient, in addition to the adaptation of the mathematical model to SKUs with other characteristics and particularities.

During the investigation, several limitations were found. Information collected for the case study, namely the average stocks, had taken into account the period of one year. However, only one picking process was analysed, a more exhaustive analysis of the order picking process would bring more accurate results. Some data has been also obtained by approximation, namely some average stocks of new SKUs and respective outgoing movements, as well as measures of certain SKUs. Due to the COVID-19 pandemic, it has not been possible to be on the ground to collect data all the time required.

After all, and taking into consideration the results obtained and the research question, it is possible to conclude that the picking process can be improved and become more efficient by adopting the proposed scenario, as well as the recommendations made.

Proposals for future work can be considered to develop this research. Most recommended is a review of stock which would lead to more available space to other SKUs, associated with a future demand forecast, which can be added to the mathematical model as an input. As mentioned before, the improvement of picking processes can be achieved through other strategies, which might be interesting to explore. It is proposed to analyse the impact and evaluate the layout change, in addition to the simulation of different picking routes that might be possible scenarios to test. The adoption of any of these scenarios may be combined with the proposed one in this research in order to achieve a better improvement. The mathematical model may be adapted depending on the environment and limitations of a given warehouse, hence the adoption of the model to other company warehouses can be taken into account.

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8. ANNEXE

Annexe A

Semi-structured Interview

Warehouse Manager	Description of the picking process – How the picking process can be described? Strategies used in picking and storage – What strategies are used in SKUs storage? What strategies are used during the picking process?
Picker	Description of the picking process – How products are storage? What strategies are used during pinking? There is any route to follow during picking?

Annexe B

The following figures represent the plans of the different warehouses.

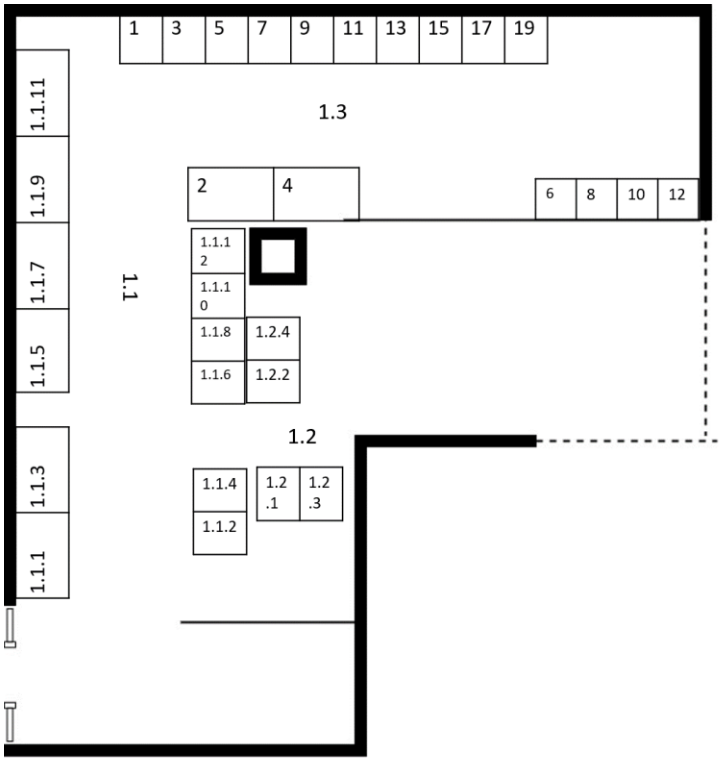

Figure 8.1 Warehouse 1

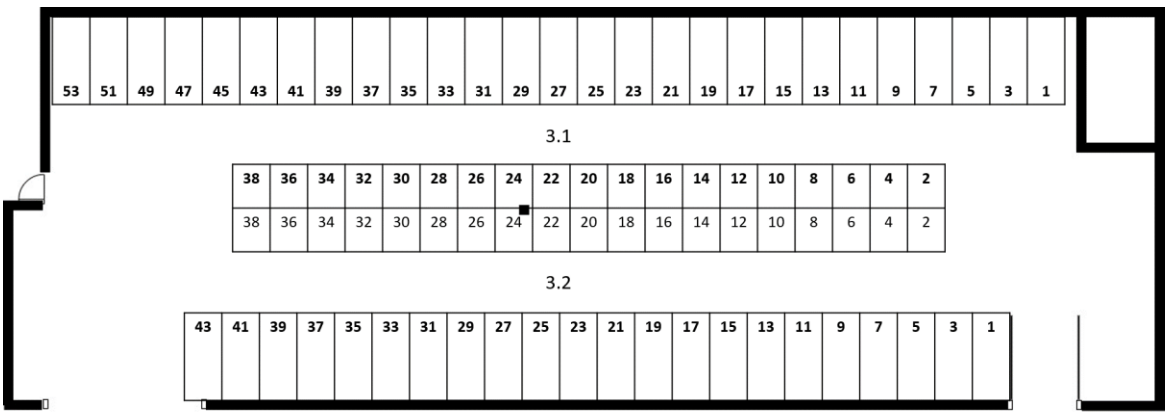

Figure 8.2 Warehouse 3

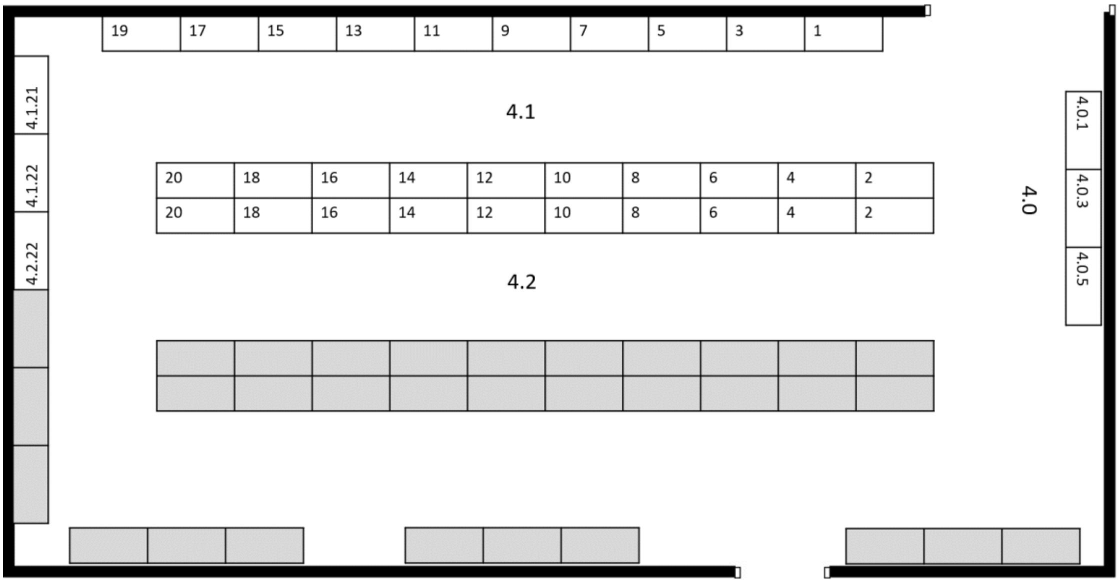

Figure 8.3 Warehouse 4

Annexe C

The following table refers to the distance from each location to the preparation area and its respective capacity in dm^3.

Table 8.1 Distance from location to preparation area and location capacity

Location	Distance (m)	Capacity (dm)	Location	Distance (m)	Capacity (dm)	Location	Distance (m)	Capacity (dm)	Location	Distance (m)	Capacity (dm)
1.1.1.1.1	181,64	800	1.1.12.1.	191,82	1200	1.3.9.1.	201,32	1200	3.1.8.2.	35,47	800
1.1.1.1.2	181,64	800	1.1.12.2.	191,82	1200	1.3.9.2.	201,32	1200	3.1.8.3.	35,47	800
1.1.1.2.1	181,64	800	1.2.1.1.	187,16	1200	1.3.10.1.1	202,82	345	3.1.9.1.	41,91	2400
1.1.1.2.2	181,64	800	1.2.1.2.	187,16	1200	1.3.10.1.2	202,82	345	3.1.9.2.	41,91	2400
1.1.1.3.1	181,64	800	1.2.2.1.	190,58	1200	1.3.10.2.1	202,82	345	3.1.10.1.	34,15	800
1.1.1.3.2	181,64	800	1.2.2.2.	190,58	1200	1.3.10.2.2	202,82	345	3.1.10.2.	34,15	800
1.1.2.1.	184,44	1200	1.2.3.1.	188,48	1200	1.3.10.3.1	202,82	345	3.1.10.3.	34,15	800
1.1.2.2.	184,44	1200	1.2.3.2.	188,48	1200	1.3.10.3.2	202,82	345	3.1.11.1.	40,59	2400
1.1.3.1.1	184,04	800	1.2.4.1.	191,9	1200	1.3.10.4.1	202,82	345	3.1.11.2.	40,59	2400
1.1.3.1.2	184,04	800	1.2.4.2.	191,9	1200	1.3.10.4.2	202,82	345	3.1.12.1.	32,83	800
1.1.3.2.1	184,04	800	1.3.1.1.	196,04	1200	1.3.11.1.	202,64	1200	3.1.12.2.	32,83	800
1.1.3.2.2	184,04	800	1.3.1.2.	196,04	1200	1.3.11.2.	202,64	1200	3.1.12.3.	32,83	800
1.1.3.3.1	184,04	800	1.3.2.1.1	193,32	800	1.3.12.1.1	203,97	345	3.1.13.1.	39,27	2400
1.1.3.3.2	184,04	800	1.3.2.1.2	193,32	800	1.3.12.1.2	203,97	345	3.1.13.2.	39,27	2400
1.1.4.1.	185,76	1200	1.3.2.2.1	193,32	800	1.3.12.2.1	203,97	345	3.1.14.1.	31,51	800
1.1.4.2.	185,76	1200	1.3.2.2.2	193,32	800	1.3.12.2.2	203,97	345	3.1.14.2.	31,51	800
1.1.5.1.1	186,44	800	1.3.2.3.1	193,32	800	1.3.12.3.1	203,97	345	3.1.14.3.	31,51	800
1.1.5.1.2	186,44	800	1.3.2.3.2	193,32	800	1.3.12.3.2	203,97	345	3.1.15.1.	37,95	2400
1.1.5.2.1	186,44	800	1.3.3.1.	197,36	1200	1.3.12.4.1	203,97	345	3.1.15.2.	37,95	2400
1.1.5.2.2	186,44	800	1.3.3.2.	197,36	1200	1.3.12.4.2	203,97	345	3.1.16.1.	30,19	800
1.1.5.3.1	186,44	800	1.3.4.1.1	195,72	800	1.3.13.1.	203,96	1200	3.1.16.2.	30,19	800
1.1.5.3.2	186,44	800	1.3.4.1.2	195,72	800	1.3.13.2.	203,96	1200	3.1.16.3.	30,19	800
1.1.6.1.	187,86	1200	1.3.4.2.1	195,72	800	1.3.15.1.	205,28	1200	3.1.17.1.	36,63	2400
1.1.6.2.	187,86	1200	1.3.4.2.2	195,72	800	1.3.15.2.	205,28	1200	3.1.17.2.	36,63	2400
1.1.7.1.1	188,84	800	1.3.4.3.1	195,72	800	1.3.17.1.	206,6	1200	3.1.18.1.	28,87	800
1.1.7.1.2	188,84	800	1.3.4.3.2	195,72	800	1.3.17.2.	206,6	1200	3.1.18.2.	28,87	800
1.1.7.2.1	188,84	800	1.3.5.1.	198,68	1200	1.3.19.1	207,92	1200	3.1.18.3.	28,87	800
1.1.7.2.2	188,84	800	1.3.5.2.	198,68	1200	1.3.19.2	207,92	1200	3.1.19.1.	35,31	2400
1.1.7.3.1	188,84	800	1.3.6.1.1	200,52	345	3.1.1.1.	47,19	2400	3.1.19.2.	35,31	2400
1.1.7.3.2	188,84	800	1.3.6.1.2	200,52	345	3.1.1.2.	47,19	2400	3.1.20.1.	27,55	800
1.1.8.1.	189,18	1200	1.3.6.2.1	200,52	345	3.1.2.1.	39,43	800	3.1.20.2.	27,55	800
1.1.8.2.	189,18	1200	1.3.6.2.2	200,52	345	3.1.2.2.	39,43	800	3.1.20.3.	27,55	800
1.1.9.1.1	191,24	800	1.3.6.3.1	200,52	345	3.1.2.3.	39,43	800	3.1.21.1.	33,99	2400
1.1.9.1.2	191,24	800	1.3.6.3.2	200,52	345	3.1.3.1.	45,87	2400	3.1.21.2.	33,99	2400
1.1.9.2.1	191,24	800	1.3.6.4.1	200,52	345	3.1.3.2.	45,87	2400	3.1.22.1.	26,23	800
1.1.9.2.2	191,24	800	1.3.6.4.2	200,52	345	3.1.4.1.	38,11	800	3.1.22.2.	26,23	800
1.1.9.3.1	191,24	800	1.3.7.1.	200	1200	3.1.4.2.	38,11	800	3.1.22.3.	26,23	800
1.1.9.3.2	191,24	800	1.3.7.2.	200	1200	3.1.4.3.	38,11	800	3.1.23.1.	32,67	2400
1.1.10.1.	190,5	1200	1.3.8.1.1	201,67	345	3.1.5.1.	44,55	2400	3.1.23.2.	32,67	2400
1.1.10.2.	190,5	1200	1.3.8.1.2	201,67	345	3.1.5.2.	44,55	2400	3.1.24.1.	24,91	800
1.1.11.1.1	193,64	800	1.3.8.2.1	201,67	345	3.1.6.1.	36,79	800	3.1.24.2.	24,91	800
1.1.11.1.2	193,64	800	1.3.8.2.2	201,67	345	3.1.6.2.	36,79	800	3.1.24.3.	24,91	800
1.1.11.2.1	193,64	800	1.3.8.3.1	201,67	345	3.1.6.3.	36,79	800	3.1.25.1.	31,35	2400
1.1.11.2.2	193,64	800	1.3.8.3.2	201,67	345	3.1.7.1.	43,23	2400	3.1.25.2.	31,35	2400
1.1.11.3.1	193,64	800	1.3.8.4.1	201,67	345	3.1.7.2.	43,23	2400	3.1.26.1.	23,59	1200
1.1.11.3.2	193,64	800	1.3.8.4.2	201,67	345	3.1.8.1.	35,47	800	3.1.26.2.	23,59	1200

Location	Distance (m)	Capacity (dm)	Location	Distance (m)	Capacity (dm)	Location	Distance (m)	Capacity (dm)	Location	Distance (m)	Capacity (dm)
3.1.27.1.	30,03	2400	3.2.2.3.	37,59	800	3.2.21.1.	24,55	2400	4.0.1.1.1	5,75	800
3.1.27.2.	30,03	2400	3.2.3.1.	36,43	2400	3.2.21.2.	24,55	2400	4.0.1.1.2	5,75	800
3.1.28.1.	22,27	1200	3.2.3.2.	36,43	2400	3.2.22.1.	24,39	800	4.0.1.2.1	5,75	800
3.1.28.2.	22,27	1200	3.2.4.1.	36,27	800	3.2.22.2.	24,39	800	4.0.1.2.2	5,75	800
3.1.29.1.	28,71	2400	3.2.4.2.	36,27	800	3.2.22.3.	24,39	800	4.0.1.3.1	5,75	800
3.1.29.2.	28,71	2400	3.2.4.3.	36,27	800	3.2.23.1.	23,23	2400	4.0.1.3.2	5,75	800
3.1.30.1.	20,95	1200	3.2.5.1.	35,11	2400	3.2.23.2.	23,23	2400	4.0.3.1.1	8,15	800
3.1.30.2.	20,95	1200	3.2.5.2.	35,11	2400	3.2.24.1.	23,07	800	4.0.3.1.2	8,15	800
3.1.31.1.	27,39	2400	3.2.6.1.	34,95	800	3.2.24.2.	23,07	800	4.0.3.2.1	8,15	800
3.1.31.2.	27,39	2400	3.2.6.2.	34,95	800	3.2.24.3.	23,07	800	4.0.3.2.2	8,15	800
3.1.32.1.	19,63	1200	3.2.6.3.	34,95	800	3.2.25.1.	21,91	2400	4.0.3.3.1	8,15	800
3.1.32.2.	19,63	1200	3.2.7.1.	33,79	2400	3.2.25.2.	21,91	2400	4.0.3.3.2	8,15	800
3.1.33.1.	26,07	2400	3.2.7.2.	33,79	2400	3.2.26.1.	21,75	1200	4.0.5.1.1	10,55	800
3.1.33.2.	26,07	2400	3.2.8.1.	33,63	800	3.2.26.2.	21,75	1200	4.0.5.1.2	10,55	800
3.1.34.1.	18,31	1200	3.2.8.2.	33,63	800	3.2.27.1.	20,59	2400	4.0.5.2.1	10,55	800
3.1.34.2.	18,31	1200	3.2.8.3.	33,63	800	3.2.27.2.	20,59	2400	4.0.5.2.2	10,55	800
3.1.35.1.	24,75	2400	3.2.9.1.	32,47	2400	3.2.28.1.	20,43	1200	4.0.5.3.1	10,55	800
3.1.35.2.	24,75	2400	3.2.9.2.	32,47	2400	3.2.28.2.	20,43	1200	4.0.5.3.2	10,55	800
3.1.36.1.	18,31	800	3.2.10.1.	32,31	800	3.2.29.1.	19,27	2400	4.1.1.1.1	2,4	1200
3.1.36.2.	18,31	800	3.2.10.2.	32,31	800	3.2.29.2.	19,27	2400	4.1.1.1.2	2,4	1200
3.1.36.3.	18,31	800	3.2.10.3.	32,31	800	3.2.30.1.	19,11	1200	4.1.1.2.1	2,4	1200
3.1.37.1.	23,43	2400	3.2.11.1.	31,15	2400	3.2.30.2.	19,11	1200	4.1.1.2.2	2,4	1200
3.1.37.2.	23,43	2400	3.2.11.2.	31,15	2400	3.2.31.1.	17,95	2400	4.1.2.1.1	2,1	800
3.1.38.1.	15,67	800	3.2.12.1.	30,99	800	3.2.31.2.	17,95	2400	4.1.2.1.2	2,1	800
3.1.38.2.	15,67	800	3.2.12.2.	30,99	800	3.2.32.1.	17,79	1200	4.1.2.2.1	2,1	800
3.1.38.3.	15,67	800	3.2.12.3.	30,99	800	3.2.32.2.	17,79	1200	4.1.2.2.2	2,1	800
3.1.39.1.	22,11	2400	3.2.13.1.	29,83	2400	3.2.33.1.	16,63	2400	4.1.2.3.1	2,1	800
3.1.39.2.	22,11	2400	3.2.13.2.	29,83	2400	3.2.33.2.	16,63	2400	4.1.2.3.2	2,1	800
3.1.41.1.	20,79	1200	3.2.14.1.	29,67	800	3.2.34.1.	16,47	1200	4.1.3.1.1	4,8	1200
3.1.41.2.	20,79	1200	3.2.14.2.	29,67	800	3.2.34.2.	16,47	1200	4.1.3.1.2	4,8	1200
3.1.43.1.	19,47	2400	3.2.14.3.	29,67	800	3.2.35.1.	15,31	2400	4.1.3.2.1	4,8	1200
3.1.43.2.	19,47	2400	3.2.15.1.	28,51	2400	3.2.35.2.	15,31	2400	4.1.3.2.2	4,8	1200
3.1.45.1.	18,15	2400	3.2.15.2.	28,51	2400	3.2.36.1.	15,15	800	4.1.4.1.1	4,5	800
3.1.45.2.	18,15	2400	3.2.16.1.	28,35	800	3.2.36.2.	15,15	800	4.1.4.1.2	4,5	800
3.1.47.1.	16,83	2400	3.2.16.2.	28,35	800	3.2.36.3.	15,15	800	4.1.4.2.1	4,5	800
3.1.47.2.	16,83	2400	3.2.16.3.	28,35	800	3.2.37.1.	13,99	2400	4.1.4.2.2	4,5	800
3.1.49.1.	15,53	2400	3.2.17.1.	27,19	2400	3.2.37.2.	13,99	2400	4.1.4.3.1	4,5	800
3.1.49.2.	15,53	2400	3.2.17.2.	27,19	2400	3.2.38.1.	13,83	800	4.1.4.3.2	4,5	800
3.1.51.1.	14,21	2400	3.2.18.1.	27,03	800	3.2.38.2.	13,83	800	4.1.5.1.1	7,2	1200
3.1.51.2.	14,21	2400	3.2.18.2.	27,03	800	3.2.38.3.	13,83	800	4.1.5.1.2	7,2	1200
3.1.53.1.	12,6	2400	3.2.18.3.	27,03	800	3.2.39.1.	12,67	2400	4.1.5.2.1	7,2	1200
3.1.53.2.	12,6	2400	3.2.19.1.	25,87	2400	3.2.39.2.	12,67	2400	4.1.5.2.2	7,2	1200
3.2.1.1.	37,75	2400	3.2.19.2.	25,87	2400	3.2.41.1.	11,35	2400	4.1.6.1.1	6,9	800
3.2.1.2.	37,75	2400	3.2.20.1.	25,71	800	3.2.41.2.	11,35	2400	4.1.6.1.2	6,9	800
3.2.2.1.	37,59	800	3.2.20.2.	25,71	800	3.2.43.1.	10,03	2400	4.1.6.2.1	6,9	800
3.2.2.2.	37,59	800	3.2.20.3.	25,71	800	3.2.43.2.	10,03	2400	4.1.6.2.2	6,9	800

Location	Distance (m)	Capacity (dm)	Location	Distance (m)	Capacity (dm)	Location	Distance (m)	Capacity (dm)	Location	Distance (m)	Capacity (dm)
4.1.6.3.1	6,9	800	4.1.16.1.1	18,9	800	4.2.4.2.1	11,53	800	4.2.20.1.1	28,33	800
4.1.6.3.2	6,9	800	4.1.16.1.2	18,9	800	4.2.4.2.2	11,53	800	4.2.20.1.2	28,33	800
4.1.7.1.1	9,6	1200	4.1.16.2.1	18,9	800	4.2.4.3.1	11,53	800	4.2.20.2.1	28,33	800
4.1.7.1.2	9,6	1200	4.1.16.2.2	18,9	800	4.2.4.3.2	11,53	800	4.2.20.2.2	28,33	800
4.1.7.2.1	9,6	1200	4.1.16.3.1	18,9	800	4.2.6.1.1	13,9	800	4.2.20.3.1	28,33	800
4.1.7.2.2	9,6	1200	4.1.16.3.2	18,9	800	4.2.6.1.2	13,9	800	4.2.20.3.2	28,33	800
4.1.8.1.1	9,3	800	4.1.17.1.1	21,6	1200	4.2.6.2.1	13,9	800	4.2.22.1.1	28,2	800
4.1.8.1.2	9,3	800	4.1.17.1.2	21,6	1200	4.2.6.2.2	13,9	800	4.2.22.1.2	28,2	800
4.1.8.2.1	9,3	800	4.1.17.2.1	21,6	1200	4.2.6.3.1	13,9	800	4.2.22.2.1	28,2	800
4.1.8.2.2	9,3	800	4.1.17.2.2	21,6	1200	4.2.6.3.2	13,9	800	4.2.22.2.2	28,2	800
4.1.8.3.1	9,3	800	4.1.18.1.1	21,3	800	4.2.8.1.1	16,33	800	4.2.22.3.1	28,2	800
4.1.8.3.2	9,3	800	4.1.18.1.2	21,3	800	4.2.8.1.2	16,33	800	4.2.22.3.2	28,2	800
4.1.9.1.1	12	1200	4.1.18.2.1	21,3	800	4.2.8.2.1	16,33	800			
4.1.9.1.2	12	1200	4.1.18.2.2	21,3	800	4.2.8.2.2	16,33	800			
4.1.9.2.1	12	1200	4.1.18.3.1	21,3	800	4.2.8.3.1	16,33	800			
4.1.9.2.2	12	1200	4.1.18.3.2	21,3	800	4.2.8.3.2	16,33	800			
4.1.10.1.1	11,7	800	4.1.19.1.1	24	1200	4.2.10.1.1	18,73	800			
4.1.10.1.2	11,7	800	4.1.19.1.2	24	1200	4.2.10.1.2	18,73	800			
4.1.10.2.1	11,7	800	4.1.19.2.1	24	1200	4.2.10.2.1	18,73	800			
4.1.10.2.2	11,7	800	4.1.19.2.2	24	1200	4.2.10.2.2	18,73	800			
4.1.10.3.1	11,7	800	4.1.20.1.1	23,7	800	4.2.10.3.1	18,73	800			
4.1.10.3.2	11,7	800	4.1.20.1.2	23,7	800	4.2.10.3.2	18,73	800			
4.1.11.1.1	14,4	1200	4.1.20.2.1	23,7	800	4.2.12.1.1	21,13	800			
4.1.11.1.2	14,4	1200	4.1.20.2.2	23,7	800	4.2.12.1.2	21,13	800			
4.1.11.2.1	14,4	1200	4.1.20.3.1	23,7	800	4.2.12.2.1	21,13	800			
4.1.11.2.2	14,4	1200	4.1.20.3.2	23,7	800	4.2.12.2.2	21,13	800			
4.1.12.1.1	14,1	800	4.1.21.1.1	26,04	800	4.2.12.3.1	21,13	800			
4.1.12.1.2	14,1	800	4.1.21.1.2	26,04	800	4.2.12.3.2	21,13	800			
4.1.12.2.1	14,1	800	4.1.21.2.1	26,04	800	4.2.14.1.1	23,53	800			
4.1.12.2.2	14,1	800	4.1.21.2.2	26,04	800	4.2.14.1.2	23,53	800			
4.1.12.3.1	14,1	800	4.1.21.3.1	26,04	800	4.2.14.2.1	23,53	800			
4.1.12.3.2	14,1	800	4.1.21.3.2	26,04	800	4.2.14.2.2	23,53	800			
4.1.13.1.1	16,8	1200	4.1.22.1.1	25,8	800	4.2.14.3.1	23,53	800			
4.1.13.1.2	16,8	1200	4.1.22.1.2	25,8	800	4.2.14.3.2	23,53	800			
4.1.13.2.1	16,8	1200	4.1.22.2.1	25,8	800	4.2.16.1.1	25,93	800			
4.1.13.2.2	16,8	1200	4.1.22.2.2	25,8	800	4.2.16.1.2	25,93	800			
4.1.14.1.1	16,5	800	4.1.22.3.1	25,8	800	4.2.16.2.1	25,93	800			
4.1.14.1.2	16,5	800	4.1.22.3.2	25,8	800	4.2.16.2.2	25,93	800			
4.1.14.2.1	16,5	800	4.2.2.1.1	9,13	800	4.2.16.3.1	25,93	800			
4.1.14.2.2	16,5	800	4.2.2.1.2	9,13	800	4.2.16.3.2	25,93	800			
4.1.14.3.1	16,5	800	4.2.2.2.1	9,13	800	4.2.18.1.1	28,33	800			
4.1.14.3.2	16,5	800	4.2.2.2.2	9,13	800	4.2.18.1.2	28,33	800			
4.1.15.1.1	19,2	1200	4.2.2.3.1	9,13	800	4.2.18.2.1	28,33	800			
4.1.15.1.2	19,2	1200	4.2.2.3.2	9,13	800	4.2.18.2.2	28,33	800			
4.1.15.2.1	19,2	1200	4.2.4.1.1	11,53	800	4.2.18.3.1	28,33	800			
4.1.15.2.2	19,2	1200	4.2.4.1.2	11,53	800	4.2.18.3.2	28,33	800			

Annexe D

The following image illustrates the existing racks in the warehouse.

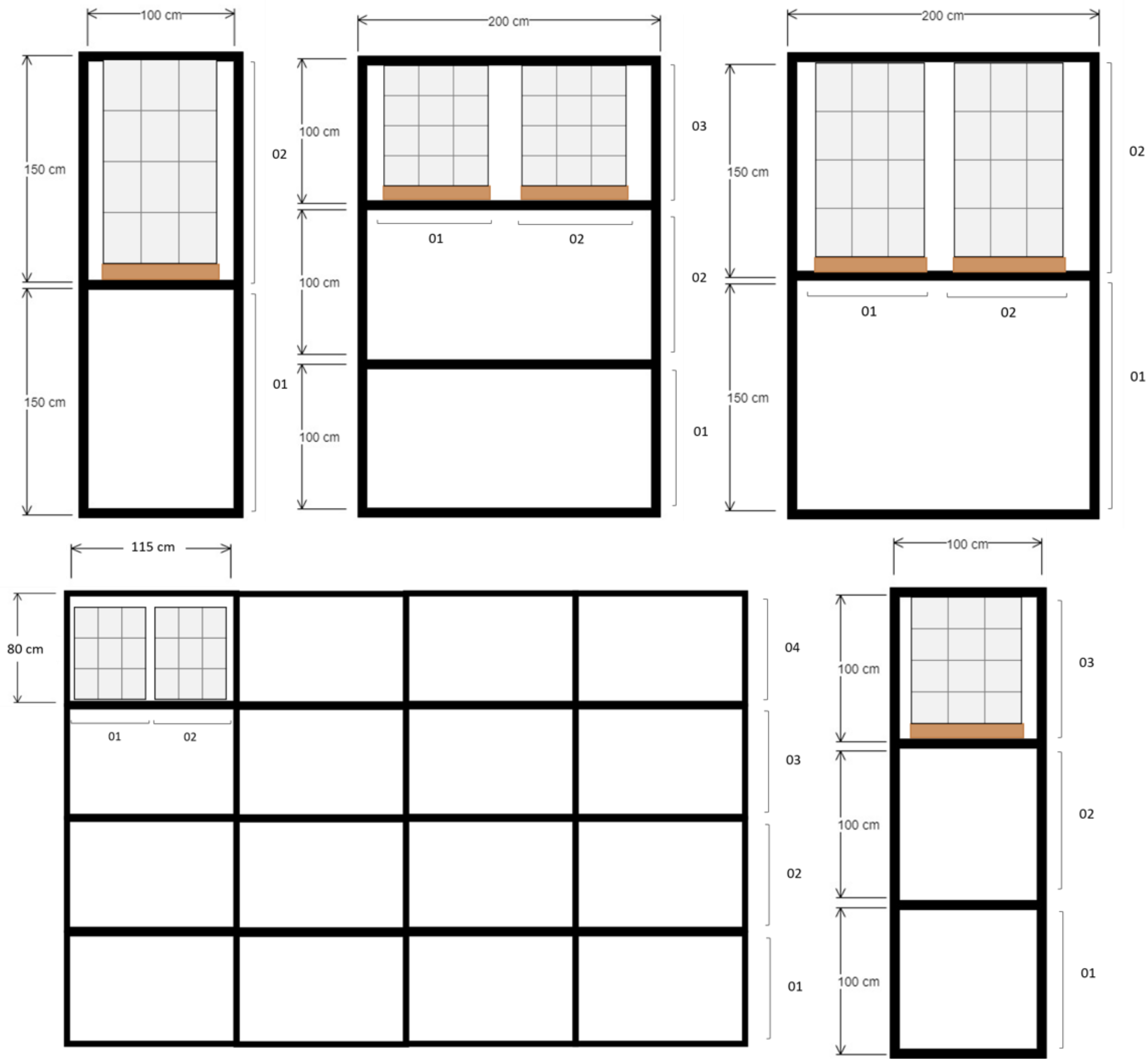

Figure 8.4 Different racks in the warehouse

Annexe E

The following table includes the different families, the number of SKUs, the number of movements and the total stock.

Table 8.2 Number of SKUs, movements and stock per family

Family	N SKUs	Movements	Stock
F1	6	223	3 824
F2	8	2 005	111 422
F3	38	2 076	67 758
F4	12	650	27 716
F5	36	3 128	71 111
F6	17	369	48 250
F7	23	2 071	81 771
F8	25	3 397	42 402
F9	20	2 038	74 227

Annexe F

The table presented below contains the stock in dm^3 of the 93 SKUs and the outgoing movements.

Table 8.3 Stock and movements of 93 SKUs in 2019

SKU	Stock dm	Movements	SKU	Stock dm	Movements	SKU	Stock dm	Movements
s1	24 193	340	s41	8 054	75	s81	1 400	7
s2	28 935	314	s42	2 710	71	s82	1 232	5
s3	33 222	305	s43	1 465	69	s83	1 168	5
s4	15 340	285	s44	2 423	68	s84	1 620	4
s5	23 868	280	s45	1 248	65	s85	1 975	4
s6	3 350	266	s46	1 467	64	s86	2 340	3
s7	2 904	231	s47	1 739	64	s87	1 320	3
s8	12 056	221	s48	2 019	61	s88	1 145	2
s9	5 065	216	s49	20 009	59	s89	3 000	2
s10	4 419	203	s50	1 145	56	s90	1 344	2
s11	23 660	199	s51	1 688	55	s91	3 545	1
s12	11 511	195	s52	1 468	53	s92	5 145	1
s13	10 161	190	s53	1 512	51	s93	1 620	1
s14	17 072	188	s54	12 434	48			
s15	7 757	183	s55	1 484	47			
s16	10 800	177	s56	2 225	44			
s17	4 056	167	s57	1 904	43			
s18	2 000	163	s58	18 599	42			
s19	3 316	146	s59	2 200	40			
s20	13 600	132	s60	1 145	36			
s21	2 438	128	s61	11 800	35			
s22	1 235	127	s62	1 425	29			
s23	3 940	126	s63	12 839	25			
s24	1 673	124	s64	2 411	22			
s25	3 519	123	s65	870	21			
s26	6 136	121	s66	1 600	21			
s27	1 814	119	s67	3 258	20			
s28	2 921	117	s68	1 181	19			
s29	10 034	114	s69	1 154	18			
s30	6 971	110	s70	2 600	17			
s31	8 490	103	s71	1 474	17			
s32	4 881	100	s72	1 400	16			
s33	6 512	97	s73	2 425	16			
s34	3 832	93	s74	945	14			
s35	4 008	93	s75	7 442	13			
s36	2 443	89	s76	945	11			
s37	5 076	85	s77	3 493	9			
s38	1 203	80	s78	1 127	8			
s39	5 104	76	s79	10 565	7			
s40	1 400	76	s80	4 820	7			

Annexe G

The table presented below contains the stock in dm^3 of the 185 SKUs and the outgoing movements.

Table 8.4 Stock and movements of 185 SKUs in 2019

SKU	Mov	Stock	SKU	Mov	Stock	SKU	Mov	Stock	SKU	Mov	Stock	SKU	Mov	Stock
s1	342	12 000	s42	127	438	s83	71	800	s124	26	800	s165	5	600
s2	338	12 193	s43	127	748	s84	70	1 910	s125	25	11 054	s166	4	568
s3	321	13 095	s44	126	487	s85	69	863	s126	24	1 785	s167	4	600
s4	307	15 840	s45	126	1 540	s86	69	602	s127	22	600	s168	4	1 020
s5	307	31 080	s46	125	2 400	s87	68	600	s128	22	1 811	s169	4	1 175
s6	303	2 142	s47	124	473	s88	67	1 823	s129	21	345	s170	4	800
s7	285	11 340	s48	123	1 200	s89	65	681	s130	21	525	s171	3	1 140
s8	284	4 000	s49	123	1 182	s90	64	567	s131	21	800	s172	3	1 200
s9	283	6 000	s50	123	2 337	s91	64	800	s132	20	800	s173	3	600
s10	277	17 868	s51	121	5 600	s92	64	667	s133	20	2 218	s174	2	720
s11	270	950	s52	121	536	s93	64	720	s134	20	1 040	s175	2	345
s12	262	2 400	s53	119	1 014	s94	63	1 019	s135	20	600	s176	2	800
s13	236	600	s54	118	800	s95	62	1 538	s136	18	581	s177	2	2 400
s14	225	2 304	s55	117	1 552	s96	59	481	s137	18	600	s178	2	600
s15	224	3 442	s56	117	1 369	s97	59	4 223	s138	18	554	s179	2	744
s16	218	8 614	s57	115	9 261	s98	58	15 786	s139	17	600	s180	1	600
s17	216	2 265	s58	112	773	s99	57	800	s140	17	2 000	s181	1	3 200
s18	215	2 800	s59	110	5 200	s100	55	345	s141	17	800	s182	1	345
s19	204	2 711	s60	110	1 771	s101	55	800	s142	17	674	s183	1	345
s20	202	1 708	s61	103	786	s102	54	888	s143	16	800	s184	1	4 800
s21	199	22 400	s62	103	7 704	s103	53	800	s144	16	600	s185	1	1 620
s22	198	1 260	s63	100	4 142	s104	53	668	s145	16	685			
s23	197	9 111	s64	99	739	s105	53	600	s146	15	1 740			
s24	192	2 400	s65	97	5 712	s106	49	912	s147	14	600			
s25	190	9 200	s66	96	800	s107	48	2 034	s148	13	345			
s26	190	961	s67	93	3 175	s108	48	10 400	s149	13	2 000			
s27	189	12 768	s68	93	657	s109	47	684	s150	12	5 442			
s28	186	4 304	s69	93	3 408	s110	47	800	s151	11	345			
s29	184	2 285	s70	93	600	s111	44	1 600	s152	10	600			
s30	182	5 472	s71	92	2 000	s112	43	625	s153	10	1 093			
s31	180	9 600	s72	86	443	s113	43	1 170	s154	8	2 400			
s32	174	1 200	s73	86	774	s114	43	734	s155	8	782			
s33	167	2 028	s74	84	4 302	s115	42	14 600	s156	8	345			
s34	167	2 028	s75	80	403	s116	42	3 999	s157	7	8 745			
s35	164	1 200	s76	79	800	s117	41	1 600	s158	7	1 820			
s36	161	800	s77	76	1 504	s118	39	600	s159	7	3 765			
s37	147	1 179	s78	76	3 600	s119	36	345	s160	7	1 055			
s38	145	2 137	s79	76	600	s120	35	800	s161	7	800			
s39	132	2 800	s80	75	800	s121	35	11 200	s162	6	600			
s40	131	10 800	s81	75	5 195	s122	34	600	s163	5	600			
s41	129	2 000	s82	74	2 859	s123	32	625	s164	5	632			

Annexe H

The following table shows the allocation of scenario A of 185 SKUs taking into account the general ABC analysis.

Table 8.5 General ABC - Scenario A allocation

Location	SKU	Location	SKU	Location	SKU	Location	SKU	Location	SKU
1.1.1.1.1	S150	1.3.1.1.	S172	3.1.13.2.	S115	3.1.37.1.	S9	3.2.14.2.	S62
1.1.1.1.2	S150	1.3.1.2.	S174	3.1.14.1.	S21	3.1.37.2.	S57	3.2.14.3.	S5
1.1.1.2.1	S149	1.3.2.1.2	S184	3.1.14.2.	S21	3.1.38.1.	S7	3.2.15.1.	S5
1.1.1.2.2	S125	1.3.2.2.1	S57	3.1.14.3.	S21	3.1.38.2.	S16	3.2.15.2.	S5
1.1.1.3.1	S165	1.3.2.2.2	S137	3.1.15.1.	S121	3.1.38.3.	S16	3.2.16.1.	S5
1.1.1.3.2	S170	1.3.2.3.1	S185	3.1.15.2.	S121	3.1.39.1.	S10	3.2.16.2.	S106
1.1.2.1.	S126	1.3.2.3.2	S127	3.1.16.1.	S21	3.1.39.2.	S10	3.2.16.3.	S5
1.1.2.2.	S149	1.3.4.1.1	S181	3.1.16.2.	S21	3.1.41.1.	S39	3.2.17.1.	S40
1.1.3.1.1	S150	1.3.4.1.2	S177	3.1.16.3.	S5	3.1.41.2.	S1	3.2.17.2.	S40
1.1.3.1.2	S159	1.3.4.2.2	S184	3.1.17.1.	S98	3.1.43.1.	S1	3.2.18.1.	S39
1.1.3.2.1	S159	1.3.5.2.	S180	3.1.17.2.	S98	3.1.43.2.	S1	3.2.18.2.	S58
1.1.3.2.2	S150	1.3.6.1.1	S183	3.1.18.1.	S5	3.1.45.1.	S31	3.2.18.3.	S10
1.1.3.3.1	S16	1.3.6.1.2	S125	3.1.18.2.	S5	3.1.45.2.	S31	3.2.19.1.	S4
1.1.3.3.2	S159	1.3.6.2.1	S69	3.1.18.3.	S5	3.1.47.1.	S23	3.2.19.2.	S4
1.1.4.1.	S171	1.3.6.3.1	S97	3.1.19.1.	S98	3.1.47.2.	S23	3.2.20.1.	S4
1.1.4.2.	S160	1.3.6.3.2	S157	3.1.19.2.	S98	3.1.49.1.	S8	3.2.20.2.	S4
1.1.5.1.1	S150	1.3.6.4.1	S134	3.1.20.1.	S40	3.1.49.2.	S7	3.2.20.3.	S3
1.1.5.1.2	S169	1.3.6.4.2	S182	3.1.20.2.	S81	3.1.51.1.	S25	3.2.21.1.	S27
1.1.5.2.1	S130	1.3.7.1.	S181	3.1.20.3.	S81	3.1.51.2.	S25	3.2.21.2.	S27
1.1.5.2.2	S157	1.3.7.2.	S81	3.1.21.1.	S5	3.1.53.1.	S29	3.2.22.1.	S59
1.1.5.3.1	S157	1.3.8.4.1	S159	3.1.21.2.	S107	3.1.53.2.	S7	3.2.22.2.	S27
1.1.5.3.2	S150	1.3.11.1.	S168	3.1.22.1.	S40	3.2.1.1.	S121	3.2.22.3.	S27
1.1.6.1.	S158	1.3.13.2.	S181	3.1.22.2.	S40	3.2.1.2.	S98	3.2.23.1.	S10
1.1.6.2.	S125	3.1.1.1.	S125	3.1.22.3.	S40	3.2.2.1.	S155	3.2.23.2.	S10
1.1.7.1.1	S158	3.1.1.2.	S125	3.1.23.1.	S21	3.2.2.2.	S121	3.2.24.1.	S10
1.1.7.1.2	S178	3.1.2.1.	S116	3.1.23.2.	S21	3.2.2.3.	S126	3.2.24.2.	S69
1.1.7.2.1	S62	3.1.2.2.	S173	3.1.24.1.	S4	3.2.3.1.	S146	3.2.24.3.	S1
1.1.7.2.2	S125	3.1.2.3.	S115	3.1.24.2.	S4	3.2.3.2.	S98	3.2.25.1.	S10
1.1.7.3.1	S169	3.1.3.1.	S108	3.1.24.3.	S4	3.2.4.1.	S163	3.2.25.2.	S10
1.1.7.3.2	S125	3.1.3.2.	S125	3.1.25.1.	S21	3.2.4.2.	S164	3.2.26.1.	S10
1.1.8.1.	S184	3.1.4.1.	S147	3.1.25.2.	S81	3.2.4.3.	S98	3.2.26.2.	S23
1.1.8.2.	S159	3.1.4.2.	S168	3.1.26.1.	S57	3.2.5.1.	S128	3.2.27.1.	S2
1.1.9.1.1	S184	3.1.4.3.	S167	3.1.26.2.	S5	3.2.5.2.	S108	3.2.27.2.	S2
1.1.9.1.2	S152	3.1.5.1.	S116	3.1.27.1.	S5	3.2.6.1.	S108	3.2.28.1.	S2
1.1.9.2.1	S157	3.1.5.2.	S115	3.1.27.2.	S5	3.2.6.2.	S90	3.2.28.2.	S62
1.1.9.2.2	S175	3.1.6.1.	S122	3.1.28.1.	S63	3.2.6.3.	S108	3.2.29.1.	S2
1.1.9.3.1	S177	3.1.6.2.	S33	3.1.28.2.	S9	3.2.7.1.	S133	3.2.29.2.	S2
1.1.9.3.2	S150	3.1.6.3.	S121	3.1.29.1.	S27	3.2.7.2.	S108	3.2.30.1.	S65
1.1.10.1.	S157	3.1.7.1.	S115	3.1.29.2.	S5	3.2.8.1.	S162	3.2.30.2.	S65
1.1.10.2.	S153	3.1.7.2.	S115	3.1.30.1.	S1	3.2.8.2.	S156	3.2.31.1.	S31
1.1.11.1.1	S5	3.1.8.1.	S97	3.1.30.2.	S1	3.2.8.3.	S166	3.2.31.2.	S31
1.1.11.2.1	S145	3.1.8.2.	S97	3.1.31.1.	S9	3.2.9.1.	S21	3.2.32.1.	S24
1.1.11.2.2	S20	3.1.8.3.	S98	3.1.31.2.	S40	3.2.9.2.	S21	3.2.32.2.	S24
1.1.11.3.1	S176	3.1.9.1.	S115	3.1.32.1.	S1	3.2.10.1.	S140	3.2.33.1.	S74
1.1.12.1.	S184	3.1.9.2.	S121	3.1.32.2.	S138	3.2.10.2.	S21	3.2.33.2.	S16
1.1.12.2.	S157	3.1.10.1.	S108	3.1.33.1.	S4	3.2.10.3.	S21	3.2.34.1.	S16
1.2.1.1.	S87	3.1.10.2.	S136	3.1.33.2.	S4	3.2.11.1.	S21	3.2.34.2.	S16
1.2.1.2.	S157	3.1.10.3.	S108	3.1.34.1.	S129	3.2.11.2.	S21	3.2.35.1.	S7
1.2.2.1.	S157	3.1.11.1.	S97	3.1.34.2.	S60	3.2.12.1.	S22	3.2.35.2.	S7
1.2.2.2.	S116	3.1.11.2.	S115	3.1.35.1.	S4	3.2.12.2.	S39	3.2.36.1.	S16
1.2.3.1.	S185	3.1.12.1.	S40	3.1.35.2.	S57	3.2.12.3.	S22	3.2.36.2.	S8
1.2.3.2.	S157	3.1.12.2.	S134	3.1.36.1.	S65	3.2.13.1.	S5	3.2.36.3.	S8
1.2.4.1.	S177	3.1.12.3.	S161	3.1.36.2.	S32	3.2.13.2.	S5	3.2.37.1.	S51
1.2.4.2.	S179	3.1.13.1.	S154	3.1.36.3.	S60	3.2.14.1.	S5	3.2.37.2.	S51

Location	SKU	Location	SKU	Location	SKU	Location	SKU
3.2.38.1.	S101	4.1.6.2.2	S38	4.1.17.1.2	S62	4.2.8.3.2	S15
3.2.38.2.	S63	4.1.6.3.1	S91	4.1.17.2.1	S148	4.2.10.1.1	S114
3.2.38.3.	S64	4.1.6.3.2	S86	4.1.17.2.2	S62	4.2.10.1.2	S59
3.2.39.1.	S63	4.1.7.1.1	S102	4.1.18.1.1	S32	4.2.10.2.1	S59
3.2.39.2.	S69	4.1.7.1.2	S49	4.1.18.1.2	S2	4.2.10.2.2	S96
3.2.41.1.	S84	4.1.7.2.1	S71	4.1.18.2.1	S62	4.2.10.3.1	S59
3.2.41.2.	S88	4.1.7.2.2	S94	4.1.18.2.2	S83	4.2.10.3.2	S59
3.2.43.1.	S50	4.1.8.1.1	S109	4.1.18.3.1	S62	4.2.12.1.1	S131
3.2.43.2.	S46	4.1.8.1.2	S103	4.1.18.3.2	S62	4.2.12.1.2	S73
4.0.1.1.1	S20	4.1.8.2.1	S104	4.1.19.1.1	S28	4.2.12.2.1	S132
4.0.1.1.2	S85	4.1.8.2.2	S71	4.1.19.1.2	S140	4.2.12.2.2	S2
4.0.1.2.1	S20	4.1.8.3.1	S99	4.1.19.2.1	S28	4.2.12.3.1	S1
4.0.1.2.2	S80	4.1.8.3.2	S72	4.1.19.2.2	S28	4.2.12.3.2	S1
4.0.1.3.1	S44	4.1.9.1.1	S30	4.1.20.1.1	S62	4.2.14.1.1	S77
4.0.1.3.2	S19	4.1.9.1.2	S113	4.1.20.1.2	S28	4.2.14.1.2	S57
4.0.3.1.1	S18	4.1.9.2.1	S30	4.1.20.2.1	S27	4.2.14.2.1	S151
4.0.3.1.2	S18	4.1.9.2.2	S30	4.1.20.2.2	S27	4.2.14.2.2	S57
4.0.3.2.1	S33	4.1.10.1.1	S67	4.1.20.3.1	S27	4.2.14.3.1	S57
4.0.3.2.2	S13	4.1.10.1.2	S119	4.1.20.3.2	S27	4.2.14.3.2	S61
4.0.3.3.1	S33	4.1.10.2.1	S67	4.1.21.1.1	S143	4.2.16.1.1	S3
4.0.3.3.2	S34	4.1.10.2.2	S70	4.1.21.1.2	S141	4.2.16.1.2	S3
4.0.5.1.1	S45	4.1.10.3.1	S30	4.1.21.2.1	S3	4.2.16.2.1	S3
4.0.5.1.2	S45	4.1.10.3.2	S67	4.1.21.2.2	S3	4.2.16.2.2	S3
4.0.5.2.1	S106	4.1.11.1.1	S26	4.1.21.3.1	S142	4.2.16.3.1	S3
4.0.5.2.2	S95	4.1.11.1.2	S25	4.1.21.3.2	S144	4.2.16.3.2	S3
4.0.5.3.1	S95	4.1.11.2.1	S7	4.1.22.1.1	S3	4.2.18.1.1	S5
4.0.5.3.2	S38	4.1.11.2.2	S30	4.1.22.1.2	S3	4.2.18.1.2	S5
4.1.1.1.1	S48	4.1.12.1.1	S25	4.1.22.2.1	S57	4.2.18.2.1	S5
4.1.1.1.2	S11	4.1.12.1.2	S55	4.1.22.2.2	S3	4.2.18.2.2	S5
4.1.1.2.1	S12	4.1.12.2.1	S51	4.1.22.3.1	S3	4.2.18.3.1	S5
4.1.1.2.2	S12	4.1.12.2.2	S25	4.1.22.3.2	S3	4.2.18.3.2	S6
4.1.2.1.1	S35	4.1.12.3.1	S120	4.2.2.1.1	S55	4.2.20.1.1	S81
4.1.2.1.2	S35	4.1.12.3.2	S52	4.2.2.1.2	S56	4.2.20.1.2	S82
4.1.2.2.1	S14	4.1.13.1.1	S23	4.2.2.2.1	S56	4.2.20.2.1	S6
4.1.2.2.2	S14	4.1.13.1.2	S74	4.2.2.2.2	S34	4.2.20.2.2	S6
4.1.2.3.1	S14	4.1.13.2.1	S23	4.2.2.3.1	S34	4.2.20.3.1	S10
4.1.2.3.2	S43	4.1.13.2.2	S23	4.2.2.3.2	S93	4.2.20.3.2	S3
4.1.3.1.1	S41	4.1.14.1.1	S117	4.2.4.1.1	S105	4.2.22.1.1	S82
4.1.3.1.2	S89	4.1.14.1.2	S74	4.2.4.1.2	S67	4.2.22.1.2	S82
4.1.3.2.1	S19	4.1.14.2.1	S25	4.2.4.2.1	S110	4.2.22.2.1	S82
4.1.3.2.2	S53	4.1.14.2.2	S117	4.2.4.2.2	S19	4.2.22.2.2	S66
4.1.4.1.1	S47	4.1.14.3.1	S59	4.2.4.3.1	S100	4.2.22.3.1	S139
4.1.4.1.2	S75	4.1.14.3.2	S118	4.2.4.3.2	S92	4.2.22.3.2	S27
4.1.4.2.1	S54	4.1.15.1.1	S78	4.2.6.1.1	S111		
4.1.4.2.2	S41	4.1.15.1.2	S65	4.2.6.1.2	S123		
4.1.4.3.1	S79	4.1.15.2.1	S78	4.2.6.2.1	S111		
4.1.4.3.2	S76	4.1.15.2.2	S78	4.2.6.2.2	S68		
4.1.5.1.1	S37	4.1.16.1.1	S65	4.2.6.3.1	S124		
4.1.5.1.2	S18	4.1.16.1.2	S65	4.2.6.3.2	S112		
4.1.5.2.1	S17	4.1.16.2.1	S59	4.2.8.1.1	S16		
4.1.5.2.2	S17	4.1.16.2.2	S77	4.2.8.1.2	S15		
4.1.6.1.1	S36	4.1.16.3.1	S25	4.2.8.2.1	S15		
4.1.6.1.2	S42	4.1.16.3.2	S135	4.2.8.2.2	S15		
4.1.6.2.1	S38	4.1.17.1.1	S3	4.2.8.3.1	S15		

Annexe I

The following table shows the allocation of scenario B of 185 SKUs taking into account the ABC analysis by families.

Table 8.6 ABC Families - Scenario B allocation

Location	SKU	Location	SKU	Location	SKU	Location	SKU
1.1.1.1.1	s5	1.2.2.1.	s21	1.3.10.3.2	s150	3.1.13.1.	s59
1.1.1.1.2	s5	1.2.2.2.	s21	1.3.10.4.1	s125	3.1.13.2.	s59
1.1.1.2.1	s5	1.2.3.1.	s21	1.3.10.4.2	s125	3.1.14.1.	s117
1.1.1.2.2	s5	1.2.3.2.	s21	1.3.11.1.	s125	3.1.14.2.	s78
1.1.1.3.1	s5	1.2.4.1.	s65	1.3.11.2.	s125	3.1.14.3.	s111
1.1.1.3.2	s5	1.2.4.2.	s123	1.3.12.1.2	s150	3.1.15.1.	s7
1.1.2.1.	s5	1.3.1.1.	s115	1.3.12.2.1	s125	3.1.15.2.	s7
1.1.2.2.	s5	1.3.1.2.	s115	1.3.12.2.2	s150	3.1.16.1.	s111
1.1.3.1.1	s5	1.3.2.1.1	s148	1.3.12.3.1	s150	3.1.16.2.	s49
1.1.3.1.2	s5	1.3.2.1.2	s65	1.3.12.3.2	s159	3.1.16.3.	s82
1.1.3.2.1	s5	1.3.2.2.1	s65	1.3.12.4.1	s150	3.1.17.1.	s2
1.1.3.2.2	s5	1.3.2.2.2	s65	1.3.12.4.2	s179	3.1.17.2.	s2
1.1.3.3.1	s5	1.3.2.3.1	s65	1.3.13.1.	s150	3.1.18.1.	s98
1.1.3.3.2	s5	1.3.2.3.2	s65	1.3.13.2.	s150	3.1.18.2.	s98
1.1.4.1.	s5	1.3.3.1.	s115	1.3.15.1.	s150	3.1.18.3.	s180
1.1.4.2.	s5	1.3.3.2.	s115	1.3.15.2.	s125	3.1.19.1.	s1
1.1.5.1.1	s5	1.3.4.1.1	s115	1.3.17.1.	s159	3.1.19.2.	s2
1.1.5.1.2	s59	1.3.4.1.2	s115	1.3.17.2.	s159	3.1.20.1.	s127
1.1.5.2.1	s21	1.3.4.2.1	s115	1.3.19.1	s159	3.1.20.2.	s3
1.1.5.2.2	s5	1.3.4.2.2	s115	1.3.19.2	s171	3.1.20.3.	s113
1.1.5.3.1	s21	1.3.4.3.1	s115	3.1.1.1.	s5	3.1.21.1.	s1
1.1.5.3.2	s21	1.3.4.3.2	s174	3.1.1.2.	s5	3.1.21.2.	s1
1.1.6.1.	s21	1.3.5.1.	s115	3.1.2.1.	s56	3.1.22.1.	s71
1.1.6.2.	s21	1.3.5.2.	s115	3.1.2.2.	s4	3.1.22.2.	s110
1.1.7.1.1	s21	1.3.6.1.1	s115	3.1.2.3.	s4	3.1.22.3.	s38
1.1.7.1.2	s21	1.3.6.1.2	s115	3.1.3.1.	s5	3.1.23.1.	s98
1.1.7.2.1	s5	1.3.6.2.1	s77	3.1.3.2.	s5	3.1.23.2.	s98
1.1.7.2.2	s21	1.3.6.2.2	s175	3.1.4.2.	s7	3.1.24.1.	s164
1.1.7.3.1	s21	1.3.6.3.1	s115	3.1.4.3.	s7	3.1.24.3.	s161
1.1.7.3.2	s21	1.3.6.3.2	s179	3.1.5.1.	s5	3.1.25.1.	s116
1.1.8.1.	s21	1.3.6.4.1	s179	3.1.5.2.	s5	3.1.25.2.	s98
1.1.8.2.	s21	1.3.6.4.2	s168	3.1.6.1.	s121	3.1.26.1.	s27
1.1.9.1.1	s112	1.3.7.1.	s115	3.1.6.2.	s172	3.1.26.2.	s31
1.1.9.1.2	s2	1.3.7.2.	s115	3.1.6.3.	s78	3.1.27.1.	s57
1.1.9.2.1	s21	1.3.8.1.1	s125	3.1.7.1.	s4	3.1.27.2.	s57
1.1.9.3.1	s7	1.3.8.1.2	s125	3.1.7.2.	s4	3.1.28.1.	s16
1.1.9.3.2	s119	1.3.8.2.1	s125	3.1.8.1.	s121	3.1.28.2.	s16
1.1.10.1.	s21	1.3.8.2.2	s125	3.1.8.2.	s121	3.1.29.1.	s10
1.1.10.2.	s21	1.3.8.3.1	s125	3.1.8.3.	s121	3.1.29.2.	s10
1.1.11.1.1	s168	1.3.8.3.2	s125	3.1.9.1.	s4	3.1.30.1.	s11
1.1.11.1.2	s163	1.3.8.4.1	s125	3.1.9.2.	s4	3.1.30.2.	s184
1.1.11.2.1	s65	1.3.8.4.2	s125	3.1.10.1.	s121	3.1.31.1.	s3
1.1.11.2.2	s156	1.3.9.1.	s125	3.1.10.2.	s121	3.1.31.2.	s3
1.1.11.3.1	s166	1.3.9.2.	s125	3.1.10.3.	s121	3.1.32.1.	s173
1.1.11.3.2	s171	1.3.10.1.1	s150	3.1.11.1.	s4	3.1.32.2.	s157
1.1.12.1.	s122	1.3.10.1.2	s125	3.1.11.2.	s4	3.1.33.1.	s24
1.1.12.2.	s21	1.3.10.2.1	s125	3.1.12.1.	s82	3.1.33.2.	s46
1.2.1.1.	s21	1.3.10.2.2	s125	3.1.12.2.	s151	3.1.34.1.	s69
1.2.1.2.	s21	1.3.10.3.1	s125	3.1.12.3.	s137	3.1.34.2.	s84

Location	SKU	Location	SKU	Location	SKU	Location	SKU
3.1.35.1.	s108	3.2.11.2.	s10	3.2.33.1.	s14	4.1.3.1.2	s34
3.1.35.2.	s149	3.2.12.1.	s82	3.2.33.2.	s29	4.1.3.2.1	s33
3.1.36.1.	s130	3.2.12.2.	s117	3.2.34.1.	s45	4.1.3.2.2	s19
3.1.36.2.	s84	3.2.12.3.	s82	3.2.34.2.	s160	4.1.4.1.1	s17
3.1.36.3.	s67	3.2.13.1.	s10	3.2.35.1.	s40	4.1.4.1.2	s76
3.1.37.1.	s27	3.2.13.2.	s57	3.2.35.2.	s40	4.1.4.2.1	s34
3.1.37.2.	s31	3.2.14.1.	s68	3.2.36.1.	s97	4.1.4.2.2	s17
3.1.38.2.	s40	3.2.14.2.	s47	3.2.36.2.	s97	4.1.4.3.1	s17
3.1.39.1.	s16	3.2.14.3.	s49	3.2.36.3.	s97	4.1.4.3.2	s20
3.1.39.2.	s16	3.2.15.1.	s10	3.2.37.1.	s25	4.1.5.1.1	s8
3.1.41.1.	s157	3.2.15.2.	s10	3.2.37.2.	s25	4.1.5.1.2	s8
3.1.41.2.	s181	3.2.16.1.	s85	3.2.38.1.	s109	4.1.5.2.1	s60
3.1.43.1.	s146	3.2.16.2.	s162	3.2.38.2.	s114	4.1.5.2.2	s15
3.1.43.2.	s157	3.2.16.3.	s116	3.2.38.3.	s104	4.1.6.1.1	s60
3.1.45.1.	s51	3.2.17.1.	s3	3.2.39.1.	s23	4.1.6.1.2	s41
3.1.45.2.	s51	3.2.17.2.	s3	3.2.39.2.	s25	4.1.6.2.1	s32
3.1.47.1.	s28	3.2.18.1.	s120	3.2.41.1.	s88	4.1.6.2.2	s15
3.1.47.2.	s28	3.2.18.3.	s71	3.2.41.2.	s39	4.1.6.3.1	s15
3.1.49.1.	s40	3.2.19.1.	s108	3.2.43.1.	s50	4.1.6.3.2	s15
3.1.49.2.	s40	3.2.19.2.	s185	3.2.43.2.	s18	4.1.7.1.1	s34
3.1.51.1.	s81	3.2.20.1.	s108	4.0.1.1.1	s8	4.1.7.1.2	s140
3.1.51.2.	s81	3.2.20.2.	s108	4.0.1.1.2	s8	4.1.7.2.2	s140
3.1.53.1.	s23	3.2.20.3.	s108	4.0.1.2.1	s55	4.1.8.1.1	s48
3.1.53.2.	s23	3.2.21.1.	s62	4.0.1.2.2	s19	4.1.8.1.2	s134
3.2.1.1.	s7	3.2.21.2.	s62	4.0.1.3.1	s55	4.1.8.2.1	s134
3.2.1.2.	s7	3.2.22.1.	s62	4.0.1.3.2	s19	4.1.8.2.2	s178
3.2.2.2.	s172	3.2.22.2.	s62	4.0.3.1.1	s63	4.1.8.3.1	s63
3.2.2.3.	s154	3.2.22.3.	s27	4.0.3.1.2	s41	4.1.8.3.2	s100
3.2.3.1.	s2	3.2.23.1.	s31	4.0.3.2.1	s63	4.1.9.1.1	s53
3.2.3.2.	s2	3.2.23.2.	s31	4.0.3.2.2	s35	4.1.9.1.2	s106
3.2.4.1.	s121	3.2.24.1.	s30	4.0.3.3.1	s41	4.1.9.2.1	s83
3.2.4.2.	s121	3.2.24.2.	s124	4.0.3.3.2	s135	4.1.9.2.2	s77
3.2.4.3.	s121	3.2.24.3.	s16	4.0.5.1.1	s36	4.1.10.1.1	s91
3.2.5.1.	s1	3.2.25.1.	s30	4.0.5.1.2	s42	4.1.10.1.2	s89
3.2.5.2.	s1	3.2.25.2.	s30	4.0.5.2.1	s129	4.1.10.2.1	s92
3.2.6.1.	s121	3.2.26.1.	s9	4.0.5.2.2	s105	4.1.10.2.2	s87
3.2.6.2.	s121	3.2.26.2.	s9	4.0.5.3.1	s145	4.1.10.3.1	s96
3.2.6.3.	s121	3.2.27.1.	s181	4.0.5.3.2	s43	4.1.10.3.2	s93
3.2.7.1.	s158	3.2.27.2.	s157	4.1.1.1.1	s12	4.1.11.1.1	s23
3.2.7.2.	s98	3.2.28.1.	s177	4.1.1.1.2	s12	4.1.11.1.2	s97
3.2.8.1.	s154	3.2.28.2.	s177	4.1.1.2.1	s37	4.1.11.2.1	s25
3.2.8.2.	s154	3.2.29.1.	s157	4.1.1.2.2	s20	4.1.11.2.2	s74
3.2.8.3.	s121	3.2.29.2.	s133	4.1.2.1.1	s32	4.1.12.1.1	s74
3.2.9.1.	s98	3.2.30.1.	s128	4.1.2.1.2	s66	4.1.12.1.2	s74
3.2.9.2.	s98	3.2.30.2.	s126	4.1.2.2.1	s35	4.1.12.2.1	s74
3.2.10.1.	s78	3.2.31.1.	s67	4.1.2.2.2	s52	4.1.12.2.2	s143
3.2.10.2.	s78	3.2.31.2.	s69	4.1.2.3.1	s48	4.1.12.3.1	s74
3.2.10.3.	s78	3.2.32.1.	s102	4.1.2.3.2	s13	4.1.12.3.2	s147
3.2.11.1.	s57	3.2.32.2.	s95	4.1.3.1.1	s33	4.1.13.1.1	s94

Location	SKU	Location	SKU	Location	SKU
4.1.13.1.2	s101	4.2.2.3.1	s63	4.2.22.1.1	s3
4.1.13.2.1	s90	4.2.4.1.1	s54	4.2.22.1.2	s3
4.1.13.2.2	s99	4.2.4.1.2	s80	4.2.22.2.1	s3
4.1.14.2.1	s58	4.2.4.2.1	s44	4.2.22.2.2	s107
4.1.14.2.2	s64	4.2.4.2.2	s86	4.2.22.3.1	s71
4.1.14.3.1	s79	4.2.4.3.1	s61	4.2.22.3.2	s107
4.1.14.3.2	s70	4.2.4.3.2	s72		
4.1.15.1.1	s141	4.2.6.1.1	s39		
4.1.15.2.1	s167	4.2.6.1.2	s118		
4.1.15.2.2	s153	4.2.6.2.1	s18		
4.1.16.1.1	s128	4.2.6.2.2	s131		
4.1.16.1.2	s126	4.2.6.3.1	s25		
4.1.16.2.1	s155	4.2.6.3.2	s23		
4.1.16.2.2	s95	4.2.8.1.1	s97		
4.1.16.3.1	s165	4.2.8.1.2	s81		
4.1.16.3.2	s152	4.2.8.2.1	s40		
4.1.17.1.1	s9	4.2.8.3.2	s160		
4.1.17.1.2	s9	4.2.10.1.1	s51		
4.1.17.2.1	s9	4.2.10.1.2	s132		
4.1.17.2.2	s6	4.2.10.2.1	s138		
4.1.18.2.1	s6	4.2.10.2.2	s136		
4.1.18.2.2	s22	4.2.10.3.1	s45		
4.1.18.3.1	s6	4.2.10.3.2	s142		
4.1.18.3.2	s22	4.2.12.1.2	s184		
4.1.19.1.1	s62	4.2.12.2.1	s184		
4.1.19.1.2	s27	4.2.12.2.2	s184		
4.1.19.2.1	s56	4.2.12.3.1	s184		
4.1.19.2.2	s108	4.2.12.3.2	s184		
4.1.20.1.1	s27	4.2.14.1.1	s27		
4.1.20.1.2	s27	4.2.14.1.2	s27		
4.1.20.2.1	s27	4.2.14.2.1	s31		
4.1.20.2.2	s27	4.2.14.2.2	s31		
4.1.20.3.1	s27	4.2.14.3.1	s27		
4.1.20.3.2	s27	4.2.14.3.2	s16		
4.1.21.1.1	s103	4.2.16.1.1	s169		
4.1.21.1.2	s73	4.2.16.2.1	s182		
4.1.21.2.1	s38	4.2.16.2.2	s183		
4.1.21.2.2	s85	4.2.16.3.1	s62		
4.1.21.3.1	s75	4.2.16.3.2	s26		
4.1.21.3.2	s38	4.2.18.1.2	s139		
4.1.22.1.1	s108	4.2.18.2.1	s113		
4.1.22.1.2	s108	4.2.18.2.2	s10		
4.1.22.2.1	s170	4.2.18.3.1	s10		
4.1.22.2.2	s169	4.2.20.1.1	s107		
4.1.22.3.1	s108	4.2.20.1.2	s10		
4.1.22.3.2	s176	4.2.20.2.1	s10		
4.2.2.1.2	s63	4.2.20.2.2	s3		
4.2.2.2.1	s63	4.2.20.3.1	s10		
4.2.2.2.2	s144	4.2.20.3.2	s116		

Annexe J

The following table shows the allocation of scenario A – AS of 185 SKUs taking into account the general ABC analysis.

Table 8.7 General ABC - Scenario A - AS allocation

Location	SKU	Location	SKU	Location	SKU	Location	SKU
1.1.1.1.1	S163	1.1.12.1.	S157	3.1.5.2.	S67	3.1.21.1.	S34
1.1.1.1.2	S159	1.1.12.2.	S159	3.1.6.1.	S143	3.1.21.2.	S31
1.1.1.2.1	S161	1.2.1.1.	S152	3.1.6.2.	S146	3.1.22.1.	S115
1.1.1.2.2	S162	1.2.1.2.	S149	3.1.6.3.	S150	3.1.22.2.	S115
1.1.1.3.1	S159	1.2.2.1.	S157	3.1.7.1.	S65	3.1.22.3.	S115
1.1.1.3.2	S164	1.2.2.2.	S157	3.1.7.2.	S65	3.1.23.1.	S29
1.1.2.1.	S137	1.2.3.1.	S154	3.1.8.1.	S140	3.1.23.2.	S30
1.1.2.2.	S140	1.2.3.2.	S157	3.1.8.2.	S139	3.1.24.1.	S107
1.1.3.1.1	S179	1.2.4.1.	S158	3.1.8.3.	S141	3.1.24.2.	S107
1.1.3.1.2	S171	1.2.4.2.	S158	3.1.9.1.	S62	3.1.24.3.	S107
1.1.3.2.1	S173	1.3.1.1.	S165	3.1.9.2.	S63	3.1.25.1.	S27
1.1.3.2.2	S174	1.3.1.2.	S160	3.1.10.1.	S131	3.1.25.2.	S27
1.1.3.3.1	S171	1.3.2.1.1	S166	3.1.10.2.	S132	3.1.26.1.	S115
1.1.3.3.2	S167	1.3.3.1.	S168	3.1.10.3.	S127	3.1.26.2.	S126
1.1.4.1.	S146	1.3.3.2.	S169	3.1.11.1.	S59	3.1.27.1.	S25
1.1.4.2.	S147	1.3.5.1.	S172	3.1.11.2.	S62	3.1.27.2.	S25
1.1.5.1.1	S182	1.3.5.2.	S170	3.1.12.1.	S125	3.1.28.1.	S106
1.1.5.1.2	S183	1.3.7.1.	S177	3.1.12.2.	S125	3.1.28.2.	S113
1.1.5.2.1	S181	1.3.7.2.	S177	3.1.12.3.	S125	3.1.29.1.	S23
1.1.5.2.2	S175	1.3.8.1.1	S151	3.1.13.1.	S57	3.1.29.2.	S23
1.1.5.3.1	S180	1.3.9.1.	S178	3.1.13.2.	S59	3.1.30.1.	S71
1.1.5.3.2	S176	1.3.9.2.	S184	3.1.14.1.	S125	3.1.30.2.	S74
1.1.6.1.	S153	1.3.11.1.	S181	3.1.14.2.	S125	3.1.31.1.	S21
1.1.6.2.	S154	1.3.11.2.	S184	3.1.14.3.	S125	3.1.31.2.	S21
1.1.7.1.1	S8	1.3.13.1.	S185	3.1.15.1.	S55	3.1.32.1.	S57
1.1.7.1.2	S19	1.3.13.2.	S181	3.1.15.2.	S51	3.1.32.2.	S57
1.1.7.2.1	S26	1.3.15.1.	S184	3.1.16.1.	S123	3.1.33.1.	S19
1.1.7.2.2	S133	1.3.15.2.	S184	3.1.16.2.	S126	3.1.33.2.	S21
1.1.7.3.1	S185	3.1.1.1.	S81	3.1.16.3.	S124	3.1.34.1.	S48
1.1.7.3.2	S56	3.1.1.2.	S82	3.1.17.1.	S40	3.1.34.2.	S41
1.1.8.1.	S157	3.1.2.1.	S155	3.1.17.2.	S46	3.1.35.1.	S16
1.1.8.2.	S157	3.1.2.2.	S156	3.1.18.1.	S122	3.1.35.2.	S16
1.1.9.1.1	S130	3.1.2.3.	S149	3.1.18.2.	S121	3.1.36.1.	S87
1.1.9.1.2	S136	3.1.3.1.	S74	3.1.18.3.	S121	3.1.36.2.	S88
1.1.9.2.1	S138	3.1.3.2.	S78	3.1.19.1.	S39	3.1.36.3.	S85
1.1.9.2.2	S148	3.1.4.1.	S150	3.1.19.2.	S40	3.1.37.1.	S14
1.1.9.3.1	S157	3.1.4.2.	S150	3.1.20.1.	S115	3.1.37.2.	S12
1.1.10.1.	S157	3.1.4.3.	S150	3.1.20.2.	S115	3.1.38.1.	S75
1.1.10.2.	S159	3.1.5.1.	S69	3.1.20.3.	S115	3.1.38.2.	S76

Location	SKU	Location	SKU	Location	SKU	Location	SKU	Location	SKU	Location	SKU
3.1.38.3.	S74	3.2.18.1.	S115	4.0.1.3.2	S6	4.1.10.2.1	S45	4.1.21.3.2	S115	4.2.18.3.1	S115
3.1.39.1.	S10	3.2.18.2.	S115	4.0.3.1.1	S10	4.1.10.2.2	S51	4.1.22.1.1	S108	4.2.18.3.2	S121
3.1.39.2.	S10	3.2.18.3.	S115	4.0.3.1.2	S18	4.1.10.3.1	S52	4.1.22.1.2	S108	4.2.20.1.1	S121
3.1.41.1.	S69	3.2.19.1.	S20	4.0.3.2.1	S16	4.1.10.3.2	S54	4.1.22.2.1	S108	4.2.20.1.2	S119
3.1.41.2.	S65	3.2.19.2.	S17	4.0.3.2.2	S16	4.1.11.1.1	S23	4.1.22.2.2	S108	4.2.20.2.1	S121
3.1.43.1.	S7	3.2.20.1.	S108	4.0.3.3.1	S13	4.1.11.1.2	S23	4.1.22.3.1	S108	4.2.20.2.2	S120
3.1.43.2.	S7	3.2.20.2.	S108	4.0.3.3.2	S18	4.1.11.2.1	S23	4.1.22.3.2	S108	4.2.20.3.1	S118
3.1.45.1.	S5	3.2.20.3.	S108	4.0.5.1.1	S31	4.1.11.2.2	S23	4.2.2.1.1	S21	4.2.20.3.2	S121
3.1.45.2.	S5	3.2.21.1.	S16	4.0.5.1.2	S30	4.1.12.1.1	S67	4.2.2.1.2	S21	4.2.22.1.1	S115
3.1.47.1.	S5	3.2.21.2.	S15	4.0.5.2.1	S28	4.1.12.1.2	S63	4.2.2.2.1	S21	4.2.22.1.2	S116
3.1.47.2.	S5	3.2.22.1.	S108	4.0.5.2.2	S27	4.1.12.2.1	S66	4.2.2.2.2	S22	4.2.22.2.1	S116
3.1.49.1.	S5	3.2.22.2.	S108	4.0.5.3.1	S26	4.1.12.2.2	S64	4.2.2.3.1	S22	4.2.22.2.2	S116
3.1.49.2.	S5	3.2.22.3.	S108	4.0.5.3.2	S31	4.1.12.3.1	S68	4.2.2.3.2	S22	4.2.22.3.1	S116
3.1.51.1.	S4	3.2.23.1.	S10	4.1.1.1.1	S1	4.1.12.3.2	S70	4.2.4.1.1	S43	4.2.22.3.2	S116
3.1.51.2.	S4	3.2.23.2.	S10	4.1.1.1.2	S1	4.1.13.1.1	S30	4.2.4.1.2	S33		
3.1.53.1.	S3	3.2.24.1.	S98	4.1.1.2.1	S2	4.1.13.1.2	S31	4.2.4.2.1	S41		
3.1.53.2.	S3	3.2.24.2.	S98	4.1.1.2.2	S2	4.1.13.2.1	S32	4.2.4.2.2	S39		
3.2.1.1.	S51	3.2.24.3.	S98	4.1.2.1.1	S2	4.1.13.2.2	S34	4.2.4.3.1	S44		
3.2.1.2.	S50	3.2.25.1.	S10	4.1.2.1.2	S2	4.1.14.1.1	S82	4.2.4.3.2	S42		
3.2.2.1.	S150	3.2.25.2.	S10	4.1.2.2.1	S2	4.1.14.1.2	S83	4.2.6.1.1	S62		
3.2.2.2.	S150	3.2.26.1.	S102	4.1.2.2.2	S2	4.1.14.2.1	S86	4.2.6.1.2	S59		
3.2.2.3.	S150	3.2.26.2.	S97	4.1.2.3.1	S2	4.1.14.2.2	S84	4.2.6.2.1	S62		
3.2.3.1.	S40	3.2.27.1.	S9	4.1.2.3.2	S2	4.1.14.3.1	S84	4.2.6.2.2	S62		
3.2.3.2.	S40	3.2.27.2.	S7	4.1.3.1.1	S3	4.1.14.3.2	S84	4.2.6.3.1	S62		
3.2.4.1.	S143	3.2.28.1.	S63	4.1.3.1.2	S2	4.1.15.1.1	S57	4.2.6.3.2	S61		
3.2.4.2.	S145	3.2.28.2.	S60	4.1.3.2.1	S2	4.1.15.1.2	S57	4.2.8.1.1	S79		
3.2.4.3.	S142	3.2.29.1.	S7	4.1.3.2.2	S2	4.1.15.2.1	S57	4.2.8.1.2	S80		
3.2.5.1.	S38	3.2.29.2.	S7	4.1.4.1.1	S3	4.1.15.2.2	S57	4.2.8.2.1	S77		
3.2.5.2.	S35	3.2.30.1.	S53	4.1.4.1.2	S3	4.1.16.1.1	S95	4.2.8.2.2	S81		
3.2.6.1.	S36	3.2.30.2.	S49	4.1.4.2.1	S2	4.1.16.1.2	S95	4.2.8.3.1	S77		
3.2.6.2.	S133	3.2.31.1.	S5	4.1.4.2.2	S2	4.1.16.2.1	S97	4.2.8.3.2	S81		
3.2.6.3.	S133	3.2.31.2.	S5	4.1.4.3.1	S3	4.1.16.2.2	S97	4.2.10.1.1	S89		
3.2.7.1.	S31	3.2.32.1.	S37	4.1.4.3.2	S4	4.1.16.3.1	S97	4.2.10.1.2	S93		
3.2.7.2.	S31	3.2.32.2.	S40	4.1.5.1.1	S4	4.1.16.3.2	S97	4.2.10.2.1	S91		
3.2.8.1.	S128	3.2.33.1.	S5	4.1.5.1.2	S4	4.1.17.1.1	S78	4.2.10.2.2	S96		
3.2.8.2.	S125	3.2.33.2.	S5	4.1.5.2.1	S4	4.1.17.1.2	S81	4.2.10.3.1	S90		
3.2.8.3.	S125	3.2.34.1.	S28	4.1.5.2.2	S4	4.1.17.2.1	S94	4.2.10.3.2	S92		
3.2.9.1.	S27	3.2.34.2.	S30	4.1.6.1.1	S10	4.1.17.2.2	S88	4.2.12.1.1	S98		
3.2.9.2.	S27	3.2.35.1.	S5	4.1.6.1.2	S10	4.1.18.1.1	S98	4.2.12.1.2	S98		
3.2.10.1.	S125	3.2.35.2.	S5	4.1.6.2.1	S9	4.1.18.1.2	S98	4.2.12.2.1	S98		
3.2.10.2.	S125	3.2.36.1.	S73	4.1.6.2.2	S9	4.1.18.2.1	S98	4.2.12.2.2	S98		
3.2.10.3.	S125	3.2.36.2.	S71	4.1.6.3.1	S6	4.1.18.2.2	S98	4.2.12.3.1	S98		
3.2.11.1.	S27	3.2.36.3.	S72	4.1.6.3.2	S9	4.1.18.3.1	S98	4.2.12.3.2	S98		
3.2.11.2.	S28	3.2.37.1.	S4	4.1.7.1.1	S9	4.1.18.3.2	S98	4.2.14.1.1	S98		
3.2.12.1.	S125	3.2.37.2.	S4	4.1.7.1.2	S8	4.1.19.1.1	S129	4.2.14.1.2	S98		
3.2.12.2.	S125	3.2.38.1.	S58	4.1.7.2.1	S8	4.1.19.1.2	S134	4.2.14.2.1	S100		
3.2.12.3.	S125	3.2.38.2.	S56	4.1.7.2.2	S8	4.1.19.2.1	S136	4.2.14.2.2	S98		
3.2.13.1.	S25	3.2.38.3.	S60	4.1.8.1.1	S21	4.1.19.2.2	S128	4.2.14.3.1	S98		
3.2.13.2.	S25	3.2.39.1.	S3	4.1.8.1.2	S21	4.1.20.1.1	S99	4.2.14.3.2	S98		
3.2.14.1.	S121	3.2.39.2.	S3	4.1.8.2.1	S21	4.1.20.1.2	S103	4.2.16.1.1	S109		
3.2.14.2.	S121	3.2.41.1.	S1	4.1.8.2.2	S21	4.1.20.2.1	S104	4.2.16.1.2	S112		
3.2.14.3.	S121	3.2.41.2.	S1	4.1.8.3.1	S21	4.1.20.2.2	S101	4.2.16.2.1	S111		
3.2.15.1.	S24	3.2.43.1.	S1	4.1.8.3.2	S21	4.1.20.3.1	S105	4.2.16.2.2	S111		
3.2.15.2.	S21	3.2.43.2.	S1	4.1.9.1.1	S11	4.1.20.3.2	S108	4.2.16.3.1	S110		
3.2.16.1.	S121	4.0.1.1.1	S5	4.1.9.1.2	S15	4.1.21.1.1	S115	4.2.16.3.2	S114		
3.2.16.2.	S121	4.0.1.1.2	S5	4.1.9.2.1	S18	4.1.21.1.2	S115	4.2.18.1.1	S117		
3.2.16.3.	S121	4.0.1.2.1	S5	4.1.9.2.2	S10	4.1.21.2.1	S115	4.2.18.1.2	S121		
3.2.17.1.	S21	4.0.1.2.2	S6	4.1.10.1.1	S47	4.1.21.2.2	S115	4.2.18.2.1	S121		
3.2.17.2.	S21	4.0.1.3.1	S4	4.1.10.1.2	S45	4.1.21.3.1	S115	4.2.18.2.2	S117		

Annexe K

The following table shows the allocation of scenario B – AS of 185 SKUs taking into account the ABC analysis by families.

Table 8.8 ABC Families - Scenario B - AS allocation

Location	SKU	Location	SKU	Location	SKU	Location	SKU
1.1.1.1.1	78	1.1.11.1.1	122	1.3.6.3.2	156	3.1.4.1.	21
1.1.1.1.2	68	1.1.11.1.2	172	1.3.6.4.1	148	3.1.4.2.	56
1.1.1.2.1	78	1.1.11.2.1	72	1.3.6.4.2	115	3.1.4.3.	56
1.1.1.2.2	49	1.1.11.2.2	154	1.3.7.1.	125	3.1.5.1.	31
1.1.1.3.1	49	1.1.11.3.1	112	1.3.7.2.	125	3.1.5.2.	62
1.1.1.3.2	78	1.1.11.3.2	123	1.3.8.4.2	171	3.1.6.1.	21
1.1.2.1.	21	1.1.12.1.	115	1.3.9.1.	125	3.1.6.2.	21
1.1.2.2.	7	1.1.12.2.	115	1.3.9.2.	125	3.1.6.3.	21
1.1.3.1.1	78	1.2.1.1.	65	1.3.10.1.1	105	3.1.7.1.	30
1.1.3.1.2	82	1.2.1.2.	59	1.3.10.1.2	77	3.1.7.2.	30
1.1.3.2.1	82	1.2.2.1.	115	1.3.10.2.1	77	3.1.8.1.	21
1.1.3.2.2	78	1.2.2.2.	115	1.3.10.2.2	77	3.1.8.2.	21
1.1.3.3.1	82	1.2.3.1.	65	1.3.10.3.1	77	3.1.8.3.	21
1.1.3.3.2	82	1.2.3.2.	65	1.3.10.3.2	100	3.1.9.1.	27
1.1.4.1.	59	1.2.4.1.	115	1.3.10.4.1	77	3.1.9.2.	27
1.1.4.2.	65	1.2.4.2.	115	1.3.11.1.	125	3.1.10.1.	21
1.1.5.1.1	111	1.3.1.1.	115	1.3.11.2.	125	3.1.10.2.	21
1.1.5.2.1	117	1.3.1.2.	115	1.3.12.1.1	145	3.1.10.3.	21
1.1.5.2.2	111	1.3.2.1.1	121	1.3.12.2.1	145	3.1.11.1.	16
1.1.5.3.1	117	1.3.2.1.2	121	1.3.12.3.2	129	3.1.11.2.	9
1.1.6.2.	59	1.3.2.2.1	154	1.3.12.4.1	175	3.1.12.1.	21
1.1.7.1.1	121	1.3.2.2.2	151	1.3.12.4.2	105	3.1.12.2.	21
1.1.7.1.2	121	1.3.2.3.1	154	1.3.13.1.	150	3.1.12.3.	21
1.1.7.2.1	121	1.3.2.3.2	137	1.3.13.2.	150	3.1.13.1.	6
1.1.7.2.2	121	1.3.3.1.	115	1.3.15.1.	150	3.1.13.2.	9
1.1.7.3.1	121	1.3.3.2.	125	1.3.15.2.	150	3.1.14.1.	7
1.1.7.3.2	121	1.3.4.1.1	179	1.3.17.1.	159	3.1.14.2.	7
1.1.8.1.	65	1.3.4.1.2	171	1.3.17.2.	159	3.1.14.3.	7
1.1.8.2.	115	1.3.4.2.1	150	1.3.19.1	168	3.1.15.1.	98
1.1.9.1.1	121	1.3.4.2.2	163	1.3.19.2	159	3.1.15.2.	98
1.1.9.1.2	121	1.3.4.3.1	174	3.1.1.1.	1	3.1.16.1.	7
1.1.9.2.1	121	1.3.4.3.2	166	3.1.1.2.	1	3.1.16.2.	7
1.1.9.2.2	121	1.3.5.1.	125	3.1.2.1.	47	3.1.16.3.	7
1.1.9.3.1	121	1.3.5.2.	125	3.1.2.2.	59	3.1.17.1.	98
1.1.9.3.2	121	1.3.6.1.1	159	3.1.2.3.	59	3.1.17.2.	71
1.1.10.1.	115	1.3.6.1.2	119	3.1.3.1.	1	3.1.18.1.	4
1.1.10.2.	115	1.3.6.2.2	125	3.1.3.2.	1	3.1.18.2.	5

Location	SKU	Location	SKU	Location	SKU	Location	SKU
3.1.18.3.	5	3.1.51.2.	63	3.2.23.2.	88	4.1.1.2.1	8
3.1.19.1.	57	3.1.53.1.	19	3.2.24.1.	2	4.1.1.2.2	35
3.1.19.2.	57	3.1.53.2.	20	3.2.24.2.	2	4.1.2.1.1	8
3.1.20.1.	4	3.2.1.1.	98	3.2.24.3.	2	4.1.2.1.2	19
3.1.20.2.	5	3.2.1.2.	98	3.2.25.1.	50	4.1.2.2.2	13
3.1.20.3.	5	3.2.2.1.	21	3.2.25.2.	74	4.1.2.3.1	66
3.1.21.1.	10	3.2.2.2.	21	3.2.26.1.	31	4.1.2.3.2	52
3.1.21.2.	10	3.2.2.3.	21	3.2.26.2.	31	4.1.3.1.1	48
3.1.22.1.	5	3.2.3.1.	57	3.2.27.1.	40	4.1.3.1.2	134
3.1.22.2.	4	3.2.3.2.	57	3.2.27.2.	40	4.1.3.2.1	37
3.1.22.3.	5	3.2.4.1.	21	3.2.28.1.	11	4.1.3.2.2	144
3.1.23.1.	3	3.2.4.2.	21	3.2.28.2.	16	4.1.4.1.1	76
3.1.23.2.	10	3.2.4.3.	21	3.2.29.1.	40	4.1.4.1.2	135
3.1.24.1.	4	3.2.5.1.	10	3.2.29.2.	39	4.1.4.2.1	43
3.1.24.2.	5	3.2.5.2.	38	3.2.30.1.	98	4.1.4.2.2	18
3.1.24.3.	5	3.2.6.1.	21	3.2.30.2.	98	4.1.4.3.1	39
3.1.25.1.	3	3.2.6.2.	21	3.2.31.1.	25	4.1.4.3.2	42
3.1.25.2.	3	3.2.6.3.	21	3.2.31.2.	25	4.1.5.1.1	54
3.1.26.1.	31	3.2.7.1.	10	3.2.32.1.	26	4.1.5.1.2	53
3.1.26.2.	27	3.2.7.2.	10	3.2.32.2.	24	4.1.5.2.1	36
3.1.27.1.	184	3.2.8.1.	21	3.2.33.1.	23	4.1.5.2.2	83
3.1.27.2.	184	3.2.8.2.	21	3.2.33.2.	23	4.1.6.1.1	89
3.1.28.1.	31	3.2.8.3.	21	3.2.34.1.	102	4.1.6.1.2	87
3.1.28.2.	31	3.2.9.1.	3	3.2.34.2.	132	4.1.6.2.1	91
3.1.29.1.	157	3.2.9.2.	3	3.2.35.1.	63	4.1.6.2.2	92
3.1.29.2.	157	3.2.10.1.	7	3.2.35.2.	140	4.1.6.3.1	93
3.1.30.1.	16	3.2.10.2.	21	3.2.36.1.	16	4.1.6.3.2	96
3.1.30.2.	27	3.2.10.3.	21	3.2.36.2.	9	4.1.7.1.1	109
3.1.31.1.	133	3.2.11.1.	181	3.2.36.3.	16	4.1.7.1.2	114
3.1.31.2.	146	3.2.11.2.	181	3.2.37.1.	41	4.1.7.2.1	118
3.1.32.1.	116	3.2.12.1.	7	3.2.37.2.	55	4.1.7.2.2	106
3.1.32.2.	158	3.2.12.2.	7	3.2.38.1.	116	4.1.8.1.1	136
3.1.33.1.	69	3.2.12.3.	7	3.2.38.2.	103	4.1.8.1.2	101
3.1.33.2.	84	3.2.13.1.	184	3.2.38.3.	110	4.1.8.2.1	130
3.1.34.1.	85	3.2.13.2.	177	3.2.39.1.	34	4.1.8.2.2	153
3.1.34.2.	46	3.2.14.1.	7	3.2.39.2.	33	4.1.8.3.1	99
3.1.35.1.	29	3.2.14.2.	7	3.2.41.1.	15	4.1.8.3.2	138
3.1.35.2.	51	3.2.14.3.	7	3.2.41.2.	17	4.1.9.1.1	147
3.1.36.1.	108	3.2.15.1.	157	3.2.43.1.	8	4.1.9.1.2	160
3.1.36.2.	108	3.2.15.2.	157	3.2.43.2.	12	4.1.9.2.1	131
3.1.36.3.	108	3.2.16.1.	4	4.0.1.1.1	44	4.1.9.2.2	143
3.1.37.1.	97	3.2.16.2.	5	4.0.1.1.2	81	4.1.10.1.1	75
3.1.37.2.	97	3.2.16.3.	5	4.0.1.2.1	72	4.1.10.1.2	98
3.1.38.1.	22	3.2.17.1.	126	4.0.1.2.2	86	4.1.10.2.1	46
3.1.38.2.	27	3.2.17.2.	128	4.0.1.3.1	80	4.1.10.2.2	46
3.1.38.3.	22	3.2.18.1.	5	4.0.1.3.2	61	4.1.10.3.1	73
3.1.39.1.	74	3.2.18.2.	5	4.0.3.1.1	104	4.1.10.3.2	98
3.1.39.2.	81	3.2.18.3.	5	4.0.3.1.2	45	4.1.11.1.1	28
3.1.41.1.	16	3.2.19.1.	51	4.0.3.2.1	45	4.1.11.1.2	51
3.1.41.2.	16	3.2.19.2.	67	4.0.3.2.2	64	4.1.11.2.1	94
3.1.43.1.	40	3.2.20.1.	5	4.0.3.3.1	28	4.1.11.2.2	69
3.1.43.2.	40	3.2.20.2.	5	4.0.3.3.2	58	4.1.12.1.1	9
3.1.45.1.	25	3.2.20.3.	5	4.0.5.1.1	141	4.1.12.2.1	180
3.1.45.2.	25	3.2.21.1.	14	4.0.5.1.2	153	4.1.13.1.1	10
3.1.47.1.	23	3.2.21.2.	28	4.0.5.2.1	152	4.1.13.1.2	10
3.1.47.2.	23	3.2.22.1.	2	4.0.5.2.2	155	4.1.13.2.1	3
3.1.49.1.	18	3.2.22.2.	5	4.0.5.3.1	142	4.1.13.2.2	10
3.1.49.2.	178	3.2.22.3.	5	4.1.1.1.1	15	4.1.14.1.1	108
3.1.51.1.	60	3.2.23.1.	81	4.1.1.1.2	32	4.1.14.1.2	108

Location	SKU	Location	SKU
4.1.14.2.1	108	4.2.6.2.2	116
4.1.14.2.2	108	4.2.6.3.1	162
4.1.14.3.1	108	4.2.6.3.2	120
4.1.14.3.2	108	4.2.8.1.1	30
4.1.15.1.1	107	4.2.8.1.2	62
4.1.15.1.2	107	4.2.8.2.1	31
4.1.15.2.1	113	4.2.8.2.2	62
4.1.15.2.2	116	4.2.8.3.1	31
4.1.16.1.1	149	4.2.8.3.2	62
4.1.16.1.2	169	4.2.10.1.1	108
4.1.16.2.1	164	4.2.10.1.2	108
4.1.16.2.2	161	4.2.10.2.1	108
4.1.16.3.1	169	4.2.10.2.2	149
4.1.16.3.2	170	4.2.10.3.1	124
4.1.17.1.1	27	4.2.10.3.2	149
4.1.17.1.2	27	4.2.12.1.1	185
4.1.17.2.1	27	4.2.12.1.2	183
4.1.17.2.2	27	4.2.12.2.1	185
4.1.18.1.1	1	4.2.12.3.1	176
4.1.18.1.2	1	4.2.12.3.2	182
4.1.18.2.2	1	4.2.14.1.1	2
4.1.18.3.1	1	4.2.14.1.2	2
4.1.18.3.2	185	4.2.14.2.1	2
4.1.19.1.1	62	4.2.14.2.2	2
4.1.19.1.2	62	4.2.14.3.1	2
4.1.19.2.1	62	4.2.14.3.2	2
4.1.19.2.2	108	4.2.16.1.1	5
4.1.20.1.1	2	4.2.16.1.2	5
4.1.20.1.2	2	4.2.16.2.1	5
4.1.20.2.1	2	4.2.16.2.2	5
4.1.20.2.2	2	4.2.16.3.1	5
4.1.20.3.1	2	4.2.16.3.2	5
4.1.20.3.2	2	4.2.18.1.1	4
4.1.21.1.1	5	4.2.18.1.2	4
4.1.21.1.2	5	4.2.18.2.1	4
4.1.21.2.1	5	4.2.18.2.2	4
4.1.21.2.2	5	4.2.18.3.1	4
4.1.21.3.1	5	4.2.18.3.2	4
4.1.21.3.2	5	4.2.20.1.1	4
4.1.22.1.1	5	4.2.20.1.2	4
4.1.22.1.2	5	4.2.20.2.1	4
4.1.22.2.1	5	4.2.20.2.2	5
4.1.22.2.2	5	4.2.20.3.1	4
4.1.22.3.1	4	4.2.20.3.2	4
4.1.22.3.2	5	4.2.22.1.1	4
4.2.2.1.1	95	4.2.22.1.2	4
4.2.2.1.2	79	4.2.22.2.1	5
4.2.2.2.1	70	4.2.22.2.2	5
4.2.2.2.2	90	4.2.22.3.1	5
4.2.2.3.1	67	4.2.22.3.2	4
4.2.2.3.2	95		
4.2.4.1.1	24		
4.2.4.1.2	165		
4.2.4.2.2	24		
4.2.4.3.1	173		
4.2.4.3.2	167		
4.2.6.1.1	158		
4.2.6.1.2	127		
4.2.6.2.1	139		

Annexe L

The table shows the picking list with the respective locations and distances the preparation area as well as the proposed scenarios.

Table 8.9 Picking List

Current Scenario				Scenario A		Scenario B		Scenario A – AS		Scenario B – AS	
SKU	Mov	Location	Distance to Preparation Area	Location	Distance to Preparation Area	Location	Distance to Preparation Area	Location	Distance to Preparation Area	Location	Distance to Preparation Area
4	307	4.2.6	13,9	3.1.35.1	24,75	3.1.2.2.	39,43	4.1.4.3.2	4,5	3.1.24.1.	24,91
7	285	"4.3.1"*	13,46	3.1.53.2	12,6	3.2.1.1.	37,75	3.2.29.1.	19,27	3.2.14.1.	29,67
8	284	3.2.6	34,95	3.2.36.2	15,15	4.0.1.1.1	5,75	4.1.7.1.2	9,6	4.1.2.1.1	2,1
9	283	"4.2.5"*	16,03	3.2.26.1	21,75	4.1.17.1.1	21,6	4.1.6.2.1	6,9	4.1.12.1.1	14,1
18	215	3.1.25	31,35	4.1.5.1.2	7,2	3.2.43.2.	10,03	4.0.3.1.2	8,15	4.1.4.2.2	4,5
20	202	3.2.12	30,99	4.0.1.1.1	5,75	4.1.1.2.2	2,4	3.2.19.1.	25,87	3.1.53.2.	12,6
35	164	1.3.9	201,67	4.1.2.1.1	2,1	4.1.2.2.1	2,1	3.2.5.2.	35,11	4.1.1.2.2	2,4
36	161	4.0.3	8,15	4.1.6.1.1	6,9	4.0.5.1.1	10,55	3.2.6.1.	34,95	4.1.5.2.1	7,2
41	129	1.3.11	202,64	4.1.4.2.2	4,5	4.1.6.1.2	6,9	4.2.4.2.1	11,53	3.2.37.1.	13,99
42	127	3.2.36	15,15	4.1.6.1.2	6,9	4.0.5.1.2	10,55	4.2.4.3.2	11,53	4.1.4.3.2	4,5
90	64	3.1.8	35,47	3.2.6.2	34,95	4.1.13.2.1	16,8	4.2.10.3.1	18,73	4.2.2.2.2	9,13

*These locations are no longer part of the warehouse

Annexe M

Table 8.10 Comparison between scenarios

Scenario	Class	Distance to preparation Area (m)	Occupied locations	Sock (dm^3)	Number of SKUs	Picking Distance (m)	Average Distance (m)
Scenario A	A	23	282	334 411	76	285,1	49
	B	33	77	90 097	40		
	C	123	116	103 973	69		
Scenario B	A	17	236	263 042	122	327,72	63
	B	78	143	185 649	28		
	C	137	117	79 790	35		
Scenario A – AS	A	21	227	334 411	76	372,72	46
	B	23	109	90 097	40		
	C	110	129	103 973	69		
Scenario B – AS	A	17	192	263 042	122	205,2	58
	B	31	202	185 649	28		
	C	192	99	79 790	35		

Annexe N

Multifactorial Analysis

Scenario	Total Distance	Picking Distance	Average Distance	Occupied Locations
Scenario A	287 184 m	285,1 m	49 m	475
Scenario B	863 136,82 m	327,72 m	63 m	496
Scenario A – AS	473 200,56 m	372,28 m	46 m	465
Scenario B – AS	1 0005 686,4 m	205,2 m	58 m	493

Scenario	50%	5%	15%	30%
Scenario A	**1,00**	**2,00**	**2,00**	**2,00**
Scenario B	3,00	3,00	4,00	4,00
Scenario A – AS	2,00	4,00	1,00	1,00
Scenario B – AS	4,00	1,00	3,00	3,00

Scenario					Total
Scenario A	0,5	0,1	0,3	0,6	**1,5**
Scenario B	1,5	0,15	0,6	1,2	**3,45**
Scenario A – AS	1	0,2	0,15	0,3	**1,65**
Scenario B – AS	2	0,05	0,45	0,9	**3,4**

Annexe O

Computational results

General ABC

MODEL STATISTICS

BLOCKS OF EQUATIONS	4	SINGLE EQUATIONS	48,786
BLOCKS OF VARIABLES	3	SINGLE VARIABLES	96,349
NON ZERO ELEMENTS	240,871	DISCRETE VARIABLES	48,174

ABC by Families

MODEL STATISTICS

BLOCKS OF EQUATIONS	5	SINGLE EQUATIONS	1,727,124
BLOCKS OF VARIABLES	3	SINGLE VARIABLES	1,724,941
NON ZERO ELEMENTS	4,408,181	DISCRETE VARIABLES	862,470