Louvain School of Management

Reorganisation of a warehouse flows and activities: case study of Kami Basics

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Preface

I did my internship in a Brussels start-up selling online zero-waste products, called Kami Basics. The name "Kami" comes from Kamikatsu a small Japanese village that decided in 2003 to become completely zero-waste by 2020. They sort their waste into 34 specific separate categories, such as aluminium cans, steel boxes, paper cartons, paper flyers, etc. (Garfield, 2017).

Fig. 1 : Logo of Kami Basics

In addition to waste sorting, the city also has a shop where people can leave clothes or furniture they don't want anymore, exchanging their old components for free items left behind by others. Today, 80% of the city's waste is recycled, reused or composted, the remainder going to landfill.

Beyond Kamikatsu, cities around the world are trying to reduce their waste footprint. For example, in 2015, San Diego announced a plan to reduce waste disposal by 75% by 2030 and become completely waste-free by 2040. New York City has equally ambitious plans, hoping to be waste-free in about 15 years (Garfield, 2017).

Introduction

Although the zero-waste movement has become quite popular in recent years, it is much older than we might think. It first appeared in the 1970s, when citizens opted for a zero-waste lifestyle, in opposition to the consumerist model that was proposed to them (Zero Déchet Touraine, 2017).

Beyond individual initiatives, it was in the 1990s that the first zero-waste communities started to exist, within the Zero Waste International Alliance, with the desire to go beyond recycling. The 2000s marked an acceleration of the movement. In 2004, the first definition of zero waste was adopted internationally by the Planning Group of the Zero Waste International Alliance:

> *"The conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health."*

Zero Waste is a set of principles focused on waste prevention that encourages the redesign of resource life cycles so that all products are reused. The goal is that no waste is sent to landfills, incinerators or the ocean. Currently, only 9% of plastic is actually recycled. In a "zero waste" system, materials will be reused up to the optimal level of consumption (Song et al., 2015). This system does not advocate that there should be no waste at all, but that those wastes, if there is any, should be either 100% recyclable or completely compostable, so that in the end there is no waste polluting the environment.

Feeling very concerned myself by the zero-waste movement, I decided to bring the knowledge acquired during my studies in business engineering and more precisely in supply chain management, to this cause. So, I did my internship, as well as my thesis related to it, at Kami Basics, a young Brussels start-up, founded in 2018.

This thesis outlines a problem of efficiency in the supply chain, in terms of time spent on different activities. Indeed, as a young start-up, one of the most important aspect is to focus the energy of workers and interns on activities that make the business grow (finding new suppliers, new customers, promote the start-up, etc). However, according to my internship supervisor, too much time was spent on basic activities, such as delivery, preparation of orders, answer to customers' problems, etc. After analysing all the process, I concluded that the aspect that could be improved and therefore save the most time is the order preparation.

The research question of this thesis is therefore to make the picking and products flow more efficient, in terms of time, in a warehouse of limited size. This analysis and optimisation of the warehouse will be based on three axes, the layout of the warehouse, the storage methods of the products, and the different ways of carrying out the picking.

Part I: Objectives and Methodologies

Thesis objective: Analyse the supply chain of the company and develop/optimise a process linked to the supply chain of the business.

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Beginning of the internship: Interview with the supervisor → efficiency problem = too much time spent on basic activities in the supply chain. (cf. 1.2. My internship's mission).

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After 3 weeks of introduction and training: List and time basic activities of the supply chain ⇒ optimise the preparation of orders. (cf. 2.2. The Work Methodology)

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After a few weeks: Analyse the positioning of the company, in order not to jeopardise it by the improvements that will be implemented. (cf. Part III: The Big Picture of Kami Basics).

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Research question: "How to make the picking and products flow, in terms of time, in a warehouse of limited size, more efficient?"

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During the internship: Selection of axes of improvement and literature review → 1. Introduction of the supply chain. 2. Activities of the warehouse. 3. Three axes of improvement (layout of the warehouse, storage assignment, picking strategy). (cf. Part II: Supply Chain & Part IV: Literature Review).

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After two months: Selection and implementation of improvement and analysis of the results in terms of time and finances. (cf. Part V: Improvement of the warehouse).

Chapter 1: My objectives

The purpose of this first chapter is to explain the initial objective of my thesis, as well as my mission during my internship.

1.1. My thesis' objective

My thesis is a project linked to an internship I completed from the 15th of January 2020, until the 15th of April 2020, at Kami Basics (cf. Part III: The big picture of Kami Basics). The general goal of this thesis was to analyse the supply chain of the company and to develop or optimise a process linked to the supply chain of the business.

1.2. My internship's mission

My mission as a trainee in supply chain management at Kami Basics was to structure the flows in the company. In other words, ensure the daily monitoring of flows within the company (ordering from the supplier, picking, packaging, delivery, etc.) as well as their optimisation, when my daily tasks were finished.

In order to fulfil the mission of my thesis, at the beginning of my internship, I conducted an interview with my internship supervisor. The purpose of this interview was to find out how the supply chain was working and how my supervisor saw its future. We concluded that as a start-up, the most important thing was to focus, the most possible, on the tasks that made the company grow, i.e., adding new suppliers and new products, canvassing new customers, etc.

He pointed out that there was an efficiency problem in the supply chain, in terms of time spent on activities. Indeed, too much time was spent on basic activities[1] and not enough on business improvement activities and on activities that actually make the business grow. In order to spend the maximum amount of time on these activities, it was necessary to reduce the time spent on basic daily tasks.

Chapter 2: The Research and Work Methodology

The purpose of this second chapter is to explain the methodology of research that was used throughout the writing of this thesis. Then, I will explain the method and results of how I selected the basic activity that I focused on during my internship as well as throughout the writing of this thesis.

2.1. The Research methodology

As explained in my internship's mission, my purpose was to reduce the time spent on basic activities, in order to spend more time on activities that make the company grow. The second point of this chapter will show you the method and results of how I selected the basic activity I decided to improve to save the maximum

[1] Basic activities: orders preparation (picking, packing…), delivery, add new products on the website, receipt of supplier orders, answer to customers problems…

amount of time. Based on the result obtained, the activity whose improvement would save the most time is the order preparation. Due to the important amount of work I had to do during this internship (beyond the mission of my thesis), I was only able to dedicate my time to the improvement of a single activity.

The second part of this thesis will be dedicated, firstly, to a general introduction about the supply chain management, secondly, to some tools that are used during this internship, and finally, an introduction to the different activities of a traditional warehouse. During this internship, I was responsible for the management of the warehouse flows. Then, the first step was to make a review of these activities. That is why this thesis includes an entire chapter dedicated to the activities of a typical warehouse. This part was written to give you a general idea of the supply chain, in case you're unfamiliar with the topic. If you already have a good knowledge of the subject, this part can be skipped.

Before working on the improvement of any company, it is important to first analyse it in depth, and understand its mechanism, its stakes, its values, etc. The understanding of its environment, as a start-up, therefore seemed essential before deciding in which direction to go for the writing of this thesis. That is why, the third part of this thesis presents the big picture of the company Kami Basics, with a focus on the supply chain. The first three chapters will be dedicated to micro attributes, macro attributes and company specifications.

Based on the analysis of the big picture of the company, the analysis of the activities of a warehouse as well as the activity I decided to improve (i.e. the order preparation), my research question is then: **"How to make the picking and products flow more efficient, in terms of time, in a warehouse of limited size?".**

To answer this question, the first step was to analyse how was structured the warehouse before the improvement I implemented. Indeed, in order to be able to make a before/after comparison of the flow in the warehouse (for the preparation of order), I timed each activity. Moreover, to have a financial analysis of the before/after situation, I analysed the time in terms of hourly wage, to check the financial impact that this improvement could have on the company, although it is not the main criterion since the work I did was for free, as a trainee. This analysis is explained in the last chapter of the third part (cf. 4.1. Financial Dimension).

Afterwards, I did a literature review in the fourth part of this thesis. I focus this review based on three axes, the layout of the warehouse, the storage methods of the products as well as the different ways of carrying out the picking. Obviously, there is a multitude of authors and articles dealing with these topics, sometimes with very few differences between the articles, sometimes with more notable differences. The way I chose these different articles are multiple, such as the reputation of the authors or the scientific journals in which these articles were published. I also focused on authors who analysed warehouses with the same characteristics as the one of Kami Basics ("low level picker to part system", Caron et al. 2000, cf. part IV chapter 1), other reasons come from a more pragmatic nature, such as the access or not to specific sources.

In the first chapter, the layout of the warehouse, I will review the five most common ways of arranging aisles in a warehouse. This chapter is mainly based on five articles: from Karasek ("An Overview of Warehouse Optimization"), Gue an Meller ("Aisle configurations for unit-load warehouses"), Gu et al. ("Research on warehouse design and performance evaluation: A comprehensive review") and Caron et al. ("Evaluation of alternative layout schemes for picking systems" and "Optimal layout in low-level picker-to-part systems").

The second chapter is dedicated to the different methods of storage. First of all, I will describe the forward-reserve allocation storage of a warehouse and then I will explain the five most used methods of storage assignment: random storage, dedicated storage, closest open location storage, class-based storage, and full turnover storage. This chapter is mainly based on five articles: from Berg ("Forward-reserve allocation in a warehouse with unit-load replenishments"), Choe and Sharp (Small parts order picking: design and operation), Hausman ("Optimal storage assignment in automatic warehousing systems"), Le Duc and De Koster ("Travel distance estimation and storage zone optimisation in a 2-block class-based storage strategy warehouse") and Petersen ("Improving orderpicking performance through the implementation of classbased storage").

The last chapter of this fourth part is dedicated to the picking. For this last part, which is more technical, I decided to rely less on scientific sources and more on the reality on the ground. That is why, the main sources come from three expert companies in the supply chain field, i.e. Newcastle Systems, 6 River Systems, and Lucas Systems. I review the main techniques of carrying out the picking with the advantages and drawbacks of each of them.

Finally, the fifth and last part of this thesis will be devoted, firstly, to a summary of all the decision variables I had in hand, before making the improvements in the warehouse (i.e. reduce the time spent on order preparation). Secondly, the results, in term of time, and the financial impact of these improvements. Moreover, I provided some recommendations for the future of the company.

2.2. The Work Methodology

Since my mission in supply chain management, throughout my internship, was a mission of continuous improvement, we work - me and my supervisor - with different tools adapted to this methodology including the Deming wheel method (PDCA) (cf. 2.3 The Deming Management Method (PDCA)).

Firstly, in the **Plan phase**, we used tools such as brainstorming or 80/20 in order to define but also to prioritize the different points on which it is most important to initiate a process. It was necessary to focus on efficiency issues and see where it was possible to save the most time. Afters 3 weeks of introduction and training, I made a graph of the time, per week, required by each activity in the supply chain, in order to visualize the most time-consuming activities, as well as the areas for improvement.

It can be noted, on the figure 2, that the most time-consuming activities are the preparation of orders, the delivery of parcels to Brussels by bike, the introduction of new products on the website, and answering customers' questions and resolving any problems they may have.

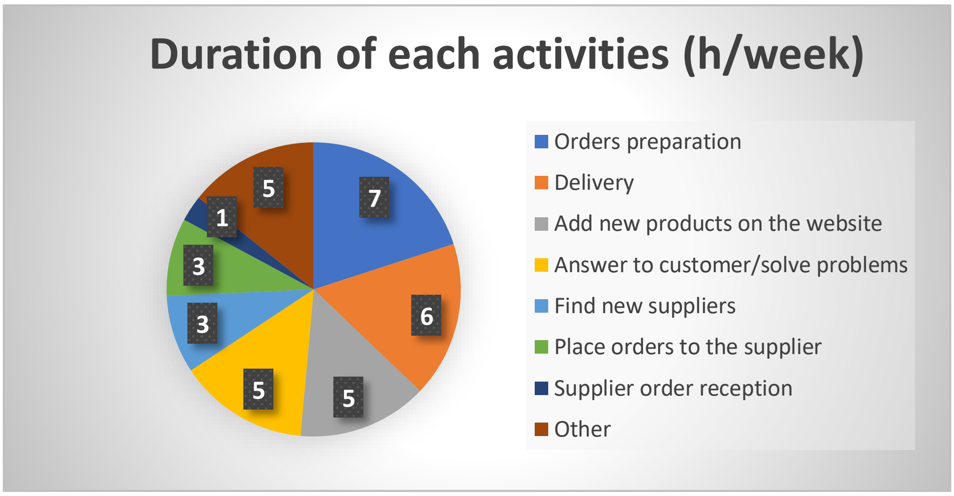

Fig 2: Duration of each activities (h/week)

- Firstly, deliveries by bike are already optimized, by making the shortest path connecting all delivery points (by using the application Google Maps). Then the only possible way to reduce this time would be to invest in an electric bike for the company or to outsource this activity to a third-party company.
- Secondly, the introduction of new products is also very time-consuming, it is needed to add product pictures, make the description of the product, make the pricing based on the recommended retail price and competitor prices, etc. Only a small reduction of time in this category can be considered, mainly with experience and habit, therefore it is not very relevant for this paper.
- Thirdly, answering customers' questions and resolving their problems is mainly done on a case-by-case basis, although a methodology could be put in place, but once again, a very limited time saving could be expected.
- Finally, we concluded with my supervisor that the area in which the best improvement could be made (from a time point of view) is the preparation of orders. Simultaneously, the time spent on receiving supplier orders could also be reduced. Indeed, the objective is to reduce the time spent on all product flows in the warehouse.

Afterwards, the second step in the Deming cycle, the **Do phase**. Before doing anything, for 2-3 weeks, I timed each individual task involved with order preparation as well as receiving and storing supplier orders. Then, based on the knowledge acquired during my master's degree in supply chain, as well as the analysis of the literature concerning the optimization of flows in a warehouse, I optimized the company's warehouse. This optimisation was based mainly on three axes, the layout of the warehouse, the storage methods of the products as well as the different ways of carrying out the picking.

In the third step, the **Check phase**, again I timed all the activities to analyse the improvement and identify which are the best's methods. I worked on a trial-and-error basis by testing and combining different techniques.

Finally, for the **Act phase**, based on the results obtained, I selected the best methods to improve the time spent for each activity and optimise the flow in the warehouse. Moreover, I provided some recommendations for the company and implemented new techniques in the warehouse. Those recommendations are divided in two parts. The one I directly implemented and made sure they remain in the long term. The second ones are the recommendations for the future, if the company changes or grows a lot and fast.

Part II: Introduction about the Supply Chain

Definition of the supply chain: One short given by Frazelle, another one, given by Stock and Boyer, based on a large amount of pre-existing definitions of the supply chain. (cf. 1.1. Definitions of the supply chain).

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History of the supply chain: Emergence of supply chain management in the 60's, MRP in the 70's, later MRPII and just-in-time, finally, ERP in the 90's. (cf. 1.2. Brief history of the Supply Chain Management).

↓

Used tools: Description of tools used during the internship and the writing of the thesis → Pareto Principle, Deming Management Method (PDCA). (cf. Chapter 2: Used Tools).

↓

The warehouse: Definition, objectives and activities → receiving, put-away, picking, checking & packing, shipping. (cf. Chapter 3: The warehouse).

Chapter 1: Introduction to the Supply Chain

1.1. Definitions of the Supply Chain

Many definitions exist to explain what the supply chain is. A relatively short one is given by Frazelle[2] (2002):

"The supply chain logistics is the flow of material, information, and money between corporations (interworkstation, interfacility, intercorporate, and intrachain)".

Nevertheless, probably the most precise definition is given by Stock and Boyer (2009). Through a study, with the aim of developing a consensus definition, they give an explanation based on a large amount of pre-existing definitions[3] of the supply chain:

[2] Edward Frazelle, Ph. D., is president and CEO of Logistics Resources International, founder of The Logistics Institute at Georgia Tech, and director of the school's Logistic Management Series.
[3] They used 173 definitions, both from the academic and practitioner literature.

> *"The management of a network of relationships within a firm and between interdependent organizations and business units consisting of material suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse flow of materials, services, finances and information from the original producer to final customer with the benefits of adding value, maximizing profitability through efficiencies, and achieving customer satisfaction."*

Most of the time, people are confused about the difference between the terms logistic and supply chain management. Frazelle (2002) distinguishes them by explaining that the supply chain is the network of facilities (warehouses, factories, stores, etc.), vehicles (trucks, trains, etc), and logistics information systems (LIS) connected by a company's supplier's suppliers and its customer's customers. Meanwhile, the logistics is what happens in the supply chain, and all the logistics activities such as inventory management, transportation, customer response, etc. that connect and activate objects in the supply chain.

1.2. Brief history of the Supply Chain Management

The term "supply chain management" appears first in the 1980s by Keith Oliver, a British top logistician and consultant[4]. Nevertheless, the concept of supply chain was important long before in the early 20th century. The era of supply chain management was highlighted in the 1960's with the first real innovation: inventory management, which focused on the optimal level of stock, replenishment periodicity, optimal order size, etc. It is one of the most important discipline for a company, which explains why one of the first indicator that international experts look to judge a company's well-being is the inventory turnover rate (Roux, M., Liu, T., 2003).

In the 70's appeared the "Material Requirement Planning" (MRP), a revolution in the supply chain world. A MRP corresponds to the detailed planning of

[4] Keith Oliver was the first using the term Supply Chain Management in public in an interview with Arnold Kransdorff of the Financial Times on 4 June 1982.

requirements from product BOMs (Bill of Material) and the planning of these requirements based on planned production dates and existing stock.

The next decade saw improvements in procedures and their sophistication. The previous MRP became MRPII, "Manufacturing Resource Planning". The two main lines of progress were: the looping on actual activity to update previous forecasts and, above all, the consideration of means, labour force and machines, and no longer only raw materials.

During this decade, the “Just-in-Time” (JIT) method also appears on the scene. The JIT is the opposite of the MRP, the latter is said to be "push-flow", because it is the orders (registered or forecast) that "push" the production. The JIT, on its side, is said “pull-flow”, because it is the last production workstation that asks the previous workstation what it needs, to fulfil the orders it has to release. Thus, step by step, the downstream stations "pull" from the upstream stations what is strictly necessary at the right time, hence the term "just-in-time" (Roux, M., Liu, T., 2003).

In the 90’s, the “Efficient Resources Planning” (ERP) appears, it is an evolution of MRP. It includes a lot of new functions, all integrated, such as the calculation of cost, the follow-up of customer orders. With this evolution, more intense and faster exchanges have also been developed with personnel management, payroll, accounting and invoicing management, etc.

Chapter 2: Used Tools

2.1 The Pareto Principle

Invented by the Italian economist of the same name, at the end of the 19th century, Pareto's law, also called the ABC classification or the 80/20 law, is an analytical tool. Briefly, this extremely simple classification method makes it possible to solve 80% of the difficulties of a problem by focusing on only 20% of the subject (Roux, M., Liu, T., 2003).

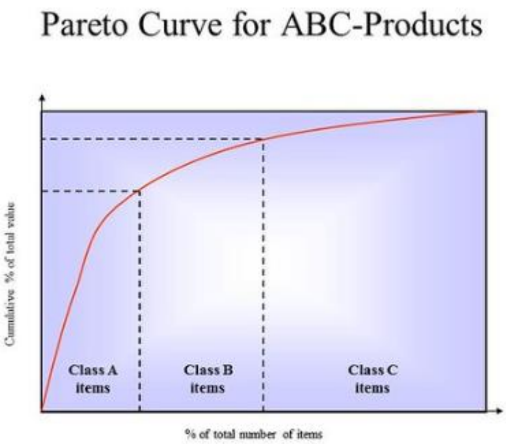

Fig 2: Pareto Curve for ABC-Products
Source: DrawPack

Indeed, it is often observed that 80% of the sales only concern 20% of the products in the catalogue. This type of ranking can be done based on the number of products sold based on the turnover.

2.2 The Deming Management Method (PDCA)

The abbreviation PDCA stands for "plan-do-check-act". This process is a continuous and repetitive four-step cycle aimed at improving the quality of management and production in companies. The four steps are completed and repeated if necessary, until the problem in question is solved (Benge, V., 2019).

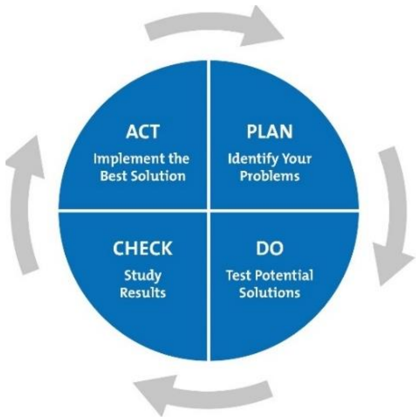

Fig 3: PDCA Cycle
Source: MindTools

Step 1: Plan

In the planning phase, a business owner analyses problems and potential causes. Then, he proposes solutions and develops plans. Standards and goals are determined. Management must also determine who will implement the plan, exactly what will be done, when it will begin, etc. It is recommended to start small and progress towards more ambitious goals.

Step 2: Do

The implementation and completion of the production process involves the execution and monitoring of the plan. If possible, break it down into small steps so that you can analyse each point in the process. The company tests the proposed changes and records the specific actions taken during the second phase in the PDCA model.

Step 3: Check

The third step is to analyse the data, to see what worked and what did not. For some businesses, this may include a comparative sales analysis to determine whether the results correspond to the forecasts made in the first step. An assessment of consumer satisfaction may be appropriate, in some cases, to see if the product has improved over a previous survey.

Step 4: Act

Firms using the PDCA cycle will use the results of the previous step to redesign, if necessary. If the process works and the objectives are met, changes to current production or management are part of the action step. If objectives and standards are not met, the PDCA model asks the company to take action by integrating what was learned and repeating the planning stage, repeating the four-step model.

Chapter 3: The warehouse

3.1 Definition and objectives

Warehouses are an essential component of any supply chain. Their major goal is to satisfy customers through the efficient use of resources and the delivery of the right product, at the right location, at the right time and in the good condition (Frazelle, 2002). According to Heragu et al (2005), the warehouse is a means of providing functions such as temporary storage, protection of goods, fulfilment of individual customer orders, packaging of goods, after-sales services, repairs, testing, inspections, just-in-time (JIT) sequencing and assembly.

3.2 Warehouse Operations

The main warehousing operations are classified as receiving, picking, storage and shipping (Gu et al. 2007). Bartholdi and Hackman (2017) divided those operations in inbound and outbound functions, as you can see on the figure 4.

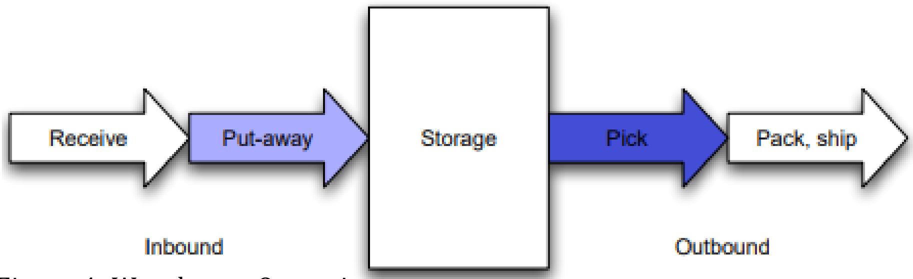

Figure 4: Warehouse Operations
Source : Bartholdi and Hackman (2017)

A general rule is that the goods should, at maximum, flow continuously in this process sequence. Every time a good is stored, it must be retrieved a little later, which constitutes a double handling. If these double manipulations are added to the thousands of Stock Keeping Units (SKUs)[5] and tens of thousands of products in a distribution centre or a warehouse, the cost can be considerable[6] (Bartholdi and Hackman, 2017).

3.2.1 Receiving

Receipt may start with prior notification of the incoming products. This allows the warehouse to plan receiving and unloading, in order to efficiently coordinate other activities within the warehouse.

Products are delivered to a warehouse by a freight forwarder. It is likely to be scanned to record its arrival in order to assume ownership, ship payments and know that it is available to meet customer demand. The product will be inspected, and any exceptions will be noted, such as damage, incorrect counts, misdescription, etc. The goods arrive most of the time in larger units, such as pallets, so labour requirements are generally not significant. In total, receiving represents only about 10% of operating costs in a typical distribution centre.

3.2.2 Put-away

Before the product can be put away, a suitable storage location should be determined. This is very important because where you store a good largely determines how quickly and cheaply it can be retrieved later for a customer order. Therefore, you need to manage a second inventory for the storage location.

When a product is stored, the storage location must also be scanned to remember where the product has been put. This information will then be used to create efficient picking lists to guide order pickers in retrieving the product for orders. Storage typically accounts for approximately 15% of warehouse operating costs (Frazelle, 1996).

Three fundamental decisions shape the storage function: A) How much stock to keep in the warehouse for each SKU. B) How often and when to replenish the

[5] Scannable bar code, most often seen printed on product labels in a retail store.
[6] In Kami Basics's case, the number of SKUs is not more than 500, so this rule is less applicable.

products. C) Where the SKUs should be stored in the warehouse (Gu et al. 2007). The first two issues (lot sizing and staggering problems) will not be discussed in this thesis. However, another section will focus on the third function, the decision of storage allocation (cf. part IV, chapter 2).

3.2.3 Order picking

An entire section will be dedicated to the order picking (cf. part IV, chapter 3). But in short, upon receipt of an order from a customer, the warehouse must carry out checks, for example, to ensure that stocks are available for shipment. After that, the warehouse has to produce the picking lists to guide order picking.

Order picking typically accounts for about 55% of warehouse operating costs and order picking itself can be further broken down as follows:

Activity	% Order-picking time
Traveling	55%
Searching	15%
Extracting	10%
Paperwork and other activities	20%

Figure 5: % Order-picking time
Source : Frazelle (1996)

Note that the travel accounts for the largest portion of order picking expenses, which is itself the most expensive part of warehouse operating costs. Much of the design of the picking process is aimed at reducing this unproductive time.

3.2.4 Checking and packing

The packing of the order is usually also quite demanding in terms of work, as each product in the order has to be handled one by one. This is the convenient time to check the order as well as making sure that it is complete and with the right products. In fact, order accuracy is paramount as a guarantee of quality towards the customer and a mark of trust, which could bring back satisfied customers.

Most of the time, an inaccurate order annoys the customer and asks him to take additional steps to contact the company and/or possibly resend the product corresponding to the error. These returns are additional costs for the company (up to ten times the cost of shipping the product).

3.2.5 Shipping

Finally, the last step is the shipping which is less labour-intensive than the picking because the packing process has consolidated products into bigger containers (boxes, pallets). Most of the time the order is scanned at this moment to update the customer by sending an inventory update.

In summary, most expenses in a typical warehouse are related to labour, most of that in order picking and most of that in travel.

Part III: The Big Picture of Kami Basics

Micro Attributes: business target of the company → price, delivery time, quality of products, quality of services, product range, product availability, customization (cf. Chapter 1: The micro attributes).

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Macro Attributes: volume and variability, the location, (cf. Chapter 2: The macro attributes).

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Company Specifications: Company values, company strategic aims, competitive advantage, the financials (cf. Chapter 3: Company specifications).

Kami Basics is a zero-waste online shop in Brussels launched in 2018. Currently, more than 400 different eco-friendly products are sold on the platform. The range of products extends from the bathroom (solid shampoo and deodorant, menstrual cup), as well as the kitchen (reusable Senseo and Nespresso capsules, wax pouches) or the baby's room (cloth diapers, organic bandages).

Apart from bamboo and stainless steel, imported from Asia, all Kami Basics suppliers are European. More than 15% of the products sold on the website are handmade in Belgium.

Chapter 1: The micro attributes

The micro attributes are the business targets of the company. By defining these attributes (price, delivery time, quality of products and services, etc.), we can define the market segment a company aims at, what type of customers the company wants to reach, and what they want or expect.

1.1. Price

Price is always important, but thanks to Kami Basics eco-friendly status, customers are willing to spend a little bit more money than in a regular shop. Indeed, customers are looking for reusable, recyclable, refillable products so they know that those products will last longer than single-use products. Moreover, even if customers pay more for a product that is reusable, instead of a single use product, the product will mostly be profitable in the long term.

Kami Basics sells products both to B2C and B2B, for B2C the margin is between 30 and 40%. However, for the B2B this margin is only about 10 to 20%, as companies are granted preferential prices.

1.2. Delivery Time

The delivery time depends on the means of transport used to deliver the package. Kami Basics offers four ways to be delivered. Firstly, a pickup on site (in Brussels, close to public transport), for free and most of the time people can pick up their parcel the same day as they order. Secondly, when the client is living in Brussels, the company proposes a delivery by bike, free from CO2, the delivery time varies between 2 and 6 days. Indeed, the packages are delivered by bike only once or twice a week, in order to group them. Finally, when the client is not living in Brussels, he can choose between a classical delivery with B-Post with a delivery time of 2 to 4 days or an eco-friendlier delivery with *Hytchers* with a delivery time of 5 to 8 days.

Hytchers is a Belgian delivery company that uses existing car flows of commuters to transport packages. In this way, as the drive is done anyway, they don't emit excessive CO2 to deliver parcels. (Hytchers, 2020).

1.3. Quality of products

Because these are mainly reusable products, customers expect the quality of the products to be good or excellent. The company tries to guarantee the highest possible quality for each of its products and does not hesitate to change suppliers to obtain a better quality.

1.4. Quality of services

There is a return policy of 14 days, in case that the product is damaged or does not meet the customer's expectations. Moreover, the company wants to provide a good after sale service, even after those 14 days. That is why the customer service manager is very reactive on the phone or by e-mail, which creates a relationship of trust between the company and the customer and motivates the latter to come back and make future purchases.

1.5. Product Range

When the company was founded in October 2018, only 7 basic zero-waste products (toothbrushes, straws, lunchboxes, etc.) were available, all in a pack. However, Jean, the founder, quickly realised that customers don't necessarily want to buy all the products at once.

From then on, Jean started to expand the range of products provided on the web shop. Currently, including all variants, colours, sizes, etc. the number of products available to the customer is around 400 different products. The target of the company is to increase this number by 30 to 50 new products every month.

1.6. Availability

Obviously, the ideal would be to never be out of stock of a product. Nevertheless, it is not always possible. The amount of stock is calculated on an ABC approach (cf. 2.1 The Pareto Principle) with the forecast based on historical sales. However, it can happen that a B2B client orders a big amount of a product that, historically, has not sold very well. When this situation happens, it can lead to an out of stock situation. Then the company must order first to the supplier before sending the package to the final client which can lead to significant order delays and customer dissatisfaction, if the situation is not clearly communicated to the customer.

1.7. Customization

Kami proposes, to B2B clients only, a customization of some of their product with the logo of the company. Typically, bottles or lunchboxes to offer to new employee with the company's logo.

However, Kami Basics does not propose a customization process of the products for private customers. For this kind of segment, customers are less demanding to have a customization of their products. Indeed, the company already proposes a large amount of sizes, colours, capacity, etc.

Chapter 2: The macro attributes

After, the micro attributes, described to understand what the customers want, come the macro attributes (volume and variability, location), which will touch upon the location of the company and the number of customers it has.

2.1. Volume and variability

As you can see on the figure 6, the average number of orders from October 2018 until April 2020 is increasing. Over this 19-month period, the average of orders is 62 orders a month, with the trend curve going from 39 orders a month until 85 orders a month. The standard error (cf. Appendix 1.1) is about 31,4 orders which is high, but can be explained because of the growing trend line. Indeed, because of this trend, at the beginning and at the end the number of orders is further away from the average than in the centre, which lead to a higher standard deviation.

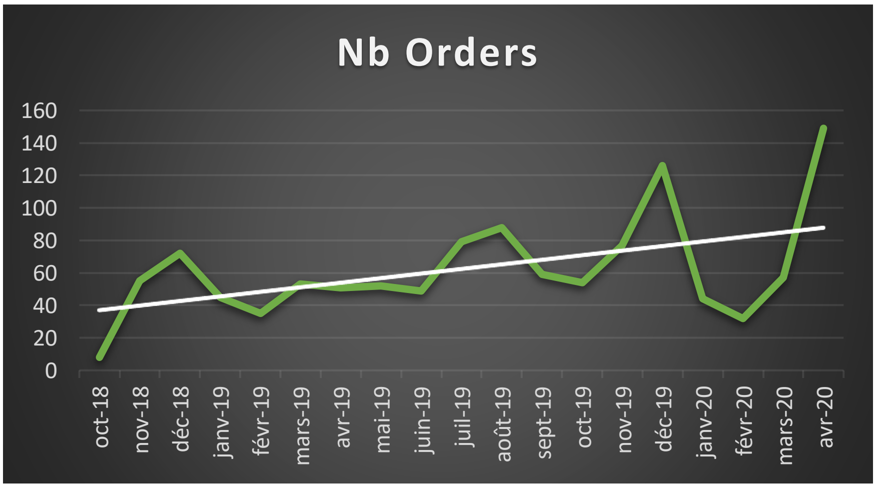


Fig. 6: Number of orders since the creation of the start-up.

From a seasonality point of view, we can see the same trend between October 2018 until February 2019 and October 2019 until February 2020, with a peak in December of both years, with the holiday season. For the rest of the forecasts, the history is not yet old enough to draw any real conclusions.

The peak in April 2020 is an exception, due to the covid-19 crisis that led to a confinement, free deliveries were made in Belgium. Furthermore, customers could benefit from numerous discounts on several products, to encourage Belgians to turn more towards zero-waste during this period.

2.2. Location

There are 1185 orders, in total, from October 2018, 95% were placed in Belgium (1126 orders), 3,3% in France (39 orders), 0,68% in The Nederlands (8 orders), the last 12 orders can be considered as exceptions (United Kingdom, Germany, Luxemburg, etc.) (cf. Appendix 1.2).

Out of the 1126 orders placed in Belgium, 694 were placed in Brussels (equivalent to 61.6% of orders booked in Belgium).[7] The remaining orders are distributed across the 10 provinces as shown on the map below. The two provinces with the most orders are those bordering Brussels, i.e. Flemish Brabant and Walloon Brabant. 43% of orders are in Flemish part while 57% are located in Wallonia (cf. Appendix 1.2).

Fig. 7: Distribution of orders in Belgium (excluding Brussels)

[7] As Kami Basics' head office is located in Brussels, it can explain that the majority of orders are placed in that region.

Chapter 3: Company specifications

Finally, in this big picture of the company, after the micro and macro attributes, come the company specifications. We are going to take a look at the company's values and goals. I will focus on what impacts the way the company will reach its business targets.

3.1. Company values

A charter of five core values has been put in place at Kami Basics, here is a summary:

1. **We put nature first, profits second**

"In a world where the opposite is true, we challenge the status quo continuously to honour our mission. Through our daily work we leave the earth in a better state than we found it. Every single sale makes the earth better off, not the opposite. We will obsess on empowering our customers to tackle climate change."

2. **We do more with less**

"Cost leadership is not only our strategy to establish a competitive advantage, it is also the way to keep our carbon footprint the lowest. We make smart choices and refuse buying what is superfluous. For example, we buy all our supplies and equipment second hand."

3. **We get things done**

"Time is running out. Scientists predict all we have is a couple of years left to make a turnaround and solve climate change. We have a bias for action. Speed matters in business. Many decisions and actions are reversible and do not need extensive study. Action always beats inaction."

4. **We learn continuously**

"We make this our top priority. We are never done learning and always seek to improve ourselves. We are humble. We know that, in order to learn, we will have to fail again and again. Failure is necessary to progress. We learn the lessons of our errors."

5. We lead by example

“We roll up our sleeves and get our hands dirty. We walk the talk. We take responsibility. We always do our best and persevere when things get hard. We follow the golden rule. We treat others as we want to be treated. We are impeccable with our word and communicate openly and non-violently.”

These values are sent to each new interns or employee and are reviewed with Jean, to make sure they understand and agree with each one of them.

3.2. Company strategic aims

Around the middle of 2019, the company received requests from a few independent organic stores to supply them with products. Then they have started developing in this new segment of the market. Six months later, they have 30 regular customers from this segment (about 10% of the total number of independent organic stores in Belgium) and they plan to fully focus on this aspect of their business in 2020, aiming to reach more than 100 shops by December 2020.

Moreover, even if the number of B2B orders is generally lower than the B2C orders, the financial amount of a B2B order is usually 5 to 10 times higher than a B2C order and the workload related to these orders is lower.

They are also negotiating with larger organic chain supermarkets to become their supplier of some of their products. Indeed, the number of customers, as well as the quantities of products sold, are generally higher in chain stores than in small independent stores. They hope to work with at least 3 chains by the end of the year.

3.3. Competitive advantage

In March 2020, Kami Basics launched “Kami Store”, a website only dedicated to B2B customers. Before then, only one website was available for both B2B and B2C customers. This new website brings advantages to B2B customers and increases the competitive advantage of the company.

Indeed, on this new website, B2B clients do not have a minimum order quantity to buy, whether they buy 1 or 10 products, the minimum price will be granted to them. They also provide a free shipping for any order above 300€. Regardless of the quantities ordered, they only pay the price of the products ordered. Finally, customers do not have any up-front payment, they will have 15 days to pay their invoice.

3.4. Cost / financials

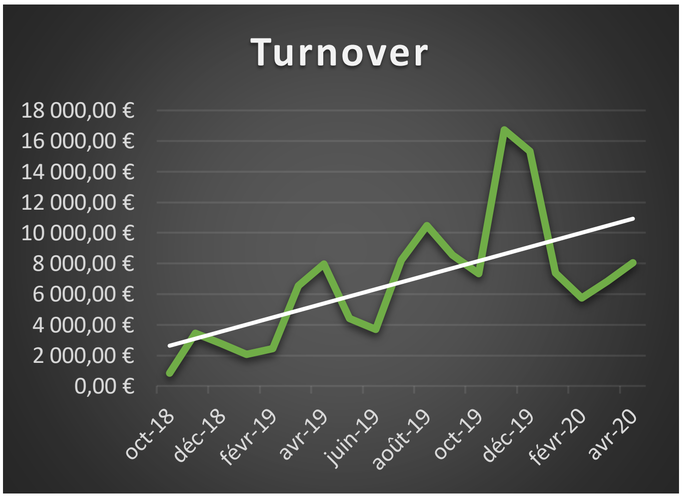


Fig. 8: Evolution of Turnover since the creation of the start-up.

As you can see on the appendix 1.3, the total turnover of the company over the 19-month period is about 129 000€. The trend curve of this turnover is growing which is a good sign for the survival of the company.

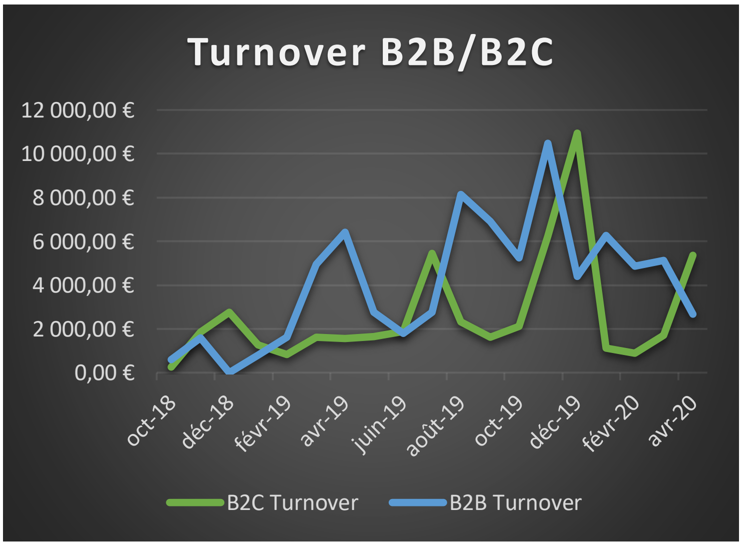


Fig. 9: Evolution of Turnover between the B2B and B2C channel

Separating turnover between the two segments allows to have a clearer view of the impact of each customer segment on the company's sales. The total turnover for the B2B is 77 340€ and for the B2C is 51 400€.

Chapter 4: Situation of the warehouse before the improvement

Layout of the warehouse: Horizontal aisle → 6 aisles of 4 pallets for 28,8 m² out of the 70m² available.

↓

Storage assignment: in alphabetical order of supplier (did not take into account the frequency of orders or the weight of the products.

↓

Picking strategy: no strategy was put in place to ensure optimal picking.

↓

Financial dimension: on average 2640€ per year for order preparation and storage costs.

When I started my internship on January 2020, the company just changed their warehouse, going from a warehouse of 18 m² to another one of 70 m². All stocks were packed in boxes and arranged in heaps (cf. Appendix 2), we had to be quick to arrange the stock in different aisles. Indeed, the orders kept coming in, and we had to get them ready as quickly as possible. So, we didn't really have time to think about any optimisation in terms of storage, location of products, how to optimise picking, etc.

On the appendix 3, you can see the floor plan of the warehouse as we originally installed it. We created horizontal aisles with pallet directly on the ground, 6 aisles of 4 pallets (1,2m x 1m = 1,2 m²). Which corresponds to a storage area of 24 pallets of 1,2 m², i.e. 28,8 m² (out of the 70 m² available), which represents only 41% of the available storage space.

Products in the aisles have been placed in alphabetical order by SKU.

Supplier code → BA; Product ID → 001

Example of an SKU : **#BA-HY-001**

Product family code → HY

Which implies that products were only located according to the name of the supplier, and did not consider whether the product was ordered frequently or not, what was its impact on the turnover, or whether it was heavy. This led to situations, where a regularly ordered product was in the last row of the warehouse or a heavy and bulky product was in the second-to-last aisle of the warehouse, which required more time and effort for picking activities.

For the picking part, no strategy was put in place to ensure optimal picking. Everyone did the picking as they saw fit, with obviously a lot of wasted time. Most of the orders were picked up one at a time, then the packaging was made and finally the label was printed. Moreover, no schedule or prioritization of orders was in place.

4.1. Financial Dimension

As an intern, I did the picking work for free. However, in order to be able to analyse the real impact of the improvements and measures taken during this internship, I will carry out a financial analysis. This analysis was done as if the picking work had been done by an employee, paid at the average wage of an order picker, i.e. a gross salary of 15.71€/hour (Salaire moyen, 2019). To carry out these calculations, I timed all the storage phases (inbound and outbound) during my 3 months internship, before and after the modifications of the warehouse in order to better reflect the reality of these improvements.

The warehouse rented by Kami Basics contains only a fixed annual cost of 20€/m^2 per year[8], for a surface including a storage area of 70 m^2 and an office of 38 m^2. Which represents a fixed annual cost of 2160€ and a monthly cost of 180€. In the following table, only the storage cost is taken into account, not the cost of the office.

[8] This extremely low warehouse cost is due to a warehouse that will be destroyed in a year's time and which is being made available this year only, to some fifteen eco-friendly Brussels start-ups.

Monthly Kami Basics Warehouse Costs Before Improvements				
Fixed Costs				
Storage cost	1,67€/m²	116,67 €		
Total Fixed Costs		**116,67 €**		
Variable Costs				
	Hourly wage	**Duration (1 parcel)**	**Costs (1 parcel)**	**Monthly Average**
Inbound costs	15,71 €			**5 parcels**
Count products		0,15h (9 min)	2,36 €	11,78 €
Check products		0,15h (9 min)	2,36 €	11,78 €
Store products		0,5h (30 min)	7,86 €	39,28 €
Administration cost		0,2h (12 min)	3,14 €	15,71 €
Total Inbound Costs		**1h (60 min)**	**15,71 €**	**78,55 €**
Outbound costs	15,71 €			**70 parcels**
Administration cost		0,05h (3 min)	0,79 €	54,99 €
Picking costs		0,1h (6 min)	1,57 €	109,97 €
Packaging costs		0,05 h (3 min)	0,79 €	54,99 €
Total Outbound Costs		**0,2h (12 min)**	**3,14 €**	**219,94 €**

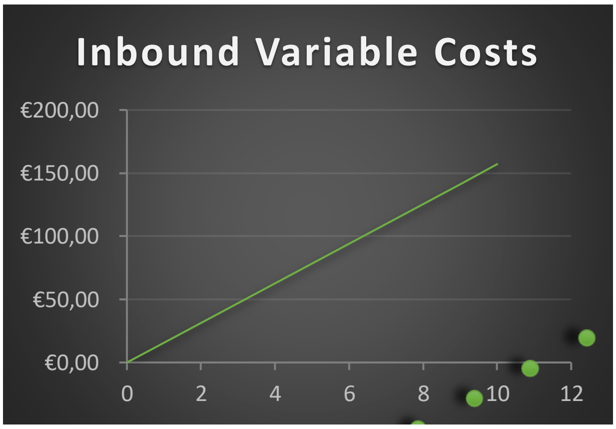


Figure 10: Variable cost of the inbound part of the warehouse, according to the number of parcels received from the supplier.

The inbound costs corresponds to all the costs of receiving a package from a supplier, (i.e. count if the number of products corresponds to the order, check the products to see if they are not damaged and if they correspond to the quality criteria), store the products in the right place in the aisles and finally the administrative, such as encoding the reception of the products in the computer system, send an email to the supplier if some products are missing or damaged, etc.

Since orders placed with a supplier are relatively rare, in order to reduce transport costs, orders are usually quite large and include many products, that is why, on average the processing time for one supplier package takes approximately 1 hour.

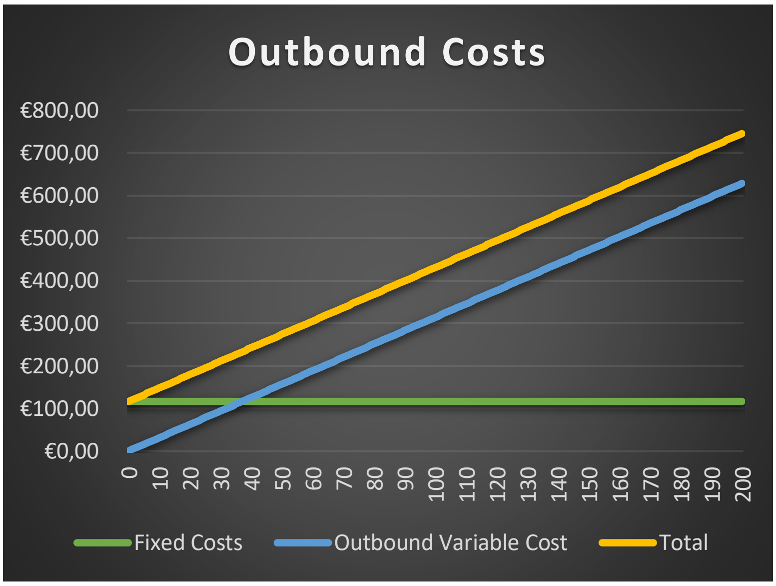


Figure 11: Variable cost of the outbound part of the warehouse, according to the number of orders sent to customers.

Regarding outbound costs, there are, on the one hand, the fixed costs, corresponding to the 70 m^2 of fixed storage, no matter how much space is actually used.

On the other hand, variable costs which correspond respectively to administration costs (creation of labels, preparation of the picking list, etc.), picking costs (the travel time between each product of an order, to remove the product from its location, etc.), and packaging costs (choose the good size of cardboard, arrange the products logically in the box, etc.).

In conclusion, I divided the activities of the warehouse into the inbound and outbound part. The inbound corresponds to the reception of a parcel from a supplier (and the activities related to it), which last generally 1 hour and costs 15,71€ with an average of 5 parcels a month which corresponds to 5 hours and 78,55€. The outbound part corresponds to the preparation of a customer's order. Which lasts generally 12 min and costs 3,14€, with an average of 70 parcels a month, then 14 hours and 219,44€. By optimizing the warehouse and the flows within it, the objective will be to reduce these durations and therefore these costs.

Part IV: Literature Review

Chapter 1: Types of warehouse layouts and travelling distance

Low-level picker-to-part System: system similar to Kami Basics' warehouse → items are stored in shelves less than 2 m high.

↓

Traditional layout: Horizontal or vertical aisle, three of them are presented → easier to put in place.

↓

Non-traditional layout: the flying-V and fishbone layout → both decrease the expected travel distance to a pick location but increase the size required for the warehouse.

The design of the warehouse layout is a key element of optimization tasks and has a significant impact on order picking and travel distances in the warehouse (Gu et al.2010). According to Caron et al (2000), layout design has an effect of more than 60% on the total travel distance, and they presented three traditional types of warehouse layout:

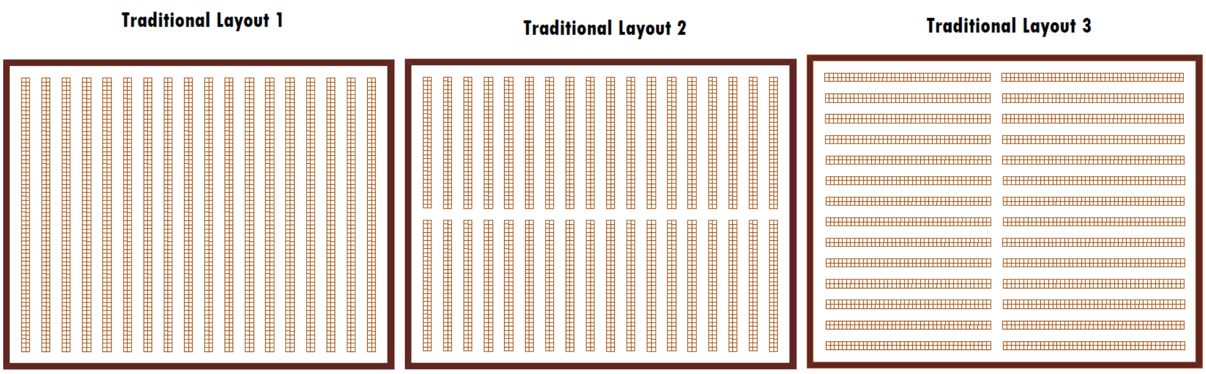


Fig. 12 : Traditional warehouse layouts.
Karasek (2013).

First of all, I will describe those three traditional warehouse layouts and I will then look at two less traditional ones: the Flying-V and Fishbone layout.

1.1. Low-level picker-to-part System

I will focus this analysis on the low-level picker-to-part system (Caron et al. 2000), because it is the one who corresponds the most to the warehouse of Kami Basics. This system corresponds to the three traditional layouts, see figure 12.

In this system, items are stored in shelves less than 2 m high, located in several picking aisles arranged in a configuration similar to the adjacent figure, and the picker walks or rolls through the aisles to retrieve the items specified on the pick list. The order picker starts at an input/output (I/O) point where he/she makes different administrative tasks (e.g. get the picking list, etc.) and eventually prepare the order, before starting a multi-stop circuit (picking tour) that connects each location specified on the pick list. The total picking time per route includes the administrative time at the point of input/output, processing time (the time spent to extract items), and the travel time between the picking locations.

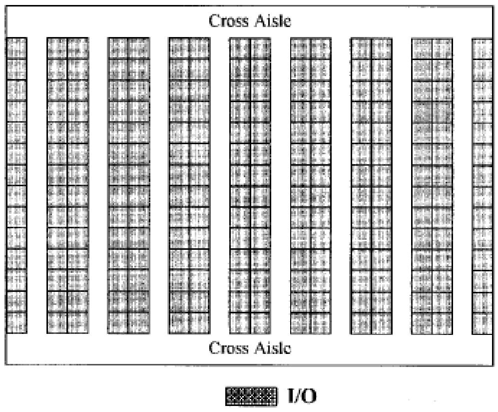


Fig. 13 : Type of warehouse layout. Caron et al (2000)

Most of the time, optimizing picking efficiency means minimizing total picking time. We consider the administrative time at the I/O point and the processing time at each picking location as constants. Which mean that, for a given picking list, significant improvements in picking efficiency, can only come from a reduction in travel time between picking locations.

This can be determined both by *layout design*, i.e. the quantity and orientation of the picking aisles, and by *operating policies*, i.e. routing (the order of the SKUs in the picklist) and storage (localisation of product in the warehouse, cf. part IV, chapter 2).

Some considerations on the relative orientation of the aisles show that the traditional layout 3 (cf. Figure 12) is sometimes preferable, as the cross-aisle travel is reduced by about half (Caron et al. 1998). Indeed, in this layout, the movement in the cross aisles to reach the picking locations, in a given section, allows the picker to immediately start picking operations in the second section, whereas in traditional layout 1 and 2, a transfer movement is required between sections.

Experimental evidence (Caron et al. 2000) has shown that the intended travel distance for the picking is strongly influenced by the layout of the picking area (differences can be more than 60%, see appendix 4), which justifies the design effort. In addition, the optimal number of lanes depends on both strategic/long-term and operational/short-term decisions. The layout is a function of the total length of the picking lanes, which, in turn, is linked to strategic decisions on long-term/short-term approach. In addition, layout preferences seem to be strongly influenced by decisions on the batching policy (number of picks in a round).

1.2. Flying-V and Fishbone layout

Gue and Meller (2009) presents two less traditional warehouse layout, the Flying-V and Fishbone layout, that you can see on figure 13.

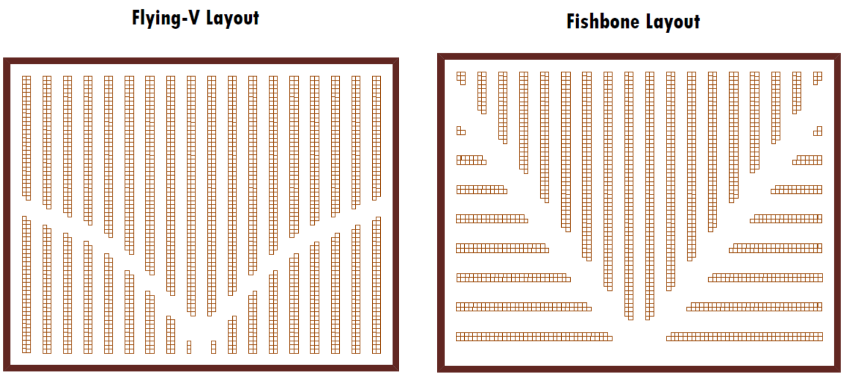


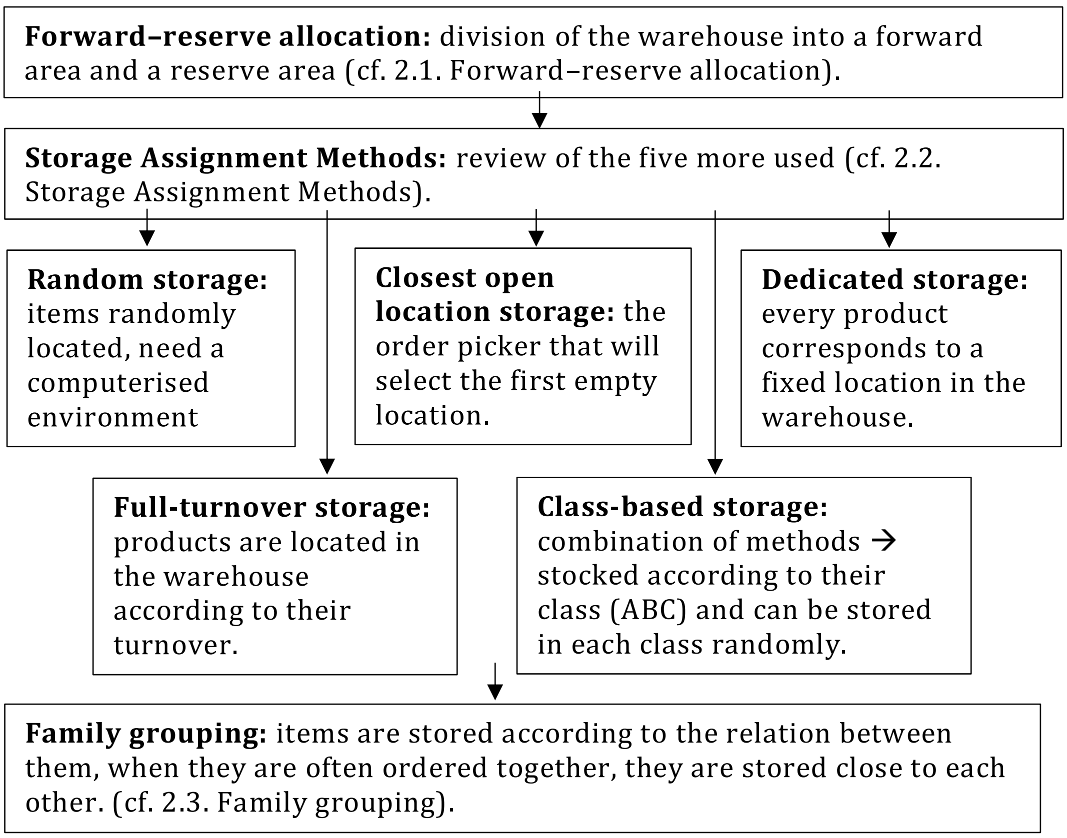
Fig. 13 : Warehouse layouts.
Karasek (2013).

They seek to minimize the expected travel distance for a single order cycle in a unit load warehouse that uses random storage. Firstly, for the Flying-V Layout, the conclusion shows that, compared to the traditional layout 1 (cf. figure 12), the expected travel distance to a pick location is generally around 8% to 12% lower (increasing with the number of aisles) with the same number of aisles as well as the same length (cf. Appendix 5). Warehouses with longer picking aisles will benefit more from the cross aisles of the Flying-V than those with shorter picking aisles. However, because of the cross aisle, this model increases the size of the warehouse by approximately 4% to 8% than a comparable traditional design.

Finally, in the Fishbone Layout, with parallel picking aisles, conclusions demonstrate that the expected travel time could be up to 20% lower than an equivalent traditional warehouse design (cf. Appendix 5) but depends on the number of aisles and the length of these one. Once again, this design occupies more space than the comparable traditional one

In conclusion, the most important factors influencing the distance travelled are the number of aisles and the number of picks stops rather than the relative orientation of the lanes.

Chapter 2: Storage Assignment



Products must be stored before they can be picked to meet customer orders (except in cross-shipping). A storage assignment method is a set of rules that can be used to assign products to storage locations. Different methods exist and each one can be optimal according to the layout of the warehouse, the picking strategy, etc. I will now review the most common methods of storage assignment.

2.1. Forward–reserve allocation

In order to reduce the quantity of labour that represents the picking (up to 55% of the distribution centre costs - cf. 3.1. What is the order picking ?), some companies divide their warehouse into a forward area and a reserve area (Berg et al. 1998). The forward area (pick stock) is used for efficient order picking, while the reserve space contains bulk storage (bulk stock). This area is used for restocking the front area and for picking products that are not assigned to the forward one. There is a limitation of space for the forward area, either because if the surface increase, it will also increase the travelling distance for the picking[9], either because a larger picking system will also increase the costs.

As a result, there is a trade-off between the additional work of the replenishment of the forward area, with products from the reserve, and the extra savings of travelling time due to this forward area. Some products should be stored only in the reserve area, when the demand for a specific SKU is low or if the demand quantity is important, in order to not refill this product too often.

2.2. Storage Assignment Methods

2.2.1. The random storage

It is probably the easiest method to apply but works only in a computerised environment. Indeed, every incoming product or pallets is assigned randomly to a place in the warehouse from all the empty locations available. The random allocation method results in a high utilisation of space (or low space requirement) at the expense of increasing the travel distance during the picking (Choe and Sharp, 1991).

2.2.2. The closest open location storage

In this method, it is not a computer that gives a random storage location to an incoming product, but it is the order picker that will select the first empty location. This will lead to a warehouse in which the location close to the depot are full and gradually the farther away from the depot, the emptier the storage spaces will be.

[9] The smaller the area, the lower the average travel time for order pickers.

This method should also be used mainly in a computerised environment recording the location of storage. According to Hausman et al. (1976) the closest open location storage has the same performance as the random location.

2.2.3. Dedicated storage

The dedicated storage is a method where every product corresponds to a fixed location in the warehouse. Because the location of each product is always the same, a computer environment is less useful. Moreover, the picking time resulting from the research of the product can be decreased as pickers become familiar with the location of each product (de Koster et al. 2007).

In this kind of warehouse, products are generally logically grouped, so it can save work. Finally, when products have different weights, because the location of the product is fixed, you can decide to put the heavy products on the bottom of the pallet while the lights product can be put on top.

However, there are some drawbacks with this method, such as that a particular location is always dedicated to each product even when it is out-of-stock. Moreover, for each SKU enough place should be reserved to store a sufficient amount of stock or in case of an unexpected increase of demands, which lead to a lower level of utilisation rate in the warehouse.

2.2.4. Full-turnover storage

In this method, products are located in the warehouse according to their turnover. Near the depot you will find product that have the highest sales rate so that they can be easily accessible. In contrast, slow moving products will be stocked somewhere towards the back of the warehouse, because less picked (de Koster et al. 2007).

This method will drastically decrease the travelling distance as the most picked products are located close to the depot. However, for better performance, this method should be combined with the dedicated storage method. Indeed, in case of a constantly varying demand rate, or if the assortment of the products frequently changes, a new ordering of the products will be required in the warehouse for each new change. This could result in a considerable amount of additional work for the warehouse employees. This problem can be solved by restocking some products, if it is relevant to move them, once per period for example.

2.2.5. Class-based storage

The last method of storage presented is the class-based storage and will combine some of the methods presented above. This way of stocking products is based on the famous Pareto's method (cf. 3.3.1. Pareto Principle) in which products are grouped according to the contribution to the turnover (e.g. 20% of the product contributes to 80% of the turnover).

By doing this classification, each class is then assigned to a specific area in the warehouse. Then, in each area, products can be randomly located. Most of the time three classes are used, the A-items, which corresponds to the fast-moving product for example, then the B-items and finally the C-items.

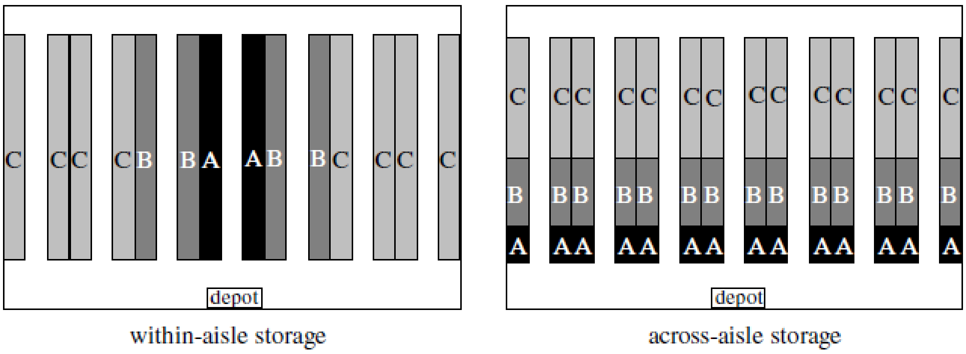


Fig. 14 : Illustration of two common ways to implement class-based storage.
Source: de Koster et al. (2007).

Even if Petersen et al. (2004) demonstrate that, in a manual order picking environment, the class-based storage is less efficient than the full-turnover storage[10], they advise, to use the class-based storage policy anyways (with two to four classes). Indeed, in practice, this method is easier to implement, requiring less time to administer than other comparable methods do.

[10] This performance difference depends on the class partitioning strategy and the routing method used.

However, this method requires also more space available. Indeed, in order to store a product in the right class region, empty slots must be available in each class area, which will consequently increase the space requirement.

Different ways exist to classify and locate A-, B- and C-items and areas in low-level picker-to-part systems, two possible configurations are depicted in figure 14. The optimal storage strategy will, of course, depend on the routing policies as well as the size of the warehouse and the number of products per picking route. And although there is no formal rule in the literature concerning an optimal distribution of classes (number of classes, number of products per class, etc.) for a low-level picker-to-part system, Le-Duc and De Koster (2005) claim that the across-aisle storage method is the closest method to the optimal.

2.3. Family grouping

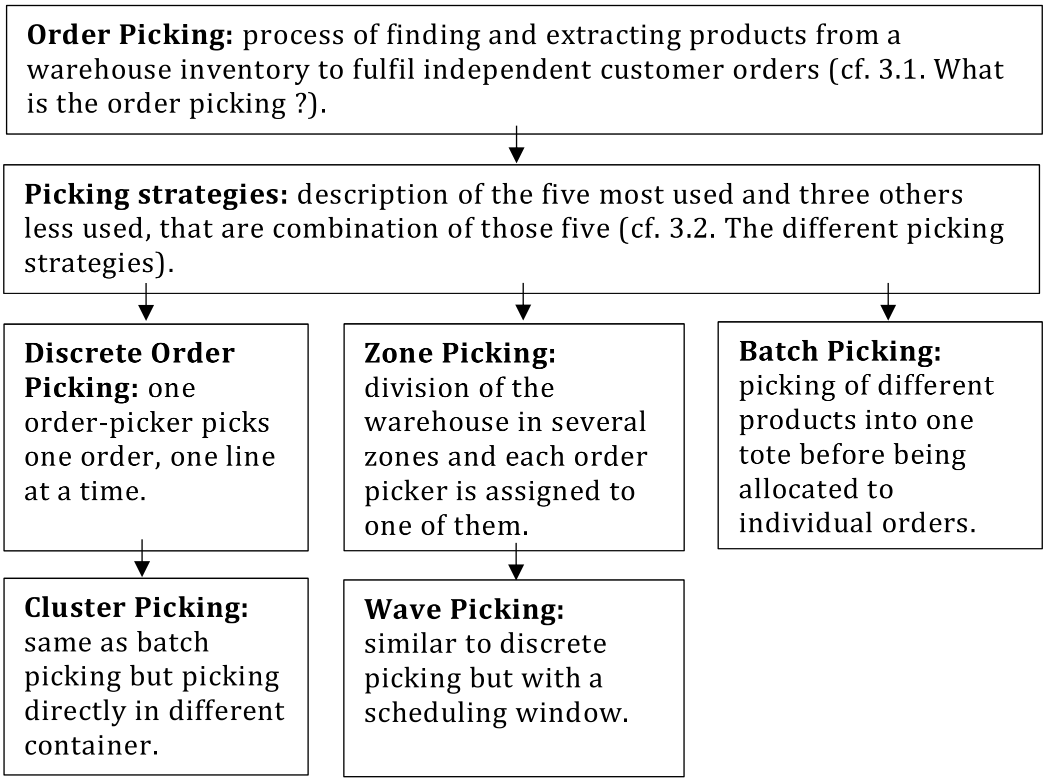
I will conclude this section by explaining one last method of stocking the product, not included in the five storage methods explained above. Indeed, this method should not be used alone, but in combination with another method.

This storage policy considers the kind of products stored as well as the relation between them. In fact, customers generally tend to buy some products with other products[11]. Therefore, it would be wise to store those ones in the same area, as close as possible to each other.

As previously mentioned, this method must be combined with some of the storage policies explained above. For instance, the family grouping can be used with the class-based storage, in order to locate product by class and simultaneously group them by family into each class. But, the way to decide in which class each product will be stored will depend on the properties of all the products into the group and the statistical correlation among products (the frequency at which these products appear in an order) should be calculated or at least predictable. This method of storage will also require a higher space than a random storage.

[11] In Kami Basic's case, we often see people buying, for example, toothbrush and toothpaste in the same order.

Chapter 3: Order picking



3.1. What is order picking ?

Order picking is the process of finding and extracting products from a warehouse inventory to fulfil independent customer orders (Murray, 2019). It consists of putting a product from warehouse stocks into the hands of the consumer. This process can be considered as a simple concept, but in practice it can be more complex than expected. It is often considered as the most labour-intensive and expensive activity of most warehouses (APS Fullfilment, Inc., 2020).

Picking might sound like the easiest aspect of a business, but according to different companies (6 River Systems, APS Fullfilment, Inc., etc.) which have done some analysis and statistics, compared to the shipping, storage and receiving stages, order picking represents up to 55% of a distribution centre's operating costs.

That is why, order picking methods is a key aspect of any warehouse. It also has a direct impact on your customers' level of satisfaction. If your warehouse picking methods are fast and accurate, your business will prosper.

Therefore, the objective of every company that fulfils orders, is to develop a warehouse picking strategy that emphasizes speed, accuracy and organization, as well as investments that can support these three points as demand evolves in the future (Glynn, 2020).

The choice of an order picking system depends on the number of requirements, including cost, complexity, volume of customer orders and the size of items and orders. Every business has unique requirements, and an order picking solution may suit one business and not another.

A good organization, a good communication, some smart investments and common sense can already help you get the most of your fulfilment process. However, as explained, best practices in picking in warehouses are not "one-size-fits-all", so I will now analyse the main picking methods and select and apply the one which looks to be the most suitable for Kami Basics' warehouse.

3.2. The different picking strategies

As explained in the previous section, there are many different types of picking for a warehouse and each one can be customized to fit the requirement of a company. Depending on the size of the warehouse and inventory, the labour force of the company, and the number of customer orders placed each day, some methods may be more efficient for a business than others. I will then explain the five picking strategies that are the most popular and used by many distribution centres and warehouses (Newcastle Systems, 6 River Systems, and Lucas Systems).

3.2.1. Discrete Order Picking

It is the most common type of picking, also called single order picking. With this strategy, one order-picker picks one order, one line at a time, going into the warehouse to find each item on the list before completing the order and before returning to the staging area for the order to be shipped (cf. Appendix 6.1). There is only one order scheduling window during a shift. As a result, orders are not scheduled and can be picked at any time on a given day.

+ This way of picking works well for a warehouse with a small team that is not overwhelmed by complex customer orders.
+ Simplicity, ideal for paper-based order picking, provides a fast response time for order fulfilment and makes it easy to track the order picker's accuracy.
- However, in many cases, the order in which orders are given to pickers and the routes they follow are not optimized. The worker regularly must make a complete trip in the warehouse to fill a single order. This is not the most efficient method.

3.2.2. Zone Picking

Also called "Pick and Pass", this method divides the warehouse in several zones and each order picker is assigned to one of these specific and physically defined zones in the pick area (cf. Appendix 6.2). The picker assigned to each zone is responsible for picking all the SKUs located in the zone for each purchase order. If an order requires products in more than one zone, each picker will pick the products in their area and then give the order to the next zone.

+ Picking by zone is a way to reduce pickers' travel as they stay within a certain zone and pass the order outside their zone to other pickers.
+ It also decreased congestion because the number of workers walking through the same aisle is lower. Pickers will be the only ones in their area, which will eliminate the time spent walking around someone else.
+ Pickers may see their productivity increase because they will be trained in a specific area that has been assigned to them. Over time, they will begin to remember where the products are located, which will increase their productivity, faster than if they were responsible for all the aisles in the warehouse.
- Depending on the operation, it may be necessary to assign an area of the warehouse to the merging of picks in a single order. This may require additional space as well as good coordination.
- Work can be very irregular amongst pickers, with some being very busy and others waiting for work.

- Pickers may enjoy interactions with their colleagues. However, in an operation where there are only one or two pickers in an area, they may spend their 8-hour shift alone. This can significantly lower employee morale and managers will need to incorporate other methods to boost motivation.

3.2.3. Batch Picking

Also called "Multi-Order Picking", each picker selects a group or batch of orders at the same time, one SKU at a time, picking different products into one large tote before allocating them to individual orders when they are packed. This is advantageous when there are several orders with the same SKUs. In this case, the picker only needs to go to the pick location for that specific SKU once to fill multiple orders (cf. Appendix 6.3). This methodology is often used when the typical order profile has only a few references (less than four) and the physical dimensions of the references are relatively small. This method works particularly well for e-commerce companies with somewhat predictable order patterns.

+ This type of picking is ideal for companies that are trying to speed up the pace and increase productivity rates by reducing travel time. Batching allows pickers to travel half the distance when preparing the orders.
+ A higher productivity rate for an employee helps them meet their requirements and exceed expectations. This will improve their morale, which could lead to better employee retention.

- At the same time, only one picking process per batch can be carried out. Otherwise, order pickers or operators of internal transport vehicles may interrupt each other.
- The volume of batches picked is limited to a single round. The batch size depends on the duration of the picking process window and the maximum capacity of the picker tote or the vehicle that has been chosen for picking. The volume of the batch that can be transported at one time also determines the quantity of orders that the batch can contain.
- Need for a preparation area in the warehouse where the sorting and consolidation process can be handled.

3.2.4. Cluster Picking

Cluster picking is similar to batch picking, but involves a single picker compiling several orders at the same time, preparing them in different containers and generally handles a variety of SKUs (cf. Appendix 6.4).

+ This method can give a serious boost in speed to warehouse, but it will need to integrate special technologies and resources to make it work in a warehouse, such as a well-trained order picker, mobile forklift, automated equipment and voice solutions.
- Of course, with this strategy, the risk of putting the product in the wrong box may be significant. A check of the orders is therefore often necessary.

3.2.5. Wave Picking

Wave picking is similar to discrete picking, but is more optimized than the simple discrete order picking and the main difference is the scheduling window (cf. Appendix 6.5). Wave picking involves a single picker grouping a variety of orders into small groups or waves. The orders are assessed after the picker has collected them, then compiled and prioritized according to time and importance, so that all shipments are delivered on time. This strategy allows "waves" of orders to be shipped throughout the day.

+ Optimizes order pickup and delivery because multiple waves can be coordinated to meet the distributor's shipping schedule.
- Once all the products have been collected in one wave, you will have to classify them into individual orders.

Part V: Improvement of Kami Basics' warehouse

Chapter 1: The decision variables

During my internship as well as throughout the writing of this thesis, I decided, based on the literature, to focus on three axes (i.e. the layout of the warehouse, the storage method and the picking). Those three axes were not chosen randomly, they are the three elements that come up most often in the literature and which are described as having the greatest impact on the time spent to prepare orders.

The first axis of decision variables concerned the layout design of the warehouse. I outlined five common layout design in warehouses. The first three are more traditional, with parallel aisles, and are equivalent from a performance standpoint. They differ by their relative orientation and the number of cross-aisle. Next, I describe two less traditional layouts: Flying-V and Fishbone layout. They both have the advantage of reducing the expected travel distance to a pick location by an average of 10% (depending on the number of aisles and the number of pick-stops) but, on the other hand, they both increase the average warehouse size by about 6%.

The conclusion of the analyse of this first axis is that the most important factors influencing the distance travelled are the number of aisles and the number of picks stops rather than the relative orientation of the lanes. Those characteristics are chosen according to the strategic decisions on the long-term/short-term approach of the company.

The second axis of analysis refers to the storage assignment of products in the warehouse. The first decision variable is the forward-reserve allocation, in which the warehouse is divided in two areas in order to reduce the travel time needed to make the picking. The second decision variable concerns the storage assignment method, for which I reviewed five common methods, i.e. the random storage, the dedicated storage, the closest open location storage, the class-based storage, and the full turnover storage.

Finally, the last axis of analysis concerns the picking of the product for the preparation of orders. I reviewed the five most common types of picking with their advantages and drawbacks, i.e. discrete order picking, zone picking, batch picking, cluster picking, and wave picking.

It was also important to decide in which sequence to achieve the improvements according to these three axes. The literature often mentions that the layout of the warehouse and the storage assignment should be a function of the strategic decisions on short-term/long-term (ST/LT) approach. In addition, most of the time, the layout preferences seem to be strongly influenced by decisions on the batching policy (number of picks in a round).

For pragmatic reasons (cf. 2.1 The layout of the warehouse), I had to begin with the layout of the warehouse. So, we could only think about the ST/LT strategy of the company, and not on the batching or picking policy. Then, we had to locate the products as fast as possible, so the second step was to select the storage assignment. Only after that, we could focus on the best picking strategy.

Chapter 2: Implementation of improvements

2.1. The layout of the warehouse

Orientation of the aisles: perpendicular to the I/O point with a cross aisle → easier to move and more pallets can be placed.

↓

Low-level picker-to-part system: based on this system, 12 shelves were added, in addition to the 3 rows of pallets already in place.

The first area where we looked for improvement concerned the orientation of the aisles. I began with this axis because of pragmatic reasons. In fact, after two months in the warehouse, we had to move from a plot to another (of the same size), so all the stocks had to be moved, which allowed us to think about the best way to rearrange the stocks. This transfer had to be done fairly quickly (another start-up was already arriving a few days later, to occupy our former location), so we were caught a bit short, in terms of time. Moreover, orders continued to be placed by customers and had to be delivered as fast as possible, to not decrease the customer's satisfaction. Then, we had to store the products in the right location, before preparing the next customers' orders. That is why we began with the layout of the warehouse, then the storage of the products and finally the picking strategy.

Furthermore, as the quantity of stock increased and new products arrived, the storage area became too small, so it was imperative to address this new issue and increase the storage area as much as possible.

After drawing several plans of the warehouse with different layouts and ideas, we selected one plan (cf. Appendix 7). We still choose a traditional plan such as the plan we had before, but this time with the relative orientation of the aisles the other way around, perpendicular to the I/O point (cf. traditional layout 2, fig. 12). Caron et al. (1998) finds it preferable to orient the aisles in the other direction (cf. traditional layout 3, fig. 12), because the I/O point is closer from cross-aisle (cf. part IV, chapter 1: Types of warehouse layouts and travelling distance). Nevertheless, based on the area made available to us (a rectangular area of 13.6m by 5.2m), it was possible to place more pallets in the other direction. Indeed, by creating 3 rows of 9 pallets, we can place three more pallets, thus increasing the storage area by 3.6 m^2 (3 x 1,2 m^2), from 28.8 m^2 (41% of the available area) to 32.4 m^2 (46.3% of the available area).

In addition, we realized that it was easier to move between the rows when arranged in this orientation. Moreover, to further increase the ease of movement we created a cross-aisle in the middle of the warehouse.

Given the small area we had at our disposal, the Flying-V and Fishbone layout were not considered in the final choice. Indeed, these layouts are interesting, by decreasing the expected travel distance to a pick location, but only when the storage area is large, with many and long aisles (those layouts increase the area needed by about 6%) which was not the particular case for Kami Basics.

I also relied on the low-level picker-to-part system (Caron et al. 2000), in which items are stored in shelves less than 2 m high. In order to increase the storage area considerably, we added a row of 12 shelves (90 cm x 30 cm x 5 levels, i.e. an area of

1.35 m^2 each) on the left side of the warehouse, which increased the storage area by 16.2 m^2 (from 32.4 m^2 to 48.6 m^2). As a result, the surface area used now represented 69.4% of the 70 m^2 available.

2.2. The storage assignment

~~**Forward area and a reserve area:**~~ lack of storage space to implement.

↓

~~**Random or closest open location storage:**~~ require a computerization → which is not the case of Kami Basics' warehouse.

↓

~~**Dedicated storage:**~~ too often new products added and products that are removed, to dedicate a fix storage to each item.

↓

Class-based storage method: based on the long-term strategy → divided into B2B and B2C products.

After looking at the layout of the warehouse to increase the ease of movement as well as increasing the storage area by 30%, I looked at how to store the products in rows in order to reduce picking time by reducing the travel distance.

Firstly, given the small amount of storage space we had, a division of the warehouse into a forward area and a reserve area was not really an option.

Then concerning all the storage assignment methods, I chose the one that fit the most the layout of the warehouse. As the warehouse is not computerized, all methods that require (or highly recommend) computerization had to be ruled out, i.e. the random storage or the closest open location storage.

The dedicated storage seemed also complicated to set up and not very relevant, given the fact that there are regularly new products that are added to the warehouse, as well as several products that are definitely removed from sale (because they do not sell well, because the supplier has gone bankrupt, etc.). As a result, dedicated storage would have to be moved or removed too regularly, which would be very labour-intensive and bring very little benefit.

Furthermore, I also looked for the method that best fit the long-term strategy of the company. As explained, Kami Basics begun its activity as a B2C seller of zero-waste products, then some B2B customers (organic shop, zero-waste shop, etc.) asked them to also be able to buy their products. That is why in March 2020 the company launched a dedicated website only available to these B2B customers. On the long-term perspective, the start-up expects to become only a B2B reseller, currently the B2B turnover represents 60% of the total turnover (April 2020).

Therefore, the method that seemed to be the most appropriate and that corresponded best to the company's strategy was the class-based storage method. This strategy combines some methods seen and is based on the Pareto's Method. With this method each class is assigned to a specific area in the warehouse and the products in each class should be located according to another strategy. It was therefore necessary to decide how many and which classes to choose as well as how to classify the products in each of these classes.

An excel document, internal to the company, exists and includes four classes, each of them corresponds to the monetary classification in stock entry, in other words, a ranking of total purchase cost of each product entry in the warehouse (cf. Appendix 7). This ranking is obviously correlated with the number of times each product has been sold (the number of order line), indeed, the more a product is sold the more it will be restocked and therefore the higher the cost of the product will be. The A-items corresponds to 80% of the product sold, B-items 80 to 95%, C-items 95 to 100% and the D-items, products that register no sale at all.

In analysing this excel table, I realized that most of the products included in class A were B2B products and those in classes B, C and D were mainly B2C products. Because all B2B products are available for both B2B and B2C customers, while B2C products are only available for B2C customers. It was therefore relatively expected that B2B products would sell more often and in larger quantities than B2C products.

Moreover, based on the long-term strategy to become only a B2B reseller, it looks easier and more convenient to classify and arrange the products according to B2B and B2C sales. As you can see on the appendix 7, the storage area has therefore been divided into two distinct parts, the largest (27.45 m^2) and closest to the I/O point dedicated to B2B products and the smallest (21.15 m^2) and furthest away from the I/O point dedicated to B2C products.

In order to facilitate picking and to allow the picker order to find the products faster, I placed the products, in each class, in alphabetical order of suppliers. On each pallet, the name of the supplier is indicated as a visual aid.

2.3. The order picking

~~Discrete order picking:~~ not optimised to make a complete trip to fulfil each order.

↓

~~Zone picking:~~ most of the time the picking was done alone.

↓

~~Batch picking:~~ time saved during the picking < time lost to separate items from the box in front of I/O point.

↓

Cluster picking and wave picking: cluster picking → 3 orders at the same time, then the packaging. Wave picking → according to B2B/B2C product and delivery method.

The third step, after the improvement of the layout of the warehouse and the storage method, I focused on the order picking. Remember that picking could represents up to 55% of a distribution centre's operating costs. The chosen method could therefore have a significant impact on the warehouse’s cost.

During my internship, I tested different techniques based on the literature reviewed. Considering the volume of customer orders, the size of items and orders, etc. some techniques suited better the business requirements than others. I am going to review the different strategies tested and their results.

First of all, the technique that was originally used was the discrete order picking. In practice, it is a good method because the warehouse of Kami Basics is not too big, and the orders are not too complex. However, even if the warehouse is not that big, you lose a huge amount of time by making a complete trip in the warehouse to fill each single order. Indeed, the order in which orders were picked and the routes I followed were not optimized.

Since most of the time I was picking alone and given the size of the warehouse, the zone picking method was not an option, and therefore untested.

Then, I tested the batch picking method during a couple of days, but I soon realized that it wasn't effective enough. Indeed, I picked the products of multiple orders into one big box, consequently, realizing only one passage per aisle of the warehouse. In terms of travel distance and time spent in the aisle, it saved some time and then the productivity of the picking increased.

However, the time spent in front of the I/O point to allocate each product to an individual order, has increased far too much compared to the time saved in terms of picking time. Indeed, this method is profitable when there are several orders with the same SKUs, because you only have to pick once every product instead of multiple times the same SKU. With 400+ different references in stock and despite the fact that some products obviously sell better than others (more picked), not enough orders included the same products. This method has therefore not been used very long and has not been retained.

Finally, after many trials and errors the method that suited best the requirement of the company was a combined method of the cluster picking and wave picking methods. The cluster picking, almost the same as the batch picking, but with the difference that the products are directly placed, during the picking tour, in an individual container, according to the order. This strategy slightly increases the picking time, compared to batch picking, but the time spent in front of the I/0 point is considerably reduced, because only the packaging has to be done.

Of course, the cluster picking strategy required a little bit of preparation and to be well-trained, but it quickly proved to be the most effective method. Most of the time 3 orders were picked at the same time, by trying to group the orders with the same SKUs together.

As mentioned above, we used a combined method of cluster picking and wave picking methods. Indeed, picking was carried out according to two criteria, the first, whether it was a B2B or a B2C order, the second, the method of delivery for the B2C orders. Based on that, different wave picking, and different windows were scheduled.

First of all, the first orders to be picked and packed were always the B2B orders. Indeed, these orders were considered as a priority. Since the long-term strategy is to work with them exclusively, these were the customers that needed to be satisfied the most and always delivered first. B2B orders were then picked and packed as fast as possible and if possible, on the day the customer placed the order. In this way, it also made it possible, if a product ran out of stock, to place the order as quickly as possible with the supplier of the product concerned.

Then, once all the B2B orders were under control, we could handle orders from B2C customers. For these orders, I set up different wave picking according to the method of delivery. Helped by an application, the picklist was made according to the different delivery methods (cf. appendix 9). As explained in the presentation of the start-up (cf. 1.2. Delivery Time), three means of transport are used by Kami Basics and can be selected by the customer. First, by the post, for short delivery time, all the orders send by the post were picked and packed in one wave to send all the orders two or three times a week, respecting the shipping hours of the nearest post office.

Afterwards, a second wave were made for the orders sent by Hytchers, for longer delivery time but more ecological, these orders were less urgent, and the customer is generally more tolerant of delivery times.

Finally, the last means of transport, only for orders in Brussels, was the delivery by bike. The biker responsible for bike deliveries came once or twice a week, so orders shipped by bike were prepared in a wave the day before or the morning of the biker's arrival.

2.4. Administrative tasks

The time spent on administrative tasks is also quite substantial and can be reduced by making a few improvements. The task for which I managed to optimize time concerns the printing of delivery labels. Originally, we used the office printer that was made available to several companies and was located quite far from the order packaging area. So, a lot of time was lost getting to the printer and sometimes queuing. That is why I suggested to the company to invest in a label printer that we could leave permanently on the I/O point and save a significant amount of time.

2.5. Financial Dimension

In order to analyse the improvements that had been implemented in the warehouse, I re-timed all the activities included in the preparation of orders, with the financial analysis based on the average wage of an order picker (gross salary of 15.71€/hour). In the table below, you can see the improvement in term of time and cost. Some costs have not changed because no improvements have been made to these activities, i.e. storage cost in the fixed costs, count, check and administration costs in the inbound part of the warehouse flows.

Concerning the activities that have been optimized and, whose time has been reduced, you will find on the appendix 10 the entire comparative table of the situation before/after the improvements, with the variations in term of costs and time (see figure 17). All these savings in terms of time are due to the improvement explained in the 5 previous points.

Remark: *The times indicated are those that were timed before and after the warehouse improvements. Other factors (other than changes in layout, picking, etc.) may explain the time reduction in activities, such as experience gained during the internship, difference in productivity, etc.*

Monthly Kami Basics Warehouse Cost After Improvements				
Fixed Costs				
Storage cost	1,67€/m^2	116,67 €		
Total Fixed Costs		**116,67 €**		
Variable Costs				
	Hourly wage	**Duration (1 parcel)**	**Costs (1 parcel)**	**Monthly Average**
Inbound costs	15,71 €			**5 packages**
Count products		0,15h (9 min)	2,36 €	11,78 €
Check products		0,15h (9 min)	2,36 €	11,78 €
Store products		0,3h (18 min)	4,71 €	23,57 €
Administration cost		0,2h (12 min)	3,14 €	15,71 €
Total Inbound Costs		**1h (60 min)**	**12,57 €**	**62,84 €**
Outbound costs	**15,71 €**			**70 parcels**
Administration cost		0,04h (2 min 30sec)	0,63 €	43,99 €
Picking costs		0,065h (3 min 50sec)	1,02 €	71,48 €
Packaging costs		0,045h (2 min 40sec)	0,71 €	49,49 €
Total Outbound Costs		**0,15h (9 min)**	**2,36 €**	**164,96 €**

For the part that concerns the inbound flows of the warehouse, only a saving of time for the storage of the products was possible. For this activity a reduction of 12 min (40%) was timed, which represents a total reduction of 20% for all inbound activities (cf. figure 17). From a financial point of view, this translates into a gain of €16 per month on average (from 78€ to 62€).

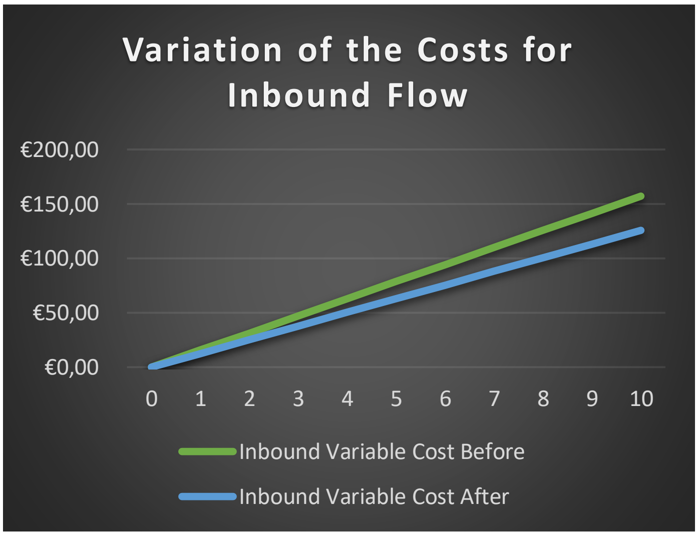


Figure 15: Variation of the cost of the inbound part of the warehouse, before and after the improvements, according to the number of parcels received from the supplier, on a monthly basis.

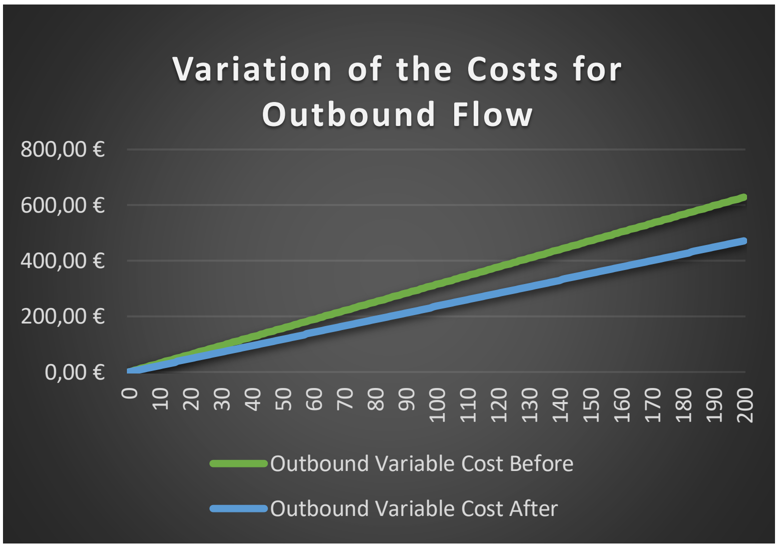


Figure 16: Variation of the cost of the outbound part of the warehouse, before and after the improvements, according to the number of orders sent to customers, on a monthly basis.

For the other part, the outbound flow of the warehouse, a decrease in time could be observed for all activities. In fact, the improvements made affect each of the activities, at different levels. The activity with the highest reduction in time, is the picking, with a reduction of 35% (from 6 min to 3min 54s). Then, the second activity is time spent on administration, a reduction of 20% was timed (from 3 min to 2min 24s). Finally, the last activity is the packaging of orders, with a reduction of 10% (from 3 min to 2min 42s). Which represents a total reduction of 25% for all outbound activities of the preparation of the orders.

Variation Before/After				
	Variation (%)	Variation (min)	Variation (€) 1 parcel	Variation (€) Monthly average
Inbound costs				**5 parcels**
Count products	0 %	0	0,00 €	0,00 €
Check products	0 %	0	0,00 €	0,00 €
Store products	- 40%	- 12 min	-3,14 €	-15,71 €
Administration cost	0 %	0	0,00 €	0,00 €
Total Inbound Costs	**-20%**	**- 12 min**	**-3,14 €**	**-15,71 €**
Outbound costs				**70 parcels**
Administration cost	-20 %	- 0min 36s	-0,16 €	-11,00 €
Picking costs	- 35 %	- 2min 6s	-0,55 €	-38,49 €
Packaging costs	- 10 %	- 0 min 18s	-0,08 €	-5,50 €
Total Outbound Costs	**-25 %**	**- 3 min**	**-0,79 €**	**-54,99 €**

Figure 17: Variation between the situation before and after the improvement made in the warehouse.

From a financial point of view, this translates into a gain of €55 per month on average (from 220€ to 165€). In the scenario where the average number of orders remains fixed, this would amount to a saving of €660 per year (from €2640 per year to €1980).

In conclusion, it is a gain of €70 each month, i.e. an annual gain of €840 (from €3583 per year to €2733). This saving of 70€ might seem insignificant but in terms of time it still represents 4.5 hours of savings each month that can be spent on activities that can make the business growth (i.e. find new suppliers, new customers, etc.). Moreover, if the number of orders double, this will represent a saving of 140€ and 9 hours of work each month.

Chapter 3: Recommendations for the future

This third and last chapter of the fifth part, contains a few recommendations about the optimisation of the warehouse for the future of the company.

Currently, the items are picked with the cluster picking strategy, generally by 3 orders with three boxes in hand. Sometimes, when the orders are big or heavy, it could be hard to hold these three boxes in your hand. That is why my first recommendation would be to buy or find a trolley to carry the orders. Furthermore, in this way more orders could be processed at the same time. It is also better for the well-being of the worker, who will have less to carry all day, which is better for their backs.

With the cluster picking strategy, an error in order picking can happen quickly. Obviously, the order picker must be very vigilant when preparing orders. If possible, I would recommend the company to carry out a double check for each order. This can be done, for example, by two order pickers, one preparing the orders and the second one doing the packaging and checking each order before sealing the package and shipping it.

Kami Basics tends to increase the number of products available to its customers, which could also mean working with new suppliers. If this trend continues, more and more different products will be stored in stock. Since the products are placed by class (B2B/B2C) and in alphabetical order of supplier within each class, the location of some SKUs will have to be changed. The frequency of product rearrangement will obviously depend on the number of new products and suppliers per month.

During my internship, the target of the company was to increase this number by 30 to 50 new products every month. With this increase, a rearrangement of stocks twice a year is sufficient. I would therefore recommend that the company rearrange the stock every six months. Moreover, during this rearrangement of stocks, it could be the good moment to make the physical count of the products. In order to check the correct quantity of stock between physical stock and computerized stock.

Another recommendation is linked to the currently available storage space. In the future, if the number of orders doubles or even triples, the storage space may become too small. That is why, I suggest the company to already think about that constraint. The easier way to do that would be to change each aisle in pallet, by an aisle of shelves or racks. If the company changes the aisles with the same shelf already installed in the warehouse the surface would increase a lot.

Every aisle in pallets could be changed by an aisle of shelves. It is possible to install 12 shelves lengthwise on a width of 2 shelves. This means that 24 shelves could be installed on each row (1,35 m^2 each), which represents a surface area of 32.4 m^2. Therefore, by replacing the three aisles of pallets with three rows of shelves, the storage area would increase from 48,6 m^2 (out of the 70 m^2 available, equivalent to 69.4% of the storage area) to 113,4 m^2, i.e. 162% of the storage area. Obviously, the installation of these 72 shelves would be very time-consuming. That is why, it would be better to find some racks that can be much longer and on which whole pallets can be directly stored. It is, most of the time, more expensive, but racks can be bought second hand, cheaper.

The last recommendations that I will give is about how to sustain the improvement made. Different tools have been developed and/or implemented during this internship as well as by former interns, namely the different operating modes and user guides and the implementation of a 5S approach. If these different solutions become obsolete as the company evolves, I recommend that they evolve with the company while maintaining their level of detail. This is in fact the last step of the 5S approach, which is to ensure the durability of these formal tools.

As explained, some of the improvement could become obsolete, while some other should be kept unaltered or eventually evolve with the growth of the business. The layout of the warehouse as well as the storage assignment method could be kept unaltered (except a rearrangement of stocks twice a year, of each class, in case of new products and new suppliers). The picking strategy, which is currently a combination of cluster and wave picking, should evolve according to the business' growth. When the number of orders has doubled, I recommend that the company analyse whether the method implemented is still the most optimal. For example, by carrying out another week's test and by timing the orders preparation.

From a human resources point of view, I recommend as much as possible to set up a week of transmission of knowledge and skills, between the different trainees in the same post (a one-week training session). This is essential in order to limit the need to immerse oneself alone in the various operating procedures and user guides, with knowledge transmission that could instead be done through interaction with the experienced trainee. From then on, the documentation would be used in majority in order to remove doubts and to come to specify the actions to be taken in case of forgetting.

Limitations

The first and main limitation in this thesis results from the crisis of Covid-19. Indeed, due to the confinement, I was not able to complete the whole of my internship at my place of work. From the 16th of March, I only went to the warehouse 1 or 2 days a week, the rest of the time I was teleworking from home. For that reason, I could not implement all the ideas I had in mind (e.g. the end of the implementation of barcode in the stocks, on each product, to scan the products and facilitate the physical count of the products).

My second limitation is also linked to Covid-19 crisis. In April, I was supposed to visit two warehouses of the same scale of Kami Basics, but those visits got cancelled. They would have allowed me to make some recommendations to Kami Basics' warehouse and maybe directly implement them.

Another limitation is linked to the scientific sources I used throughout this thesis. Indeed, most of the sources are quite old, one is from 1976 and some other are from the 90s. This could be a negative aspect, but I think that those sources are still relevant. Because those articles outline ideas about manually generated (and not computerized) warehouses, which is also the case for Kami Basics. So, in my opinion the conclusions of these articles are still relevant today.

Conclusions

Throughout those three months of internship in a very dynamic Brussels start-up, I had the chance to learn a lot of things (e.g. responsibility, autonomy, warehouse expertise, etc.) , and I was also able to bring my knowledge to develop the supply chain of Kami Basics.

The problem that was identified at the beginning of my internship by my supervisor was an efficiency issue in the supply chain, in terms of time spent on different activities. The objective of my internship was therefore to optimize one of Kami Basics' supply chain activities. The final goal was to reduce the time spent on the start-up's basic activities and thus obtain more time for activities with a real added value for the company, allowing it to grow faster.

Based on the analysis carried out, it appeared that the activity that would save the most time was the preparation of orders. Then, after analysing the positioning of the company as well as the big picture of the supply chain and the different activities of a warehouse, I have been looking into warehouse optimization. From the literature on warehouse optimization, three areas for improvement have emerged, namely the layout of the warehouse, the storage assignment methods of the products as well as the different strategies of carrying out the picking.

Firstly, for the layout of the warehouse, the layout that appeared to be the most optimal, is the traditional layout 2 (cf. figure 12), with 3 aisles of pallets perpendicular to the I/O point with a cross aisle at the half of the warehouse. A fourth row of shelves has been added on the left side to increase the storage area by 16.2 m^2. In conclusion, this layout was the easiest way to move across the aisle and allow us to increase the storage area from 28,8 m^2 to 48,6 m^2, out of the 70 m^2 available. Moreover, if the company follows my recommendation to change all the aisles in shelves, instead of the current pallets, the storage area could be increased up to 113.4 m^2 (i.e. 162% of the storage area).

The second step in the warehouse's optimisation concerns the storage assignment method of the products. Different ways of locating products have been considered, but the one that has emerged as the optimal is the class-based storage method. Indeed, it was important to build on the company's long-term strategy of becoming a distributor for B2B customers and gradually reducing the offer for B2C customers. Indeed, with this segment, the amounts spent by B2B customers are generally 5 to 10 times higher than those of B2C customers and since the number of orders is lower, the workload is lower as well. With this segment, Kami Basics realised that turnover was increasing with less logistics to manage.

That is why the warehouse was divided into 2 parts, the one closest to the I/O point for B2B products (available for B2B and B2C customers), the items from class A, whereas in the back part of the warehouse are located the products exclusively reserved for B2C customers, the items from classes B, C and D.

Finally, the last axis of improvement was the picking strategy. Once again different strategies were tested and timed to assess the potential of each of those techniques. The optimal strategy was a combination of two strategies: cluster picking and wave picking. Cluster picking allows the picking of several orders at the same time by arranging the SKUs directly in an individual container, according to the order (by opposition to the batch picking). With this strategy, the time spent on picking increases slightly (compared to the batch picking), but the time spent on packaging at the I/O point is reduced considerably.

With wave picking, different windows of preparation of orders were scheduled, according to the type of order (B2B or B2C orders) and the method of delivery (by post, by bike, etc.). Firstly, all the B2B orders were prepared (all delivered by post) then the B2C orders, depending on the delivery method.

In conclusion, the results of those improvements of the flows in the warehouse were calculated from a time and financial points of view. In terms of time, the saving was 4.5 hours per month (from 19 hours dedicated to order preparation to 14.5 hours). Financially, this gain was 70€ per month (from 298,5€ to 227,8€) or annually, a saving of 840€.

All the data's collected during this thesis stop in April 2020, with the end of my internship. From then on, I no longer had access to the company's internal data. Nevertheless, at the beginning of August 2020, Jean, the manager of Kami Basics, kept me informed of the company's financial situation. The turnover rose to €30,000 per month in June and July and the same trend is shaping up for August. This increase is partly due to improved logistics in the warehouse: the lead time for certain orders is reduced; the storage area has increased, then more products can be stored and therefore there are fewer out-of-stocks; order preparation time has been reduced, then more time is spent on adding new products and suppliers. All these improvements help to strengthen ties with customers and maintain them.

****

From a personal point of view, this thesis was really enriching and allowed me, in addition to my internship, to learn new things and deepen my knowledge on a subject I was already somewhat familiar with, thanks to my master's degree in supply chain management. This thesis allows me to confront my academic knowledge with the reality of the field. I mainly developed my knowledge about the different ways of picking in a warehouse, as well as the different methods and strategies for storing products.

Moreover, I feel that I have developed, throughout the writing of this thesis, various personal skills. In particular, the management of a long-term work, which a priori seemed almost impossible. However, with a good management, a planning and a clear timetable of milestones to be achieved, it seemed much more achievable.

Indirectly, this thesis also allowed me to develop and improve many soft skills such as autonomy and sense of responsibility within the warehouse management. I also feel that I have developed skills through the research activity, such as interpersonal skills (adaptability, collaborative work), as well as professional qualities (writing skills, expertise related to the management of a warehouse).

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Appendix

Appendix 1.1

Mean and Standard Deviation			
Month	**X**	**$\bar{x}$**	**$\sum(X-\bar{x})^2$**
oct-18	8	62,4	2955,9
nov-18	55	62,4	54,3
déc-18	72	62,4	92,8
janv-19	45	62,4	301,7
févr-19	35	62,4	749,0
mars-19	53	62,4	87,8
avr-19	51	62,4	129,2
mai-19	52	62,4	107,5
juin-19	49	62,4	178,7
juil-19	79	62,4	276,6
août-19	88	62,4	657,0
sept-19	59	62,4	11,3
oct-19	54	62,4	70,0
nov-19	77	62,4	214,1
déc-19	126	62,4	4049,0
janv-20	44	62,4	337,4
févr-20	32	62,4	922,2
mars-20	57	62,4	28,8
avr-20	149	62,4	7505,0
TOTAL	**1185**		**18728,4**
$S^2 = \sum(X-\bar{x})^2/n$	985,7		
$S = sqrt(\sum(X-\bar{x})^2/n)$	31,4		

Appendix 1.2

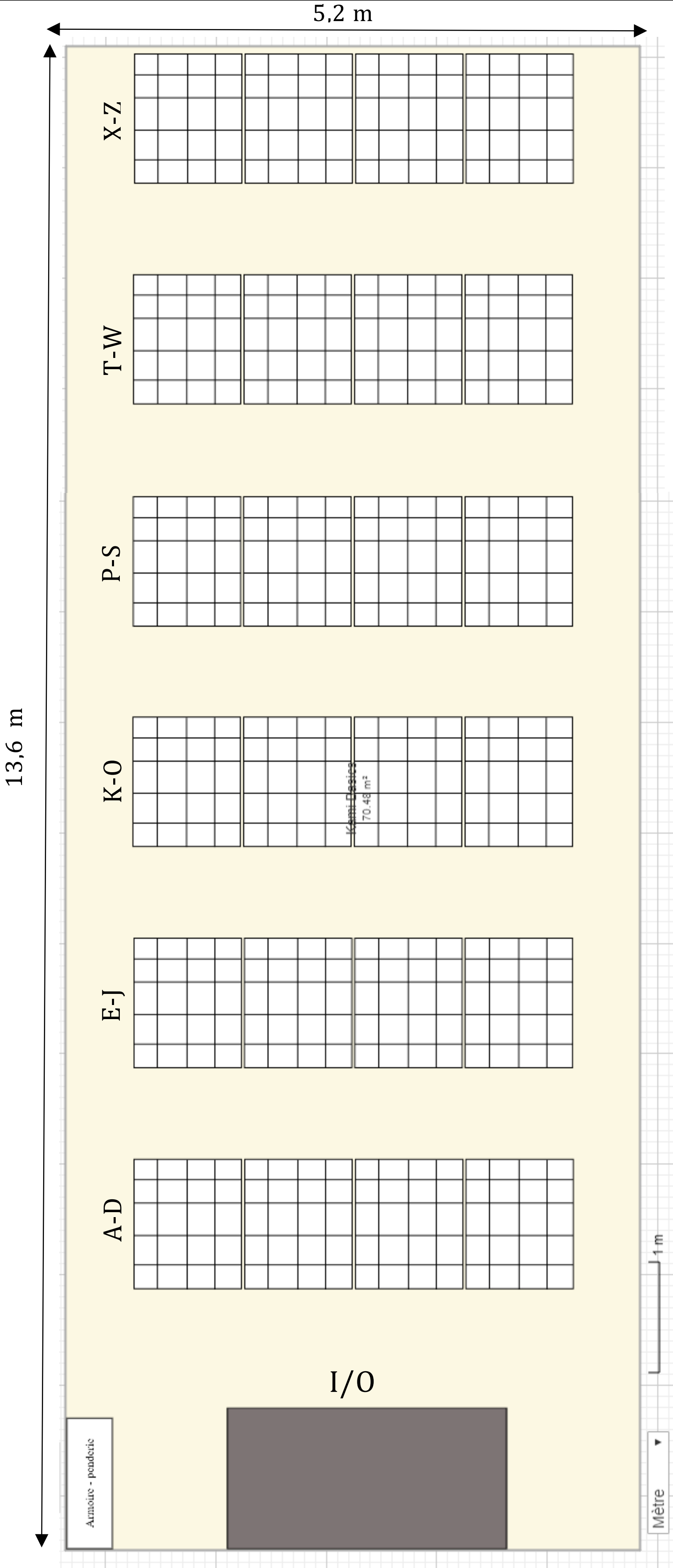
Brussels (61,6%)	694	Belgium (95%)	1126	World	1185
Bruxelles	167	Bruxelles	694	BE	1126
Schaerbeek	90	Brabant Wallon	74	FR	39
Etterbeek	59	Brabant Flamand	82	NL	8
Ixelles	83	Hainaut	71	GB	4
Saint-Gilles	28	Luxembourg	7	DE	2
Anderlecht	38	Namur	34	Others	6
Molenbeek	15	Liège	57		
Koekelberg	10	Limbourg	10		
Berchem	3	Flandre Orientale	26		
Ganshoren	6	Flandre Occidentale	25		
Jette	7	Anvers	46		
Evere	7				
Woluwe-Saint-Pierre	28	**Flandre (43,7%)**	189		
Auderghem	24	**Wallonie (56,3%)**	243		
Watermael-Boitsfort	15				
Uccle	28				
Forest	27				
Woluwe-Saint-Lambert	55				
Saint-Josse	4				

Appendix 1.3

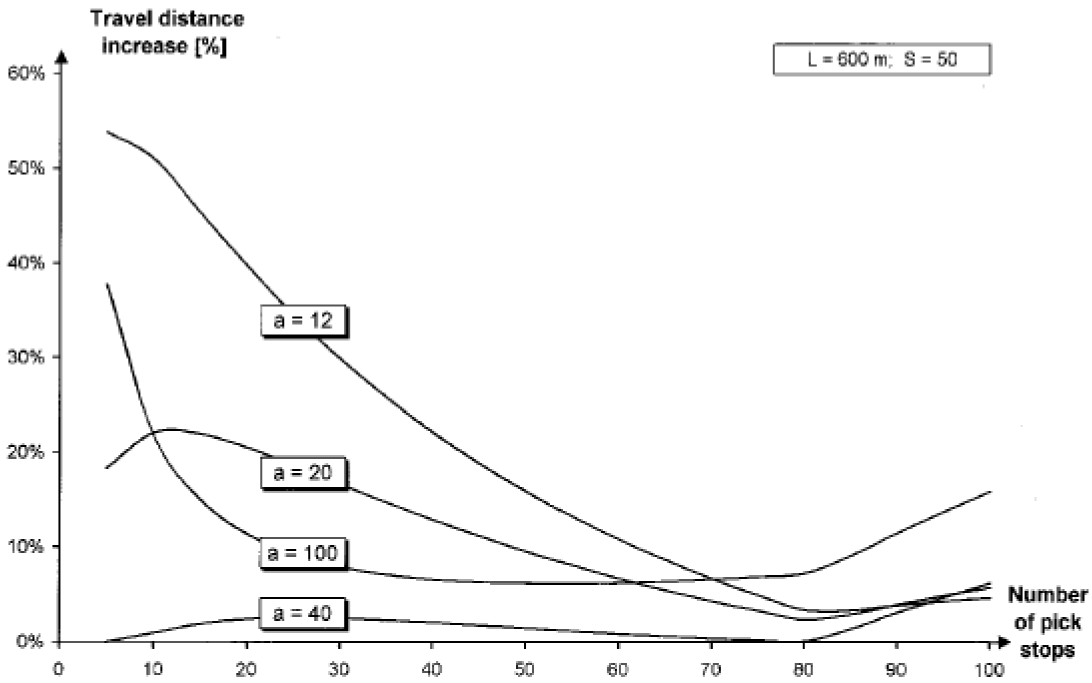
Month	Nb Orders	Turnover	B2C Turnover	B2B Turnover
oct-18	8	837,19 €	255,29 €	581,90 €
nov-18	55	3 433,67 €	1 845,17 €	1 588,50 €
déc-18	72	2 769,16 €	2 769,16 €	0,00 €
janv-19	45	2 063,99 €	1 259,99 €	804,00 €
févr-19	35	2 444,50 €	816,00 €	1 628,50 €
mars-19	53	6 553,42 €	1 611,45 €	4 941,97 €
avr-19	51	7 950,46 €	1 548,11 €	6 402,35 €
mai-19	52	4 414,47 €	1 658,04 €	2 756,43 €
juin-19	49	3 694,79 €	1 887,86 €	1 806,93 €
juil-19	79	8 198,14 €	5 442,67 €	2 755,47 €
août-19	88	10 458,64 €	2 322,45 €	8 136,19 €
sept-19	59	8 533,53 €	1 628,85 €	6 904,68 €
oct-19	54	7 335,23 €	2 104,71 €	5 230,52 €
nov-19	77	16 729,73 €	6 252,54 €	10 477,19 €
déc-19	126	15 344,18 €	10 941,83 €	4 402,35 €
janv-20	44	7 369,36 €	1 108,27 €	6 261,09 €
févr-20	32	5 751,77 €	885,31 €	4 866,46 €
mars-20	57	6 822,20 €	1 705,87 €	5 116,33 €
avr-20	149	8 032,14 €	5 353,19 €	2 678,95 €
TOTAL	**1185**	**128 736,57 €**	**51 396,76 €**	**77 339,81 €**

Appendix 2

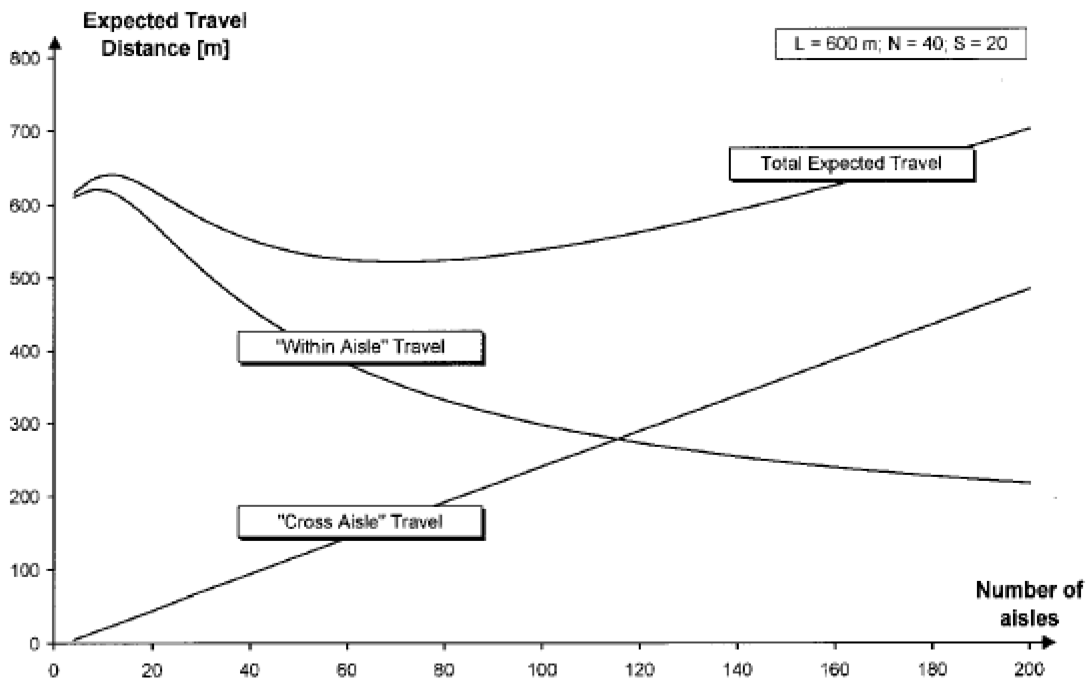
Appendix 3



Appendix 4

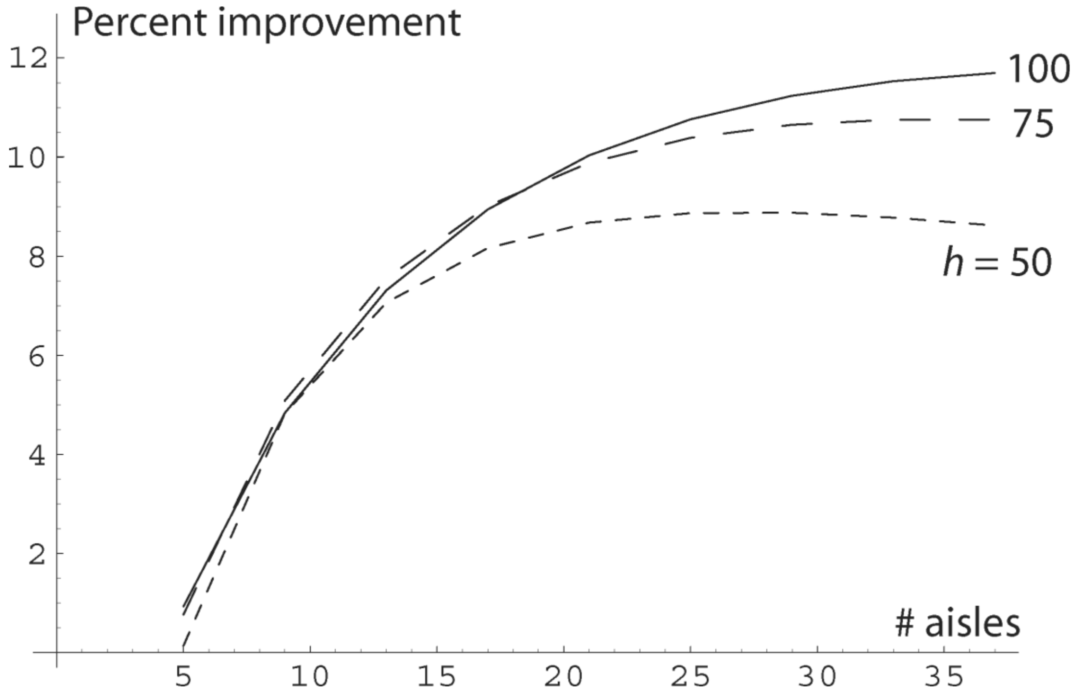


Percentage increase in picking travel distance with respect to the optimal solution for varying values of *N* resulting from the adoption of 12, 20, 40 and 100 aisles (*L* - 600m; *S* - 50).
Source: Caron et al (2000)

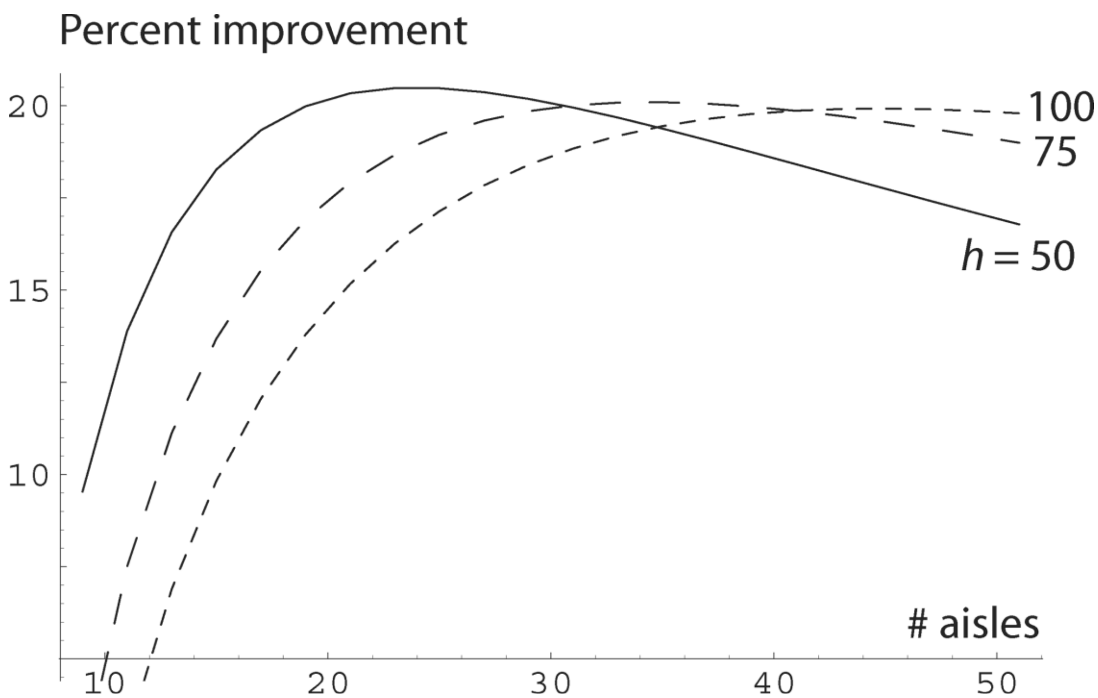


Expected travel distance per tour as a function of the number of aisles (*L* - 600 m; *N* - 40 picks; *S* - 20, i.e. random storage).
Source: Caron et al (2000)

Appendix 5

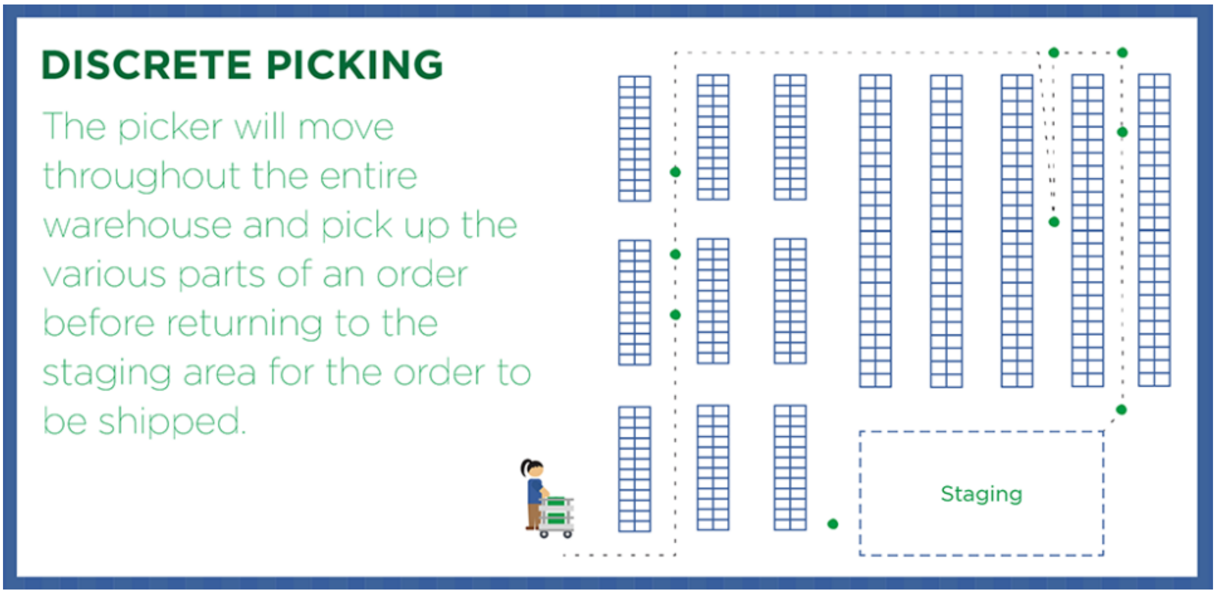


Percent improvement for warehouses with a Flying-V cross aisle, compared to a traditional warehouse.
Source: Gue and Meller (2009)



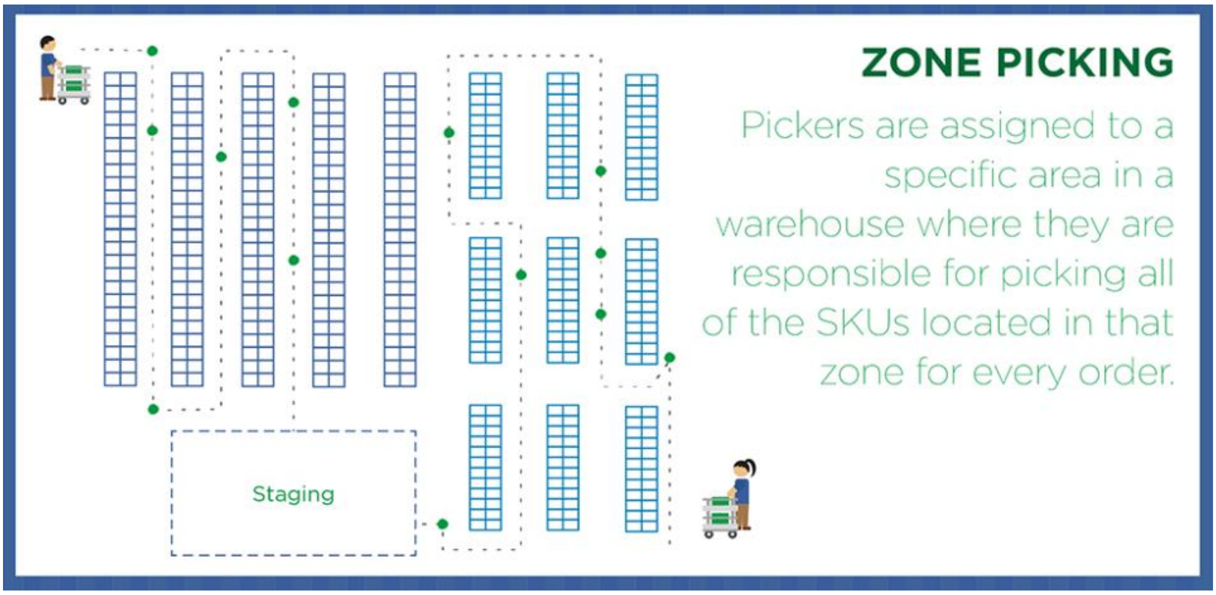
Percent improvement of a fishbone aisle design over a traditional design for several configurations.
Source: Gue and Meller (2009)

Appendix 6.1



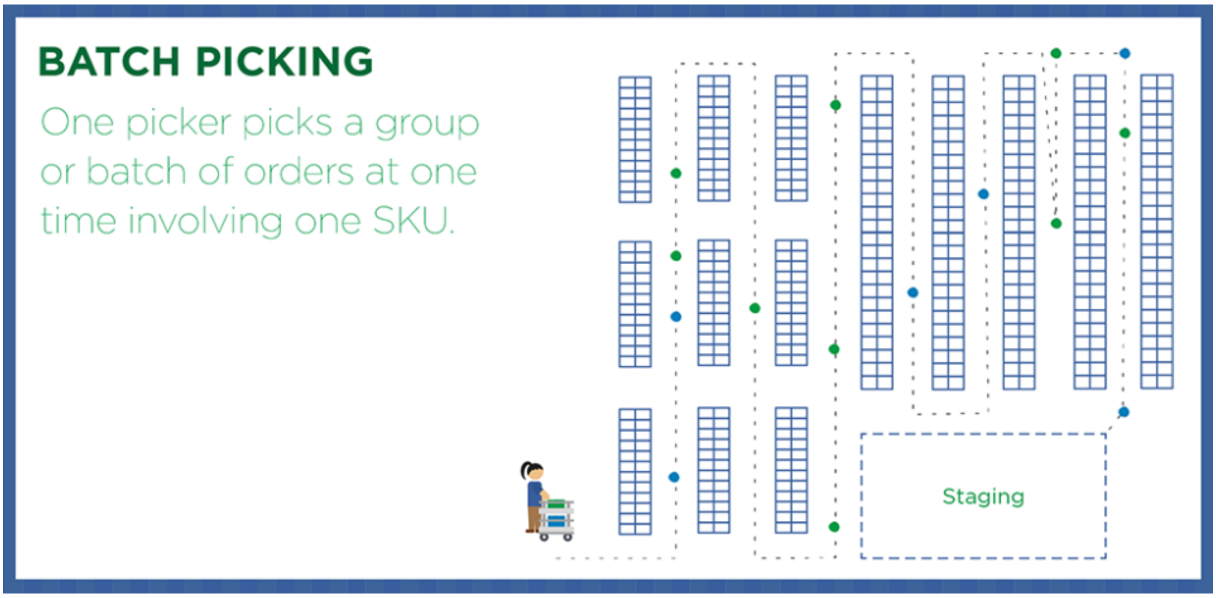
Source: Lucas Systems

Appendix 6.2



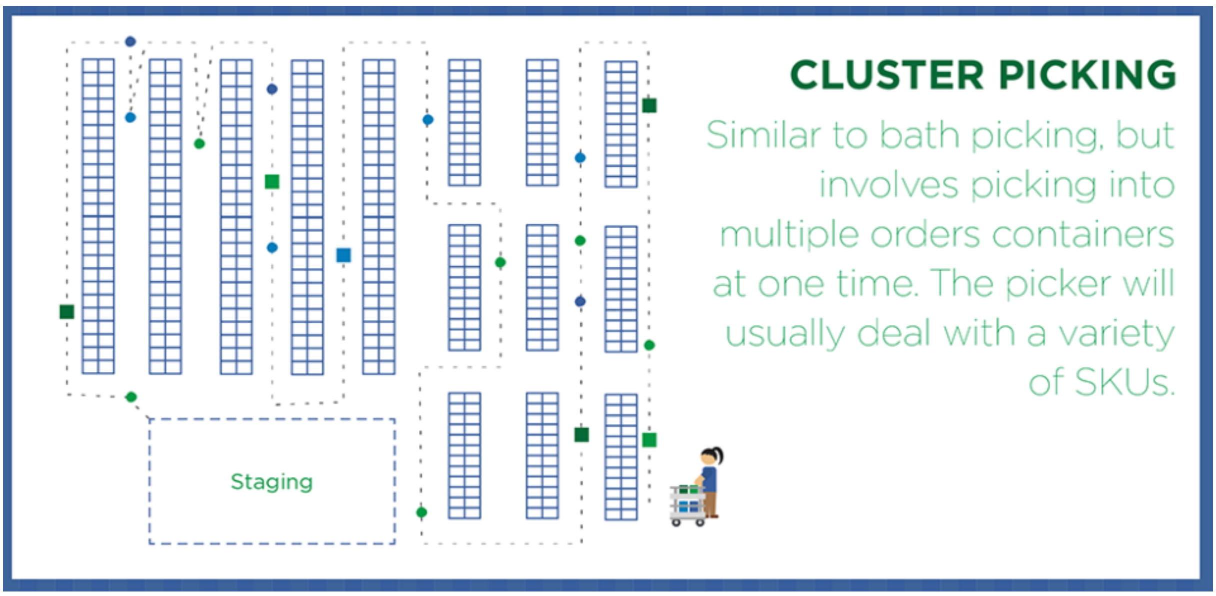
Source: Lucas Systems

Appendix 6.3



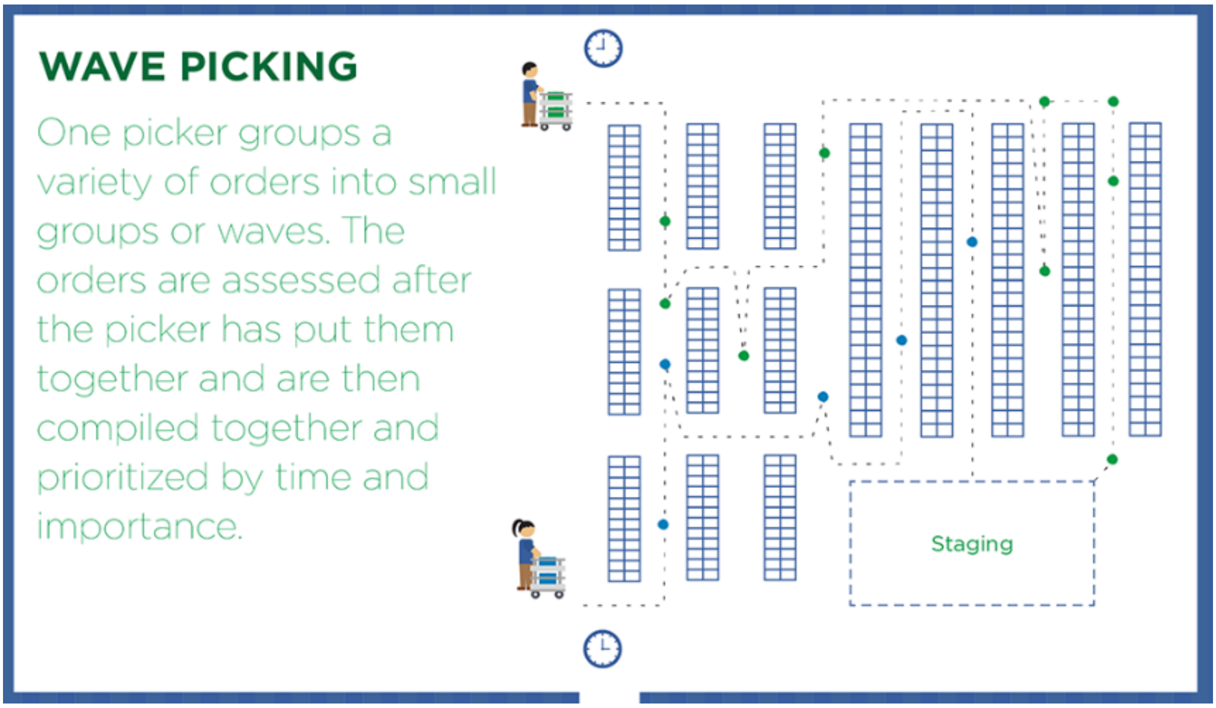
Source: Lucas Systems

Appendix 6.4



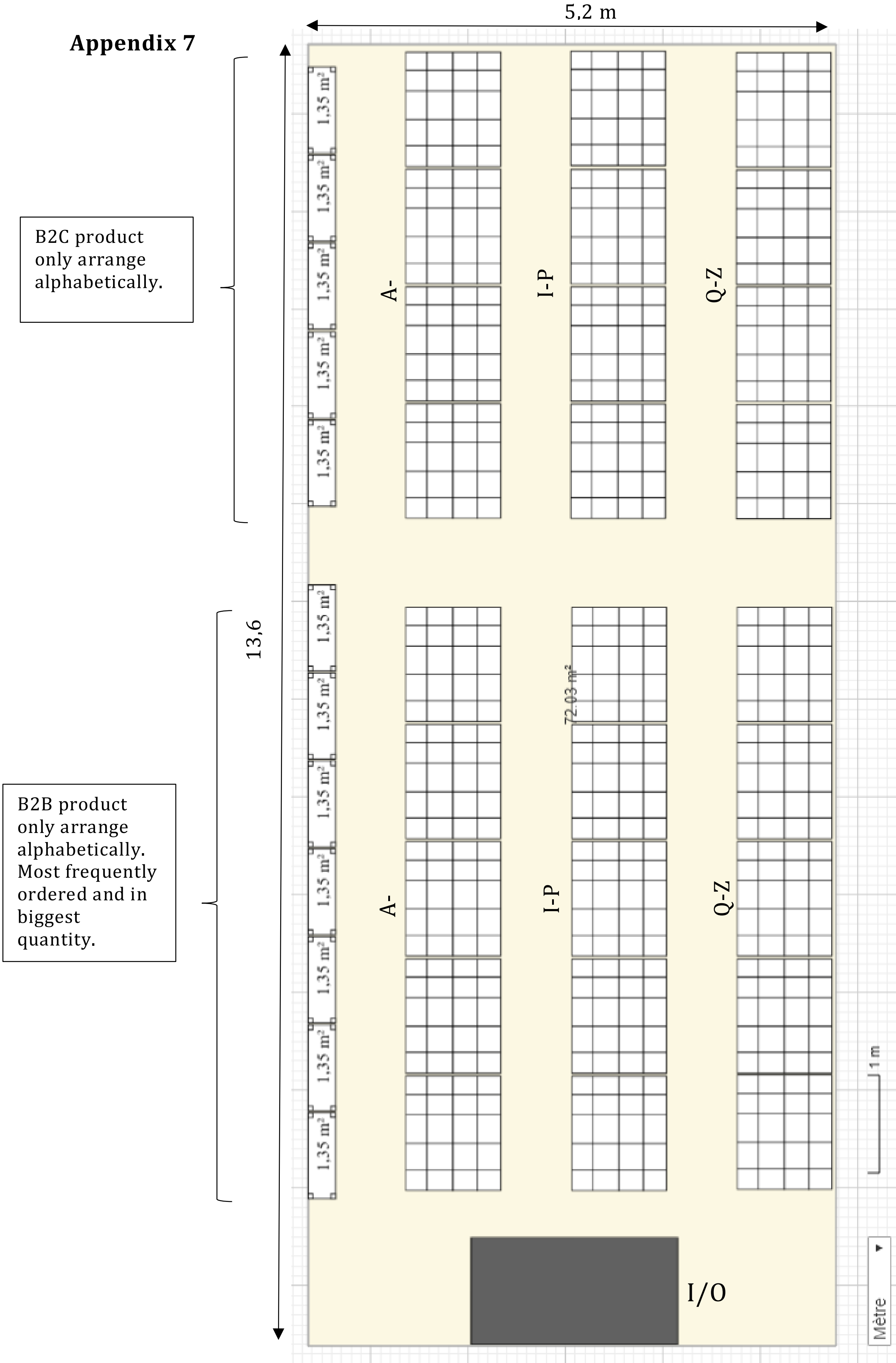
Source: Lucas Systems

Appendix 6.5



Source: Lucas Systems

Appendix 7

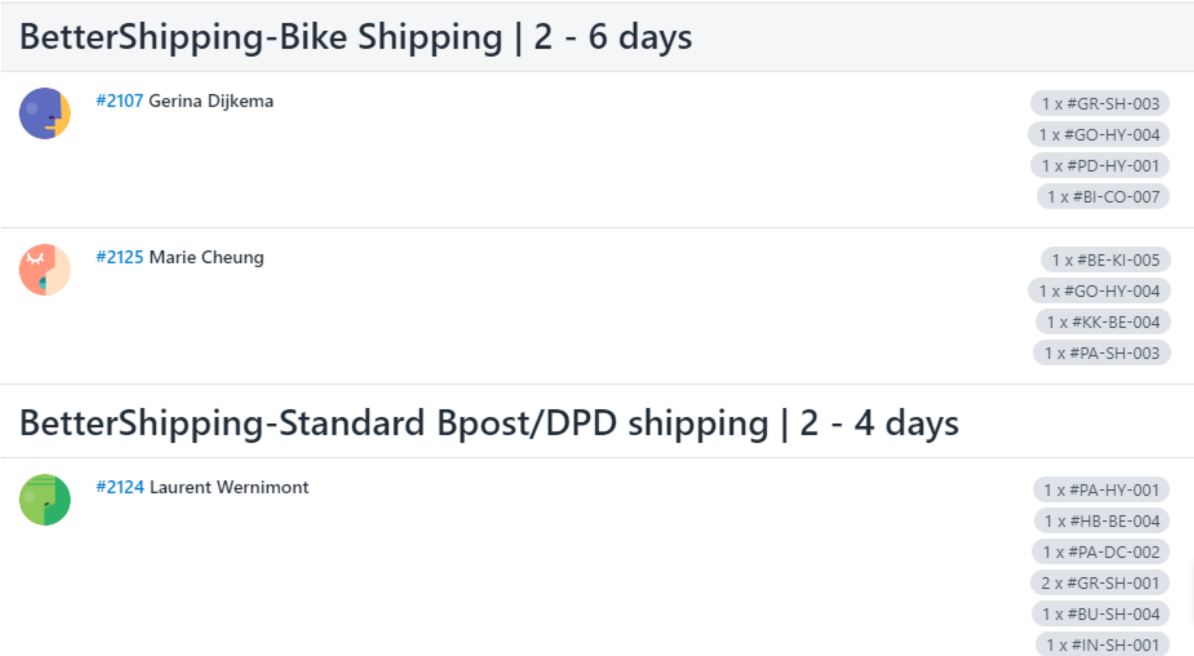

5,2 m
13,6
B2C product only arrange alphabetically.
B2B product only arrange alphabetically. Most frequently ordered and in biggest quantity.
1,35 m²
A-
I-P
Q-Z
72,03 m²
I/O
1 m
Mètre

Appendix 8

Monetary Rotation for Last Year	Pourcentage	Pourcentage cumulé	Classification ABC	Furnisher Code
€196,56	0,24%	77,70%	Classe A	BA
€194,88	0,24%	77,94%	Classe A	SE
€192,00	0,24%	78,18%	Classe A	BL
€190,80	0,24%	78,41%	Classe A	LA
€187,53	0,23%	78,65%	Classe A	BA
€183,16	0,23%	78,87%	Classe A	GR
€180,00	0,22%	79,10%	Classe A	NA
€179,44	0,22%	79,32%	Classe A	BO
€177,32	0,22%	79,54%	Classe A	DR
€176,96	0,22%	79,76%	Classe A	IN
€176,88	0,22%	79,98%	Classe A	BE
€176,61	0,22%	80,19%	Classe B	SE
€175,50	0,22%	80,41%	Classe B	TI
€175,50	0,22%	80,63%	Classe B	BI
€175,11	0,22%	80,85%	Classe B	EL
€171,43	0,21%	81,06%	Classe B	IN
€159,90	0,20%	81,26%	Classe B	PA
€159,60	0,20%	81,45%	Classe B	KK

Appendix 9

Application used to help us making the pick list for the orders according to the method of delivery.



Appendix 10

Monthly Kami Basics Warehouse Cost Before/After Improvements											
Fixed Costs											
Storage cost	1,67€/m^2	116,67 €									
TOTAL		**116,67 €**									
Variable Costs											
		Before the improvements			**After the improvements**			**Variation Before/After**			
	H. wage	**Duration (1 parcel)**	**Costs (1 parcel)**	**Average**	**Duration (1 parcel)**	**Costs (1 parcel)**	**Average**	**Variation (%)**	**Variation (min)**	**Variation (€) 1 parcel**	**Variation (€) Average**
Inbound costs	**15,71 €**			**5 parcels**			**5 parcels**				**5 parcels**
Count products		9 min	2,36 €	11,78 €	9 min	2,36 €	11,78 €	0 %	0	0,00 €	0,00 €
Check products		9 min	2,36 €	11,78 €	9 min	2,36 €	11,78 €	0 %	0	0,00 €	0,00 €
Store products		30 min	7,86 €	39,28 €	18 min	4,71 €	23,57 €	- 40%	- 12 min	-3,14 €	-15,71 €
Administration cost		12 min	3,14 €	15,71 €	12 min	3,14 €	15,71 €	0 %	0	0,00 €	0,00 €
Total Inbound Costs or Variation		**60 min**	**15,71 €**	**78,55 €**	**48 min**	**12,57 €**	**62,84 €**	**-20%**	**- 12 min**	**-3,14 €**	**-15,71 €**
Outbound costs	**15,71 €**			**70 parcels**			**70 parcels**				**70 parcels**
Administration cost		3 min	0,79 €	54,99 €	2min 24s	0,63 €	43,99 €	-20 %	- 0min 36s	-0,16 €	-11,00 €
Picking costs		6 min	1,57 €	109,97 €	3min 54s	1,02 €	71,48 €	- 35 %	- 2min 6s	-0,55 €	-38,49 €
Packaging costs		3 min	0,79 €	54,99 €	2min 42s	0,71 €	49,49 €	- 10 %	- 0 min 18s	-0,08 €	-5,50 €
Total Outbound Costs or Variation		**12 min**	**3,14 €**	**219,94 €**	**9 min**	**2,36 €**	**164,96 €**	**-25 %**	**- 3 min**	**-0,79 €**	**-54,99 €**

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