Double Degree Master Thesis:

Spare parts inventory management: a structured method to improve the overall performance
A study of Drake & Farrell

Supervisor:

Professor Alessandro Zattoni

Co-supervisor:

Professor Federica Brunetta

Candidate:

Chiara Belfiore

Academic year 2018/2019

TABLE OF CONTENTS

TABLE OF FIGURES

MANAGEMENT SUMMARY

Purpose – The purpose of this research thesis is to present an efficient inventory control tool that can ensure an optimized spare parts inventory management. By means of this tool, a reverse logistics company would be able to reduce most of the inventory costs and increase its overall performance. In light of this, it will be necessary to define a literature framework in which the problems, inefficiencies and high costs of a reverse logistics company related to inventory management will be analyzed and how these can be solved. In order to prove what is deduced in the theoretical framework, the case of Drake & Farrell, a reverse logistics provider located in Bleiswijk (NL), has been investigated. Interviews conducted with company's managers and employees showed that current inventory management is inefficient and costly. In this regard, in the theoretical framework it has been analyzed a method that allows to carry out an optimal inventory control: it consists of the classification of spare parts into different classes according to different parameters. From the analysis of this specific case it will then be possible to draw a broad conclusion applicable to similar fashion reverse logistics companies or organizations that encounter the same problems. In that way, an exhaustive answer to the following research question will be outlined: *How could a company be more efficient in the spare parts inventory management achieving an optimal control and an overall cost reduction?*

Design/ methodology – Semi-structured interviews based on the literature and on the problem identification were conducted in the Netherlands, to the managers and employees of Drake & Farrell. The results of the interviews as well as all the company documents and reports are used to form the empirical findings.

Findings – The results revealed that Drake & Farrell's inventory management is inefficient. The main problem is caused by the high costs incurred by the company due to the high stock levels to be maintained. The company adopts a single replacement policy of all spare parts, often having many stocks that are subject to obsolescence. This reveals the lack of a classification tool that allows to distinguish spare parts into different classes and to adopt different reordering policies based on the class to which they belong.

Research limitations – A limitation of this study concerns the lack of a detailed analysis of all inventory costs. Moreover, a recommendation for future research is to focus on the real impact that the spare parts classification tool could have on overall costs and performance.

1. INTRODUCTION

This introductory chapter presents the theme of the research. The first section describes the background of the problem. The second section illustrates the research question and the conceptual model. Lastly, an overview of the following chapters will be presented.

1.1. Problem identification

Nowadays, many companies focus on efficient and effective inventory management to achieve a distinct competitive advantage and improve their market position (Naliaka et al., 2015). In this regard, the management of inventory plays a major role in the global economy.

As stated by Prempeh (2015), inventory management is a fundamental asset of the company with an economic value. Better inventory management can ensure high growth and profitability.

Effective and optimal inventory management helps companies to define the perfect reordering policy for each type of stock-keeping unit, and to reduce various costs such as the holding cost, reordering cost, and shortage cost that occurs in the event of stock out (Singh et al., 2011).

"*Inventory management is the art and science of maintaining stock levels of a given group of items incurring the least cost consistent with other relevant targets and objectives set by management*" (Jessop, 1999).

Efficient inventory management is a main goal for both traditional or forward companies and for reverse logistics providers. Controlling and optimally managing the inventory in reverse logistics becomes complicated due to high uncertainties with regard to returned parts and products. In these companies, the collection of returned products is driven by supply rather than market demand. Therefore, as it cannot be controlled directly by the company, high uncertainties arise in terms of quality, time and quantity of returned products (Tomašić et al., 2013).

This element of uncertainty that characterizes reverse logistics companies makes inventory management even more complicated (Tomašić et al., 2013). Once the different old products and parts have been returned, these companies start a process of recovery of the asset, which can include the purchase of new parts in the event that the old ones are broken, damaged or no longer usable. A related problem is to ensure an efficient reordering policy of new spare parts, as it is difficult to decide how many new parts the companies will have to order, which parts they will have to order and how often to place the order for each part.

Often, companies face a trade-off between maintaining low levels of stock or high levels of stock in inventory. The first option is to buy only when necessary, which means low costs but

high risks in the event of a lack of stock. The second option is to hold high stock levels with high costs (high ordering costs, more inventory, more storage costs, high obsolescence, high working capital) but with a low risk of stock out (Slack et al., 2010).
To address this problem and to ensure optimal inventory management, companies should adopt different reordering policies for different classes of spare parts in order to keep low inventory levels while guaranteeing high efficiency and effectiveness.
"*The optimal inventory control methodologies intend to reduce the supply chain cost by controlling the inventory in an effective manner*" (Singh et al., 2011).
"*Optimal supply of spare parts (…) can be maintained only with quality planning, management and selection of decision criteria that management provides as a basis for managing business processes for supply optimization*" (Tomašić et al., 2013).
An optimal methodology to ensure efficient management of the spare parts inventory is the implementation of a classification tool. This allows to classify and distinguish all spare parts in different categories according to specific characteristics in order to adopt different strategic behaviors for each class. This tool has proven to be useful in order to address the described problems, so that companies can be able to reduce costs and inefficiencies, thereby achieving an overall improved performance.

Based on the foregoing and in order to demonstrate it, the case of Drake & Farrell has been examined, as it fits perfectly with the aim of this research. In fact, this company is one of the leading experts in reverse logistics but, above all, it is a company that is currently facing major problems and inefficiencies related to the management of spare parts inventory.
In this regard, Drake & Farrell is a leading Dutch third-party logistics provider based in Bleiswijk (NL), which cooperates with major consumer goods companies to improve their logistics processes. The company's business units are:

- Product lifecycle solutions: the aim of this activity is to deal with product returns in order to maximize the recovered product revenue, collect and handle product returns, combine usable and new parts into a new product, and dispose of unusable parts.
- Procurement and storage management: organizing their customers' inventories, preparing and shipping orders.
- Value-added logistics: managing inbound and outbound shipments and their handling, quality control, repackaging and repairs.
- Other solutions tailored to specific problems.

As for the first business unit, Drake & Farrell acts as a *third-party reverse logistics provider*[1]. Its main B2B customers are television services and telecom providers such as KPN, the largest telecommunications company in the Netherlands[2].

Figure 1: example of products of the first business unit (source: Drake & Farrell's website)

Drake & Farrell manages KPN's customer returns for routers and remote controls. After obtaining the different used parts and products directly from KPN's customers, the company assesses which parts are reusable and which ones should be disposed of. If these reusable parts are not enough to complete the final device, the reverse logistics company must purchase the remaining parts (the company is fully dependent on KPN which has a direct contract with a Chinese manufacturer: when Drake & Farrell needs new spare parts, it sends a request to KPN which places the order with the manufacturer).

In this way, two different spare-parts flows are generated: the first comes from the harvesting process and is characterized by a high uncertainty of the returned products in terms of quantity and quality, while the second flow derives from the purchasing process.

The high uncertainty in the return of products that characterizes the reverse logistics process, causes difficulties in inventory management. Since the company does not know the exact type, the quantity and the quality of the old products in advance, the whole process of inventory management becomes more complicated. This has considerable effects on inventory levels and costs incurred by the company.

---

[1] In order to reach efficiency and major flexibility, some organizations decide to outsource their reverse logistics activities to third-party reverse logistics providers (3PRLPs) that directly collaborate with traditional companies from which they receive end-of-use or end-of-life products (Murali et al., 2011).

[2] Source: KPN website

Drake & Farrell adopts an inventory policy of "MIN and MAX" whose levels are established based on past performance. When the quantity of stock drops below a certain level, Drake & Farrell automatically orders a certain quantity of new spare parts. However, given the uncertainty about the quality of incoming products and to avoid stock out and therefore to guarantee a high service level, the company always orders a large number of new pieces in order to ensure enough stock in inventory. The main problem is that this is done by applying a general and unique reordering policy, without differentiating between different spare parts and therefore without taking into account the rotation of the components and their consumption value. This process leads to several negative consequences: - high inventory levels; - relevant storage cost and inventory cost; - high product obsolescence given the high technological content of the products.
Although Drake & Farrell has a high-performance indicator, that is a high service level, it does not use efficient inventory management tools that would allow it to maintain low stock levels with consequent lower costs.

The above brief summary is useful as it provides a theoretical background that can support the focal point of this research thesis. The aim is to analyze and examine in detail how a company can ensure efficient and optimal management of the spare parts inventory thus obtaining several benefits and economic advantages. In light of the above, a structured method that can help a company to improve its overall performance consist of the implementation of tools for the classification of spare parts into different classes. This allows the company to customize its ordering policy and to behave differently for each category of spare parts, leading to lower overstock and thus achieve cost reductions, a much more efficient management system and improved overall performance. In light of this, the theoretical framework will provide a clearer understanding of the methods and tools of classification and the benefits associated with it.

1.2. Research question

Based on the information described and explained in the problem identification, the following research question is created:

How could a company be more efficient in the spare parts inventory management achieving an optimal control and an overall cost reduction?

In order to provide a concrete and comprehensive answer to the research question, a case study analysis was carried out. Analyzing a phenomenon through a specific case is beneficial because it allows a much deeper, truthful and detailed investigation to be carried out. It also makes it possible to demonstrate what can be deduced from the theoretical framework. Through the implications of this study, it will be possible to draw a broader conclusion. Specifically, it will be possible to demonstrate how a tool for the classification of spare parts and inventory management can solve inefficiencies and ensure better overall performance.

In order to achieve this solution, the literary framework will initially introduce the concept of reverse logistics and how the problems associated with it affect inventory management. In this regard, all the high costs that derive from inefficient inventory management will be analyzed. The spare parts inventory with all related policies and indicators will then be analyzed. Lastly, to answer the research question, an important inventory management tool will be introduced that allows companies to classify spare parts into different classes and thus to adopt different reordering policies and strategies for each type of stock.

1.3. Conceptual model

The issue that many companies face, such as the case of Drake & Farrell as described in the problem identification, can be conceptualized. For this reason, a conceptual model is created which is useful to study the problem in depth. Furthermore, this conceptualization is helpful to link the problem with the current theory and literature.

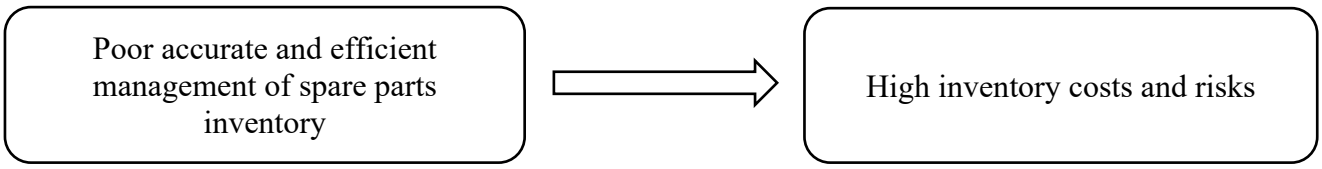

Figure 2: conceptual model

1.4. Thesis outline

The structure of this thesis is organized as follows. This research consists of five main chapters: the first is an introductory chapter that shows the problem identification and the research question.

In the second chapter, the theoretical framework is presented. This is a central section that aims to summarize all the available literature on reverse logistics, spare parts inventory management, the main tools for inventory control, and the resulting economic benefits. More specifically,

the first part presents a general overview of reverse logistics, the uncertainties in the product returns and how uncertainties affect inventory causing some problems in its management. In that section, all the problems and high costs that a company could incur will be analyzed. In the second part of the literature, the main tool that can guarantee an optimal and efficient inventory control will be presented.

The third chapter illustrates the methodology of this research thesis: it includes how the data are collected and analyzed. The fourth chapter shows all the empirical results derived from the study, interviews and data collection.

The last chapter of this research presents the implications, conclusion and gives recommendations for future research. In this section, an answer to the research question is given.

2. THEORETICAL FRAMEWORK

Reverse logistics companies face several problems in the management of their inventory. In the following chapter, a comprehensive review of the theory related to the returned products in reverse logistics and its uncertainties are presented. Later, it is shown how these uncertainties impact inventory management and all the associated costs. Before introducing a tool for efficient inventory management, the spare parts inventory and its related policies are analyzed. At the end, a paragraph is included that illustrates how companies can manage stock levels at lower costs. In this regard, a classification method is presented that allows companies to behave differently depending on the category and therefore to adopt different reordering policies based on the class of spare parts. The literature outlined in this chapter represents the backbone on which to ground all the empirical study.

2.1. Reverse logistics: definition, activities and flows

In recent decades the world scenario has been characterized by several radical changes caused by scarce resources. This has led companies not to focus only on efficiency, but to start considering "*sustainable development and new market opportunities*" (Blumberg, 2004).

An important change at company level has involved the introduction of a new type of function, the so-called Reverse Logistics, as opposed to the traditional or forward supply chain logistics. European Working Group on REVLOG, defined Reverse Logistics as "*the process of planning, implementing and controlling backward flows of raw materials, in-process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal*" (Dekker et al., 2013).

Generally, the products are returned to the company because they are no longer usable or because they are no longer needed. The aim of a reverse logistics provider is to deal with product returns, collect and handle them in order to maximize the recovered product revenue (Bonev, 2012). As stated by Thierry et al. (1995), the goal of that activity is "*to recover as much of the economic (and ecological) value as reasonably possible, thereby reducing the ultimate quantities of waste*".

Several studies have been carried out to define the activities that characterize the reverse logistics. The first scholar interested in this topic is Fleischmann who identifies three phases that make up this reverse channel (Fleischmann et al., 1997): 1. reverse distribution planning (this phase concerns the collection and transport of returned products); 2. inventory management (activity carried out to ensure integration between the flow of returned products and the forward production process); 3. production planning.

In a later study, Fleischmann et al. (2000) identify the general characteristics of a *recovery product network* and they outline the following activities:

- *collection*: collection, transport and storage of used products at suitable collection points;
- *inspection / selection / sorting process*: activities that aim to determine whether the products are actually recoverable and how;
- *disposal*: disposal of products and parts that cannot be recovered for technical or economic issues;
- *re-processing*: it regards the transformation of an old product into a new one and it consists of three phases: *disassembly*, *remanufacturing* / *repair*, *reassembly.*
- *re-distribution*: distribution of the new product to the market.

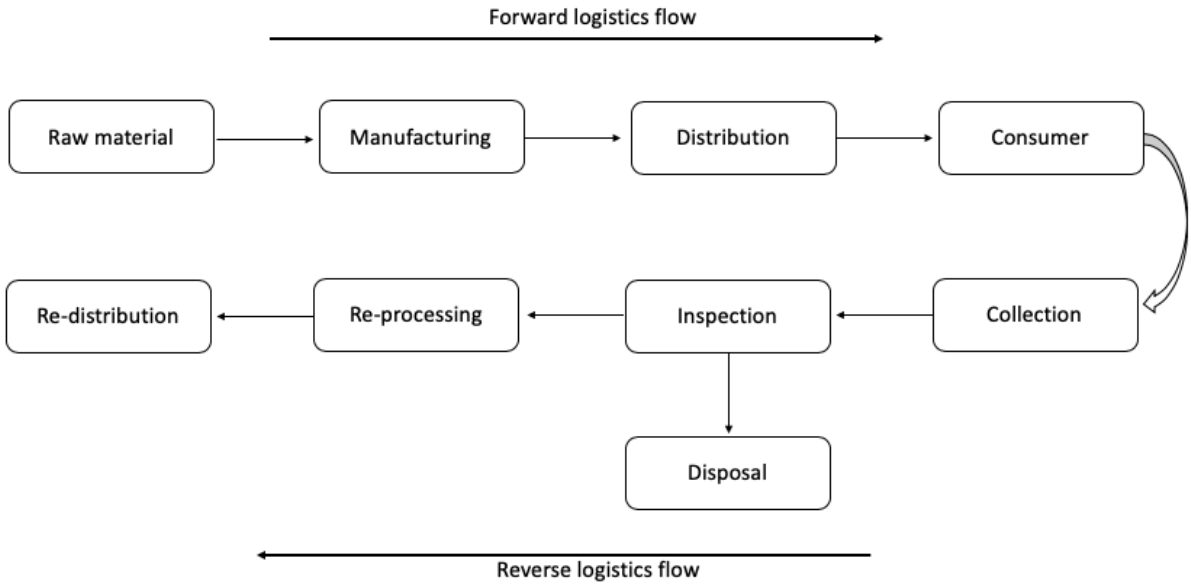

Figure 3: reverse and forward logistics framework (adapted from Fleischmann et al., 2000)

2.1.1. How uncertainties in product returns affect inventory

As stated by De Brito et al. (2004), the importance of reverse logistics providers has increased in the last decades. However, unlike traditional companies, reverse logistics face several problems related to the management of the inventory of returned parts and products. Indeed, a reverse logistics provider is characterized by high uncertainty and little control over the supply side due to returned products. These uncertainties regard the quality status (i.e. the conditions of the goods), the quantity and the timing of product returns (Tomašić et al., 2013).

As stated by Blumberg (2004), these problems related to return flows lead companies to ignore the conditions of the goods as well as when the products will enter the system.

Several researchers have also analyzed the uncertainties that affect reverse logistics companies classifying them into dimensions and groups. As can be seen from the table below, the two main factors that influence both internal and external uncertainties are *time* and *cost*. On the right side, the uncertainties are divided into internal (the ones easily controllable by the company) and external (those that cannot be directly managed).

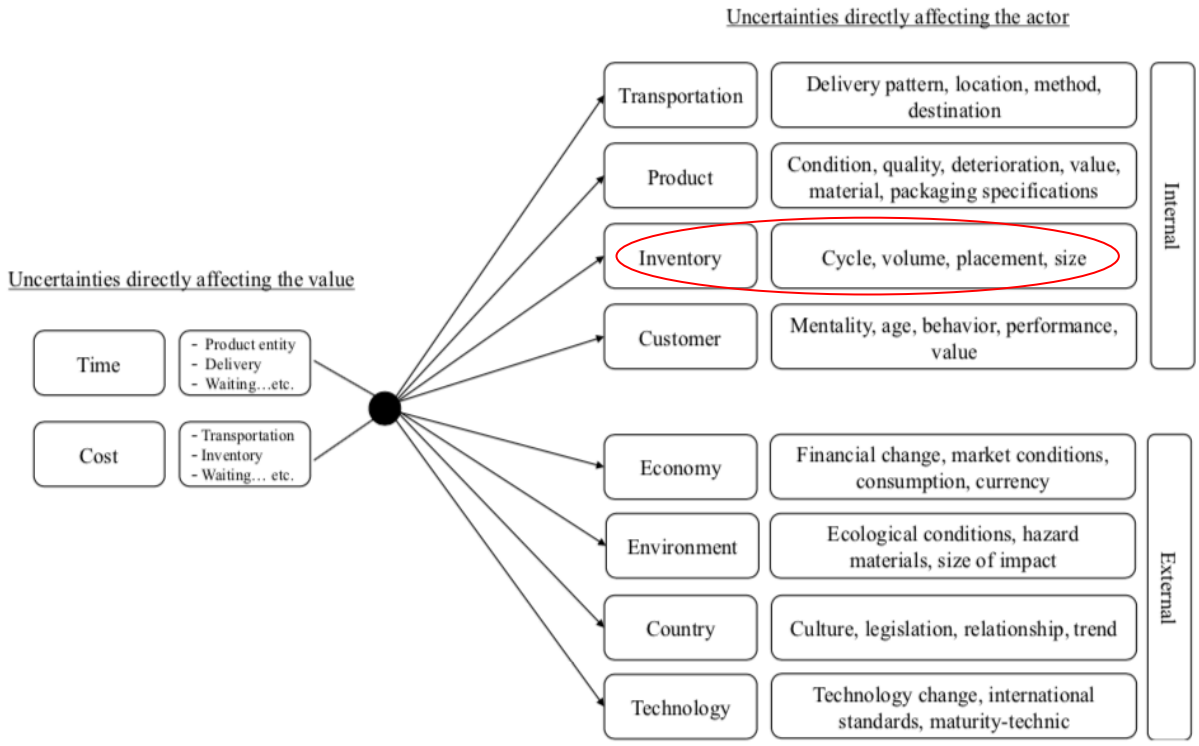

Figure 4: factors of uncertainties (adapted from Bonev, 2012)

As the right side of the figure ("factors of uncertainties") shows, among the various internal uncertainties, there is one relating to the inventory which includes cycle, size and volume problems. Indeed, these high uncertainties in returned parts and products cause many difficulties in the inventory management leading to several problems and high costs.

"*Product returns seriously complicate all processes in the supply chain, in particular inventory decisions. Return flows are often characterized by considerable uncertainty regarding timing and quantity*" (De Brito et al., 2009).

Therefore, the different uncertainties can lead to difficulties in the inventory management and stock levels to be maintained. The reason is that not knowing exactly which products will be returned and in what conditions, causes some complications in the inventory and stock level.

In fact, reverse logistics companies often purchase different types of new spare parts when they are out of stock or when old parts are broken, damaged and therefore no longer reusable. However, this uncertainty factor leads reverse logistics companies to increase the number of new parts purchased frequently and therefore the level of stocks in the warehouse. In this way, the depletion of stocks is avoided and therefore possible interruptions of production are avoided, thus guaranteeing high service levels.
The consequence is that the inventory can increase to undesirable levels. When this inventory becomes too large, there will also be high inventory holding costs.

2.1.2. Costs of inefficient inventory management

From the literature about the impact of uncertainty on the inventory, various problems can be deduced: - the uncertainty of the number of products and their status leads companies to ignore how often to order new parts to complete the production process and which parts to order; - high inventory levels; - high costs.
As pointed out by Slack et al. (2010), the different costs incurred by the company, especially when it has to maintain high levels of inventory, are:

1. *Cost of placing the order*: at the moment the company places an order to supply the inventory, various transactions incur with associated costs. These include all the procurement costs such as the administrative costs related to the management of the orders and the costs of transport.
2. *Maintenance costs*: these include all the costs of preserving the products unaltered in terms of quality and quantity until they are transferred to the production or to the final consumer. This cost covers all the activities carried out in the warehouse and represents the daily management of stocks by the logistics function (Mariano, 2015).
    1. *Storage costs*: these costs include all expenses related to the physical storage of products in stock.
    2. *Obsolescence costs*: when the company orders and maintains high levels of stock in inventory, very often it can incur costs related to a product that becomes obsolete or deteriorates over time. In this case, the item can no longer be used.
    3. *Working capital costs*: these are all investment costs. Since the inventory belongs to the current assets, it directly impacts the working capital: an increase in the inventory leads to an increase in working capital (high financial charges) and vice versa.

To sum up, the uncertainty in the return of products creates some difficulties in choosing the number of new parts the companies will have to order, which parts will have to order and how often to place the order for each part. This leads the company to increase the quantity and level of stock to ensure high service levels while sustaining high costs. "*Too much inventory consumes physical space, creates a financial burden, and increases the possibility of damage, spoilage, and loss*" (Teno et al.).
In addition, management difficulties increase when companies do not use some parameters and indicators to classify spare parts. This leads to inefficiency and ineffectiveness by incurring high costs as described above. In this regard, it becomes necessary to use an optimal and efficient management tool that allows to categorize spare parts in different classes and to behave differently according to the characteristic of each class. In such a way, it would be guaranteed a low level of stocks as well as a relevant saving to the company.

Before analyzing this method in detail, it is necessary to present an overview of spare parts inventory and the various management policies.

2.2. Spare parts inventory: definition

The spare parts inventory management plays a main role in a logistics company. Good and optimal management can lead to high performance and efficiency (i.e. reduction of lead time, adequate stock level without fluctuations, low inventory space and low product obsolescence). Do Rego et al. (2011), defined the role of SPI claiming that "*spare parts inventory is needed for maintenance and repair of final products, vehicles, industrial machines and equipment*". Indeed, this type of inventory is useful to ensure a quick and easy replacement in case of lack of spare parts or failed components.
In their study, Driessen et al. (2015) distinguished two main typologies of spare parts: • repairable spare parts (spare parts that can be refurbished economically or technically to make them reusable); and • non-repairable spare parts (scrapped parts).
Many authors in literature have analyzed the spare parts inventory and its main difference from other manufacturing inventories.
The contribution of Kennedy et al. (2002) is very important. They made a distinction between the function of three types of inventories: work-in-process, finished product and spare parts inventory. The first aims to reduce the anomalies in the manufacturing flow usually due to "*changes in product mix*"; the second type of inventory has to guarantee a "*source of products for delivery to customers*" and has the function to safeguard in case of variation of lead time or

quality problems. Lastly, as mentioned before, the function of the spare parts inventory is to ensure that there is always the provision and availability of new product parts that can be used in the event of shortages, broken or damaged parts.

2.2.1. Replenishment policies

Companies usually use the general principles of inventory optimization to control and manage their spare parts inventory even though *"the management of spare parts inventory remains a major challenge for many organizations because spare parts have characteristics that differentiate them from other products*" (Huiskonen, 2001). Indeed, while the level of work-in-process and finished product inventories can be modified through "*changing production rates and schedules*", the amount of spare parts kept in inventory depends on the current status and quality of the products and how they are maintained.

The literature on the management and optimization of spare parts inventory classifies two main replenishment policies (they refer to the ordering decisions) in turn divided into two sub-policies.

T :Periodicity / Q :Quantity	Fixe	Variable
Fixe	-	(s,Q)
Variable	(T, S) ; (T,s,S)	(s,S)

Figure 5: replenishment policies in inventory control (Ghorbel et al., 2014)

1. *continuous review policy*: in this case, there is always full knowledge about the stock level. It means that the inventory quantities are constantly tracked, and when these quantities drop below a certain level, the company places new orders. This policy involves more costs, but it provides a real-time update of inventory levels (Fraser, 2019). Moreover, it can be divided into:
    1. *policy (s, Q)*: this policy is characterized by a fixed quantity of supply and a variable reordering periodicity. When the inventory level drops below a certain point, called *s*, the company automatically places an order with a fixed quantity (*Q*).

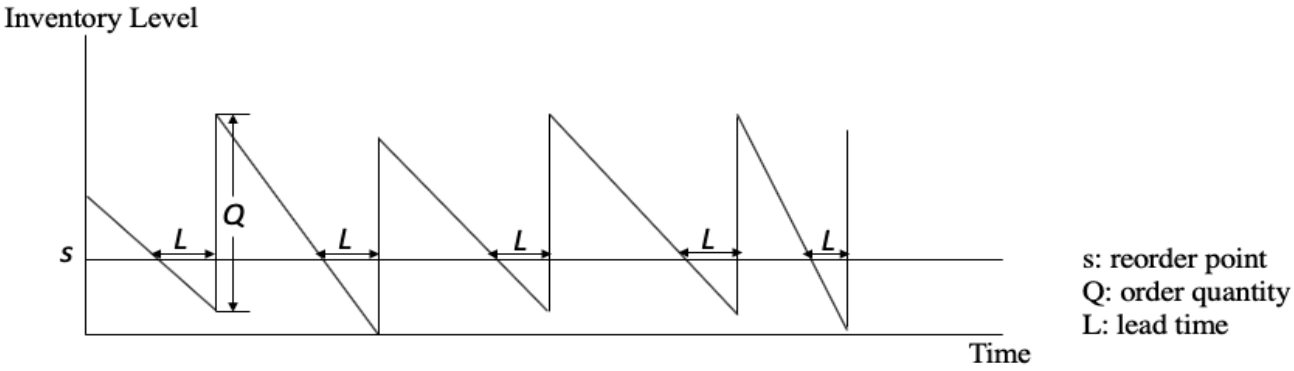

Figure 6: continuous review policy (s, Q) (adapted from Porteus, 2002)

2. *policy (s, S)*: opposite to the previous one, this policy is characterized by a variable quantity of supply and by a variable periodicity of reordering. When the inventory level drops below a certain point, called *s*, the company automatically places an order with variable quantity to bring the inventory up to a given level, *S*. This policy is also called "min and max" method, in which the maximum level corresponds with the order-up-to level.

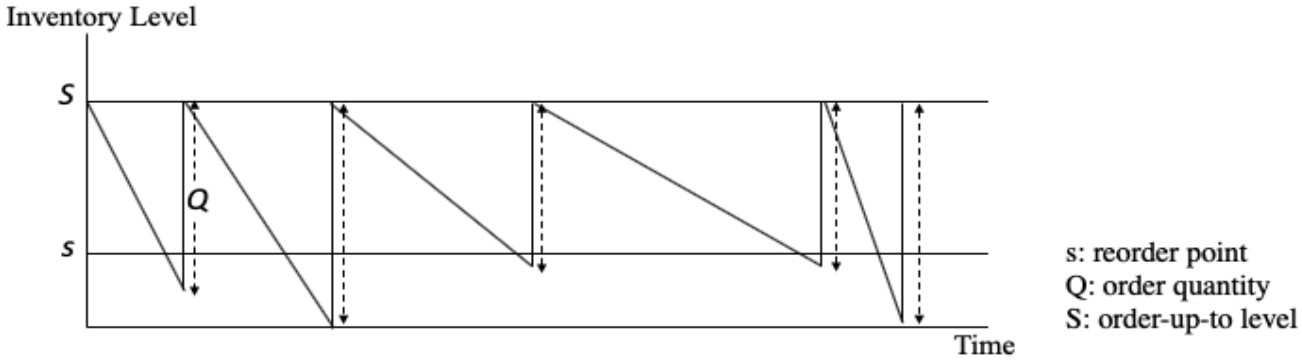

Figure 7: continuous review policy (s, S) (adapted from Sehgal, 2018)

2. *periodic review policy*: the review is performed according to a programmed periodicity. This policy implies that "*the inventory status tracked at specified time intervals, performed periodically, and reorder was made to raise the inventory level to a predetermined point*" (Rizkya et al., 2018). With periodic inventory, at the end of each week or each month, the company counts the level of available stock. So, the calculation takes place at a programmed time. Unlike the previous policy, this is less expensive and simple to conduct, but often turns out to be inaccurate. Two policies belonging to this category are:

1. *policy (T, S)*: the new items are reordered at a fixed time intervals (*T*). At each review, the company places an order of a variable quantity sufficient to bring the inventory up to a given level, *S*.

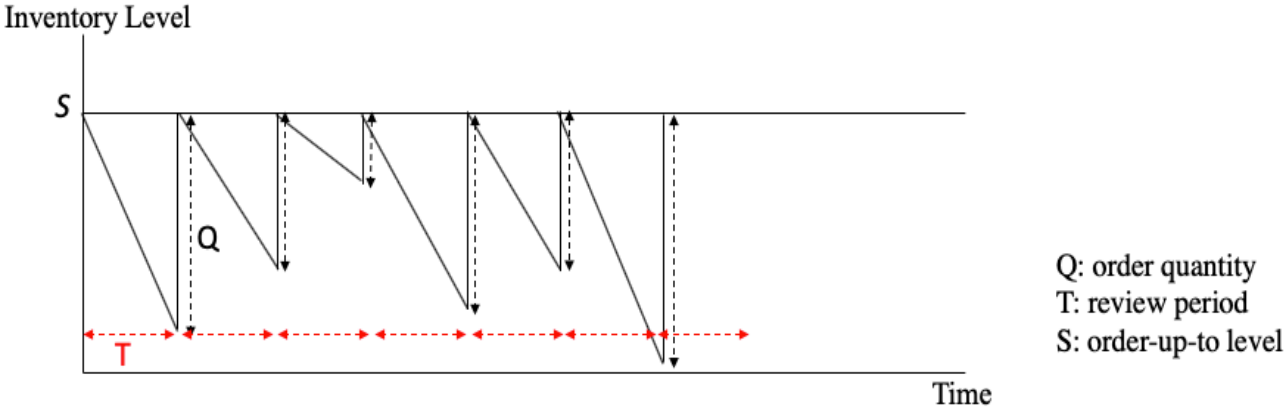

Figure 8: periodic review policy (T, S) (source: the author)

2. *policy (T, s, S)*: in this case, the company always reorders at fixed time intervals (*T*), but if at the time of the review the inventory level has not fallen below the *s* level, no order is placed. On the contrary, if at the moment of the review the current level of the inventory is below the level *s*, the company places an order of a sufficient variable quantity to bring back the inventory to the pre-established level, *S*.

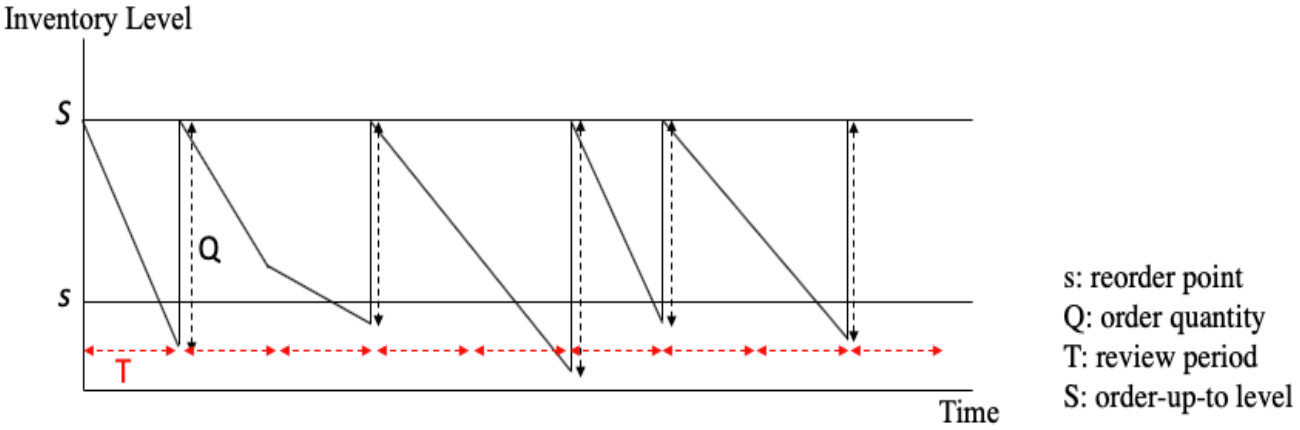

Figure 9: periodic review policy (T, s, S) (adapted from Ghorbel et al., 2014)

The description of the two main inventory policies is presented because in the empirical part (Chapter 4) it will be explained how Drake & Farrell currently manages its spare parts inventory and what reordering policy it uses.

2.2.2. Stock level decisions and service level

Inventory management and control also includes the choice of minimum and maximum stock levels to be maintained: deciding how much stock to have in inventory (Slack et al., 2010). The decision to keep low or high stocks has significant consequences, especially on the service level.

First of all, it is important to present all the advantages and disadvantages related to an inventory decision.

Having a low level of stocks leads to:

- Advantages: lower costs (storage, holding costs), low inventory space, low product obsolescence.
- Disadvantages: high risk of stock-out that leads to low service level (increased likelihood of poor customer service).

Having a high level of stocks leads to:

- Advantages: no risk of stock-out and thus high service level, high responsiveness (easier and more flexible to react to demand variability) (Radasanu, 2016).
- Disadvantages: higher inventory space, higher costs, higher product obsolescence (items could perish or become obsolete), supply chain efficiency reduced due to high costs.

"*High inventory levels are a sign that something is suboptimal in the supply chain, and other strategies such as variability reductions may be more beneficial than inventory increases*" (Minnich et al., 2006).

As already stated, the decision on the stock level to be maintained also impacts the **service level** guaranteed by the company. This is one of the main KPIs that measures effectiveness. "*In inventory management, the service level is the expected probability of not hitting a stock-out during the next replenishment cycle or the probability of not losing sales*" (Radasanu, 2016). It is always expressed in percentage and it can be calculated in several ways depending on the individual goal of the company:

CRITERIA	SERVICE LEVEL FORMULA
Readiness to deliver	Number of quantities delivered on time/ total quantity of the demand
Stock out	Number of quantities delivered/ total quantity of demand
Loss of sales	Value of quantities delivered on time/ value of the total quantity of the demand
Stock out period	Number of days with stockout/ total number of days

Figure 10: service level options (adapted from Hoppe, 2006)

In light of this, companies often face a trade-off between costs and service level (high stocks→ high costs→ high service level, and vice versa) when they have to make decisions about stock levels to be held in inventory.
In order for efficient decisions to be made, it is often necessary to adopt a method of classifying spare parts that allows companies to take different choices based on different types of stock. This leads to: • an optimal and efficient inventory control and management; • avoid wastes in the inventory[3], • a considerable costs reduction, • an overall reduction in the level of stocks, • the optimal purchase for each type of spare parts (Merritt).

2.3. Main tools for inventory control

In order to ensure optimal and efficient control and inventory management, it is very important to adopt a classification tool that allows the company to organize all the stocks in the inventory according to different parameters (Slack et al., 2010).
"*The items classification is an essential part of the inventory management systems, in order to determine the adequate level of managerial attention; allow the choice of inventory control methods; and establish different performance goals at the inventory turnover and service levels between categories*". (Do Rego et al., 2011).
As stated by Ravinder et al. (2014), several criteria for inventory classification are used. This allows companies to better manage their inventories and be more competitive on the market.

The most commonly used method of inventory organization is the **ABC classification** of the inventory which discriminates all the items according to their usage or consumption value[4] (Slack et al., 2010).
This analysis is based on the Pareto law which states that most effects depend on a limited number of causes. This is also called the Pareto 80:20 rule, according to which 80% of effects depend on 20% of causes.

[3]Having high stock levels in the inventory can often be a waste causing excessive costs and a lot of space taken up unnecessarily in the warehouse. This waste is called "Muda" and can be avoided through optimal inventory management and control (Palmer, 2001).
[4]It is defined as usage rate multiplied by the individual value of the item (Slack et al., 2010).

Used in inventory management, the ABC analysis identifies which products have the greatest impact on costs and revenues. In this way, the products are divided into three classes (Teunter et al., 2010):

- Class A items: they generate the highest sales volumes and make up about 80% of the total value; this class generally includes 20% of the items. As these items determine the company's highest profit, high service levels and tight inventory control must be guaranteed.
- Class B items: they are medium consumption value products; they include 30% of the stock and are worth about 15% of the annual consumption value.
- Class C items: items with the lowest consumption value (approximately 50% of the stock); they cover a value close to 5% of turnover.

In the picture below, the ABC curve is shown: 20% of the items (class A) contribute to about 75% of the turnover, while 70% of the items (class B and C) generate only 25%.

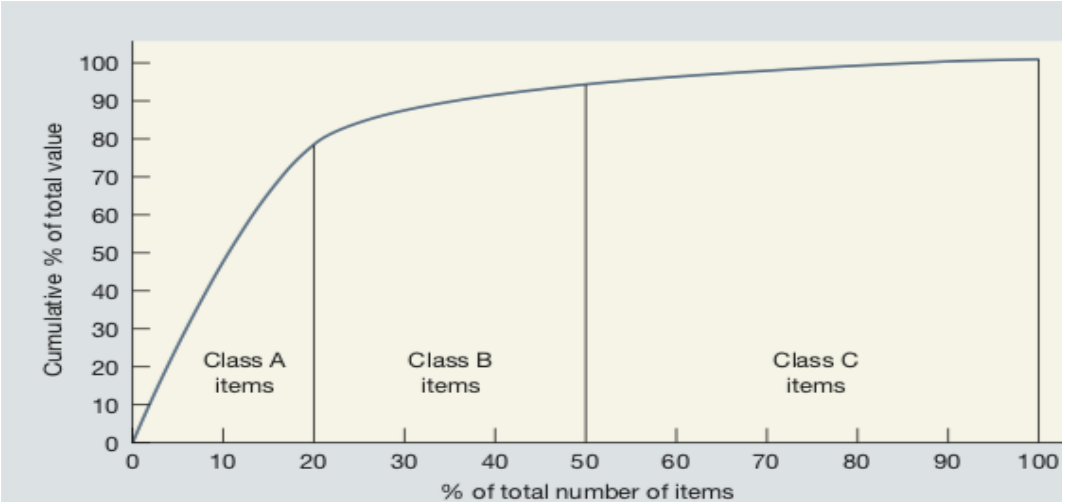

Figure 11: ABC curve (Slack et al., 2010)

In addition to this analysis, there are a variety of parameters and indicators that can be used to classify the inventory. Another important classification of stocks used by companies is based on the turnover ratio that estimates the efficiency of inventory management. This indicator is calculated for each item and it allows to evaluate which are the items that remain in the inventory for a short time (high rotation) and those that, instead, remain there for longer (low rotation) (Mitra et al., 2015).

In this regard, a common stock classification is called **FSN analysis** based on the consumption rate and the quantity of each item.

"*While performing this particular analysis the turnover ratio of each item has to be calculated because the items are sorted and analyzed according to the turnover ratio it possesses*." (Kumar et al., 2017).

This classification divides all items into three categories: (Kumar et al., 2017).

- Fast-moving class: this class includes all items whose turnover ratio is greater than 3. These items are used frequently and in large quantities. This class represents 10-15% of all stocks.
- Slow-moving class: this category includes all items whose turnover ratio is between 1 and 3. These items are used in small quantities and with low frequency; they represent 30-35% of total item.
- Non-moving class: items with a turnover ratio is less than 1. This class represents 60-65% of total item. These items are not used for a certain period of time.

2.4. Consequences of stock classification: benefits and advantages

The use of a stock classification tool allows the company to diversify the reordering policy: according to the different types and classes of stocks, a different policy can be adopted in order to minimize costs and increase efficiency and overall performance (Silver et al., 1998).

With regard to the ABC classification based on value, Silver et al., (2016) present the different reordering policies that must be adopted by the company according to the class of the various items. As can be seen from the table below, for the class C items, companies should adopt a manual periodic or continuous review policy: in fact, given the low savings associated with this class of items, companies should devote less effort.

	Continuous review policy	**Periodic review policy**
Class A items	(s, S)	(T, s, S)
Class B items	(s, Q)	(T, S)
Class C items	manual (s, Q)	manual (T, S)

Figure 12: best reordering policies (adapted from Silver et al., 2016)

With regard to the analysis based on fast and slow movers, Kumar et al. (2017) present different parameters that differ between the three classes. For each parameter the various characteristics are defined.

	Fast-movers items	Slow-movers items	Non-movers items
Stock	High	Intermediate	Low
Control	High	Intermediate	Low
Check	Tight	Intermediate	No

Figure 13: characteristics of FSN analysis (adapted from Kumar et al., 2017)

In addition, from this table can be deduced that the company must implement different policies depending on the type of item. In fact, differentiating the reordering policies is fully beneficial because it allows reducing all the costs related to inventory management. For example, fast-movers (i.e. items that are used and consumed very frequently) need to be reordered more frequently and in larger quantities than slow-movers. If the company ordered the slow movers at a high frequency, it would lead to high product obsolescence and high costs (Kumar et al., 2017).

"*The company should use the information from the FSN analysis to shape which goods should have priority in the warehouse and which items should go*" (Melanie, 2018).

While for fast-movers items it is possible to adopt a continuous replenishment policy based on min and max (s, S) (companies can set a maximum/ order-up-to level, as they will never have problems of obsolescence given the high turnover index of these items), for slow movers, there are greater complications for the determination of the best reordering policy.

Taking as reference a study by Kocer et al. (2011) on slow movers, it can be said that companies should adopt a different reordering policy for this class of items in order to bear lower costs. That is, a (s, Q) continuous replenishment policy would be more suitable, since the companies, according to their needs and requirements, could calculate the optimal quantity of items that should have in inventory as well as the best reorder level.

By adopting different reordering policies for the various classes, it is easier for the company to determine the optimum levels of stock to be kept. Therefore, as stated in the previous paragraphs, this classification also helps to determine how much stock to maintain.

As pointed out by Miranda et al. (2014), inventory management policies must be differentiated according to the characteristics of the item; among these, it is essential to take into account the indicators of effectiveness and efficiency.

This classification is also very useful to control and avoid the product obsolescence, and to reduce all the costs analyzed in paragraph 2.1.2, since the company would work on lower inventory levels.

As pointed out by Hamlett, the main benefits related to an optimal inventory control are: • low inventory costs: if the inventory is well controlled, the costs will be lower due to the lower amount of inventory (the company is able to determine how much inventory it needs for each category leading to low overall costs); • higher service level; • competitive advantages over other companies: thanks to the use of specific tools and systems the company is able to better manage the inventory and obtain superior advantages over its competitors.

2.5. Section records

The theoretical framework described in the previous paragraphs represents the backbone on which the case of Drake & Farrell and its empirical results will be based. Starting from the research question, the purpose of this research thesis is to understand how a company can manage its spare parts inventory more efficiently and reduce all the consequent high costs and risks. To do this, the classification tool ABC and FSN as presented by Slack et al. (2010) and by Kumar et al. (2017) was used to carry out the entire research.

In the first paragraph, the framework provided by Fleischmann et al. (2000) highlighted the different processes that describe a reverse logistics company. Subsequently, the study carried out by Bonev (2012) has been presented to explain the several uncertainties that a reverse logistics company faces. This is fundamental as it shows that a major problem faced by reverse logistics companies is related to the totally inefficient inventory management.

Slack et al. (2010) has therefore highlighted all the costs that are incurred by these companies which are very high in the event that a tool for classifying spare parts is not used. In this regard, the study by Silver et al. (2016) and Kumar et al. (2017) has been presented to demonstrate how different policies, strategies and actions can be implemented by a company when using a classification tool. This also leads to several economic advantages and benefits.

3. METHODOLOGY

The following chapter provides and analyses the methodology adopted in this research. It consists of four main sections: the choices related to the adopted strategy, the description of research design, the explanation of the methods used for the data collection and data analysis, and finally a section about rigor in research.

3.1. Research strategy

Using the insights obtained from the literature and theory on the management of the spare parts inventory and the tool for classifying stocks according to various parameters, it will be possible to show how companies can manage inventory in a more efficient way, thus increasing control and reducing all the high associated costs.

Indeed, the main purpose of this research is to demonstrate how a company can ensure efficient and optimal management of the spare parts inventory thus obtaining several benefits and economic advantages.

Given the above, a structured method and tool that consists of the classification of the stocks in different classes according to specific characteristics and parameters will be presented as a feasible and possible solution.

To draw the final conclusion, the case of Drake & Farrell will be analyzed. In light of the foregoing, it is possible to state that the used approach is exploratory: the already existing theories have been the starting point of this research. As pointed out by Labaree (2009), the theoretical framework is helpful to generate new hypotheses, theories and, finally, find an applicable solution. Moreover, studying and analyzing a real problem can be helpful to increase its understanding and to find an applicable solution. In this research, after having studied the problem from a theoretical point of view, an exploratory analysis of a specific case will be carried out, showing that what has been deduced in theory can also be applied in real cases generating new hypotheses and solutions.

An empirical investigation is used to understand the issue through an inductive study since the final goal is to generate a new theory emerging from the data analyzed and to come up with a solution to a current problem (Gabriel, 2013). Indeed, the purpose of this present work is to generalize and expand the above-mentioned theory through the exploration and analysis of a specific case. In this regard, the outcome and solutions that emerged from the analyzed case can be easily extended and generalized to similar companies that face the same problems.

As stated by Bryman et al. (2011) qualitative research supports an inductive study. According to the purpose of the research, this study will be conducted as a qualitative research which aim

is to investigate all the phenomena and solve the empirical problem taking as reference the existing literature (Denzin et al., 2011). Moreover, this type of research is characterized by the fact that the data take the form of words, text and picture. Unlike quantitative research, qualitative research is highly subjective because the perspective of the researcher emerges a lot. Nevertheless, even if quantitative research is more transparent and clearer, qualitative research appears to be the most suitable research method for the purpose of this study.

3.2. Research design

Research design refers to the collection of data, how data have been analyzed, and which tool has been used. Moreover, it includes the research type, the strategy and the structure of the study.

The following in-depth and detailed research has the objective to understand and to find a real and applicable solution to companies that face problems in the inventory management and in the associated high risks and costs. In light of that, the most suitable research design is the case study. It allows to investigate contemporary phenomena (single case or a small number of cases) and to use multiple sources of evidence (information derived from different sources and data). Only with this method, the investigator aims to expand and generalize theories (Eisenhardt, 1989). For that reason, this research analyses a real case of a third-party reverse logistics company, Drake & Farrell, in order to present the problem the company is currently dealing with and try to solve it through a structured method.

The case of Drake & Farrell has been chosen thanks to a collaboration with Tilburg University, which is carrying out a project with several companies involved in logistics. In this regard, the company Drake & Farrell is one of the leading experts in reverse logistics in the Netherlands. In addition, it is a company that is currently encountering several problems and inefficiencies related to inventory management.

In the light of the above, through the study of this specific case, the existing theory can be expanded, finding a solution that can better solve the current problem, thus ensuring a meaningful development for this thesis.

In this type of research design, the presence of literature review plays a dominant role since the researched theory allows to create an orienting framework (Creswell, 1994) describing the characteristics and policies of the spare parts inventory and how the classification of spare parts can guarantee a decrease of costs and an overall higher performance.

As stated by Creswell (1994), the case study is necessary to discover new and useful variables that can lead to beneficial and valuable conclusions through deep analysis. This concept is also

confirmed by Zikmund (2003) who pointed out that the purpose of the research is not to provide a detailed and accurate measurement or quantification, but to clarify the problem and analyze the effects.

3.3. Data collection

Data collection is defined as a procedure to gather and collect all the data and information available that could be useful to solve a current research problem. There are two methods to collect and analyze data: • quantitative data collection (the data are expressed as number. There are several methods to collect and analyze quantitative data such as questionnaires, regression or correlation, median or statistical procedure); • qualitative data collection (the data take the form of words, pictures or text. It uses surveys, questionnaires and structured or unstructured interviews to collect words-based data).

As mentioned above, this study was conducted as qualitative research. Indeed, the methods used to gather all information were semi-structured and unstructured interviews. Moreover, to validate what people say and to guarantee a high validity and reliability level, some company reports, databases and other types of data were used (i.e. table, images, database).

In the following paragraph, it is presented how primary and secondary data can be gathered.

3.3.1. Secondary data collection

"*Secondary analysis refers to the use of existing research data to find an answer to a question that was different from the original work*" (Tripathy, 2013). Moreover, as stated by Sreejesh et al. (2014), the secondary data collection is useful to decrease the confusion and guarantee a clear overview through a deep definition and identification of all aspects.

In order to clearly define the problem related to inventory management, it was needed to carry out an accurate online and "desk research". This was optimal to get more information, insights and theoretical knowledge related to efficient spare parts management. This important step was necessary to define a literature framework allowing the reader and the author to increase his knowledge about the topic.

Once having concluded this first research, a clear research question has been outlined, which summarizes the scope of the entire research.

Later, a theoretical review was carried out though the use of academic papers, online books, articles and newspapers. These external secondary data were available through the online Tilburg University library website, Luiss University library and through some research databases such as Google Scholar.

In order to facilitate online research and collect the most relevant and useful papers for the purposes of this study, some filters and keywords were used. Among these, the most used were: "reverse logistics", "uncertainties in product returns", "spare parts inventory management", "spare parts inventory policy", "spare parts classification", "inventory stock level", "service level".

3.3.2. Primary data collection

"*A primary data source is an original data source, that is, one in which the data are collected first-hand by the researcher for a specific research purpose or project*" (Salkind, 2010).

Primary data were collected through several methods such as questionnaire, observations and interviews (it is a common method in which two or more people are involved and that requires an oral verbal stimulus and verbal responses).

In this study, semi-structured interviews were used that better fit with the scope of this exploratory research. "*The semi-structured interview is a qualitative data collection strategy in which the researcher asks informants a series of predetermined but open-ended questions*" (Given, 2008).

The interview is a useful method to recognize and understand how Drake & Farrell is currently managing the spare parts inventory and which are all the inefficiencies, problems and high costs that the company incurs. For that reason, quantitative information and data taken from the company's documents and reports have been used to make the research and the analysis stronger. In that way, these additional data were used as a support of the qualitative data.

Given the final goal of this study, an interview protocol has been prepared (also called *interview guide*), characterized by a list of several questions or topics based on the literature that have been asked during the conversation. Usually, what characterizes the semi-structured interviews is the fact that the interviewer asks about a set of themes by means of predetermined questions but the order in which the themes are covered may vary. Moreover, the interviewer may ask additional questions that seem to fit the topic.

The interview protocol (see Appendix I) contains several questions related to the management of spare parts inventory, the policies used to control it, how many spare parts are received, how often they are received and how often the company orders new parts. Moreover, questions related to the problems and inefficiencies that the company faces in the management of spare parts inventory are included. In light of that, some questions about the high costs and type of costs Drake & Farrell encounter have been asked.

Since the discussion may diverge from the interview protocol and may be difficult to take notes, the interviews were recorded via smartphone, and summary transcript was created (see Appendix II). Although this transcription process is time-consuming, it proves to be necessary since it ensures and improve the objectivity, accuracy and validity of results and data collection. Furthermore, the transcription of the interviews is also useful to avoid the misinterpretation of information.

All the interviews have been conducted face-to-face at an appropriate location, the company's headquarters. In addition to this, conference calls, e-mails and phone calls have been made. "*Face-to-face interviewing may be appropriate where the depth of meaning is important and the research is primarily focused in gaining insight and understanding*" (Newton, 2010).

3.3.3. Sampling

The problem has been investigated through deep observation and interviews at participating companies. Going into more detail, the sample of this research is represented by the company's employees and managers. People were carefully selected with regard to their function in the company and the information needed to carry out this study.

The people interviewed were managers who work in the logistics sector, and therefore those involved in the inventory management, data-driven manager, and manager responsible for the overall planning and production department.

Thanks to these interviews, it has been possible to understand in a complete way how Drake & Farrell manages all recovery process, how it manages and controls the spare parts inventory, and what are all the problems and high costs it encounters. The same questions were asked to different people, in order to have a more general and accurate result.

This interview process was necessary to gather different information and insights useful to analyze and solve the real case but above all to outline a more complete answer to the research question.

The figure below provides a sample of the interviewees, reporting the company of appurtenance and their role in the company.

Interviewee Identify	Company of Appurtenance	Role within the Company	Form of the interview
Berry Selhorst	Drake & Farrell	Manager responsible for all operations activities	Face-to-face
Janko van den Haak	Drake & Farrell	Planning and production scheduler	Face-to-face
Edward van Dam	Drake & Farrell	Director finance	Face-to-face
Thijs Bender	Drake & Farrell	Director Business development	Face-to-face
Employee	Drake & Farrell	Responsible of refurbishment phase	Face-to-face

Figure 14: sample of the interviewees (source: the author)

3.4. Data analysis

The process of data analysis is useful to examine and investigate in depth the data and information obtained through interviews with managers of Drake & Farrell.

In this research, once the collection phase of the different types of data has been completed, all the information emerging from the interviews and all the useful data emerging from company reports and databases were illustrated and processed in a clear and rigorous manner.

As stated before, the data were collected through semi-structured interviews obtaining both numerical and qualitative data. After showing these data, it was necessary to take into consideration the concepts and theories described in the theoretical framework used as a backbone to support the analysis. The qualitative data were useful to deeply understand how the company currently manages its inventory and the related problems that make the inventory inefficient. All these information and data that emerged from the interviews as well as from the literature review were used to develop a coding scheme (see Appendix 3).

That analysis was helpful to answer the research question and to draw a final feasible conclusion.

3.5. Rigor in research

In order to ensure the rigor and the quality of the research, it is important to consider two criteria: validity and reliability. Berg (2004) pointed out two ways to ensure the high quality of the qualitative research: by improving the reliability and the validity of the research design.

3.5.1. Reliability

Reliability is usually considered as a measure of research quality. Thyer (2010) stated that reliability in qualitative research refers to the dependability and trustworthiness of the data. It is defined as "*the extent to which results are consistent over time and (...) a study is referred to as reliability and if the results of a study can be reproduced under a similar methodology (...)*" (Joppe, 2000).

McLeod (2007) distinguished internal and external reliability. The former assesses the consistency of results and refers to the fact that more researches get the same results and conclusions after analyzing the same data. The latter indicates the extent to which if the study is repeated, the researchers would find the same results.

In order to develop and improve the reliability of qualitative research, it is important to organizing interview according to a structured method: using a questionnaire in which each person is asked the same set of question in the same order. Moreover, to improve reliability it is important to use transparent and logical reasoning through documenting and deeply describing all the steps taken and results. In order to cope with this, it is necessary to implement all the information and data acquired during the interviews with other documents (such as materials, emails or insights gained from meetings). To reduce the risk of misunderstanding, all the interviews were recorded and transcribed.

Reliability can also be improved through data triangulation: it consists in acquiring as much information as possible from multiple data sources. In that way, it is possible to get to data saturation[5]. The last way to increase reliability is by asking respondents for feedbacks: they could be helpful by providing judgment and more insights.

In the present research, several people have been asked the same questions. Moreover, reliability was also improved through the literature framework, which allowed to better understand the current problem and to become acquainted with it. This was useful to avoid and reduce the interviewer bias.

3.5.2. Validity

Joppe (2000) stated that "*validity determines whether the research truly measures that which it was intended to measure or how truthful the research results are*. (…) *Researchers generally*

[5] It is reached when the researcher has collected enough data and information to replicate the study.

determine validity by asking a series of questions and will often look for the answers in the research of others". Therefore, it can be stated that validity is the trustworthiness of the results that are obtained throughout the research process.

Several researchers analyze three main types of validity in qualitative research (Yin, 2009):

- Concept validity: this is achieved when there is a correspondence between literature and empirical results in terms of concepts. In this research, the literature framework tries to explain different theories and concepts to support practical problem analyzed. Moreover, the literature review was also deployed to outline the interview guide.
- Internal validity: it indicates the degree of results accountability obtained in the research. Usually, it is not completely computable, in fact, it is mainly based on judgment. It is the extent to which the results obtained are true in the context of a particular case.
- External validity: it "*examines whether or not an observed causal relationship should be generalized to and across different measures, persons, settings, and times*" (Calder et al., 1982). Therefore, it is the extent to which a study can be generalized and extended to other places and situations.

  In this study, the research strategy is a case study and thus the generalizability is limited (there is not a high degree of external validity). However, there may be other similar fashion reverse logistics companies or organizations with some problems in the management of spare parts inventory that can learn from this research and that can apply and adapt the solution achieved in this research.

4. EMPIRICAL FINDINGS

In the following section, all the results emerging from the data collection process are shown. Moreover, it provides a deep analysis of the empirical findings and results obtained during the interviews with the company's managers, integrated with the company's report and databases. These types of documents are useful to strengthen the analysis and make it more trustworthy and reliable.

The first section of this chapter tries to define and explain in detail how Drake & Farrell currently manage and control its spare parts inventory. Subsequently, the second paragraph shows all the problems the company is dealing with, and therefore the high inventory costs and risks incurred by Drake & Farrell. It tries to highlight all the issues that derive from an inefficient control and management of the inventory. That part plays a fundamental role, as it provides the basis for defining the final conclusion and solution.

4.1. Drake & Farrell inventory management

Drake & Farrell is a third-party reverse logistics provider located in Bleiswijk (NL) that performs the whole recovery process for the market leader KPN, the most important telecommunications and IT provider in the Netherlands. The products that are returned for refurbishment are mainly mobile phones, modems, router, TVs and so on.

Drake & Farrell's goal is to provide a good service to companies in order to reduce their costs, increase their efficiency, availability, punctuality, satisfaction and most importantly, decrease waste. In light of this, the aim of this reverse logistics company is to be as sustainable as possible, trying to reduce all types of waste in order to achieve a positive environmental impact. At the moment, Drake & Farrell is dealing with some problems and inefficiencies in the management of its spare parts inventory leading to a lack of control and above all to high costs.

The activities of Drake & Farrell can be explained in three detailed steps:

1. Receiving and collecting old products directly from the end-user of KPN who decides to return the product because it is no longer usable or because the subscription period is over: the customer contacts KPN to notify its decision to return the product. KPN informs Drake and Farrell that will send an empty box to the customer in which he will put the product and send it directly to Drake & Farrell.
2. Recovery process: testing, sorting and cleaning the old products to create a new one. During the testing phase, it is determined whether a return is technically functional. When the product arrives at Drake & Farrell, it is scanned and verified its technical

status by distinguishing it in "good" or "not good". The "not good" products (i.e. those that can no longer be reused) go to scrap (to waste or to recycling) or to repair, while the "good" products go to the cleaning phase. During this stage, it is determined if a product should be refurbished or not. If it has been established that some parts need to be replaced, the re-processing phase takes place. What is important at this stage of the process is the availability of spare parts (*reparable* spare parts, i.e. parts that can be economically or technically refurbished to make them reusable). In fact, if the parts that should be replaced are not available in the inventory, Drake & Farrell must purchase new parts from a Chinese manufacturer to combine and produce the final products. At that point, Drake & Farrell must notify KPN of the need for new parts and KPN will immediately place the order with the Chinese manufacturer. Subsequently, the new parts will be delivered directly to Drake & Farrell. After this phase, the new product will be ready to be redistributed in the market.

3. Sending the finished products to KPN: once the product has been refurbished, the kitting phase takes place. This means that the product is boxed and completed with the necessary components (adaptors, cables, etc.). When it is ready, it is shipped to KPN, which will take care of the final redistribution to the market of the recovered product.

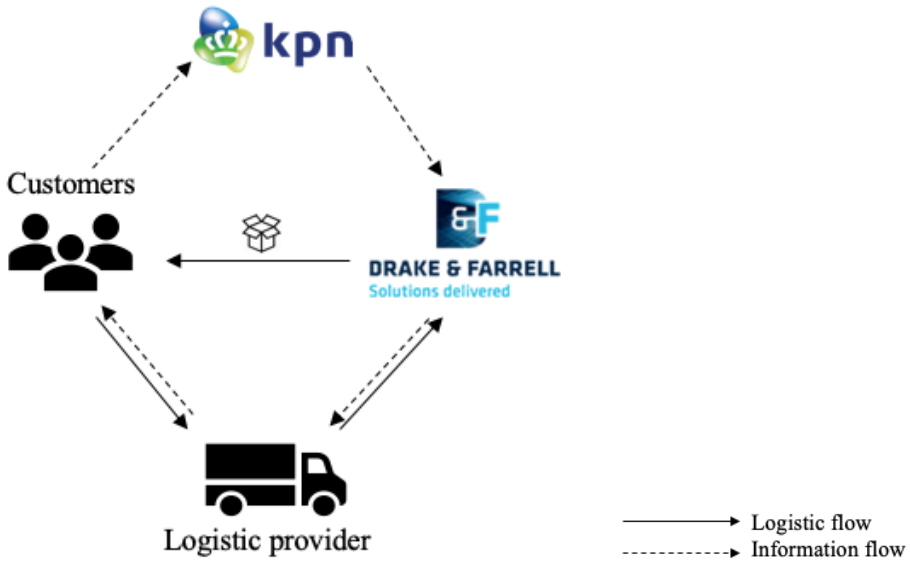

Figure 15: collection process at Drake & Farrell (source: the author)

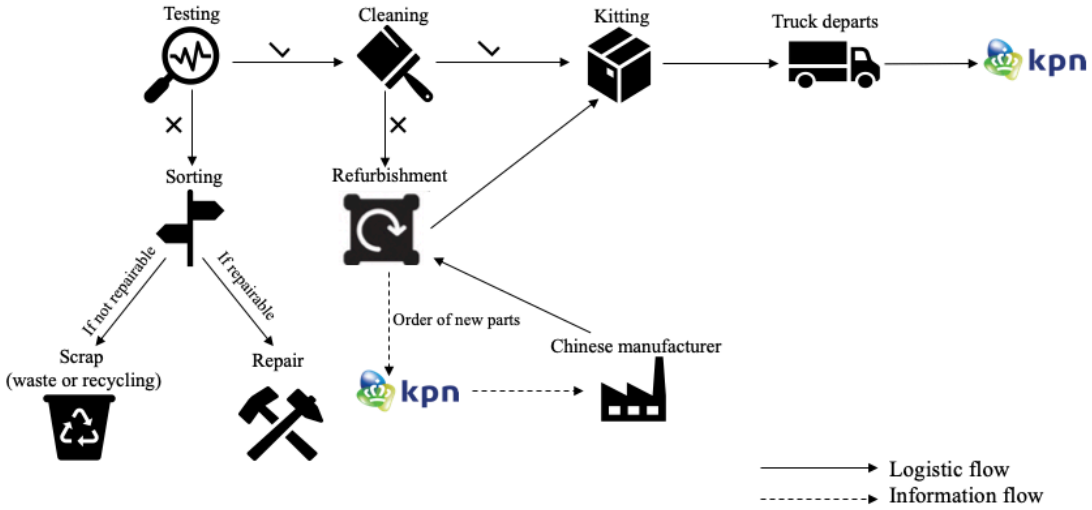

Figure 16: reverse logistics process at Drake & Farrell (source: the author)

As explained above, very often Drake & Farrell has to buy new spare parts in order to complete and produce a new product. This happens either because some parts of the old product obtained by customers can no longer be used because they are damaged or broken (i.e. a customer sends back a router whose socket cannot be adjusted or refurbished because it is broken), or because some pieces are missing in the package sent back by customers (i.e. a customer sends back a package in which there is a router but not the socket).

From this detailed overview of the whole process carried out by Drake & Farrell, it can be clearly seen that the company has to manage two different flows of spare parts:

1. the first flow of spare parts derives from the harvesting process: it is characterized by all returned and old products coming from the end-user of KPN;
2. the second flow of spare parts comes from the purchasing process: it consists of new products and parts purchased from a Chinese manufacturer.

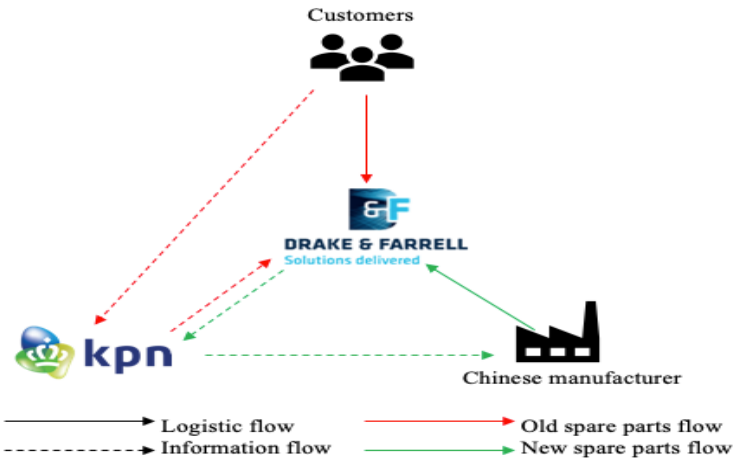

Figure 17: two spare parts flows of Drake & Farrell (source: the author)

These two types of spare parts and products build up the inventory of Drake & Farrell.

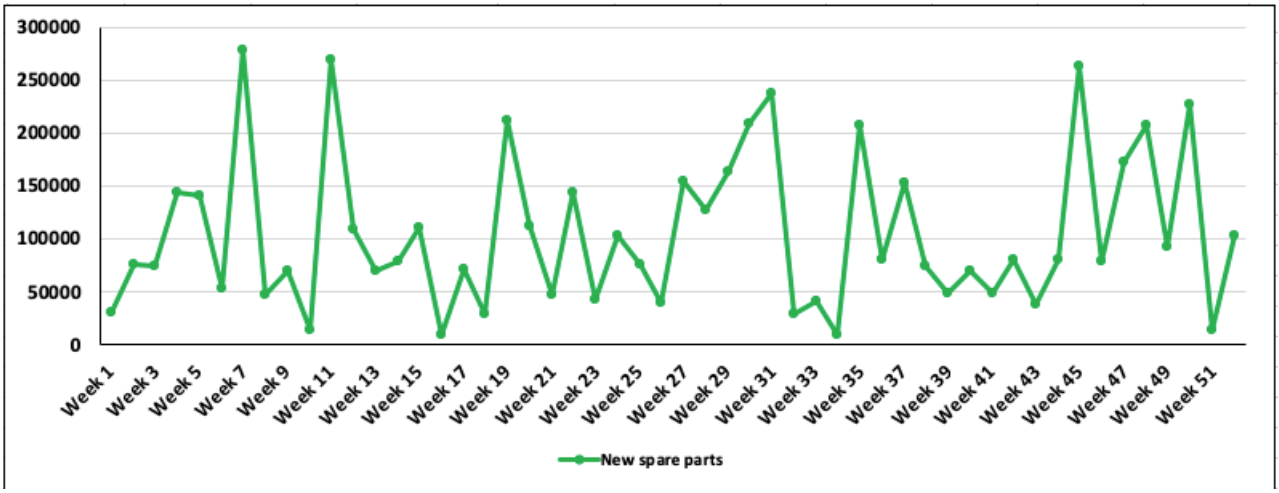

Figure 18: week-to-week amount of new spare parts in 2018 (source: the author)

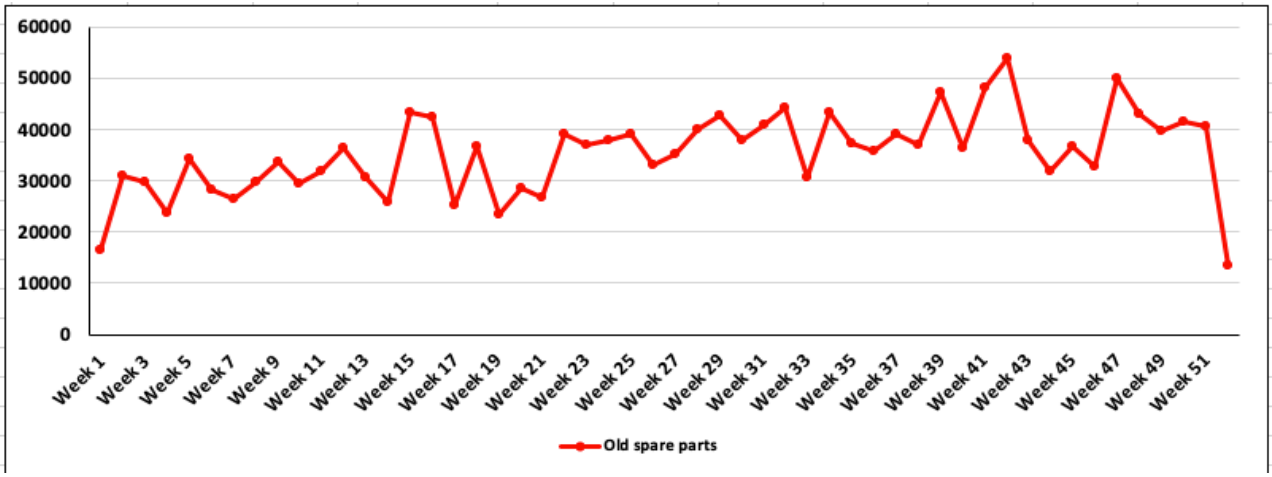

Figure 19: week-to-week fluctuations of harvested[6] spare parts in 2018 (source: the author)

In general, the flow of old spare parts is characterized by high uncertainty: the company has no clue and timely information about the daily amount of incoming returns and the moment in which they will arrive.

The above chart (figure 19) presents the current situation: each week Drake & Farrell receives different amounts of old spare parts from customers.

In light of this, it becomes clear that neither the quality nor the type of products are known until they reach the recovery facility. This internal uncertainty creates complications and difficulties

[6] Harvesting means all components (old spare parts) that Drake & Farrell receives back from the customers.

in inventory management. Inventory management means how many old and new stocks Drake & Farrell has available, how many new orders must be made and how often to place them. With regard to quality, and therefore the condition and status of the products received back, it is difficult for Drake & Farrell to determine in advance how many of the old products can be reused and how many cannot (it is not possible to determine in advance if the product should be subjected to the remanufacturing process, if it represents a scrap or if it should be cleaned). Not all of these products received can be reused in the refurbish process (many pieces could be broken, damaged and therefore no longer used. These parts are directly thrown away). From the graph below, it is possible to see that some of the old products are no longer useful and therefore are scrapped or recycled.

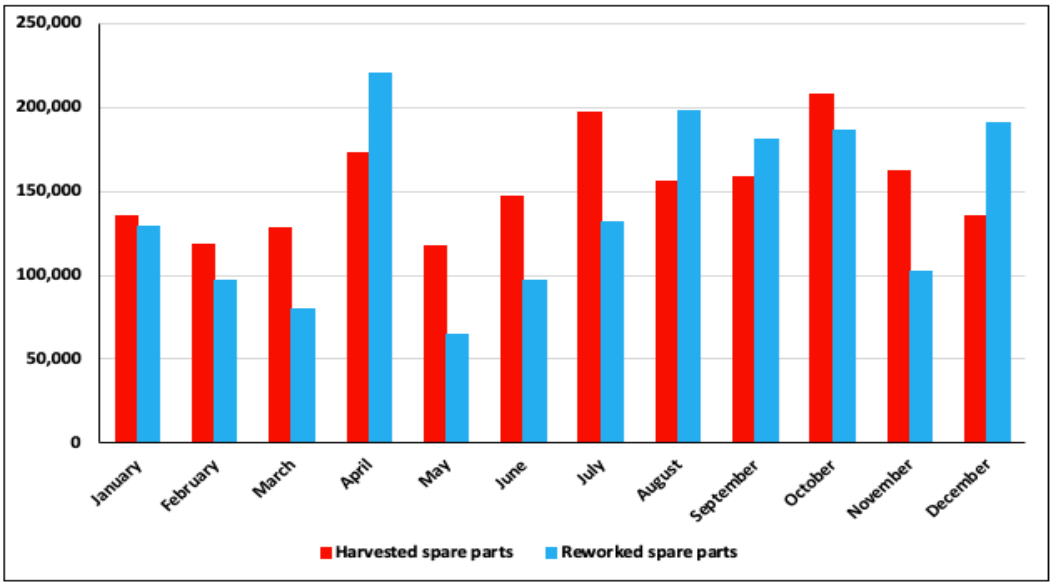

Figure 20: comparison between the number of old spare parts received back and the number of reused spare parts in 2018 (source: the author)

From the data obtained by Drake & Farrell, it emerges that generally only a part of the received spare parts can be reused, while the rest is recycled because it is probably broken or damaged. There is an exception in some months where the number of reworked spare parts is higher than the number of harvested spare parts. This happens because there is a lead time in the rework: this means that products received in a certain month are reworked in the following month. In fact, it is possible to see that in the months in which there is a much higher number of reworked parts than the harvested spare parts, in the following months an opposite situation occurs.

In total, in 2018, the reverse logistics company received back 1,838,139 old spare parts, of which 1,677,585 components were reprocessed. Therefore, 91.27% of old spare parts were reused in the entire refurbishing process.
As a result, each month the company must ensure a quantity of new spare parts available in the inventory that has to be used to complete the final product.
In this regard, the uncertainty leads the company to take precautions in the event that spare parts are missing (so-called stock-out) and therefore to avoid possible production problems and to ensure that the refurbishing process could be completed. For this reason, Drake & Farrell orders lots of new spare parts.
The interviews clearly showed that, despite the existence of this element of uncertainty that characterizes Drake & Farrell and all its activities, the main problem lies in the fact that the current inventory management is completely inefficient, as no inventory management tool or method is used that can ensure an efficient, cost-effective and optimal control.

The inventory is currently managed by adopting the minimum and maximum policy for all types of spare parts[7], regardless of their consumption value or their rotation. That is, the company, based on past data and past history, predicts and establish a minimum and maximum level of stock that must be kept in the inventory. When the available stock drops below the identified threshold (the minimum), the company places an order with a variable quantity of new pieces to bring the inventory up to a given level (the maximum).
Among the various replacement policies identified in the literature framework, this model belongs to the continuous review policies (s, S): there is always full knowledge about the stock level since the quantities are constantly tracked and counted.

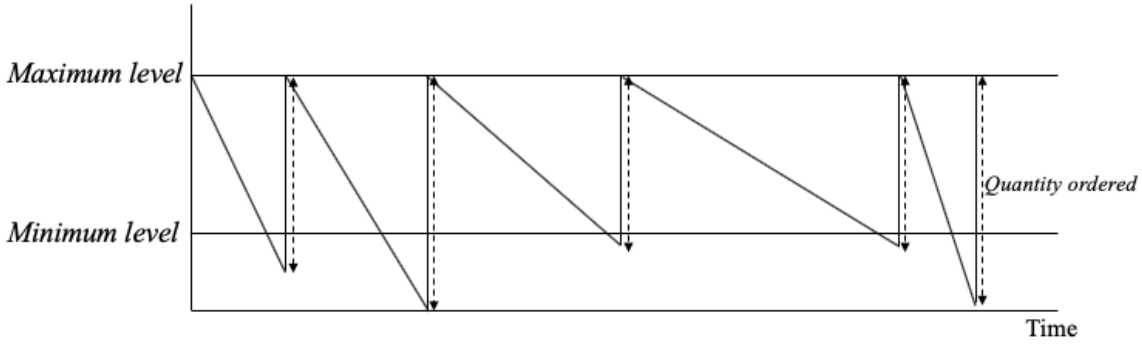

Figure 21: replenishment policy at Drake & Farrell (source: the author)

[7] The types of spare parts stored in the inventory are cables, sockets, plugs, remote controls, adapters, buttons, elastics, adhesive tapes, batteries, screws, wires and so on.

The company simply orders new pieces only when needed and therefore when the inventory falls below the minimum level. For this reason, there is a high volatility in the ordering of new spare parts.
As mentioned above, Drake & Farrell adopts this replacement policy for all types of spare parts without making any distinction between them.
This leads to have and to maintain very high levels of stock incurring therefore in high costs and problems in the management of the inventory that will be explained later.
It is important to state that, although the reverse logistics process is surrounded by high uncertainty, Drake & Farrell always tries to provide a high service level. For this reason too, the company constantly maintains high levels of stock in the warehouse, always purchasing new spare parts (to ensure that production does not stop causing bottlenecks in the event of missing or broken parts).
The service level currently guaranteed by Drake & Farrell is calculated as on time-in full, which means the number of quantities delivered in time with respect to the demand.

$$\text{SL: } \frac{number\ of\ quantities\ delivered\ on\ time}{total\ quantity\ of\ the\ demand} = \textbf{99.2\% YTD}$$

Obviously, as it has also been explained in the literature review, having high levels of stock that can ensure a high service level leads to high costs incurred by the company. This happens because Drake & Farrell does not maintain the right level of stock in the inventory for every type or class of spare parts.
Having a high KPI but incurring high costs for its maintenance leads the company to be still inefficient.

4.2. Consequences of current inventory management

As explained in detail in the previous paragraph, the current inefficient management of spare parts inventory leads the company to have high levels of stock. In turn this leads to several negative consequences, mainly represented by high costs and risks incurred by Drake & Farrell. These are listed below:

- *Obsolescence of the product*: the company has many obsolete stocks and therefore no longer usable, given the high technological content of the products.

Therefore, this "min and max" policy adopted for each type of spare part could prove to be inefficient as it leads the company to order more, causing possible obsolescence of some parts. It can therefore be stated that there is currently inaccurate stock planning. In facts, as shown by the interviews, the obsolescence of products is mainly limited to slow movers (and thus, on those products that are used infrequently and that remain in the inventory for a long time). However, some of these products have a very high value and therefore they have a heavy impact on the costs incurred.

- *Storage costs*: when Drake & Farrell orders many new parts, it also has to bear high storage costs. Very often there are spare parts that remain in the inventory for a long time and have a negative impact on the costs incurred by the company.
  The company sometimes needs more space to store its materials. Drake & Farrell constantly makes continuous investments in storage space, in handling technologies, and in the workforce.
- *Working capital*: the most important and costly consequence is the increase in the working capital (high financial charges). Indeed, maintaining a high level of stock implies high investment costs (i.e. high purchasing costs) and high level of risks. Since this fixed capital does not generate interest, it is seen as a high-risk factor.
  From the interviews conducted with managers, it emerges that this cost is one of the most impacting and that one of the goals is certainly to reduce working capital to be able to allocate it to other types of investment.
- *Cost of placing the order*: having a high level of stock leads to negative consequences mainly on transport and purchase costs: if the company was able to establish an accurate amount of orders for each type of spare parts, the cost of transport would be lower.
  Since the products transported are materials subject to customs duties (as they arrive from China) they still impact on the costs of the company even if they are subject to an Incoterm DDP. The transport cost is directly supported by KPN (because KPN has the contract with the Chinese manufacturer), but since KPN and Drake & Farrell collaborate and work in a circular economy, the reverse logistics company is also affected by this high cost.

From this analysis and as it has been asserted by managers, it is possible to state that the obsolescence of the products as well as the costs of working capital are the most impacting.
Therefore, tools are needed to optimize inventory control and reduce all inventory related costs.

Having examined in detail the current situation of the reverse logistics company Drake & Farrell and all the different problems and high costs incurred by the company, it is easier to outline a feasible solution.
Currently, the company manages all its inventory and the different stocks without any structured method and implementing a single replenishment policy for all spare parts. In this regard, during the interviews, it emerged from the managers that the implementation of a specific tool could be a favorable solution that can ensure a more efficient management of the entire inventory. Until now, the lack of implementation is also due to the fact that it is a very young company, not yet experienced in all the methods of efficient management.

After having outlined this complete framework, it is possible to draw the conclusions of this study, by suggesting how the implementation of a classification method can best solve the problems that the company is facing.

5. CONCLUSION, LIMITATIONS AND FUTURE RESEARCH

In the following chapter, the conclusion of the research thesis is provided, giving an answer to the research question mentioned in the first chapter.

How could a company be more efficient in the spare parts inventory management achieving an optimal control and an overall cost reduction?

In order to provide a concrete answer to the above question, in the previous chapter, the empirical results have been examined by linking them to the literature and theoretical framework described in the second chapter. On the basis of the above, a feasible and applicable solution is proposed. In the following paragraphs, a summary of the main results will be provided in order to have a clearer overview. At that point, a solution will be proposed that will allow the company to achieve substantial benefits.

Finally, the limitation of this research thesis will be highlighted, together with possible future improvements and researches.

5.1. Implications

Interviews with Drake & Farrell's managers (a manager responsible for all operations activities, a planning and production manager, a finance director, a business development director) and some employees have been conducted in order to in-depth investigate the case. Moreover, several databases and report of Drake & Farrell have been used to prove and demonstrate the current situation. These have proved to be useful for outlining a clearer picture of the problem the company is dealing with.

As it has emerged from the empirical findings, Drake & Farrell, as a reverse logistics provider, is surrounded by many uncertainties that make complicated and difficult the overall management of the spare parts inventory.

Specifically, Drake & Farrell has no upfront information on the products that will be returned by KPN's consumers. That is, the company does not know the type of products and especially the quality and condition of such products or parts. In this respect, the company becomes aware of these characteristics only when the product arrives at the facility and the remanufacturing process begins.

These circumstances have generated some inefficiencies and difficulties in the management of the spare parts inventory leading to very high costs and therefore to have a lower performance.

Not knowing exactly and in advance the state in which the products are, leads the company to be very cautious in the process of reordering new spare parts. In fact, the products returned can be broken, damaged, or obsolete, leading the company to have to buy from a third-party supplier those parts or products. For this reason, and therefore to ensure that there are always enough stock in the inventory and to ensure a high service level, the company frequently buys many new spare parts. This leads the company to always maintain high levels of stock in inventory which involve very high costs.

However, the main problem that Drake & Farrell is facing, is related to the management of its entire inventory and its related replacement policy. In particular, the company uses a single reordering policy for all types of spare parts, without differentiating between them and therefore without taking into account the rotation of the components and their consumption value. The policy implemented is that of minimum and maximum: Drake & Farrell, based on the past history, forecasts and predicts the minimum and maximum level of inventory to be maintained. At that point, the company orders new spare parts when the amount available in stock drops below a given threshold.

This model has been compared to a continuous replenishment policy analyzed in the literature framework: the reverse logistics company constantly tracks the level of the stock available in the inventory. In order to maintain such a level, the company frequently orders new spare parts without a programmed and periodic frequency.

The fact that the company does not adopt different reordering policies based on the types and classes of spare parts, and therefore the fact that no differentiation is made between them, leads to very high stock level. In this way, the company incurs in incredibly high costs of storage, maintenance costs, working capital costs, and above all, it is exposed to the risk of obsolescence (if a component is not used could easily become obsolete given the high technological content of the products).

So, although the company always tries to maintain a high service level, it is constantly exposed to high risks and costs of inventory management making it inefficient and uncontrollable.

For the above reasons and as it also emerged from the empirical findings, it is necessary to adopt a tool or method of inventory management that can help Drake & Farrell to be more efficient, reducing overall costs while maintaining a high service level.

This tool would allow the company to classify all spare parts according to different parameters. Only in this way, the company could adopt different reordering policies for each type and class of spare part lowering the stock level and the associated costs.

Specifically, a possible and feasible solution that can be proposed to Drake & Farrell is to perform an FSN analysis: this means that the company should classify all spare parts in fast, slow, and non-movers. To do this, it is necessary to use a performance indicator, currently not implemented by the company: the *inventory turnover ratio*. This must be calculated for each item or spare part in order to analyze which are the items that remain in the inventory for a short time and those that remain there for longer. At that point, as it also emerges from the analysis of Kumar et al., (2017), Drake & Farrell should behave differently according to the different three categories: for the fast movers items the company would carry out a very high and tight check and control having to keep always high stock in the inventory (for these items it is possible to adopt a continuous replenishment policy based on min and max (s, S): Drake & Farrell can set an order-up-to level, as for these items there are not obsolescence problems given their high turnover index), while for the slow and not movers items there would be a low-intermediate check (for these items, in order to bear lower costs, Drake & Farrell should adopt a (s, Q) continuous replenishment policy: the company can calculate the optimal quantity of items that should have in inventory as well as the best reorder level according to its needs and requirements).

Performing this analysis based on the movement of inventory is useful because it allows the company to ensure continuous availability in the inventory only of those products with high turnover. In addition, it allows the company to take a risk of stock failure only for low turnover products. For this class of products, the risk of stock failure is not very high, and therefore it would not have a high impact on costs.

With the implementation of the FSN analysis the general level of the inventory would be reduced because all the level of slow and non-movers items, that corresponds to about 80% of stock-keeping unit (SKU), would go down.

Subsequently, in order to have a more complete and accurate analysis, Drake & Farrell has to calculate the consumption value or usage value for each type of spare part. At that point the ABC classification will be implemented, distinguishing the different spare parts on the basis of their value. It is therefore optimal to perform an ABS-FSN matrix, that allows Drake & Farrell to analyze and understand how to behave for each individual spare part class, giving the characteristics associated with value and frequency of use.

	A	B	C
F	Products or spare parts with high turnover ratio and with a high value. They need a tightest control and a correct definition of the stock levels in order to avoid both an excessive stock level that would lead to high costs, and a low stock level that could cause stock out (the stock out of the fast movers is very expensive). Frequent, daily monitoring	Very used products with medium value. These products require a reduced frequency in cycle counting, while the level of stock to be maintained may be marginally increased	Widely used products with low value. As a result, maintaining a high stock level is not very expensive. So, Drake & Farrell can work with higher minimum stock levels (the stock level can be significantly increased) in order to make sure they do not incur a stock failure
S	Products or spare parts that are not widely used but cost a lot of money. Therefore, for these products, it is necessary to use the above-mentioned policy (s, Q). However, it must be kept in mind that despite the cost of stock out is less relevant than fast movers, keeping these products in stock would cost a lot of money	Products or spare parts that are little used with medium value. For these products, a reduced frequency in cycle counting is required	Products or spare parts that are little used and have low consumption value. These products require a low frequency in cycle counting (minimum supervision): Moreover, it must be disposed of the excess quantity in order to avoid unnecessary costs given the low use. Maintaining generally low levels of stock with infrequent ordering
N	Not used products or spare parts but that cost a lot. As a result, disposal must be expedited in order to free up costs, as they are products with a high value	Not used products or spare parts with medium value. As a result, disposal must be speeded up in order to free up not only the costs but also the storage space	Not used products or spare parts with low value. Consequently, the disposal must be speeded up in order to free up the storage space (no costs because they are spare parts of class C)

Figure 22: cross-classification matrix ABC - FSN (source: the author)

By adopting different reordering policies for the various classes, it is easier for the company to determine the optimum levels of stock to be kept. Therefore, the classification also helps to determine how much stock to have.

The implementation of these two analyses is used to reduce the impact of working capital and the impact of product obsolescence. As the interviews showed, the obsolescence of products

occurs mainly on that spare parts that the company uses very little, but which have a very high value and a high impact on costs.
Therefore, with these two cross analyses, Drake & Farrell would be able to reduce the obsolescence on those products used very little (i.e. slow movers) because it would maintain low inventory levels for that category, without buying frequently and in large quantities.
These tools would help the company to maintain a high service level, but above all to decrease the costs it incurs, because different levels of stock and different replacement policies will be set, based on different types and classes of spare parts.
The positive consequences will be:

- Lower working capital costs because the company would work on lower stock levels, lowering its value to 80% of the components.
- Lower storage costs because with a lower overall stock, the quantities and volumes would also be reduced, thus incurring reduced handling and storage costs.
- Lower product obsolescence because spare parts classified as slow or no movers will no longer occupy a large part of the warehouse. For this reason, the risk of incurring high obsolescence for those parts would totally decrease. In fact, at the time when a product becomes obsolete (and therefore the obsolescence of that product occurs), it will have a lower level of stock and therefore the related costs will be lower.

With the implementation of the above tools and the consequent reduction of all costs, Drake & Farrell will be able to guarantee a completely efficient and optimal inventory control and management with improved overall performance.

5.2. Conclusions

On the basis of the study conducted and the implications and solution outlined for the company, it is now possible to provide a comprehensive answer to the research question that has been formulated in the first chapter.

How could a company be more efficient in the spare parts inventory management achieving an optimal control and an overall cost reduction?

Starting from what emerges from the empirical results, it is feasible to affirm that in order to be much more efficient in the inventory management and therefore to have real economic

benefits, the companies should consider the implementation of a classification tool that allows to organize and classify all the stocks in different classes according to different parameters.
This method is an essential tool for inventory management as it allows companies to adopt and take different strategic decisions based on different categories of items. This is why the level of stock to be kept in inventory as well as the control, attention and check are different for each category, so as to maximize efficiency while minimizing the effort, costs and risks associated with inventory management. With the use of this method the company can then define different replenishment policies in such a way as to always have the necessary level of stock available, without incurring in out of stock or excessive stock.
In this regard, companies can use different criteria for stock classification depending on whether they want to perform an analysis based on usage/consumption value or on the consumption rate and quantity of each item. The first analysis, called ABC, allows identifying the stocks that have a greater and lesser impact on costs and revenues. The second, instead, called FSN analysis, carries out an analysis relative to the efficiency of the inventory and therefore it studies the rotation of the components in warehouse dividing the stocks in high and low rotating stock.
According to their needs, companies can implement several classifications based on different parameters. For the specific case of Drake & Farrell, a cross-classification matrix has been proposed with which stocks are divided according to a double parameter, i.e. according to both FSN and ABC classification. Through this double classification, it was suggested to the company how to behave for each type of stock. This cross-matrix proposed to Drake & Farrell can also be applied to all companies with a high degree of uncertainty about the flow of goods characterized mainly by a high technological level and therefore subject to high obsolescence.
The results of this exploratory study allow to expand the existing theory as they provide more knowledge about the applicability of this tool and how it can increase the efficiency of the whole management process as well as the business performance. This has been made possible by the study and analysis of an existing phenomenon thanks to which it has been possible to reach a feasible solution that can be generalized to more than one company.
In the light of the above, the economic and market benefits that can be obtained by companies that implement different management strategies depending on the type and characteristics of the item, are linked to a reduction in inventory costs (such as purchase costs, handling costs, costs of maintaining stock levels) and risks, such as product obsolescence. Moreover, the companies will be able to determine more easily the exact level of stock to be kept in inventory for each type of item, thus guaranteeing a high service level.

5.3. Limitations

This research study has two main limitations. The first is related to the fact that this research thesis was carried out taking into consideration the example and the problems faced by a single company. However, the external validity of the research is not entirely limited, as the conclusion outlined can also be applied to similar fashion reverse logistics companies or organizations that encounter similar problems in the spare parts inventory management.

Another limitation regards the omission of a deep and detailed analysis of the costs and the impact that the implementation of these classifications has at the organizational level and at the financial performance level. Due to the limited time available and the lack of knowledge about them, it was not possible to analyze all costs arising from the current management of the inventory.

5.4. Future research

Recommendations for future research can be suggested. A first important suggestion can be to put into practice this type of solution, doing a validity analysis and then evaluating the strong and weak points. A further study can address the gaps of the present study, by focusing on the real positive impact that these spare parts classification tools could have on costs. The researcher could evaluate each type of cost related to the inventory management and therefore analyze the influence that the classification tool has on that cost.

Another suggestion could be to carry out research among reverse logistics companies to evaluate how they deal with different spare parts and which reordering policies they adopt in order to maintain low stock levels with subsequent low costs.

REFERENCES

Abbaszadeh, M. (2012). Validity and reliability in qualitative researches. Journal of Applied Sociology, 45(10): 19-34.

Andrade C. (2018). Internal, External, and Ecological Validity in Research Design, Conduct, and Evaluation. *Indian journal of psychological medicine*, *40*(5), 498–499.

Bashir, M., Afzal, M. T., & Azeem, M. (2008). Reliability and validity of qualitative and operational research paradigm. *Pakistan journal of statistics and operation research*, *4*(1), 35-45.

Berg, B. L. (2004). *Qualitative Methods for the Social Sciences*. Boston: Pearson.

Blumberg, D. F. (2004). *Introduction to management of reverse logistics and closed loop supply chain processes*. CRC Press.

Bonev, M. (2012). *Managing reverse logistics using system dynamics: A generic end-to-end approach*. Diplomica Verlag.

Bryman A., Bell E., (2011). Business research methods. 3rd Edition. Oxford university press.

Calder, B. J., Phillips, L. W., & Tybout, A. M. (1982). The concept of external validity. *Journal of Consumer Research*, *9*(3), 240-244.

Coghlan, D., & Brydon-Miller, M. (2014). *The SAGE encyclopedia of action research*. Sage.

Cohen, D., & Crabtree, B. (2006). Qualitative research guidelines project.

Creswell, J. W. (1994). Research design. Thousand Oaks, CA: Sage publications.

De Brito, M. P., & Dekker, R. (2004). A framework for reverse logistics. In *Reverse logistics* (pp. 3-27). Springer, Berlin, Heidelberg.

De Brito, M. P., & Van Der Laan, E. A. (2009). Inventory control with product returns: The impact of imperfect information. *European journal of operational research*, *194*(1), 85-101.

De Smidt-Destombes, K. S., van der Heijden, M. C., & van Harten, A. (2009). Joint optimisation of spare part inventory, maintenance frequency and repair capacity for k-out-of-N systems. *International Journal of Production Economics*, *118*(1), 260-268.

Dekker, R., Fleischmann, M., Inderfurth, K., & van Wassenhove, L. N. (Eds.). (2013). *Reverse logistics: quantitative models for closed-loop supply chains*. Springer Science & Business Media.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2011). The Sage handbook of qualitative research. Sage.

Do Rego, J. R., & de Mesquita, M. A. (2011). Spare parts inventory control: a literature review. *Produção*, *21*(4), 645-655.

Driessen, M., Arts, J., van Houtum, G. J., Rustenburg, J. W., & Huisman, B. (2015). Maintenance spare parts planning and control: a framework for control and agenda for future research. *Production Planning & Control*, *26*(5), 407-426.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of management review*, *14*(4), 532-550.

Fleischmann, M., Bloemhof-Ruwaard, J. M., Dekker, R., Van der Laan, E., Van Nunen, J. A., & Van Wassenhove, L. N. (1997). Quantitative models for reverse logistics: A review. *European journal of operational research*, *103*(1), 1-17.

Fleischmann, M., Krikke, H. R., Dekker, R., & Flapper, S. D. P. (2000). A characterisation of logistics networks for product recovery. *Omega*, *28*(6), 653-666.

Fraser, S. (2019) "What Is the Difference Between a Periodic and Continuous Inventory Review Policy?" *Small Business - Chron.com*.

Gabriel, D. (2013). Inductive and deductive approaches to research. *Accessed on February*, *13*.

Ghafouri, R., & Ofoghi, S. (2016). Trustworth and rigor in qualitative research. *International Journal of Advanced Biotechnology of Applied Behavioral Science*, *7*, 90-101.

Ghorbel, N., Addouche, S. A., El Mhamedi, A., & Boujelbene, Y. (2014). Bayesian approach for spare parts replenishment policies under uncertainties. *International Journal of Engineering Research and Development*, *10*(11), 28-45.

Given, L. M. (Ed.). (2008). *The Sage encyclopedia of qualitative research methods*. Sage publications.

Gobbi, C., & Jensen, P. L. (2008). *The reverse supply chain: Configuration, integration and profitability: Considerations derived from a qualitative case study investigation*.

Hamlett, Kenneth. (n.d.). The Advantages of Inventory Control. *Small Business - Chron.com*. Retrieved from http://smallbusiness.chron.com/advantages-inventory-control-2228.html

Hoppe, M. (2006). *Inventory optimization with SAP*. Bonn: Galileo Press.

Huiskonen, J. (2001). Maintenance spare parts logistics: Special characteristics and strategic choices. *International journal of production economics*, *71*(1-3), 125-133.

Ingram, David. (2019). Types of Inventory Costs. *Small Business - Chron.com*. Retrieved from http://smallbusiness.chron.com/types-inventory-costs-11787.html

Iraqi, Z., Barkany, A. E., & Biyaali, A. E. (2016). Models of spare parts inventories' optimisation: a literature review. *International Journal of Services, Economics and Management*, *7*(2-4), 95-110.

Joppe, M. (2000). *The Research Process*. Retrieved December 16, 2006, from http://www.ryerson.ca/~mjoppe/rp.htm

Kennedy, W. J., Patterson, J. W., & Fredendall, L. D. (2002). An overview of recent literature on spare parts inventories. *International Journal of production economics*, *76*(2), 201-215.

Kocer, U. U., & Tamer, S. (2011). Determining the inventory policy for slow-moving items: a case study. In *Proceedings of the World Congress on Engineering* (Vol. 1, pp. 6-8).

Kumar, Y., Khaparde, R. K., Dewangan, K., Dewangan, G. K., Dhiwar, J., S., Sahu, D. (2017). FSN Analysis for Inventory Management – Case Study of Sponge Iron Plant. *International Journal for Research in Applied Science & Engineering Technology (IJRASET). Volume 5 Issue II.*

Labaree, R. V. (2009). Research Guides: Organizing Your Social Sciences Research Paper: Types of Research Designs.

Mariano, C. (2015). I costi di mantenimento impliciti delle scorte: definizione e loro ruolo nelle simulazioni. *Logistica efficiente*.

Maxwell, J. (1992). Understanding and validity in qualitative research. *Harvard educational review*, *62*(3), 279-301.

McLeod, S. A. (2007). What is reliability?. Retrieved from https://www.simplypsychology.org/reliability.html

Melanie. (2018). Understanding FSN Analysis. *Unleashedsoftware.com*

Merritt, C. (n.d.) Advantages and Disadvantages of ABC Analysis Inventory. *Your business. Azcentral.*

Miller, R. L., & Brewer, J. D. (Eds.). (2003). *The AZ of social research: a dictionary of key social science research concepts*. Sage.

Minnich, D., & Maier, F. (2006). *Supply Chain Responsiveness and Efficiency: Complementing or Contradicting Each Other?*. School of Business Administration.

Miranda, S., Roda, I., Macchi, M., & Montera, G. (2014). A criticality-driven methodology for the selection of spare parts stock management policies: the case of a beverage industry company. *Proceedings of XIX Summer School "Francesco Turco," Senigallia*, 9-12.

Mitra, S., Reddy, M. S., Prince, K. (2015). Inventory control using FSN analysis–a case study on a manufacturing industry. *IJISET-International Journal of Innovative Science, Engineering & Technology*, *2*(4).

Murali, S., Pugazhendhi, S., & Ganesh, K. (2011). Role of third party logistics providers in reverse logistics. *International Journal of Operations System and Human Resource Management*, *1*(1-2), 77-84.

Naliaka, V. W., & Namusonge, G. S. (2015). Role of inventory management on competitive advantage among manufacturing firms in Kenya: A case study of Unga Group Limited. *International Journal of Academic Research in Business and Social Sciences*, *5*(5), 87-104.

Newton, N. (2010). The use of semi-structured interviews in qualitative research: strengths and weaknesses.

Palmer, V. S. (2001). Inventory management KAIZEN. In *Proceedings 2nd International Workshop on Engineering Management for Applied Technology. EMAT 2001* (pp. 55-56). IEEE.

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, CA: Sage.

Porteus, E. L. (2002). *Foundations of stochastic inventory theory*. Stanford University Press.

Prempeh, K. B. (2015). The impact of efficient inventory management on profitability: evidence from selected manufacturing firms in Ghana.

Radasanu, A. C. (2016). Inventory management, service level and safety stock. *Journal of Public Administration, Finance and Law*, (09), 145-153.

Ravinder, H., & Misra, R. B. (2014). ABC analysis for inventory management: Bridging the gap between research and classroom. *American journal of business education*.

Rizkya, I., Syahputri, K., Sari, R. M., Siregar, I., & Ginting, E. (2018). Comparison of Periodic Review Policy and Continuous Review Policy for the Automotive Industry Inventory System. In *IOP Conference Series: Materials Science and Engineering* (Vol. 288, No. 1).

Rogers, D. S., & Tibben-Lembke, R. (2001). An examination of reverse logistics practices. *Journal of business logistics*, *22*(2), 129-148.

Rubio, S., & Jiménez-Parra, B. (2014). Reverse logistics: Overview and challenges for supply chain management. *International Journal of Engineering Business Management*, *6*, 12.

Salkind, N. J. (Ed.). (2010). *Encyclopedia of research design*(Vol. 3). Sage.

Sehgal, V. (2018). Replenishment Policies and Inventory Planning. *Supply chain musings*.

Silver E. A., D. F. Pyke, R. Peterson. (1998). *Inventory Management and Production Planning and Scheduling',* 3rd Ed. ed John Wiley & Sons, New York.

Silver, E. A., Pyke, D. F., & Thomas, D. J. (2016). *Inventory and production management in supply chains*. CRC Press.

Singh, S. R., & Kumar, T. (2011). Inventory optimization in efficient supply chain management. *International Journal of Computer Applications in Engineering Sciences*, *1*(4).

Slack, N., Chambers, S., & Johnston, R. (2010). *Operations management*. Pearson education.

Sreejesh, S., Anusree, M. R., & Mohapatra, S. (2014). Business Research Methods - An Applied Orientation. Switzerland: Springer International Publishing.

Stebbins, R. A. (2001). *Exploratory research in the social sciences* (Vol. 48). Sage.

Stock, J. R. (1992). *Reverse logistics*. Council of Logistics Management.

Tanwari, A., Lakhiar, A. Q., & Shaikh, G. Y. (2000). ABC analysis as a inventory control technique. *Quaid-E-Awam University research journal of engineering, science and technology*, *1*(1).

Teno, M. N., Anyingang, R. A., & Chenaa, T. A. Inventory Management Practices and Cost: Evidence of Selected Small-Scale Cosmetics Enterprises in Douala, Littoral Region of Cameroon.

Teunter, R. H., Babai, M. Z., & Syntetos, A. A. (2010). ABC classification: service levels and inventory costs. *Production and Operations Management*, *19*(3), 343-352.

Thierry, M., Salomon, M., Van Nunen, J., & Van Wassenhove, L. (1995). Strategic issues in product recovery management. *California management review*, *37*(2), 114-136.

Thyer, B. A. (2010). The *Handbook of Social Work Research Methods*. London: Sage Publications.

Tomašić, D., Đukić, G., & Šafran, M. (2013). Inventory management in reverse logistics-analysis of Croatian Automotive industry postsale practices. *Tehnickivjesnik*, *20*(3), 541-547.

Tripathy J. P. (2013). Secondary Data Analysis: Ethical Issues and Challenges. *Iranian journal of public health*, *42*(12), 1478–1479.

Tysseland, B. E. (2009). Spare parts optimization process and results: OPUS10 cases in the Norwegian Defence. *International Journal of Physical Distribution & Logistics Management*, *39*(1), 8-27.

Vaisakh, P. S., & Unni, D. J. N. (2013). Inventory Management of Spare Parts by combined FSN VED (CFSNVED) Analysis. *International Journal of Engineering and Innovation technology*, *2*(7).

Yilmaz, K. (2013). Comparison of quantitative and qualitative research traditions: Epistemological, theoretical, and methodological differences. *European Journal of Education*, *48*(2), 311-325.

Yin, R. K. (2009). Case Study Research: Design and Methods (4th ed.). Thousand Oaks, CA: Sage Publications.

Zikmund, W. G. (2003). Business Research Methods, 7th Edition. Nashville, TN: South-Western Publishing.

APPENDICES

Appendix I: interview guide

Design: semi-structured 1-on-1 interview, English language

Duration: ±60 minutes

a. Introduction

- Introduction of the researcher
- Explaining the purpose of the interview and research

b. Background

- Could you briefly introduce yourself and describe your company's position?

c. Spare parts inventory management

- Can you describe how the remanufacturing process is currently managed? In light of this, could you explain in general terms how all phases of product recovery are carried out?
  - In this regard, how does the process of purchasing new spare parts work?
  - Do the uncertainties that characterize any reverse logistics negatively affect inventory management?
  - Is the quality of old spares monitored?
  - Do you think that the fact that you don't know in advance which parts are broken or should be repaired creates some problems in inventory management?
- Can you clarify the difference between the two spare parts flows?
  - How many and which types of spare parts are available in stock?
  - How often do you receive returned products?
  - How many returned products do you receive each time?
  - How often do you order new spare parts?
  - How many pieces do you order each time?
- How is the spare parts inventory currently managed?
  - What policy do you use to control it?
  - Do you order the spare parts when needed or do you use a specific policy for each class of spare parts?
  - Does the current replenishment policy take account of the spare parts turnover or usage value? In this regard, do you use and take into consideration any KPIs?
  - How do you decide which parts and how many parts should be in stock?

  - Is the stock regularly counted? If so, how often? Do you use any method (i.e ABC, FSN classification)?
  - Do you tend to hold high levels of inventory to avoid stock-outs? Why?
  - How do you compute the service level? How do you keep it high?
- Which are your current inventory control issues?
  - Which are the problems related to product obsolescence?
  - In this regard, is the obsolescence of the products verified on all the products or only on some of them?
  - Have you ever stopped the reprocessing of an item due to the lack of needed spare parts? Do these problems cause some issues in the production phase?
  - Which are the high costs you currently incur? What has the biggest impact?
  - Do you believe that existing system which you are following is an efficient one?

Appendix II: example of interview

Type of interview: face-to-face interview
Date: 22 May 2019
Location: Drake & Farrell headquarter

a. Introduction

- *Introduction of the researcher*: 24, SCM, Tilburg University, master thesis at Drake & Farrell
- *Explaining the purpose of the interview and research*: getting information about how the spare parts inventory is currently managed and in which problems, issues and costs they incur

b. Background

- *Could you briefly introduce yourself and describe your company's position?*
  I am Berry Selhorst, Manager operations, responsible for all operations activities within Drake & Farrell Bleiswijk, LCL Czech Republic and Industrial Solutions Zoeterwoude. My main objective is to establish and control the service and performance levels for the operation. Furthermore, I manage and control warehouse security procedures and initiate improvement actions to optimize the production and logistics processes.

c. Spare parts inventory management

- *Can you describe how the remanufacturing process is currently managed? In this regard, could you explain in general terms how all phases of product recovery are carried out?*
  When the subscription is ended or when the device is defected, the customers decide to send the product back. In this regard, the customer contacts KPN that will send an email to Drake and Farrell. Therefore, D&F has the order to send an empty box to the customer where he will put the device to send it back directly to us.
  Once the package arrives here, it goes to the De-Kit department, where the box is opened and the number on the label is scanned and put in the system that keeps track of the incoming products. Then the production starts. The first phase is testing, that says if a product is "good" or "not good" (and so, if the item is technically functional or not). What is "good" goes through the process, what is "not good" can go to repair or to scrap. All the parts of the product which can be reused are kept as spare parts in our stock. What is "good" go to the cleaning phase. This is important since it can make the article or device "as new",

but it also determines if the device needs to be refurbished or not. If it needs to be refurbished (in this case, the item is technically good but cosmetically not) goes to refurbishment, otherwise it goes straight to kitting. Kitting means the device will be packed in a box with its components like power adaptors, cables etc. We scan the box; a label comes out of the system and goes on the top of the box. Finally, we scan it to a pallet, and then it goes in the stock.

Throughout this process, an important step concerns the purchase of new spare parts. This happens when the entire product received or a part of it is broken, damaged or simply no longer usable and recoverable.

– *In this regard, how does the process of purchasing new spare parts work?*

  In the current process, we are dependent on KPN, which has the contract with a Chinese manufacturer in its hands. We simply follow KPN. We have no control over the contracts that KPN has with its suppliers. We have zero influence on that Chinese manufacturer.

  What happens is that when we need some new parts, we send a request directly to KPN which places the order with the Chinese manufacturer.

  At that point, the Chinese manufacturer sends the new parts directly to us. So, we are going to say: “I need 7000 units and we hope that in a short time we will receive those products”.

  We have no direct influence on lead time because we have not a direct contract with the Chinese manufacturer.

  However, last year there was a big issue with the biggest Chinese manufacturer. The manufacturer said: I am not going to send anymore to Drake & Farrell (because there was a problem in telecom market between China and America). So, what we did was that we searched for another supplier: we found another one that maybe was better than the previous: we had full in our own control, we save a lot of money because it was in our control, in our hands.

– *Do the uncertainties that characterize any reverse logistics negatively affect inventory management?*

  As you said, the whole process is characterized by uncertainty about the return of products. We don't know when the customer will give back the used product and the condition of the product. Obviously, this causes problems in the management of spare

parts inventory as it becomes difficult to understand and plan how much stock to have in inventory and how many new parts to buy.

– *Is the quality of old spares monitored?*

No. As I told you before we don't know the conditions (I mean, the quality and the status) of the old products as well as the moment in which the product will be returned.

– *Do you think that the fact that you don't know in advance which parts are broken or should be repaired creates some problems in inventory management?*

Yes, it creates some difficulties in managing new and old parts. For this reason, we try to be as cautious as possible by buying lots of new parts.

- *Can you clarify the difference between the two spare parts flows?*

We are dependent on the return process of the customer. There are two sides: one flow coming from a Chinese manufacturer, and one flow coming from the customers. Therefore, we have one flow for which we buy new products, and we have a flow which is not new, but the customer is going to send all the products back.

The biggest difference is that the flow that is not new (the one that is being returned) is characterized by a high uncertainty: we don't know how many pieces will be returned and we don't know the percentages that can be used as new again (and so, we actually don't know the status and quality of these old parts and products). The second spare parts flow is the one that comes from the manufacturer: the new flow. Unlike the previous, I know the quantities and the quality of these products and parts.

– *How many and which types of spare parts are available in stock?*

I can't tell you the exact number of spare parts available in our warehouse. With regard to the type, we have several pieces, such as cables, plugs, modems, remote controls, screws, wires, batteries, etc.

– *How often do you receive returned products?*

I show you a database and a report. As you can see, in general it is a surprise for us how many products we will receive each day. We cannot know in advance the return of old products, so there are some days in which we receive a lot of trucks full of old spare parts, and other days in which we don't receive anything. I have just a prediction based on history.

– *How many returned products do you receive each time?*

The amount has increased during the years: they are not throwing anything away, so they send everything back. They completely reused old products.

– *How often do you order new spare parts?*

Of course, it depends on the needs and so on the stock level. I show and send you all the data about it. In that case too, we have not a precise and stable frequency of order quantity. We simply order when we need, but to be as cautious as possible (i.e. to always have enough good spare parts in stock), we always try to order a lot. Of course, this leads to high costs and inefficiencies difficult to control.

– *How many pieces do you order each time?*

Thousands of pieces? It depends. We always order, but there are times that we order more and times that we order less.

- *How is the spare parts inventory currently managed?*

The main components are the current stock volume (I mean the stock level) and the forecasting. Our forecast is a working in progress. The forecast that we do is simply based on history. We just make a guess for the future. In this way we try to control and manage the inventory but as you can imagine it becomes very complicated.

We don't have a specific and differentiated inventory policy. We use a type of policy that is based on a MIN-MAX: it basically says that on the moment we receive a product, a spare part, we insert it in our inventory and we also got to use that for our production process, and on the moment it drops below a certain point, we automatically going to order new spare parts. We have an inventory level and if that particular level drops down a certain point (MIN), we should order new products, new spare parts.

We strongly believe that our current management of the inventory is completely inefficient since it leads to high costs.

– *What policy do you use to control it?*

As I mentioned before, the model that we use to control our inventory can be seen as a continuous replenishment or ordering policy since we have not a programmed periodicity. Moreover, we control and track the quantities of spare parts every time, every day, and therefore we order always new pieces. As I told you before, when these quantities fall below a level, we order new parts.

– *Do you order the spare parts when needed or do you use a specific policy for each class of spare parts?*

Absolutely not. We use this policy for all spare parts available in stock. We don't make any difference between them. It may seem strange to you, but we are a very young company with even inexperienced employees (for example, it is difficult to calculate the different KPIs). That's why we now use a single and unique replenishment policy for all parts.

– *Does the current replenishment policy take account of the spare parts turnover or usage value? In this regard, do you use and take into consideration any KPIs?*

Unfortunately, no. We do not take into account any KPIs, neither the turnover nor the consumption value of spare parts.

– *How do you decide which parts and how many parts should be in stock?*

Simply by seeing the current inventory level and counting the available stocks. At that moment, we place the order for all new parts.

– *Is the stock regularly counted? If so, how often? Do you use any method (i.e ABC, FSN)?*

There is no precise frequency with which we count the available stock. It can happen every day or once a week.

No, we do not use any method to classify spare parts. They are all treated and managed in the same way.

– *Do you tend to hold high levels of inventory to avoid stock-outs? Why?*

Our first concern is to avoid stock-outs and thus prevent production from stopping. For this reason, and because we do not know what products and parts will arrive and under what conditions, we always try to maintain high levels of inventory. Specifically, we order a lot of new parts of different types. Of course, this inefficient policy leads to considerable high costs.

– *How do you compute the service level? How do you keep it high?*

We always try to maintain a high service level by setting a target of 99%. We are always able to keep this target high, sometimes even with overperformance. In general, we do not calculate it as a number of quantities to be delivered with respect to the total demand, but as a number of quantities to be delivered in time with respect to the demand. Generally, having high stocks in stock allows us to keep the service level always high. Of course, the costs incurred are very high.

- *Which are your current inventory control issues?*

KPN is the most important player in our process because they tell us: you have to produce 800 pieces and we are going to produce 800 pieces. The forecast about customer demand is lying at KPN, but we never receive that information. We directly receive the customer returns: but we don't know when the customer will return the products.

As we always want to ensure a high service level and therefore meet the needs and demands of KPN as much as possible, we try to keep inventory levels high. The uncertainty factor plays a fundamental role because not knowing when but especially the conditions of the incoming products leads us to buy many more new pieces (and therefore to increase considerably the inventory levels to be maintained). Obviously, this leads to high inventory costs and especially high obsolescence of products.

Obviously, this causes great problems in the management of the inventory and in the level to maintain. The stock volumes would be higher than the preferable. Surely, what is missing is an efficient method of management of the spare parts in such a way to determine the right levels to maintain for every type of stock.

If we have better control, we can keep the inventory level at a good level: we could save half million. What we could save is the space, the interest and the risk involved with stock. When we have high stock level, it takes space and it costs money. There is the risk that the stock you have cannot be used anymore (so it can lead to product obsolescence). There is also the interest or investment cost related to the money invested in it. If we are able to guarantee a good stock and inventory control, of course all these costs will be lower.

– *Which are the problems related to product obsolescence?*

  The obsolescence of the product is very important. I can make an example with iPhone 5: we bought many components for iPhone 5, however the iPhone 5 is not going to be produced anymore, so we have a lot of stock that is obsolete: we can do nothing with that stock. If we have a high stock level that we actually don't use because we don't need it, it could cause product obsolescence.

  Surely, in the current inventory management, product obsolescence is one of the biggest problems we have.

– *In this regard, is the obsolescence of the products verified on all the products or only on some of them?*

  No, it does not occur on all products but only on some. Often only certain types of spare parts in stock become obsolete.

The obsolescence of products occurs mainly on that spare parts that we use very little. In particular, some of these have a very high value and consequently they have a big impact on our costs. For this reason, this type of costs is one of the most important.

– *Have you ever stopped the reprocessing of an item due to the lack of needed spare parts? Do these problems cause some issues in the production phase?*

Normally not. We always try to have enough stock to keep our production going. In fact, when we set the minimum level to be maintained, we also consider a significant safety stock. However, the maintenance of high stock levels is very expensive for us and we often run the risk of having obsolescence of products.

– *Which are the high costs you currently incur? What has the biggest impact?*

As I told you before we always try to keep high levels of stock in our inventory. Obviously, this causes us many problems related to the high costs incurred. Surely the two most impacting costs are that of product obsolescence and that of working capital: a very important cost and risk is that of products that become obsolete and can no longer be used. With regard to working capital, we would like to try to reduce it so that it can be used for other types of investments.

Other costs incurred by us are those of storage and the cost of placing the order. Sometimes it happens that we need more space to store products (given the high levels of stock maintained). For this reason, we make continuous investments in warehouse space, handling technology, and the workforce.

Regarding the cost of placing the order, it is KPN that has the contract with the Chinese manufacturer. So, it is KPN that directly bears the transport costs, but obviously because we are in a circular economy, these costs also affect us. The more we buy, the higher the costs we incur.

The products purchased are subject to customs duty despite the contract defines an Incoterm DDP.

– *Do you believe that existing system which you are following is an efficient one?*

Absolutely not. We realize that despite having a high service level, we are incurring high costs of inventory management making the whole process inefficient. That's why we need some methods and solutions that can help us make inventory management and control more efficient and optimal.

Appendix III: coding scheme and definitions

	Spare parts inventory management				
Code	SPIM				
Classification	Recovery process	Spare parts flows	Product return uncertainties	Inventory management and policy	Inventory inefficiencies
Sub code	RP	SPF	PRU	IMP	II
Berry Selhorst	If the customer wants to send the product back, he contacts KPN who will send us an e-mail. Then, we send an empty box to the customer where he will put the device to send it back directly to us. At this point the whole recovery process begins, which ends with the delivery of the reconditioned products to KPN.	One flow coming from Chinese manufacturer, and one flow coming from the customers	We don't have any kind of information about the returns. We don't know the conditions (the quality and the status) of the old products as well as the moment in which the product will be returned	We use a type of policy that is based on a MIN-MAX: it basically says that on the moment the inventory drops down a certain point, we automatically order new spare parts	Due to the uncertainty about the quality of the old products we always buy a lot of new spare parts. This allows us to be very cautious and also to guarantee a high service level (about 99%). However, the main problem is the high costs we incur to maintain the high levels of stock. Very high working capital costs and product obsolescence costs
Janko van den Haak	There are 3 main stages: first the collection of all used products,	The flow that is returned is characterized by a high uncertainty.	We don't know the status of the product until it is unboxed.	We have a model based on the MIN-MAX policy: when the quantities of spare parts drop below a	We do not differentiate between spare parts, and we use a single review policy. We have

	then the regeneration of old products, finally the distribution to the final customer	The second spare parts flow is the one that comes from the manufacturer: the new flow	We don't predict the volumes of the returns	certain point, we order new spare parts	very high stock levels with consequent very high costs
Thijs Bender	We are responsible for recovering the old product, while the distribution of the new product to the market depends on KPN. As for the collection phase, it is the customer who sends us the old products	We manage two different flows of spare parts: one flow is made up of all the old products, while the second is made up of all the new products	We don't know when the customer will return the product. We have no advance information on the quality of returns	We don't have a specific inventory policy, in the sense that we use a single reorder policy for all spare parts available in stock	The main cost is related to the obsolescence of products because maintaining very high levels of stock in inventory, often many spare parts become obsolete and no longer usable
Edward van Dam	The recovery process is carried out within our facility, and the phases are: testing, cleaning and kitting. The refurbishment phase, which involves the purchase of new spare parts, is fundamental	The first flow is certainly that of old and used products coming from the market, while the second flow is that of new products coming from a Chinese manufacturer	There are many uncertainties about the return of products that cause inventory management issues and inefficiencies	The management of our inventory is currently very difficult because we try to maintain very high levels of stock incurring in high costs. The policy we use is that of "MIN and MAX"	Inventory inefficiencies are related to the high costs we incur in maintaining high stock levels (which are often higher than what we need). The costs are: storage costs, working capital costs and high risk of product obsolescence

Double Degree Master Thesis:

Spare parts inventory management: a structured method to improve the overall performance
A study of Drake & Farrell

Supervisor:

Professor Alessandro Zattoni

Co-supervisor:

Professor Federica Brunetta

Candidate:

Chiara Belfiore

Academic year 2018/2019

TABLE OF CONTENTS

TABLE OF FIGURES

SUMMARY

Introduction

Nowadays, many companies focus on efficient and effective inventory management to achieve a distinct competitive advantage and improve their market position (Naliaka et al., 2015). In this regard, the management of inventory plays a major role in the global economy.

As stated by Prempeh (2015), inventory management is a fundamental asset of the company with an economic value. Better inventory management can ensure high growth and profitability.

Effective and optimal inventory management helps companies to define the perfect reordering policy for each type of stock-keeping unit, and to reduce various costs such as the holding cost, reordering cost, and shortage cost that occurs in the event of stock out (Singh et al., 2011).

"*Inventory management is the art and science of maintaining stock levels of a given group of items incurring the least cost consistent with other relevant targets and objectives set by management*" (Jessop, 1999).

Efficient inventory management is a main goal for both traditional or forward companies and for reverse logistics providers. Controlling and optimally managing the inventory in reverse logistics becomes complicated due to high uncertainties with regard to returned parts and products. In these companies, the collection of returned products is driven by supply rather than market demand. Therefore, as it cannot be controlled directly by the company, high uncertainties arise in terms of quality, time and quantity of returned products (Tomašić et al., 2013).

This element of uncertainty that characterizes reverse logistics companies makes inventory management even more complicated (Tomašić et al., 2013). Once the different old products and parts have been returned, these companies start a process of recovery of the asset, which can include the purchase of new parts in the event that the old ones are broken, damaged or no longer usable. A related problem is to ensure an efficient reordering policy of new spare parts, as it is difficult to decide how many new parts the companies will have to order, which parts they will have to order and how often to place the order for each part.

Often, companies face a trade-off between maintaining low levels of stock or high levels of stock in inventory. The first option is to buy only when necessary, which means low costs but high risks in the event of a lack of stock. The second option is to hold high stock levels with high costs (high ordering costs, more inventory, more storage costs, high obsolescence, high working capital) but with a low risk of stock out (Slack et al., 2010).

To address this problem and to ensure optimal inventory management, companies should adopt different reordering policies for different classes of spare parts in order to keep low inventory levels while guaranteeing high efficiency and effectiveness.

"*The optimal inventory control methodologies intend to reduce the supply chain cost by controlling the inventory in an effective manner*" (Singh et al., 2011).

"*Optimal supply of spare parts (…) can be maintained only with quality planning, management and selection of decision criteria that management provides as a basis for managing business processes for supply optimization*" (Tomašić et al., 2013).

An optimal methodology to ensure efficient management of the spare parts inventory is the implementation of a classification tool. This allows to classify and distinguish all spare parts in different categories according to specific characteristics in order to adopt different strategic behaviors for each class. This tool has proven to be useful in order to address the described problems, so that companies can be able to reduce costs and inefficiencies, thereby achieving an overall improved performance.

Based on the foregoing and in order to demonstrate it, the case of Drake & Farrell has been examined, as it fits perfectly with the aim of this research. In fact, this company is one of the leading experts in reverse logistics but, above all, it is a company that is currently facing major problems and inefficiencies related to the management of spare parts inventory.

In this regard, Drake & Farrell is a leading Dutch third-party reverse logistics provider based in Bleiswijk (NL), which cooperates with major consumer goods companies to improve their logistics processes. Its main B2B customers are television services and telecom providers such as KPN, the largest telecommunications company in the Netherlands.

Drake & Farrell manages KPN's customer returns for routers and remote controls. After obtaining the different used parts and products directly from KPN's customers, the company assesses which parts are reusable and which ones should be disposed of. If these reusable parts are not enough to complete the final device, the reverse logistics company must purchase the remaining parts. In this way, two different spare-parts flows are generated: the first comes from the harvesting process and is characterized by a high uncertainty of the returned products in terms of quantity and quality, while the second flow derives from the purchasing process.

The high uncertainty in the return of products that characterizes the reverse logistics process, causes difficulties in inventory management. Since the company does not know the exact type, the quantity and the quality of the old products in advance, the whole process of inventory management becomes more complicated. This has considerable effects on inventory levels and costs incurred by the company.

Drake & Farrell adopts an inventory policy of "MIN and MAX" whose levels are established based on past performance. When the quantity of stock drops below a certain level, Drake & Farrell automatically orders a certain quantity of new spare parts. However, given the uncertainty about the quality of incoming products and to avoid stock out and therefore to guarantee a high service level, the company always orders a large number of new pieces. The main problem is that this is done by applying a unique reordering policy, without differentiating between spare parts and therefore without taking into account the rotation of the components and their consumption value. This process leads to several negative consequences: - high inventory levels; - relevant storage cost and inventory cost; - high product obsolescence given the high technological content of the products.

Although Drake & Farrell has a high-performance indicator, that is a high service level, it does not use efficient inventory management tools that would allow it to maintain low stock levels with consequent lower costs.

The above brief summary is useful as it provides a theoretical background that can support the focal point of this research thesis. The aim is to analyze and examine in detail how a company can ensure efficient and optimal management of the spare parts inventory thus obtaining several benefits and economic advantages. In light of the above, a structured method that can help a company to improve its overall performance consist of the implementation of tools for the classification of spare parts into different classes. This allows the company to customize its ordering policy and to behave differently for each category of spare parts, leading to lower overstock and thus achieve cost reductions, a much more efficient management system and improved overall performance. In light of this, the theoretical framework will provide a clearer understanding of the methods and tools of classification and the benefits associated with it.

Based on the information described and explained in the problem identification, the following research question is created:

How could a company be more efficient in the spare parts inventory management achieving an optimal control and an overall cost reduction?

In order to provide a concrete and comprehensive answer to the research question, a case study analysis was carried out. Analyzing a phenomenon through a specific case is beneficial because it allows a much deeper and truthful investigation to be carried out. It also makes it possible to demonstrate what can be deduced from the theoretical framework. Through the implications of this study, it will be possible to draw a broader conclusion. Specifically, it will be possible to demonstrate how a tool for the classification of spare parts and inventory management can solve inefficiencies and ensure better overall performance.

Theoretical Framework

In recent decades the world scenario has been characterized by several radical changes caused by scarce resources. An important change at company level has involved the introduction of a new type of function, the so-called Reverse Logistics. European Working Group on REVLOG, defined Reverse Logistics as "*the process of planning, implementing and controlling backward flows of raw materials, in-process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal*" (Dekker et al., 2013). The aim of a reverse logistics provider is to deal with product returns, collect and handle them in order to maximize the recovered product revenue (Bonev, 2012).

As stated by De Brito et al. (2004), unlike traditional companies, reverse logistics face several problems related to the management of the inventory of returned parts and products. Indeed, a reverse logistics provider is characterized by high uncertainty and little control over the supply side due to returned products. The high uncertainties in returned parts and products cause many difficulties and high costs in the inventory management and stock levels to be maintained. The reason is that not knowing exactly which products will be returned and in what conditions, causes some complications in the inventory and stock level. The uncertainty in the return of products creates some difficulties in choosing the number of new parts the companies will have to order, which parts will have to order and how often to place the order for each part. This leads the company to increase the quantity and level of stock, avoiding the depletion of stocks and ensuring high service levels while sustaining high costs. The consequence is that the inventory can increase to undesirable levels. When this inventory becomes too large, there will also be high inventory costs (*cost of placing the order*; *maintenance costs*; *storage costs*; o*bsolescence costs*; *working capital costs*).

In addition, management difficulties increase when companies do not use some parameters and indicators to classify spare parts. This leads to inefficiency and ineffectiveness by incurring high costs as described above. In this regard, it becomes necessary to use an optimal and efficient management tool that allows to categorize spare parts in different classes and to behave differently according to the characteristic of each class. In such a way, it would be guaranteed a low level of stocks as well as a relevant saving to the company.

By implementing a specific tool, a company would be also able to better define the exact inventory level to be maintained for each type of stock. The decision to keep low or high stocks has significant consequences, especially on the service level.

Having a low level of stocks leads to lower costs, low inventory space, low product obsolescence, but high risk of stock-out (and thus low service level). Having a high level of stocks leads to no risk of stock-out and thus high service level, but higher inventory space, costs and product obsolescence.

Usually companies often face a trade-off between costs and service level when they have to make decisions about stock levels to be held in inventory.

In order for efficient decisions to be made, it is necessary to adopt a method of classifying spare parts that allows companies to act differently according to each stock category.

"*The items classification is an essential part of the inventory management systems, in order to determine the adequate level of managerial attention; allow the choice of inventory control methods; and establish different performance goals at the inventory turnover and service levels between categories*". (Do Rego et al., 2011).

As stated by Ravinder et al. (2014), several criteria for inventory classification are used. The most commonly used method of inventory organization is the **ABC classification** which discriminates all the items according to their usage or consumption value (Slack et al., 2010). This analysis is based on the Pareto law which states that most effects (80%) depend on a limited number of causes (20%).

ABC classification identifies which products have the greatest impact on costs and revenues. In this way, the products are divided into three classes (Teunter et al., 2010): 1. Class A items (they generate the highest sales volumes and make up about 80% of the total value; this class generally includes 20% of the items); 2. Class B items (they are medium consumption value products); 3. Class C items (items with the lowest consumption value: 50% of the stock and they cover a value close to 5% of turnover).

Another important classification of stocks used by companies is based on the turnover ratio that estimates the efficiency of inventory management. This indicator is calculated for each item and it allows to evaluate which are the items that remain in the inventory for a short time (high rotation) and those that, instead, remain there for longer (low rotation) (Mitra et al., 2015). In this regard, a common stock classification is called **FSN analysis** based on the consumption rate and the quantity of each item. This classification divides all items into three categories: 1. Fast-moving class (items used frequently and in large quantities; this class represents 10-15% of all stocks); 2. Slow-moving class (items used in small quantities and with low frequency; they represent 30-35% of total item); 3. Non-moving class (60-65% of total item; these items are not used for a certain period of time).

The use of a stock classification tool allows the company to diversify the reordering policy: according to the different types and classes of stocks, a different policy can be adopted in order to minimize costs and increase efficiency and overall performance (Silver et al., 1998). With regard to the ABC classification, Silver et al., (2016) present the different reordering policies that must be adopted by the company according to the class of the various items.

	Continuous review policy	Periodic review policy
Class A items	(s, S)	(T, s, S)
Class B items	(s, Q)	(T, S)
Class C items	manual (s, Q)	manual (T, S)

Figure 1: best reordering policies (adapted from Silver et al., 2016)

With regard to the FSN analysis, Kumar et al. (2017) present different action that should be implemented by a company according to the type of item.

	Fast-movers items	Slow-movers items	Non-movers items
Stock	High	Intermediate	Low
Control	High	Intermediate	Low
Check	Tight	Intermediate	No

Figure 2: characteristics of FSN analysis (adapted from Kumar et al., 2017)

Differentiating the reordering policies is fully beneficial because it allows reducing all the costs related to inventory management. For example, fast-movers need to be reordered more frequently and in larger quantities than slow-movers. For them it is possible to adopt a continuous replenishment policy based on min and max (s, S) (companies can set an order-up-to level, as they will never have problems of obsolescence given the high turnover index).

By adopting different reordering policies, it is easier for the company to determine the optimum levels of stock to be kept. This classification tool is also very useful to control and avoid the product obsolescence and to reduce all the costs, since the company would work on lower inventory levels. As pointed out by Hamlett, the main benefits related to an optimal and efficient inventory control are: • low inventory costs (due to low amount of inventory); • higher service level; • competitive advantages over other companies.

Methodology

This chapter analyses how the research has been developed by highlighting the adopted research strategy, the research design and the methods used for the data collection and data

analysis. The choice of research strategy has been made by taking into consideration the research question. In that case, the used approach is exploratory, since the already existing theories have been the starting point of this research. Using the insights obtained from the literature on the spare parts inventory management and the tool for classifying stocks according to various parameters, it will be possible to show how companies can ensure efficient and optimal inventory management thus increasing control and reducing all the high associated costs.

To draw the final conclusion, the case of Drake & Farrell will be analyzed. Studying a specific problem can be helpful to increase its understanding and to find an applicable solution.

An empirical investigation is used to understand the issue through an inductive study since the final goal is to generate a new theory emerging from the data analyzed and to come up with a solution to a current problem (Gabriel, 2013). Indeed, the purpose of this present work is to generalize and expand the above-mentioned theory through the exploration and analysis of a specific case. In this regard, the outcome and solutions that emerged from the analyzed case can be easily extended and generalized to similar companies that face the same problems. According to the purpose of the research, this study will be conducted as a qualitative research which aim is to investigate all the phenomena and solve the empirical problem taking as reference the existing literature (Denzin et al., 2011).

Regarding the research design, the most suitable is the case study: it allows to investigate contemporary phenomena and to use multiple sources of evidence. For that reason, this research analyses a real case of a third-party reverse logistics company, Drake & Farrell, in order to present the problem the company is currently dealing with and try to solve it through a structured method. The case of Drake & Farrell has been chosen thanks to a collaboration with Tilburg University; the company is one of the leading experts in reverse logistics in the Netherlands that is currently encountering several problems and inefficiencies related to inventory management. In the light of the above, through the study of this specific case, the existing theory can be expanded, finding a solution that can better solve the current problem, thus ensuring a meaningful development for this thesis.

The data collection is divided into secondary and primary data collection. The former is useful to decrease the confusion and guarantee a clear overview through a deep definition and identification of all aspects. In order to define the problem, it was needed to get more information by using articles, books, academic papers and publications. This important step was necessary to define a literature framework.

Primary data were collected through several methods such as questionnaire, observations and

semi-structured interviews. The interview is a useful method to recognize how Drake & Farrell is currently managing the spare parts inventory and which are all the inefficiencies, problems and high costs that the company incurs. For that reason, quantitative information and data taken from the company's documents and reports have been used to make the research and the analysis stronger. Given the final goal of this study, an interview protocol has been prepared that contains several questions related to the management of spare parts inventory, the policies used to control it, how many spare parts are received, how often they are received and how often the company orders new parts. Moreover, questions related to the problems and inefficiencies that the company faces in the management of spare parts inventory are included. The interviewees are represented by the company's employees and managers. People were carefully selected with regard to their function in the company and the information needed to carry out this study. Thanks to these interviews, it has been possible to understand in a complete way how Drake & Farrell manages all recovery process, how it manages and controls the spare parts inventory, and what are all the problems and high costs it encounters.

Empirical findings

Drake & Farrell inventory management

Drake & Farrell is a third-party reverse logistics provider located in Bleiswijk (NL) that performs the whole recovery process for the market leader KPN, the most important telecommunications and IT provider in the Netherlands. The products that are returned for refurbishment are mainly mobile phones, modems, router, TVs and so on.

Drake & Farrell's goal is to provide a good service to companies in order to reduce their costs, increase their efficiency, availability, punctuality, satisfaction and most importantly, decrease waste. In light of this, the aim of this reverse logistics company is to be as sustainable as possible, trying to reduce all types of waste in order to achieve a positive environmental impact. At the moment, Drake & Farrell is dealing with some problems and inefficiencies in the management of its spare parts inventory leading to a lack of control and above all to high costs. The activities of Drake & Farrell can be explained in three detailed steps:

1. Receiving and collecting old products directly from the end-user of KPN who decides to return the product because it is no longer usable or because the subscription period is over: the customer contacts KPN to notify its decision to return the product. KPN informs Drake and Farrell that will send an empty box to the customer in which he will put the product and send it directly to Drake & Farrell.

2. Recovery process: testing, sorting and cleaning the old products to create a new one. During the testing phase, it is determined whether a return is technically functional. When the product arrives at Drake & Farrell, it is scanned and verified its technical status by distinguishing it in "good" or "not good". The "not good" products (i.e. those that can no longer be reused) go to scrap (to waste or to recycling) or to repair, while the "good" products go to the cleaning phase. During this stage, it is determined if a product should be refurbished or not. If it has been established that some parts need to be replaced, the re-processing phase takes place. What is important at this stage of the process is the availability of spare parts (*reparable* spare parts, i.e. parts that can be economically or technically refurbished to make them reusable). In fact, if the parts that should be replaced are not available in the inventory, Drake & Farrell must purchase new parts from a Chinese manufacturer to combine and produce the final products. At that point, Drake & Farrell must notify KPN of the need for new parts and KPN will immediately place the order with the Chinese manufacturer. Subsequently, the new parts will be delivered directly to Drake & Farrell. After this phase, the new product will be ready to be redistributed in the market.
3. Sending the finished products to KPN: once the product has been refurbished, the kitting phase takes place. This means that the product is boxed and completed with the necessary components (adaptors, cables, etc.). When it is ready, it is shipped to KPN, which will take care of the final redistribution to the market of the recovered product.

As explained above, very often Drake & Farrell has to buy new spare parts in order to complete and produce a new product. This happens either because some parts of the old product obtained by customers can no longer be used because they are damaged or broken (i.e. a customer sends back a router whose socket cannot be adjusted or refurbished because it is broken), or because some pieces are missing in the package sent back by customers (i.e. a customer sends back a package in which there is a router but not the socket).

From this detailed overview of the whole process carried out by Drake & Farrell, it can be clearly seen that the company has to manage two different flows of spare parts:

1. the first flow of spare parts derives from the harvesting process: it is characterized by all returned and old products coming from the end-user of KPN;
2. the second flow of spare parts comes from the purchasing process: it consists of new products and parts purchased from a Chinese manufacturer.

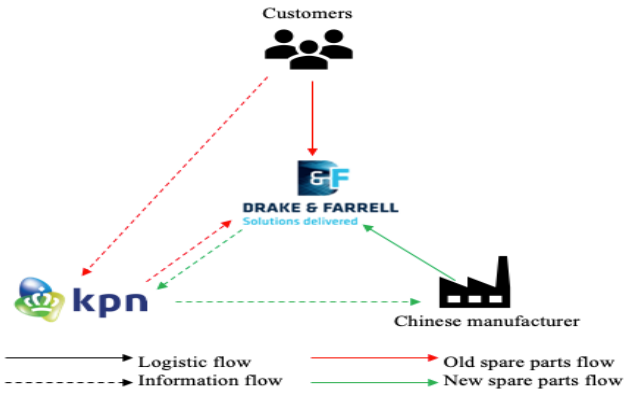

Figure 3: two spare parts flows of Drake & Farrell (source: the author)

These two types of spare parts and products build up the inventory of Drake & Farrell.

In general, the flow of old spare parts is characterized by high uncertainty: the company has no clue and timely information about the daily amount of incoming returns and the moment in which they will arrive. Each week Drake & Farrell receives different amounts of old spare parts from customers.

In light of this, it becomes clear that neither the quality nor the type of products are known until they reach the recovery facility. This internal uncertainty creates complications and difficulties in inventory management. Inventory management means how many old and new stocks Drake & Farrell has available, how many new orders must be made and how often to place them.

With regard to quality, and therefore the condition and status of the products received back, it is difficult for Drake & Farrell to determine in advance how many of the old products can be reused and how many cannot (it is not possible to determine in advance if the product should be subjected to the remanufacturing process, if it represents a scrap or if it should be cleaned). Not all of these products received can be reused in the refurbish process (many pieces could be broken, damaged and therefore no longer used. These parts are directly thrown away). From the graph below, it is possible to see that some of the old products are no longer useful and therefore are scrapped or recycled.

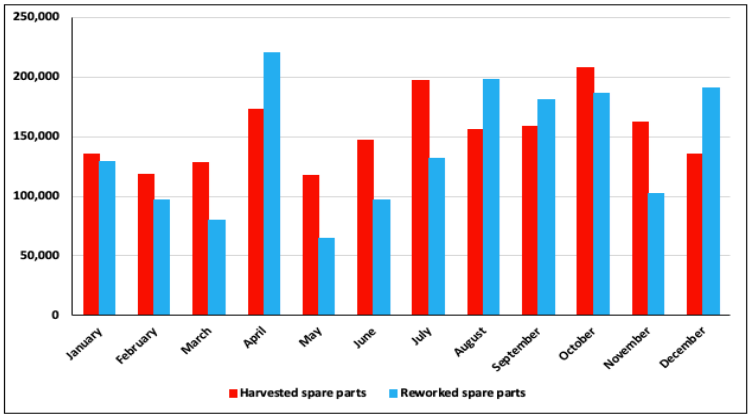

Figure 4: comparison between the number of old spare parts received back and the number of reused spare parts in 2018 (source: the author)

From the data obtained by Drake & Farrell, it emerges that generally only a part of the received spare parts can be reused, while the rest is recycled because it is probably broken or damaged. There is an exception in some months where the number of reworked spare parts is higher than the number of harvested spare parts. This happens because there is a lead time in the rework: this means that products received in a certain month are reworked in the following month. In fact, it is possible to see that in the months in which there is a much higher number of reworked parts than the harvested spare parts, in the following months an opposite situation occurs.

As a result, each month the company must ensure a quantity of new spare parts available in the inventory that has to be used to complete the final product.

In this regard, the uncertainty leads the company to take precautions in the event that spare parts are missing (so-called stock-out) and therefore to avoid possible production problems and to ensure that the refurbishing process could be completed. For this reason, Drake & Farrell orders lots of new spare parts.

The interviews clearly showed that, despite the existence of this element of uncertainty that characterizes Drake & Farrell and all its activities, the main problem lies in the fact that the current inventory management is completely inefficient, as no inventory management tool or method is used that can ensure an efficient, cost-effective and optimal control.

The inventory is currently managed by adopting the minimum and maximum policy for all types of spare parts, regardless of their consumption value or their rotation. That is, the company, based on past data and past history, predicts and establish a minimum and maximum level of stock that must be kept in the inventory. When the available stock drops below the identified threshold (the minimum), the company places an order with a variable quantity of new pieces to bring the inventory up to a given level (the maximum).

Among the various replacement policies identified in the literature framework, this model belongs to the continuous review policies (s, S): there is always full knowledge about the stock level since the quantities are constantly tracked and counted. The company simply orders new pieces only when needed and therefore when the inventory falls below the minimum level. For this reason, there is a high volatility in the ordering of new spare parts.

As mentioned above, Drake & Farrell adopts this replacement policy for all types of spare parts without making any distinction between them.

This leads to have and to maintain very high levels of stock incurring therefore in high costs and problems in the management of the inventory that will be explained later.

It is important to state that, although the reverse logistics process is surrounded by high uncertainty, Drake & Farrell always tries to provide a high service level. For this reason too, the company constantly maintains high levels of stock in the warehouse, always purchasing new spare parts (to ensure that production does not stop causing bottlenecks in the event of missing or broken parts).

The service level currently guaranteed by Drake & Farrell is calculated as on time-in full, which means the number of quantities delivered in time with respect to the demand.

$$\text{SL: } \frac{number\ of\ quantities\ delivered\ on\ time}{total\ quantity\ of\ the\ demand} = \textbf{99.2\% YTD}$$

Obviously, as it has also been explained in the literature review, having high levels of stock that can ensure a high service level leads to high costs incurred by the company. This happens because Drake & Farrell does not maintain the right level of stock in the inventory for every type or class of spare parts. Having a high KPI but incurring high costs for its maintenance leads the company to be still inefficient.

Consequences of current inventory management

As explained in detail in the previous paragraph, the current inefficient management of spare parts inventory leads the company to have high levels of stock. In turn this leads to several negative consequences, mainly represented by high costs and risks incurred by Drake & Farrell.

1. *Obsolescence of the product*: the company has many obsolete stocks and therefore no longer usable, given the high technological content of the products. Therefore, this "min and max" policy adopted for each type of spare part could prove to be inefficient as it leads the company to order more, causing possible obsolescence of some parts. As shown by the interviews, the obsolescence of products is mainly limited to slow movers. However, some

of these products have a very high value and therefore they have a heavy impact on the costs incurred.

2. *Storage costs*: when Drake & Farrell orders many new parts, it also has to bear high storage costs. Very often there are spare parts that remain in the inventory for a long time and have a negative impact on the costs incurred by the company. The company sometimes needs more space to store its materials. Drake & Farrell constantly makes continuous investments in storage space, in handling technologies, and in the workforce.
3. *Working capital*: the most important and costly consequence. Indeed, maintaining a high level of stock implies high investment costs (i.e. high purchasing costs) and high level of risks. Since this fixed capital does not generate interest, it is seen as a high-risk factor. From the interviews conducted with managers, it emerges that one of the goals is to reduce working capital to be able to allocate it to other types of investment.
4. *Cost of placing the order*: having a high level of stock leads to negative consequences mainly on transport and purchase costs: if the company was able to establish an accurate amount of orders for each type of spare parts, the cost of transport would be lower.

From this analysis and as it has been asserted by managers, it is possible to state that tools are needed in order to optimize inventory control and reduce all inventory related costs. Having examined in detail the current situation of the reverse logistics company Drake & Farrell and all the different problems and high costs incurred by the company, it is easier to outline a feasible solution.

Conclusions

Implications

As it has emerged from the empirical findings, Drake & Farrell, as a reverse logistics provider, is surrounded by many uncertainties that make complicated and difficult the overall management of the spare parts inventory. Specifically, Drake & Farrell has no upfront information on the products that will be returned by KPN's consumers. That is, the company does not know the type of products and especially the quality and condition of such products or parts. In this respect, the company becomes aware of these characteristics only when the product arrives at the facility and the remanufacturing process begins.

These circumstances have generated some inefficiencies and difficulties in the management of the spare parts inventory leading to very high costs and therefore to have a lower performance. Not knowing exactly and in advance the state in which the products are, leads the company to be very cautious in the process of reordering new spare parts. In fact, the products returned can

be broken, damaged, or obsolete, leading the company to have to buy from a third-party supplier those parts or products. For this reason, and therefore to ensure that there are always enough stock in the inventory and to ensure a high service level, the company frequently buys many new spare parts. This leads the company to always maintain high levels of stock in inventory which involve very high costs. However, the main problem that Drake & Farrell is facing, is related to the management of its entire inventory and its related replacement policy. In particular, the company uses a single reordering policy for all types of spare parts, without differentiating between them and therefore without taking into account the rotation of the components and their consumption value. The policy implemented is that of minimum and maximum: the company simply orders new spare parts when the amount available in stock drops below a given threshold. The fact that the company does not adopt different reordering policies based on the types of spare parts, and therefore the fact that no differentiation is made between them, leads to very high stock level. In this way, the company incurs in incredibly high costs of storage, maintenance costs, working capital costs, and above all, it is exposed to the risk of obsolescence.

For the above reasons it is necessary to adopt a tool of inventory management that can help Drake & Farrell to be more efficient, reducing overall costs while maintaining a high service level. This tool would allow the company to classify all spare parts according to different parameters. Only in this way, the company could adopt different reordering policies for each type and class of spare part lowering the stock level and the associated costs.

Specifically, a feasible solution that can be proposed to Drake & Farrell is to perform an FSN analysis. Performing this analysis based on the movement of inventory is useful because it allows the company to ensure continuous availability in the inventory only of those products with high turnover. In addition, it allows the company to take a risk of stock failure only for low turnover products. With the implementation of the FSN analysis the general level of the inventory would be reduced because all the level of slow and non-movers items, that corresponds to about 80% of stock-keeping unit (SKU), would go down. Subsequently, Drake & Farrell should implement an ABC classification. At that point, it is optimal to perform an ABS-FSN matrix, that allows Drake & Farrell to understand how to behave for each individual spare part class.

	A	B	C
F	Products or spare parts with high turnover ratio and with a high value. They need a tightest control and a correct definition of the stock levels in order to avoid both an excessive stock level that would lead to high costs, and a low stock level that could cause stock out (the stock out of the fast movers is very expensive). Frequent, daily monitoring	Very used products with medium value. These products require a reduced frequency in cycle counting, while the level of stock to be maintained may be marginally increased	Widely used products with low value. As a result, maintaining a high stock level is not very expensive. So, Drake & Farrell can work with higher minimum stock levels (the stock level can be significantly increased) in order to make sure they do not incur a stock failure
S	Products or spare parts that are not widely used but cost a lot of money. Therefore, for these products, it is necessary to use the above-mentioned policy (s, Q). However, it must be kept in mind that despite the cost of stock out is less relevant than fast movers, keeping these products in stock would cost a lot of money	Products or spare parts that are little used with medium value. For these products, a reduced frequency in cycle counting is required	Products or spare parts that are little used and have low consumption value. These products require a low frequency in cycle counting (minimum supervision): Moreover, it must be disposed of the excess quantity in order to avoid unnecessary costs given the low use. Maintaining generally low levels of stock with infrequent ordering
N	Not used products or spare parts but that cost a lot. As a result, disposal must be expedited in order to free up costs, as they are products with a high value	Not used products or spare parts with medium value. As a result, disposal must be speeded up in order to free up not only the costs but also the storage space	Not used products or spare parts with low value. Consequently, the disposal must be speeded up in order to free up the storage space (no costs because they are spare parts of class C)

Figure 5: cross-classification matrix ABC - FSN (source: the author)

By adopting different reordering policies for the various classes, it is easier for the company to determine the optimum levels of stock to be kept. Therefore, the classification also helps to determine how much stock to have. The implementation of these two analyses is used to reduce the impact of working capital and the impact of product obsolescence (Drake & Farrell would be able to reduce the obsolescence on those products used very little because it would maintain low inventory levels for that category). This tool would help the company to maintain a high service level, but above all to decrease the costs it incurs: • lower working capital costs because the company would work on lower stock levels, lowering its value to 80% of the components; • lower storage and handling costs; • lower product obsolescence (the risk of incurring high obsolescence would totally decrease: at the time when a product becomes obsolete, it will have a lower level of stock and therefore the related costs will be lower).

Conclusions

On the basis of the study conducted and the implications and solution outlined for the company, it is now possible to provide a comprehensive answer to the research question that has been formulated in the first chapter. Starting from what emerges from the empirical results, it is

feasible to affirm that in order to be much more efficient in the inventory management and therefore to have real economic benefits, the companies should consider the implementation of a classification tool that allows to organize and classify all the stocks in different classes according to different parameters. This method is an essential tool for inventory management as it allows companies to adopt and take different strategic decisions based on different categories of items. This is why the level of stock to be kept in inventory as well as the control, attention and check are different for each category, so as to maximize efficiency while minimizing the effort, costs and risks associated with inventory management. With the use of this method the company can then define different replenishment policies in such a way as to always have the necessary level of stock available, without incurring in out of stock or excessive stock. In this regard, companies can use different criteria for stock classification depending on whether they want to perform an analysis based on usage/consumption value or on the consumption rate and quantity of each item. The first analysis, called ABC, allows identifying the stocks that have a greater and lesser impact on costs and revenues. The second, instead, called FSN analysis, carries out an analysis relative to the efficiency of the inventory and therefore it studies the rotation of the components in warehouse dividing the stocks in high and low rotating stock. According to their needs, companies can implement several classifications based on different parameters. For the specific case of Drake & Farrell, a cross-classification matrix has been proposed with which stocks are divided according to a double parameter, i.e. according to both FSN and ABC classification. Through this double classification, it was suggested to the company how to behave for each type of stock. This cross-matrix proposed to Drake & Farrell can also be applied to all companies with a high degree of uncertainty about the flow of goods characterized mainly by a high technological level and therefore subject to high obsolescence.

The results of this exploratory study allow to expand the existing theory as they provide more knowledge about the applicability of this tool and how it can increase the efficiency of the whole management process as well as the business performance. This has been made possible by the study and analysis of an existing phenomenon thanks to which it has been possible to reach a feasible solution that can be generalized to more than one company.

In the light of the above, the economic and market benefits that can be obtained by companies that implement different management strategies depending on the type and characteristics of the item, are linked to a reduction in inventory costs and risks, such as product obsolescence. Moreover, the companies will be able to determine more easily the exact level of stock to be kept in inventory for each type of item, thus guaranteeing a high service level.

REFERENCES

Abbaszadeh, M. (2012). Validity and reliability in qualitative researches. Journal of Applied Sociology, 45(10): 19-34.

Andrade C. (2018). Internal, External, and Ecological Validity in Research Design, Conduct, and Evaluation. *Indian journal of psychological medicine*, *40*(5), 498–499.

Bashir, M., Afzal, M. T., & Azeem, M. (2008). Reliability and validity of qualitative and operational research paradigm. *Pakistan journal of statistics and operation research*, *4*(1), 35-45.

Berg, B. L. (2004). *Qualitative Methods for the Social Sciences*. Boston: Pearson.

Blumberg, D. F. (2004). *Introduction to management of reverse logistics and closed loop supply chain processes*. CRC Press.

Bonev, M. (2012). *Managing reverse logistics using system dynamics: A generic end-to-end approach*. Diplomica Verlag.

Bryman A., Bell E., (2011). Business research methods. 3rd Edition. Oxford university press.

Calder, B. J., Phillips, L. W., & Tybout, A. M. (1982). The concept of external validity. *Journal of Consumer Research*, *9*(3), 240-244.

Coghlan, D., & Brydon-Miller, M. (2014). *The SAGE encyclopedia of action research*. Sage.

Cohen, D., & Crabtree, B. (2006). Qualitative research guidelines project.

Creswell, J. W. (1994). Research design. Thousand Oaks, CA: Sage publications.

De Brito, M. P., & Dekker, R. (2004). A framework for reverse logistics. In *Reverse logistics* (pp. 3-27). Springer, Berlin, Heidelberg.

De Brito, M. P., & Van Der Laan, E. A. (2009). Inventory control with product returns: The impact of imperfect information. *European journal of operational research*, *194*(1), 85-101.

De Smidt-Destombes, K. S., van der Heijden, M. C., & van Harten, A. (2009). Joint optimisation of spare part inventory, maintenance frequency and repair capacity for k-out-of-N systems. *International Journal of Production Economics*, *118*(1), 260-268.

Dekker, R., Fleischmann, M., Inderfurth, K., & van Wassenhove, L. N. (Eds.). (2013). *Reverse logistics: quantitative models for closed-loop supply chains*. Springer Science & Business Media.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2011). The Sage handbook of qualitative research. Sage.

Do Rego, J. R., & de Mesquita, M. A. (2011). Spare parts inventory control: a literature review. *Produção*, *21*(4), 645-655.

Driessen, M., Arts, J., van Houtum, G. J., Rustenburg, J. W., & Huisman, B. (2015). Maintenance spare parts planning and control: a framework for control and agenda for future research. *Production Planning & Control*, *26*(5), 407-426.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of management review*, *14*(4), 532-550.

Fleischmann, M., Bloemhof-Ruwaard, J. M., Dekker, R., Van der Laan, E., Van Nunen, J. A., & Van Wassenhove, L. N. (1997). Quantitative models for reverse logistics: A review. *European journal of operational research*, *103*(1), 1-17.

Fleischmann, M., Krikke, H. R., Dekker, R., & Flapper, S. D. P. (2000). A characterisation of logistics networks for product recovery. *Omega*, *28*(6), 653-666.

Fraser, S. (2019) "What Is the Difference Between a Periodic and Continuous Inventory Review Policy?" *Small Business - Chron.com*.

Gabriel, D. (2013). Inductive and deductive approaches to research. *Accessed on February*, *13*.

Ghafouri, R., & Ofoghi, S. (2016). Trustworth and rigor in qualitative research. *International Journal of Advanced Biotechnology of Applied Behavioral Science*, *7*, 90-101.

Ghorbel, N., Addouche, S. A., El Mhamedi, A., & Boujelbene, Y. (2014). Bayesian approach for spare parts replenishment policies under uncertainties. *International Journal of Engineering Research and Development*, *10*(11), 28-45.

Given, L. M. (Ed.). (2008). *The Sage encyclopedia of qualitative research methods*. Sage publications.

Gobbi, C., & Jensen, P. L. (2008). *The reverse supply chain: Configuration, integration and profitability: Considerations derived from a qualitative case study investigation*.

Hamlett, Kenneth. (n.d.). The Advantages of Inventory Control. *Small Business - Chron.com*. Retrieved from http://smallbusiness.chron.com/advantages-inventory-control-2228.html

Hoppe, M. (2006). *Inventory optimization with SAP*. Bonn: Galileo Press.

Huiskonen, J. (2001). Maintenance spare parts logistics: Special characteristics and strategic choices. *International journal of production economics*, *71*(1-3), 125-133.

Ingram, David. (2019). Types of Inventory Costs. *Small Business - Chron.com*. Retrieved from http://smallbusiness.chron.com/types-inventory-costs-11787.html

Iraqi, Z., Barkany, A. E., & Biyaali, A. E. (2016). Models of spare parts inventories' optimisation: a literature review. *International Journal of Services, Economics and Management*, *7*(2-4), 95-110.

Joppe, M. (2000). *The Research Process*. Retrieved December 16, 2006, from http://www.ryerson.ca/~mjoppe/rp.htm

Kennedy, W. J., Patterson, J. W., & Fredendall, L. D. (2002). An overview of recent literature on spare parts inventories. *International Journal of production economics*, *76*(2), 201-215.

Kocer, U. U., & Tamer, S. (2011). Determining the inventory policy for slow-moving items: a case study. In *Proceedings of the World Congress on Engineering* (Vol. 1, pp. 6-8).

Kumar, Y., Khaparde, R. K., Dewangan, K., Dewangan, G. K., Dhiwar, J., S., Sahu, D. (2017). FSN Analysis for Inventory Management – Case Study of Sponge Iron Plant. *International Journal for Research in Applied Science & Engineering Technology (IJRASET). Volume 5 Issue II.*

Labaree, R. V. (2009). Research Guides: Organizing Your Social Sciences Research Paper: Types of Research Designs.

Mariano, C. (2015). I costi di mantenimento impliciti delle scorte: definizione e loro ruolo nelle simulazioni. *Logistica efficiente*.

Maxwell, J. (1992). Understanding and validity in qualitative research. *Harvard educational review*, *62*(3), 279-301.

McLeod, S. A. (2007). What is reliability?. Retrieved from https://www.simplypsychology.org/reliability.html

Melanie. (2018). Understanding FSN Analysis. *Unleashedsoftware.com*

Merritt, C. (n.d.) Advantages and Disadvantages of ABC Analysis Inventory. *Your business. Azcentral.*

Miller, R. L., & Brewer, J. D. (Eds.). (2003). *The AZ of social research: a dictionary of key social science research concepts*. Sage.

Minnich, D., & Maier, F. (2006). *Supply Chain Responsiveness and Efficiency: Complementing or Contradicting Each Other?*. School of Business Administration.

Miranda, S., Roda, I., Macchi, M., & Montera, G. (2014). A criticality-driven methodology for the selection of spare parts stock management policies: the case of a beverage industry company. *Proceedings of XIX Summer School "Francesco Turco," Senigallia*, 9-12.

Mitra, S., Reddy, M. S., Prince, K. (2015). Inventory control using FSN analysis–a case study on a manufacturing industry. *IJISET-International Journal of Innovative Science, Engineering & Technology*, *2*(4).

Murali, S., Pugazhendhi, S., & Ganesh, K. (2011). Role of third party logistics providers in reverse logistics. *International Journal of Operations System and Human Resource Management*, *1*(1-2), 77-84.

Naliaka, V. W., & Namusonge, G. S. (2015). Role of inventory management on competitive advantage among manufacturing firms in Kenya: A case study of Unga Group

Limited. *International Journal of Academic Research in Business and Social Sciences*, *5*(5), 87-104.

Newton, N. (2010). The use of semi-structured interviews in qualitative research: strengths and weaknesses.

Palmer, V. S. (2001). Inventory management KAIZEN. In *Proceedings 2nd International Workshop on Engineering Management for Applied Technology. EMAT 2001* (pp. 55-56). IEEE.

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, CA: Sage.

Porteus, E. L. (2002). *Foundations of stochastic inventory theory*. Stanford University Press.

Prempeh, K. B. (2015). The impact of efficient inventory management on profitability: evidence from selected manufacturing firms in Ghana.

Radasanu, A. C. (2016). Inventory management, service level and safety stock. *Journal of Public Administration, Finance and Law*, (09), 145-153.

Ravinder, H., & Misra, R. B. (2014). ABC analysis for inventory management: Bridging the gap between research and classroom. *American journal of business education*.

Rizkya, I., Syahputri, K., Sari, R. M., Siregar, I., & Ginting, E. (2018). Comparison of Periodic Review Policy and Continuous Review Policy for the Automotive Industry Inventory System. In *IOP Conference Series: Materials Science and Engineering* (Vol. 288, No. 1).

Rogers, D. S., & Tibben-Lembke, R. (2001). An examination of reverse logistics practices. *Journal of business logistics*, *22*(2), 129-148.

Rubio, S., & Jiménez-Parra, B. (2014). Reverse logistics: Overview and challenges for supply chain management. *International Journal of Engineering Business Management*, *6*, 12.

Salkind, N. J. (Ed.). (2010). *Encyclopedia of research design*(Vol. 3). Sage.

Sehgal, V. (2018). Replenishment Policies and Inventory Planning. *Supply chain musings*.

Silver E. A., D. F. Pyke, R. Peterson. (1998). *Inventory Management and Production Planning and Scheduling',* 3rd Ed. ed John Wiley & Sons, New York.

Silver, E. A., Pyke, D. F., & Thomas, D. J. (2016). *Inventory and production management in supply chains*. CRC Press.

Singh, S. R., & Kumar, T. (2011). Inventory optimization in efficient supply chain management. *International Journal of Computer Applications in Engineering Sciences*, *1*(4).

Slack, N., Chambers, S., & Johnston, R. (2010). *Operations management*. Pearson education.

Sreejesh, S., Anusree, M. R., & Mohapatra, S. (2014). Business Research Methods - An Applied Orientation. Switzerland: Springer International Publishing.

Stebbins, R. A. (2001). *Exploratory research in the social sciences* (Vol. 48). Sage.

Stock, J. R. (1992). *Reverse logistics*. Council of Logistics Management.

Tanwari, A., Lakhiar, A. Q., & Shaikh, G. Y. (2000). ABC analysis as a inventory control technique. *Quaid-E-Awam University research journal of engineering, science and technology*, *1*(1).

Teno, M. N., Anyingang, R. A., & Chenaa, T. A. Inventory Management Practices and Cost: Evidence of Selected Small-Scale Cosmetics Enterprises in Douala, Littoral Region of Cameroon.

Teunter, R. H., Babai, M. Z., & Syntetos, A. A. (2010). ABC classification: service levels and inventory costs. *Production and Operations Management*, *19*(3), 343-352.

Thierry, M., Salomon, M., Van Nunen, J., & Van Wassenhove, L. (1995). Strategic issues in product recovery management. *California management review*, *37*(2), 114-136.

Thyer, B. A. (2010). The *Handbook of Social Work Research Methods*. London: Sage Publications.

Tomašić, D., Đukić, G., & Šafran, M. (2013). Inventory management in reverse logistics-analysis of Croatian Automotive industry postsale practices. *Tehnickivjesnik*, *20*(3), 541-547.

Tripathy J. P. (2013). Secondary Data Analysis: Ethical Issues and Challenges. *Iranian journal of public health*, *42*(12), 1478–1479.

Tysseland, B. E. (2009). Spare parts optimization process and results: OPUS10 cases in the Norwegian Defence. *International Journal of Physical Distribution & Logistics Management*, *39*(1), 8-27.

Vaisakh, P. S., & Unni, D. J. N. (2013). Inventory Management of Spare Parts by combined FSN VED (CFSNVED) Analysis. *International Journal of Engineering and Innovation technology*, *2*(7).

Yilmaz, K. (2013). Comparison of quantitative and qualitative research traditions: Epistemological, theoretical, and methodological differences. *European Journal of Education*, *48*(2), 311-325.

Yin, R. K. (2009). Case Study Research: Design and Methods (4th ed.). Thousand Oaks, CA: Sage Publications.

Zikmund, W. G. (2003). Business Research Methods, 7th Edition. Nashville, TN: South-Western Publishing.

APPENDICES

Appendix I: interview guide

Design: semi-structured 1-on-1 interview, English language

Duration: ±60 minutes

a. Introduction

- Introduction of the researcher
- Explaining the purpose of the interview and research

b. Background

- Could you briefly introduce yourself and describe your company's position?

c. Spare parts inventory management

- Can you describe how the remanufacturing process is currently managed? In light of this, could you explain in general terms how all phases of product recovery are carried out?
  - In this regard, how does the process of purchasing new spare parts work?
  - Do the uncertainties that characterize any reverse logistics negatively affect inventory management?
  - Is the quality of old spares monitored?
  - Do you think that the fact that you don't know in advance which parts are broken or should be repaired creates some problems in inventory management?
- Can you clarify the difference between the two spare parts flows?
  - How many and which types of spare parts are available in stock?
  - How often do you receive returned products?
  - How many returned products do you receive each time?
  - How often do you order new spare parts?
  - How many pieces do you order each time?
- How is the spare parts inventory currently managed?
  - What policy do you use to control it?
  - Do you order the spare parts when needed or do you use a specific policy for each class of spare parts?
  - Does the current replenishment policy take account of the spare parts turnover or usage value? In this regard, do you use and take into consideration any KPIs?
  - How do you decide which parts and how many parts should be in stock?

  - Is the stock regularly counted? If so, how often? Do you use any method (i.e ABC, FSN classification)?
  - Do you tend to hold high levels of inventory to avoid stock-outs? Why?
  - How do you compute the service level? How do you keep it high?
- Which are your current inventory control issues?
  - Which are the problems related to product obsolescence?
  - In this regard, is the obsolescence of the products verified on all the products or only on some of them?
  - Have you ever stopped the reprocessing of an item due to the lack of needed spare parts? Do these problems cause some issues in the production phase?
  - Which are the high costs you currently incur? What has the biggest impact?
  - Do you believe that existing system which you are following is an efficient one?

Appendix II: example of interview

Type of interview: face-to-face interview
Date: 22 May 2019
Location: Drake & Farrell headquarter

a. Introduction

- *Introduction of the researcher*: 24, SCM, Tilburg University, master thesis at Drake & Farrell
- *Explaining the purpose of the interview and research*: getting information about how the spare parts inventory is currently managed and in which problems, issues and costs they incur

b. Background

- *Could you briefly introduce yourself and describe your company's position?*
  I am Berry Selhorst, Manager operations, responsible for all operations activities within Drake & Farrell Bleiswijk, LCL Czech Republic and Industrial Solutions Zoeterwoude. My main objective is to establish and control the service and performance levels for the operation. Furthermore, I manage and control warehouse security procedures and initiate improvement actions to optimize the production and logistics processes.

c. Spare parts inventory management

- *Can you describe how the remanufacturing process is currently managed? In this regard, could you explain in general terms how all phases of product recovery are carried out?*
  When the subscription is ended or when the device is defected, the customers decide to send the product back. In this regard, the customer contacts KPN that will send an email to Drake and Farrell. Therefore, D&F has the order to send an empty box to the customer where he will put the device to send it back directly to us.
  Once the package arrives here, it goes to the De-Kit department, where the box is opened and the number on the label is scanned and put in the system that keeps track of the incoming products. Then the production starts. The first phase is testing, that says if a product is "good" or "not good" (and so, if the item is technically functional or not). What is "good" goes through the process, what is "not good" can go to repair or to scrap. All the parts of the product which can be reused are kept as spare parts in our stock. What is "good" go to the cleaning phase. This is important since it can make the article or device "as new",

but it also determines if the device needs to be refurbished or not. If it needs to be refurbished (in this case, the item is technically good but cosmetically not) goes to refurbishment, otherwise it goes straight to kitting. Kitting means the device will be packed in a box with its components like power adaptors, cables etc. We scan the box; a label comes out of the system and goes on the top of the box. Finally, we scan it to a pallet, and then it goes in the stock.

Throughout this process, an important step concerns the purchase of new spare parts. This happens when the entire product received or a part of it is broken, damaged or simply no longer usable and recoverable.

– *In this regard, how does the process of purchasing new spare parts work?*

  In the current process, we are dependent on KPN, which has the contract with a Chinese manufacturer in its hands. We simply follow KPN. We have no control over the contracts that KPN has with its suppliers. We have zero influence on that Chinese manufacturer.

  What happens is that when we need some new parts, we send a request directly to KPN which places the order with the Chinese manufacturer.

  At that point, the Chinese manufacturer sends the new parts directly to us. So, we are going to say: "I need 7000 units and we hope that in a short time we will receive those products".

  We have no direct influence on lead time because we have not a direct contract with the Chinese manufacturer.

  However, last year there was a big issue with the biggest Chinese manufacturer. The manufacturer said: I am not going to send anymore to Drake & Farrell (because there was a problem in telecom market between China and America). So, what we did was that we searched for another supplier: we found another one that maybe was better than the previous: we had full in our own control, we save a lot of money because it was in our control, in our hands.

– *Do the uncertainties that characterize any reverse logistics negatively affect inventory management?*

  As you said, the whole process is characterized by uncertainty about the return of products. We don't know when the customer will give back the used product and the condition of the product. Obviously, this causes problems in the management of spare

parts inventory as it becomes difficult to understand and plan how much stock to have in inventory and how many new parts to buy.

– *Is the quality of old spares monitored?*

No. As I told you before we don't know the conditions (I mean, the quality and the status) of the old products as well as the moment in which the product will be returned.

– *Do you think that the fact that you don't know in advance which parts are broken or should be repaired creates some problems in inventory management?*

Yes, it creates some difficulties in managing new and old parts. For this reason, we try to be as cautious as possible by buying lots of new parts.

- *Can you clarify the difference between the two spare parts flows?*

We are dependent on the return process of the customer. There are two sides: one flow coming from a Chinese manufacturer, and one flow coming from the customers. Therefore, we have one flow for which we buy new products, and we have a flow which is not new, but the customer is going to send all the products back.

The biggest difference is that the flow that is not new (the one that is being returned) is characterized by a high uncertainty: we don't know how many pieces will be returned and we don't know the percentages that can be used as new again (and so, we actually don't know the status and quality of these old parts and products). The second spare parts flow is the one that comes from the manufacturer: the new flow. Unlike the previous, I know the quantities and the quality of these products and parts.

– *How many and which types of spare parts are available in stock?*

I can't tell you the exact number of spare parts available in our warehouse. With regard to the type, we have several pieces, such as cables, plugs, modems, remote controls, screws, wires, batteries, etc.

– *How often do you receive returned products?*

I show you a database and a report. As you can see, in general it is a surprise for us how many products we will receive each day. We cannot know in advance the return of old products, so there are some days in which we receive a lot of trucks full of old spare parts, and other days in which we don't receive anything. I have just a prediction based on history.

– *How many returned products do you receive each time?*

The amount has increased during the years: they are not throwing anything away, so they send everything back. They completely reused old products.

– *How often do you order new spare parts?*

Of course, it depends on the needs and so on the stock level. I show and send you all the data about it. In that case too, we have not a precise and stable frequency of order quantity. We simply order when we need, but to be as cautious as possible (i.e. to always have enough good spare parts in stock), we always try to order a lot. Of course, this leads to high costs and inefficiencies difficult to control.

– *How many pieces do you order each time?*

Thousands of pieces? It depends. We always order, but there are times that we order more and times that we order less.

- *How is the spare parts inventory currently managed?*

The main components are the current stock volume (I mean the stock level) and the forecasting. Our forecast is a working in progress. The forecast that we do is simply based on history. We just make a guess for the future. In this way we try to control and manage the inventory but as you can imagine it becomes very complicated.

We don't have a specific and differentiated inventory policy. We use a type of policy that is based on a MIN-MAX: it basically says that on the moment we receive a product, a spare part, we insert it in our inventory and we also got to use that for our production process, and on the moment it drops below a certain point, we automatically going to order new spare parts. We have an inventory level and if that particular level drops down a certain point (MIN), we should order new products, new spare parts.

We strongly believe that our current management of the inventory is completely inefficient since it leads to high costs.

– *What policy do you use to control it?*

As I mentioned before, the model that we use to control our inventory can be seen as a continuous replenishment or ordering policy since we have not a programmed periodicity. Moreover, we control and track the quantities of spare parts every time, every day, and therefore we order always new pieces. As I told you before, when these quantities fall below a level, we order new parts.

– *Do you order the spare parts when needed or do you use a specific policy for each class of spare parts?*

Absolutely not. We use this policy for all spare parts available in stock. We don't make any difference between them. It may seem strange to you, but we are a very young company with even inexperienced employees (for example, it is difficult to calculate the different KPIs). That's why we now use a single and unique replenishment policy for all parts.

– *Does the current replenishment policy take account of the spare parts turnover or usage value? In this regard, do you use and take into consideration any KPIs?*

Unfortunately, no. We do not take into account any KPIs, neither the turnover nor the consumption value of spare parts.

– *How do you decide which parts and how many parts should be in stock?*

Simply by seeing the current inventory level and counting the available stocks. At that moment, we place the order for all new parts.

– *Is the stock regularly counted? If so, how often? Do you use any method (i.e ABC, FSN)?*

There is no precise frequency with which we count the available stock. It can happen every day or once a week.

No, we do not use any method to classify spare parts. They are all treated and managed in the same way.

– *Do you tend to hold high levels of inventory to avoid stock-outs? Why?*

Our first concern is to avoid stock-outs and thus prevent production from stopping. For this reason, and because we do not know what products and parts will arrive and under what conditions, we always try to maintain high levels of inventory. Specifically, we order a lot of new parts of different types. Of course, this inefficient policy leads to considerable high costs.

– *How do you compute the service level? How do you keep it high?*

We always try to maintain a high service level by setting a target of 99%. We are always able to keep this target high, sometimes even with overperformance. In general, we do not calculate it as a number of quantities to be delivered with respect to the total demand, but as a number of quantities to be delivered in time with respect to the demand. Generally, having high stocks in stock allows us to keep the service level always high. Of course, the costs incurred are very high.

- *Which are your current inventory control issues?*

KPN is the most important player in our process because they tell us: you have to produce 800 pieces and we are going to produce 800 pieces. The forecast about customer demand is lying at KPN, but we never receive that information. We directly receive the customer returns: but we don't know when the customer will return the products.

As we always want to ensure a high service level and therefore meet the needs and demands of KPN as much as possible, we try to keep inventory levels high. The uncertainty factor plays a fundamental role because not knowing when but especially the conditions of the incoming products leads us to buy many more new pieces (and therefore to increase considerably the inventory levels to be maintained). Obviously, this leads to high inventory costs and especially high obsolescence of products.

Obviously, this causes great problems in the management of the inventory and in the level to maintain. The stock volumes would be higher than the preferable. Surely, what is missing is an efficient method of management of the spare parts in such a way to determine the right levels to maintain for every type of stock.

If we have better control, we can keep the inventory level at a good level: we could save half million. What we could save is the space, the interest and the risk involved with stock. When we have high stock level, it takes space and it costs money. There is the risk that the stock you have cannot be used anymore (so it can lead to product obsolescence). There is also the interest or investment cost related to the money invested in it. If we are able to guarantee a good stock and inventory control, of course all these costs will be lower.

– *Which are the problems related to product obsolescence?*

  The obsolescence of the product is very important. I can make an example with iPhone 5: we bought many components for iPhone 5, however the iPhone 5 is not going to be produced anymore, so we have a lot of stock that is obsolete: we can do nothing with that stock. If we have a high stock level that we actually don't use because we don't need it, it could cause product obsolescence.

  Surely, in the current inventory management, product obsolescence is one of the biggest problems we have.

– *In this regard, is the obsolescence of the products verified on all the products or only on some of them?*

  No, it does not occur on all products but only on some. Often only certain types of spare parts in stock become obsolete.

The obsolescence of products occurs mainly on that spare parts that we use very little. In particular, some of these have a very high value and consequently they have a big impact on our costs. For this reason, this type of costs is one of the most important.

– *Have you ever stopped the reprocessing of an item due to the lack of needed spare parts? Do these problems cause some issues in the production phase?*

Normally not. We always try to have enough stock to keep our production going. In fact, when we set the minimum level to be maintained, we also consider a significant safety stock. However, the maintenance of high stock levels is very expensive for us and we often run the risk of having obsolescence of products.

– *Which are the high costs you currently incur? What has the biggest impact?*

As I told you before we always try to keep high levels of stock in our inventory. Obviously, this causes us many problems related to the high costs incurred. Surely the two most impacting costs are that of product obsolescence and that of working capital: a very important cost and risk is that of products that become obsolete and can no longer be used. With regard to working capital, we would like to try to reduce it so that it can be used for other types of investments.

Other costs incurred by us are those of storage and the cost of placing the order. Sometimes it happens that we need more space to store products (given the high levels of stock maintained). For this reason, we make continuous investments in warehouse space, handling technology, and the workforce.

Regarding the cost of placing the order, it is KPN that has the contract with the Chinese manufacturer. So, it is KPN that directly bears the transport costs, but obviously because we are in a circular economy, these costs also affect us. The more we buy, the higher the costs we incur.

The products purchased are subject to customs duty despite the contract defines an Incoterm DDP.

– *Do you believe that existing system which you are following is an efficient one?*

Absolutely not. We realize that despite having a high service level, we are incurring high costs of inventory management making the whole process inefficient. That's why we need some methods and solutions that can help us make inventory management and control more efficient and optimal.

Appendix III: coding scheme and definitions

	Spare parts inventory management				
Code	SPIM				
Classification	Recovery process	Spare parts flows	Product return uncertainties	Inventory management and policy	Inventory inefficiencies
Sub code	RP	SPF	PRU	IMP	II
Berry Selhorst	If the customer wants to send the product back, he contacts KPN who will send us an e-mail. Then, we send an empty box to the customer where he will put the device to send it back directly to us. At this point the whole recovery process begins, which ends with the delivery of the reconditioned products to KPN.	One flow coming from Chinese manufacturer, and one flow coming from the customers	We don't have any kind of information about the returns. We don't know the conditions (the quality and the status) of the old products as well as the moment in which the product will be returned	We use a type of policy that is based on a MIN-MAX: it basically says that on the moment the inventory drops down a certain point, we automatically order new spare parts	Due to the uncertainty about the quality of the old products we always buy a lot of new spare parts. This allows us to be very cautious and also to guarantee a high service level (about 99%). However, the main problem is the high costs we incur to maintain the high levels of stock. Very high working capital costs and product obsolescence costs
Janko van den Haak	There are 3 main stages: first the collection of all used products,	The flow that is returned is characterized by a high uncertainty.	We don't know the status of the product until it is unboxed.	We have a model based on the MIN-MAX policy: when the quantities of spare parts drop below a	We do not differentiate between spare parts, and we use a single review policy. We have

	then the regeneration of old products, finally the distribution to the final customer	The second spare parts flow is the one that comes from the manufacturer: the new flow	We don't predict the volumes of the returns	certain point, we order new spare parts	very high stock levels with consequent very high costs
Thijs Bender	We are responsible for recovering the old product, while the distribution of the new product to the market depends on KPN. As for the collection phase, it is the customer who sends us the old products	We manage two different flows of spare parts: one flow is made up of all the old products, while the second is made up of all the new products	We don't know when the customer will return the product. We have no advance information on the quality of returns	We don't have a specific inventory policy, in the sense that we use a single reorder policy for all spare parts available in stock	The main cost is related to the obsolescence of products because maintaining very high levels of stock in inventory, often many spare parts become obsolete and no longer usable
Edward van Dam	The recovery process is carried out within our facility, and the phases are: testing, cleaning and kitting. The refurbishment phase, which involves the purchase of new spare parts, is fundamental	The first flow is certainly that of old and used products coming from the market, while the second flow is that of new products coming from a Chinese manufacturer	There are many uncertainties about the return of products that cause inventory management issues and inefficiencies	The management of our inventory is currently very difficult because we try to maintain very high levels of stock incurring in high costs. The policy we use is that of "MIN and MAX"	Inventory inefficiencies are related to the high costs we incur in maintaining high stock levels (which are often higher than what we need). The costs are: storage costs, working capital costs and high risk of product obsolescence