Staying ahead of trends

processing commercial returns on time, all the time

From: wehkamp

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Colophon

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Preface

Hereby I present to you my final master thesis. It concludes more than five and a half years of studying at the University of Twente, in which I took great pleasure. While writing this, I already started at my first actual job and it is still hard to comprehend that I am no longer a student. This thesis would not have existed without the help of a lot of people. In the following paragraphs, I would like to thank a few of them.

First of all, I want to thank Remco Wilting. Not only for being my company supervisor and facilitating this assignment, but also for his enthusiasm regarding my research, and data driven improvements. I experienced it as a great stimulus to improve my work, analyse more data and examine more scenarios. Next to Remco I also want to thank Jerry Vos and Michel de Leeuw for “adopting” me into the Data Science team, helping me find my way within Wehkamp as a company and in the available data sources. I also own a thanks to the departments Marketing Intelligence, Business Intelligence and all others who helped me at Wehkamp’s head office and in the Logistic Service Center Zwolle-Hessenpoort. Their help, interest, hospitality and constant motivation to improve Wehkamp as a whole, made the seven months I spent at Wehkamp a great experience, one that I will definitely never forget.

I would also like to thank Peter Schuur and Ahmad Al Hanbali for their help as first and second supervisor from the University of Twente. They pinpointed the flaws in my writing and explained what was missing or overdone. It is hard to see those flaws when (re)reading your own work for seven months and I would not have been able to produce the same quality of writing without their help. Our discussions about the broadest range of topics made every meeting interesting.

Last but certainly not least I hereby thank my friends, family and girlfriend for sticking up with me for the last couple of months. In between football training and matches, my part-time job(s), doing a pre-master psychology and working on this graduation assignment I did not spend enough time with them, which I will make up for the next few months (or years).

Enschede, 4 February 2016

Management summary

Motivation

Wehkamp is a large player in the Dutch ecommerce market and must deal with large amounts of returned products in the Logistic Service Centre Zwolle-Hessenpoort. These returned products are mostly fashion items and are commercial returns i.e., products that are returned within 14 days without the necessity of an explicit reason for returning the product. Most processes in the logistic service centre are automated, except for the sorting and checking of returned products. The processing of returned products is subject to a lot of variability. Examples are different amounts of products coming in each day, different productivity levels per employee and different arrival times of trucks that transport these returned products. Wehkamp tries to buffer for this variability by having variability buffers. These buffers are:

- Work to be done: buffering an amount of roll cages with returned products, waiting to be processed so that not fully utilising workforce is prevented.
- Capacity: having enough stations to process more returns than can come in on one day, when all stations are occupied the entire day.
- Time: the window of time in which the products that are returned should be processed. Officially this window is 14 days, but this period is incidentally exceeded.
- Workforce flexibility: planning different number of employees to avoid underutilization or not meeting the Service Level Agreement (SLA from now). Determine and inform required workforce only a few days in advance and sometimes sending some employees home.

To reduce cost, increase customer satisfaction, improve product availability and make full use of all product's value, Wehkamp wants to improve the processing of returned products.

Main research question and methods

This research is constructed around the main research question which is the following:

How to process product returns efficiently, now and in the future, by balancing variability buffers and through planning aided by forecasting?

From this main research question follow several different other research questions. To answer these questions and work towards deliverables several methods are used. Most important methods are a context analysis, a scientific literature study and a simulation study. The context analysis is made to provide insight in the current situation. Second, the scientific literature study is the source for the alternative solutions. The purpose of the simulation model is to examine the influence of the variability buffers on the whole process. This cannot be analysed from historical data. Additionally, the simulation model is used to provide insight in the possible benefits of the constructed alternative solutions.

Alternative solutions

A set of alternative solutions follow from the literature analysis that focusses on planning, variability and supply chain management. A selection of feasible alternative solutions are tested through the simulation model. The alternative solutions that are considered in the experimenting phase are:

- Improve the forecast of returned products
- Improve the planning of workforce
- Striving for a constant level of work in progress
- Preponement and reason coding

Most of these alternatives are self-explanatory to a certain degree, except for preponement and reason coding. Preponement is identifying how many steps are required to process a returned product as soon as possible. Reason coding gives customers the possibility to indicate why they returned a product.

Results and conclusions

The constructed simulation model results in 52 weeks of trustworthy data per run, one year of valuable data, which is easily comparable to historic data. Results show the process did not benefit from a possible improvement of the forecast, that processing time is of practically no influence, that WIP ensures high utilization and that flexibility can be helpful in reducing WIP and the required processing capacity. The alternative solutions all have their pros and cons, but an improvement of the forecast, a constant level of work in progress, preponement and reason coding showed disappointing results overall. The results of an improved planning however were very promising. Planning two shorter shifts was beneficial for almost every performance indicator in the simulation model. Especially given the fact that the model did not allow for a night shift while experimenting with such planning policy.

Recommendation

All different alternative solutions were tested and planning different clearly out performed all others. As said this was the improved planning solution, which consists of two shorter shifts from 7:00 to 13:00 and 13:00 to 19:00 instead of the traditional 8:00 to 17:00 shift. Wehkamp is strongly recommended to implement this form of planning as it holds the following benefits:

- More processing hours per day, an effective increase of 31%
    - a lower occupation level of all work stations, leaving room for flexibility
    - increased throughput per regular shift
    - lower maximum demand for returned products per hour
- Less night shifts required, in the model a reduction of 100%
- Lower average WIP without the loss of utilisation, a reduction of 9% on average.

Wehkamp must however think carefully about how to handle the introduction of such change. Creating support among its workforce is crucial since a small decline in productivity, due to motivation issues for example, has a large impact upon the performance of the entire process. Giving employees certainty about when they are supposed to work more days in advance, can be a fair exchange with the sacrifice of the traditional working hours. To do so, Wehkamp must at least maintain the performance of the forecast of returned products

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Glossary

Bandwidth	Difference between upper and lower value
Big tickets	Products stored in the manual are in the LSCZ because they are too big for the OSR
CDW	Customer Data Warehouse
CLSCM	Closed-loop Supply Chain Management
Commercial product return	A product that is returned within the 14-day period after receiving a product and without the requirement of a legitimate reason.
DES	Discrete Event Simulation
EOL	End Of Life
Fill rate	Term used in the LSCZ to measure the average number of individual products a container contains
Flats	Different name for the OSR category of fashion, both terms are used within Wehkamp
FTE	fulltime-equivalent
Hanging goods	Products that are not stored in the OSR since they are not supposed to be folded
Inbound	The stream of products in the LSCZ that represents the products newly acquired by Wehkamp that go to stock
Kiala bag	A big bag containing multiple packages with returned products that was used as a means of transport
LSC	Logistic Service Centre
LSCZ	Logistic Service Centre Zwolle-Hessenpoort
MVT	Marginal Value of Time
OSR	Order Storage and Retrieval system
OSR category	The category in which a product is stored in the OSR
Outbound	The stream of products in the LSCZ that represent the products going to the customer
Over planning	Planning excess capacity compared to forecasted amount of returns coming in
Productivity	Products processed per hour
Return lag	Time it takes for a product return to be processed measured from the moment it is sold
Returned product	A product that is received by the customer and returned through DHL
Run	Simulating a predetermined amount of time in a model with different random numbers within an experiment and equal random numbers across experiment runs.
SLA	Service Level Agreement
SCM	Supply Chain Management
SD	Standard Deviation
WMS	Warehouse Management System

1. Introduction

In order to complete the Master program Industrial Engineering & Management at the University of Twente, this research is conducted. The research is done at and for Wehkamp in the Netherlands. Wehkamp was established in the 1960's as a post order company for mattresses and swim wear. Over time it evolved into an ecommerce company that sells 180,000 different products in several categories, offering same day delivery for most products. Wehkamp sells its products in the Netherlands. Fashion is Wehkamp's biggest product category and accounts for the largest portion of product sales and turnover. Wehkamp has to deal with a large number of returns and has difficulties meeting the target service levels efficiently. The processing of these products that are returned within the review period of 14 days, also called commercial returns, is the subject of this research.

As one might suspect, this chapter serves as an introduction to the report. Next to a general description of the company and a research motivation in the first two sections, the focus of this chapter is to elaborate on the problem description, scope of the research and research approach. The latter three subjects will be treated in Section 1.3, Section 1.4 and Section 1.5 in the corresponding order as they are named above.

1.1 Company description

The following paragraphs hold a brief and general introduction. Wehkamp's history, products, logistics service centre and some figures are presented as an introduction to the context in which this research takes place. Section 1.1.1 gives a general description of Wehkamp. Followed by a summary of facts and figures. The third and final part of Section 1.1 is a description of the LSC Zwolle-Hessenpoort.

1.1.1 General information

The post order company Wehkamp was founded in 1952 by Herman Wehkamp and originally sold mattresses and swim wear. In 1995 Wehkamp was the first Dutch company with an online store running on a website: "*www.wehkamp.nl*". For a few years the traditional catalogue, that was sent out every six months, ran alongside the website, until the year of 2008, in which Wehkamp became a 100% e-commerce company. Through the years Wehkamp served so many different customers that around 90% of all households in the Netherlands is, or once was a customer. One of the things that make Wehkamp unique is a broad product range in different product categories. Where most other ecommerce companies aim at one product category like fashion or electronics, Wehkamp sells products of both categories and more. Wehkamp is ranked first, second or third, in almost every category in which it sells products regarding ecommerce market share. In 2014 Wehkamp launched the .be website in order to expand into the Belgium market. Wehkamp is part of the RFS Holland Holding B.V. which also owns Lacent and owned Fonq.nl. Lacent handles all financial related customer interactions for Wehkamp. The most recent development is the take-over of the RFS Holland Holding B.V., including Wehkamp, by Apax.

1.1.2 Facts & Figures

Wehkamp sells approximately 180,000 different products which are divided over five separated categories. There are two more categories, but the products of these two are divided over the first five categories. The five strictly separated categories are:

- Fashion
- Home & Garden
- Electronics
- Sport & Leisure
- Beauty & Health

Figure 1.1 Examples of products Wehkamp sells

The two remaining categories are Mother & Child and Cooking & dining. Fashion is the largest category considering turnover and number of products sold. This is not only due to products Wehkamp purchases from manufacturers. Approximately half of the fashion products are sold for other retailers, like C&A. Such partners are called alliances, they supply their products to Wehkamp just as any other supplier. Wehkamp does not buy the products from their alliances, but only receives a fee for selling products owned by alliances. This enables Wehkamp to offer a bigger product range without the risk involved with ownership. If such product is not sold at the end of the season, it is up to the alliance to bear the consequences and decide on what to do with the product. Products sold for alliances are treated the same way physically and on the website as any other product. Pricing and imaging is often done by the alliance.

Wehkamp now has 1.7 million returning customers who place more than 80,000 orders per day, resulting in more than 7 million packages per year. The website receives over 120 million visits per year and the average visitor spends 21 minutes on it. Wehkamp has two Logistic Service Centres (LSC from now). One in Zwolle-Hessenpoort and one in Maurik. In LSC Maurik all products are stored that are too big for LSC Zwolle-Hessenpoort (bigger than a boxed vacuum cleaner, as a rule of thumb). Wehkamp has 660 employees, divided over three locations LSC Zwolle-Hessenpoort, LSC Maurik and the headquarters in Zwolle. Wehkamp as a whole had an average turnover of approximately €550 million last year and continues to grow.

1.1.3 Zwolle-Hessenpoort

As one of the biggest companies in the Dutch market of fast developing and fiercely competitive ecommerce, Wehkamp is continuously challenged to optimize and innovate in many aspects. Not only online, concerning the website, social media, communication and marketing, but also regarding operations and supply chain management. One of the biggest and quite recent projects was building the modern and heavily automated Logistic Service Centre in Zwolle-Hessenpoort (LSCZ from now).

The project of the new LSCZ started 11 July 2013 and finished in the summer of 2015. By then it was officially opened by the king of the Netherlands. The total area occupies 66.000m2, housing

32.000 m2 of warehousing space and 2.200 m2 of offices and other supporting facilities. On the roof of the LSCZ a large solar panel field was build. The solar panel field is able to provide over 40% of the required electrical power (upper left corner in Figure 1.2). Next to the solar panels the new LSCZ is equipped with energy efficient lighting, smart climate control, a seasonal thermal energy storage system, a grey water saving system and many other features that reduce the impact of the LSCZ on the environment.

The warehouse part of the LSCZ, the so called Order Storage and Retrieval system (OSR from now), is built by KNAPP. The OSR houses a little under 480.000 picking locations. These locations are reached by 468 automatically guided vehicles which are able to pick around 12.350 items per hour. The process of storing, retrieving and packing is almost fully automated. This results in a ready for delivery time of under 30 minutes for every product located in the OSR, in case of no backlog at hand. Next to the classical warehouse activities of inbound, storage and outbound, the LSCZ also processes all returns of products that originate from the LSCZ. The processing of returns inside the LSCZ is the core subject of this research. The following section explains why the processing of returns is so important.

Figure 1.2 LSCZ, its solar panels and totes inside the OSR

1.2 Research Motivation

The following section is not subdivided, although different motivations are treated. In order to fully understand this motivation a short introduction about product returns at Wehkamp in general is given. It provides insight in how many products are returned and how many customers return products. After this brief introduction of the subject of product returns, four main reasons that together form the motivation to do this research will be described.

Since Wehkamp operates in several product categories there are big differences in how many, when and why products are returned. Not to mention the state in which some of the returned products are. The category fashion, which accounts for a relatively large portion of the turnover, is the category with the highest average amount of returns. Approximately 49% of all products sold in the category fashion of last year is returned. This can be concluded from Figure 1.3, where the impact of the category fashion becomes even more clear.

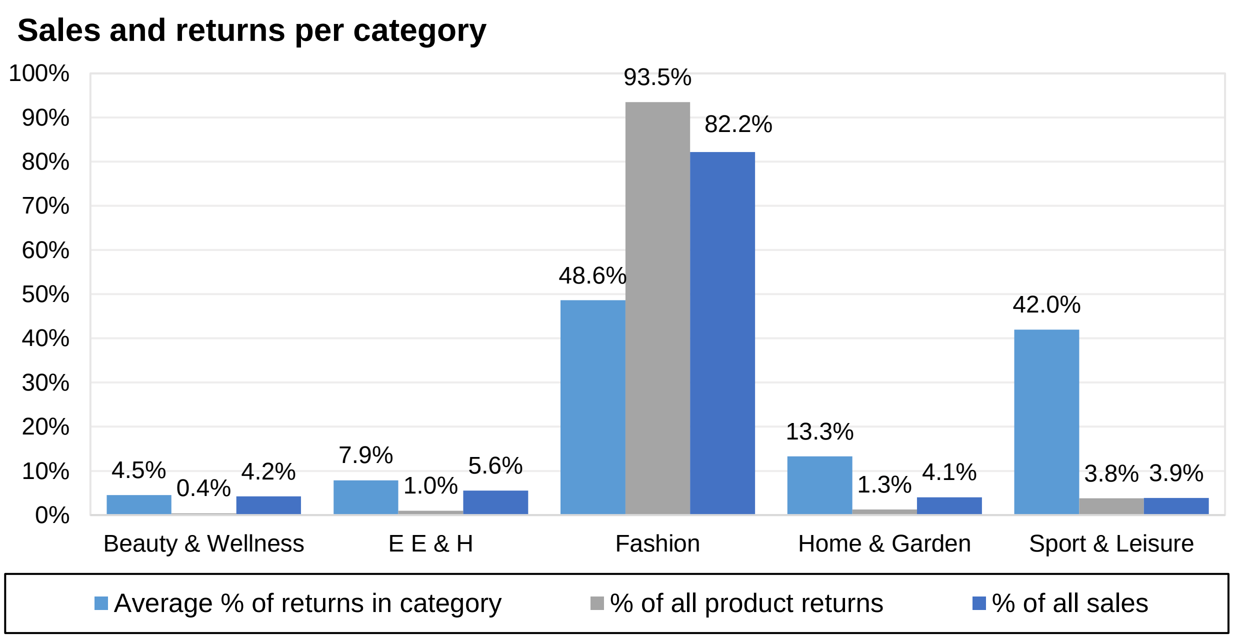

Figure 1.3 Sales, returns and return percentage per category

Wehkamp has to deal with a lot of returned products from a lot of different customers. Approximately 49% of all unique customers, who ordered in the last year (data from 01-08-2015 to 01-08-2016), returned at least one product. The processing of returns has a direct impact on customer satisfaction of this large portion of Wehkamp's clientele. To satisfy customers as Wehkamp has done for years now, the processing of returns has to be of top quality.

It is clear from the information presented above that the processing of returns concerns a lot of products and a lot of customers. Its impact upon the four factors described below is therefore high.

Cost
At first sight the processing of returns adds no real value. Roughly speaking returned products are lost sales that require processing in order to bring a product back to stock or sometimes discard it. A customer is merely interested in how fast the returned product is processed, and subsequently, if and when he or she gets his or her money back. Besides from receiving status updates, a customer takes no further interest in how this is done operationally. For these reasons the processing of returns can be seen as a costly necessity without further benefits.

Customer satisfaction
Luckily, a customer might not care about the operation itself, but is more than interested in the status updates and getting their money or credit back fast. Research shows that the whole process of returns is also an important aspect of customer satisfaction (Mollenkopf, Rabinovich, Laseter & Boyer, 2007). Satisfying a customer first time right is even more important for ecommerce stores than for brick and mortar stores, since online customers can easily search without any real cost and have instant access to competitors. A brief online search often results in a broad range of stores that offer the exact same product. In the early days of ecommerce Kuttner (1998) stated:

"The Internet is a nearly perfect market because information is instantaneous and buyers can compare the offerings of sellers worldwide. The result is fierce price competition and vanishing brand loyalty."

Most recent research indicates that although the impact on prices is not always what was expected, clear is that for homogenous products prices converge (Cavallo, 2016; Lee, Lee, Kim & Lee, 2003). Therefore, customers emphasize other aspects over the relatively small price differences. Satisfaction concerning previous interactions is one of such aspects. As a result, satisfied customers more often become loyal customers (Mollenkopf et al., 2007) and loyalty is key to profitability for ecommerce companies (Srinivasan, Anderson & Ponnavolu, 2002). Recently a large customer survey was sent out to benchmark different ecommerce companies that operate in several of the same categories as Wehkamp. See Figure 1.4 for an overview of customer appreciation on different aspects.

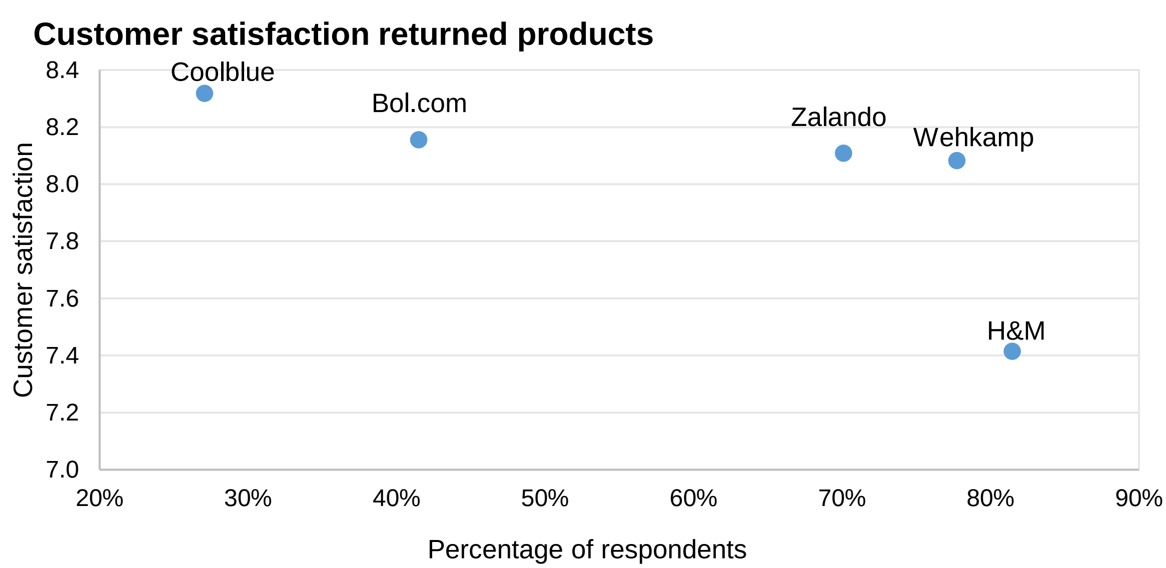

Figure 1.4 Customer satisfaction concerning returned products

As we can see, customer satisfaction scores concerning product returns does not differ greatly between the lowest (H&M, 7.4) and highest (Coolblue, 8.3) score. A small detail can change the top performer into the worst performer. A side note here is that there is no competitor that offers the wide range of products as Wehkamp does. For an in-depth overview of these results see appendix A.

Product Value

Next to the impact on customer satisfaction previously discussed, the processing of returns is costly. Not only the operation itself, but also its impact on product value. This especially is the case for Fashion where product life cycles are often no longer than 6 months. As a retailer, you do not want to end up with a lot of leftovers of previous season. Wehkamp offers all sorts of sales and actively marks down their prices to reduce the number of leftovers. Given its short lifecycle and low price when a product progresses in its life cycle, the value of a fashion product, but also that of electronic products, can be seen as a slowly decreasing line. This line might even reach the point that it is not even profitable anymore to sell the product to a customer. The impact of time on the value of products should not be underestimated, which is a third reason to process returns as soon as possible.

Product availability

Another important reason to process returned products fast, is the fact that products that are back on stock can be sold again, where products waiting to be processed cannot. A missed sale because a returned product has not been processed is quite painful since A: a sale was lost while the item was available. B: a customer is unnecessarily disappointed C: there is a chance that you end up not selling the product, while there was demand. This tri-factor makes this final reason quite disastrous. To conclude, the processing of returns directly affects:

- Operations cost
- Customer satisfaction
- Product value
- Product availability

As this section motivates why the subject is of crucial importance, the third section elaborates on what is exactly the challenge Wehkamp faces concerning product returns.

1.3 Problem description

Because of the motivation provided in the previous section, Wehkamp wants to optimize the processing of returns. The processing of product returns comes with a lot of variability. There is variability in the sense that:

- Different products require different processing times
- Customers send their products back within a window of zero to 14 days after receiving them
- Products sent back from different regions may take different times to arrive at the LSCZ
- DHL not always directly send every product to the LSCZ, but might gather batches or wait till trucks are fully filled
- The percentage of products returned differs per product, order and customer
- The productivity of different employees differs
- The returns might be composed of completely different product types per year, season or even month, day and week

Given all these factors of variability, forecasting daily workloads and estimating required capacity is rather hard. What makes it even harder is that most fashion products tend to have a life cycle span of approximately half a year. So, given the fact that there are a lot of new products every season, there is no product specific historical data available concerning return rates or processing time required. Wehkamp uses four buffers to cope with variability:

- Work to be done: buffering an amount of roll cages with returned products, waiting to be processed so that not fully utilising workforce is prevented.
- Capacity: Having enough stations to process more returns than can come in on one day, when all stations are occupied the entire day.
- Time: The window of time in which the products that are returned should be processed. Officially this window is 14 days, but this period is incidentally exceeded.
- Workforce flexibility: planning different number of employees to avoid underutilization or not meeting the Service Level Agreement (SLA from now). Determine and inform required workforce only a few days in advance and sometimes sending some employees home.

There is no insight in how to balance these buffers in order to achieve high certainty of meeting the SLA optimally with minimal resources. Nor is there a forecast of returns based upon actual sales, which can be combined with returned products waiting to be processed to determine current and future workloads. Since all factors of variability interfere, the effects of individual factors are unknown. Finally, Wehkamp suspects that performance on the KPIs can be improved and wants to know if the processing of returns as it is, can hold up with future trends and developments.

Since these aspects all interfere to some degree changing one will always have influence on the others. The leads to a rather broad scope. To narrow it down to a respectable level there are certain aspects that are not considered. Section 1.4 describes which aspects are in and which are out of the research scope, starting with the latter.

1.4 Research scope

The scope of the research is outlined in this section. After summarizing all topics that are out of scope, this section ends with a short summary of what is within the scope.

The subject of this research is the processing of returns at the LSCZ. This excludes the LSC in Maurik since its products and operations are completely different. The fast majority of product returns are received by the LSCZ as we can see in Table 1.1, which contains data of last year. In this table the number of returned products received by the LSCZ is compared to all other options.

Origin	% of total sold products	% of total returns
LSCZ	94.56%	98.43%
Other	5.44%	1.57%

Table 1.1 Products sold and returned ratios

The category “Other” consists of products that are returned to the LSC Maurik, but also products that are returned directly to suppliers and companies specialized in repairing products. By far the largest amount is returned to the LSCZ, as can be concluded from Table 1.1.

Some products are treated different within the LSCZ since they cannot be stored within the OSR. Boxes that are too big for the OSR ("Big tickets"), but also fashion products that should not be folded, are processed and stored separately ("Hanging goods"). In Table 1.2 these two categories are compared to the "OSR categories", with data of the past year. OSR categories are the three different categories in which a product, which is stored in the OSR, is placed. The three different options are "Shoes", "Fashion" and "Electronics". Somewhat confusing is the fact that fashion category also contains other relatively flat product and is therefore also referred to as "Flats". There is also a category "Food", but this category contains a very limited number of products, resulting in zero returns in more several months of previous years.

Year	Month	Big tickets and Hanging goods	Shoes	Fashion	Electronics
2015	October	1,822	426	5,339	598
2015	November	11,319	3,264	13,825	3,371
2015	December	1,268	78,432	243,237	3,821
2016	January	111	76,114	410,223	4,912
2016	February	10,864	39,721	557,618	9,426
2016	March	8,467	45,499	610,689	6,182
2016	April	7,756	69,014	745,813	5,559
2016	May	6,448	6,985	687,835	4,946
2016	June	6,885	84,674	862,727	5,552
2016	July	7,349	77,863	867,219	6,342
2016	August	1,889	15,296	191,972	1,264
Total		86,579	560,153	5,320,922	51,973
% of total		1.44%	9.31%	88.39%	0.86%

Table 1.2 Product returns divided per OSR category

The Big tickets and Hanging goods account for approximately 1.5% of all returns coming in, as we see in Table 1.2. As said processing such returns differs from products that are stored in the OSR. Big tickets and Hanging goods are fetched out of the stream of returns as soon as possible and processed manually in a specific area in the LSCZ. Since these returns make up a small portion and processing differs heavily from OSR products, the Big tickets and Hanging goods are out of scope.

Also, excluded from the scope are problems concerning the OSR. Preliminary research pointed out that these have a critical impact on all processes in the LSCZ. The problems with the OSR are highly unpredictable and have a critical impact on the whole process of the LSCZ. The situation concerning the OSR is not to Wehkamp's satisfaction and will not remain unchanged. Several improvement projects have already been initiated and there is a close cooperation with the manufacturer of the OSR. Next to that the OSR is relatively new, one cannot conclude upon its reliability with enough certainty to take this into account in any model, prediction or policy.

As said, the time a customer perceives until their money is refunded has a strong influence on customer satisfaction. After a product is successfully processed in the LSCZ there is still some delay caused by the bank transfer. Wehkamp's website states that after processing this will take approximately two days. The scope of this research stops at the point where the operations in the

LSCZ gives the “green light” to transfer the money back to the customer. For products that can go back to stock this is the point where a product has successfully (re)entered the OSR. This means that the final part of the processing of returns, the time required to refund a customer, is not in the scope of this research. Next to the fact that the most of the delay is caused by the bank transfer, it is not the responsibility of Wehkamp. Lacent initiates the refund and banks handles those payments.

Last but not least, to prevent confusion, reducing the number of returns is not the goal of this research. Wehkamp has done a lot regarding the reduction of product returns. An example is a procedure that completely analyses products that exceed the average percentage of returns within their category by a certain level. For a fashion product, this means checking the description, making new photo’s, fitting all sizes to determine its exact measures and sometimes even stop selling the product completely.

To conclude with a summary of what is indeed inside the scope after all these exclusions. The processing of returns within the LSCZ, its KPIs, how KPIs are measured, current performance on those KPIs, personnel planning, personnel productivity, variability buffers and available forecasts.

Within this more focussed scope a central research question is formed which goal is to face the challenges described in Section 1.3. In order to do that, there are a lot of questions that can and should be answered. Section 1.5 describes the research approach and contains the research questions, objectives, deliverables and a description of the structure of this report.

1.5 Research approach

This section, the final section of this chapter, contains the research approach to fulfil this research. The three different smaller sections hold the subjects: the relevant research questions, the deliverables and an overview of this project’s structure. The relevant research questions need to be answered in order to answer the central research question. They consist not only of practical and analytical questions but also questions that aim at forming a theoretical basis on which proposed improvements can be based. The research questions represent Section 1.5.1. In Section 1.5.2 there is a list of objectives and deliverables that this research should produce. To conclude this chapter, the structure of this report is outlined in the final Section 1.5.3.

1.5.1 Research questions

From the problem description, a central research question follows that fits within the described research scope. The central question of this research is the following:

How to process product returns efficiently, now and in the future, by balancing variability buffers and through planning aided by forecasting?

In order to answer the main research question, a set of sub-questions have to be answered first. Even these sub-questions can be divided into smaller practical questions, of which some will come forth in the small elaborations below.

1. How are returned products processed in the LSCZ?

The purpose of this question is to gain insight in the process. From the moment a customer decides to return a product, until the moment it is again safely stored in the OSR, repaired, sold to a jobber or discarded. Relevant sub-questions are for example: what steps must a product fulfil successfully to be put back to stock, and what other processes have impact on the processing of returns. Next to the physical steps a product must go through, it is useful to know at which step data like timestamps are recorded. Also, aspects influencing the processing of returns, like personnel planning and forecasting are examined through these questions. Sub-questions are:

- What steps are required?
- How much time do different steps take?
- How is the workforce planned?
- How are product returns forecasted?
- What are the KPIs of the processing of product returns and how are they measured?

Approach and sources:
Most customer related steps are available on the website, which everyone can access freely. Information of how products are processed within the LSCZ is acquired through personal research within the LSCZ, process descriptions, interviews with managers, team leaders and other employees. Wehkamp also provided access to all relevant data in different data systems. Timestamps are retrieved from relevant data systems. When no detailed information is available an estimation will be made accompanied by a detailed explanation about the assumptions made. To determine how workforce is planned an interview with the planner responsible for the planning will be conducted. Furthermore, there is a dashboard available that keeps track of how many hours are spent and how many products are processed. This is also an important source. Next to the dashboard an interview with the controller of the LSCZ will be conducted. Last but not least an interview with the persons responsible for the forecasts, to determine how it is made.

2. What causes the underperformance of KPIs and the need for large variability buffers?

The previous question and its sub-questions are aimed at describing the current situation, the answer to this question should identify causes. What causes serious deviations from targets? Why are the large variability buffers necessary? This question should identify what issues are the cause of not meeting targets. Since a lot of factors influence the processing of returns at the same time a model is built on which analysis can be performed.

Approach and sources:
Relevant data from data systems. Personal research in the LSCZ and interviews with the team leaders and controller. Next to that conclusions will be based upon information found in the previous question and its sources. Since it is highly likely that the answer to this question cannot be found by doing mere analyses, a simulation model will be constructed in order to test for different scenarios in Plant Simulation.

3. What scientific sources are available?

This is a supportive question in the sense that scientific literature will be the foundation on which the proposed solutions will be based. One of the most important aspects of this question is the applicability to this specific research and the LSCZ.

- What are different forms of planning as described by scientific literature?
- How should be dealt with variability in the LSCZ according to scientific literature?
- Are there scientific sources that describe how to process large amounts of commercial product returns from a supply chain management perspective?
- What is the best type of modelling for this research according to scientific literature?

Approach and sources:
Literature review concerning peer reviewed articles and books, which are retrieved from Scopus, Google scholar and UTfind (the digital library of the University of Twente).

4. What are the alternative solutions that can be formulated in order to balance variability buffers and process returns more efficiently?

The full answer to this question should be a set of alternative solutions. Every alternative is composed by a set of different interventions or changes. Important sub-questions are:

- What are the relevant criteria to compare alternatives?
- How does an alternative influence the current processes at Wehkamp?
- What changes are required to successfully implement an alternative?
- What does the alternative aim to improve?
- What are the expected results?

Every alternative has its own specific pros and cons. Based on the result of this question a set of alternative solutions that will be tested through the model will be determined.

Approach and sources:
Based on scientific sources, input from interviews and observations, a set of alternatives will be constructed. Since the processing of returns is complex, incorporates a lot of variability and depends on a lot of different factors it is hard to predict or calculate the effects of changes upon the whole system. Therefore, the model described as an approach to find an answer to Question 2 will also be used to analyse the expected performance of different alternatives.

5. What specific solution should Wehkamp consider?

Based on the analysis of possible alternatives in the previous research question, a final advice on what is the most beneficial option is the goal of this research question. Where the previous question reviewed the individual alternatives and their specific pros and cons, this question must provide an overall advice. Meaning: what is the overall best solution regarding the processing of returns and the environment it operates in.

Approach and sources:
This question should conclude the search for a solution to balance the variability buffers and process returns more efficiently through planning aided by forecasting. It will be answered regarding all other information gathered during this research and briefly summarize the most important findings.

The following paragraphs will be elaborated on the objectives and deliverables that are determined in this first research phase.

1.5.2 Objective and deliverables

There are several objectives for this research. Attached to these objectives there are certain deliverables. The deliverables are presented in this report or described in this report. All are listed below, in Table 1.3.

	Deliverable	Objective
1	Report with findings	To gain insight in the processing of product returns in general, its performance, suspected performance gap and root causes.
2	Advice on how to balance buffers to meet SLA's efficiently	To optimize the use of different buffers against variability: Time, Capacity, Work to be done and workforce flexibility. What is the best policy to meet the SLA as efficient as possible?
3	Insight in robustness of the process	Analysis of processing of product returns based upon different return percentages, productivity levels and turnover developments.
4	Decision support tool in excel	A tool to aid the planning that incorporates different forecasting models and workload at this point in time.
5	Simulation model	A simulation model that represents the processing of returns in the areas that are in scope

Table 1.3 Objectives and deliverables

To come to these deliverables and fulfil the objectives of the research there are quite some steps that have to be fulfilled. For an overview of what can be found in which section of this report, see the following section.

1.5.3 Structure of this report

This final section concludes the first chapter with an overview of the report. The order of chapters is such that first the current situation is examined in more detail in Chapter 2. Information is gathered to create solutions in Chapter 3. After which solutions are described in the subsequent chapter, Chapter 4. To determine the potential benefit of different solutions a simulation study will be conducted, this study is the subject of Chapter 5. The results will be the topic of Chapter 6 whereas the last chapter, Chapter 7, will hold the conclusions and a section devoted to the discussion and further research.

Chapter 2. 'Context analysis'
The second chapter contains the analysis of the current situation, it is called the context analysis. Its main goal is to answer research question 1 and parts of research question 2 in detail. In the preamble is a more detail description of what can be found where in Chapter 2. Not all analyses are a direct result of a sub research questions, since the research itself resulted in more questions. The concluding section of chapter 2 recaps and relates all data and information of the previous section to variability buffers.

Chapter 3. ‘Scientific review’
Chapter 3 is the scientific literature review. Not all four subjects mentioned in research question 3 are examined in this chapter. The sources that provide information about simulation are treated in a different chapter. Chapter 3 gives a short overview of scientific work concerning planning, an in depth analysis of supply chain literature and a review of variability in manufacturing processes.

Chapter 4. ‘Alternative solutions’
This chapter describes the alternative solutions that will be tested for performance on several KPIs for their performance. The alternatives are compared based on the following criteria: flexibility, work in progress, pressure put on the workforce, cycle time and cost. Whereas a more funded estimation of their performance will be determined through simulation experiments.

Chapter 5. ‘Simulation study: Framework and problem definition’
In the fifth chapter simulation as a tool is introduced. This chapter starts with the scientific sources that were used and motivates the choices made concerning the type of simulation study. After this general part the first of three phases of the simulation study is described.

Chapter 6. ‘Simulation study: Model construction and experiments’
The second chapter that focusses only on the simulation study concerns the data fitting and model construction. The process of data fitting is finding distributions that “fit” i.e., can represent certain types of variables to introduce variability in the simulation model. The construction of the model is described by presenting parts of the actual model. The chapter concludes with the experiment design and conducting the experiments.

Chapter 7. ‘Results’
This chapter reviews the results that are the outcome of the experiments conducted. This chapter does not only concern the reviewing of numbers, but also reflects on how the outcomes of the experiments can be explained, where there is room for improvement and if there are any practical limitations to the results found.

Chapter 8. ‘Conclusions, recommendations and discussion’
The final chapter of the entire research contains the three topics that are in its title. The conclusions will not only reflect on which alternatives are most suitable, but also on what is learned about the entire process concerning product returns. The recommendations based on not only the experiments conducted but also all other information gathered. Finally, the discussion will concern the limitations of this research and opportunities for further research.

The description of the final chapter is also the final part of the first chapter. The next chapter contains the analysis of the current situation or ‘context analysis’ for short. Its structure is mostly related to the relevant sub questions of the first research question as described in Section 1.5.1.

2. Context analysis

This chapter is an analysis of the current situation, a so called context analysis. It consists of six large sections. The first section does not answer a specific research question. It serves as an in-depth introduction, which is necessary to fully understand the processing of returns. The remaining sections hold the following subjects:

The goal of section one to five is to answer the first research question:

1. **How are returned products processed in the LSCZ?**

The last section, Section 2.6, is a short analysis of the variability buffers performance and why they performed the way they did. Where the other sections focus on answering research question 1, this section tries to answer research question 2. The goal is to identify the bottlenecks that are the cause of the difficulties Wehkamp experiences. Such analysis can only answer the second research question to a certain extent and therefore the analytical simulation model will examine different scenarios.

2.1 Introduction to the LSCZ

In order to give a clear view of the environment in which the processing of returns occurs, the first section of this chapter introduces the LSCZ and product returns in general at Wehkamp. Although this might seem unnecessary, or more suited in the previous chapter, this section is placed here to slowly build up the level of detail towards the actual processing of returns (Section 2.2) and other more detailed relevant subjects such as the forecasting of returns.

2.1.1 LSCZ

Within the LSCZ there are three streams of products that are handled. The stream of products that has to be sent out towards customers. This stream is called “Outbound”. The stream of products that arrive from suppliers and is brought to stock, which is called “Inbound”. Finally, there is the stream of products that are returned by customers called “Returns”. The LSCZ aims to use different docks for these three streams. Generally, there is no need to deviate from the standard dock allocation. In front of the corresponding docks there is some storage space for the specific streams. For outbound and returns roll cages (Figure 2.1) are used to move packages. Inbound products arrive in different boxes depending on the supplier and sometimes Wehkamp repacks the products, which is done to simplify the Inbound process at the LSCZ. The

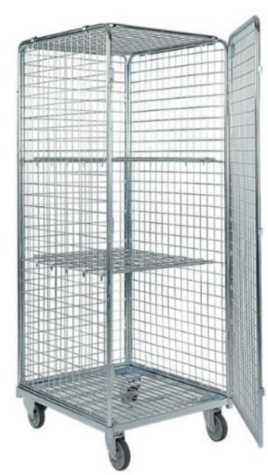

Figure 2.5 Standard roll cage

different processing steps within the three main streams of the LSCZ can operate fully parallel and will normally not interfere, although the outbound of packages has the highest priority, since delivery windows must be met. To deal with this pressure, the personnel planning for outbound is done such that they must be able to meet a 10% increase in demand compared to what is forecasted. It is not considered normal for an employee to switch between jobs related to different streams during a single work day.

Outbound	**Inbound**	**Returns**
336,022 products picked 94 FTE	231,002 products to stock 39 FTE	175,301 products to stock 175 FTE

Figure 2.6 Outbound, inbound and returns

In Figure 2.2 an overview of how many products and personnel hours are involved in the different streams. Since this data is only for a specific week, keep in mind that the ratios between the three different streams in the LSCZ can be different. The information is provided to give a general idea about the large amount of products that flow through the LSCZ in a given week.

Within the LSCZ there are two very clearly separated areas where products are kept on stock. There are products that are stored in the OSR and there are those products that are stored in a separate area. The picking and storing processes are completely different for these two areas. Based upon which products do and which do not fit inside the totes of the OSR products are divided over the two areas. Products that do not physically fit in the OSR are called “Big Tickets”. Everything that fits in a tote is stored in the OSR except for products that, although they might fit in a tote, should not be folded. These are also stored outside the OSR and named “Hanging goods”. The products that do not go into the OSR are stored and picked manually in and from (pallet) racks. Products that are too big for the tote usually have a maximum size of a boxed vacuum cleaner, since products that are larger are stored in and picked from the LSC Maurik (lounge sets, couches, refrigerators, big screen TVs’s etc.). The products that enter the OSR are separated in the categories “Fashion”, “Shoes” and “Electronics” through a manual sorting process. Different names are used within Wehkamp for the different categories, but these three names are maintained in this report. The products that are returned are processed separately based on their OSR category. There are other categories called “Valuables”, “Food” and “Customer complaints” which are treated different, but these separate categories account for less than 0.1% of all returns. Processing these types of returns is done manually and separately.

In the LSCZ there are employees who work for Wehkamp directly and those who work for Wehkamp through an employment agency called Timing. Most of the employees working at Wehkamp through Timing are doing jobs directly at one of the streams Inbound, Outbound or Returns. The way employees are contracted has an influence upon how much they cost per hour, how flexible they can be planned and if the must be paid even though workloads is too low. Employees who work for Wehkamp through Timing cost less per hour, planned fewer days in advance (Section 2.3) and can be sent home when necessary. With the side note that when one comes to the LSCZ he or she always receives three hours of pay, no matter how little time he or she actually worked. Employees who work directly for Wehkamp cannot be sent home since they have to work a certain amount of hours due to Dutch regulations and their contracts. They can only be asked if it is to their liking to take a certain part of the day (or a full day) off, or should have already reached the minimal number of hours in their contract. Most common activities and tasks on an operational level related to the processing of returns are:

- Blue Area returns and valuables processing
- Big Tickets and Hanging Goods picking storing and checking
- Processing of returned electronical products
- Processing of returned fashion products
- Processing of returned shoes
- Key-users (team leaders)
- Mistakes per different category of returns
- Sorting
- Transporting roll cages from storage to stations
- Quality Assurance

To give an idea of the amount of returns the LSCZ has to process throughout the year a general analysis of sales and product returns is made. It is presented in the next part of this section.

2.1.2 Overview of sales & returns

Wehkamp's sales volume fluctuates a lot. Not all due to obvious causes, but examples of factors with great influence are the different seasons, the weather, discounting and holidays. In the past year the amount of products sold, the amount of products returned and the overall returns percentage for the whole of Wehkamp is shown in Figure 2.3.

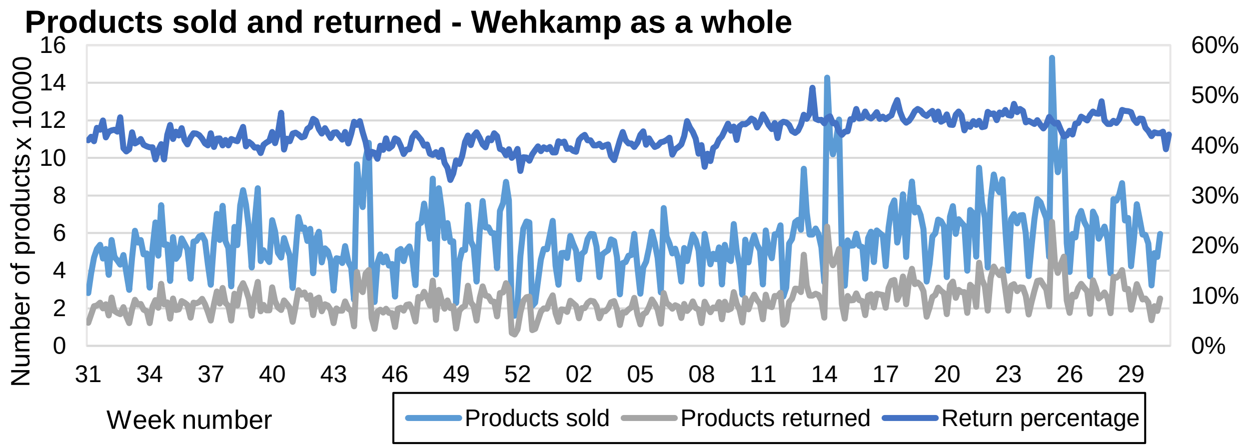

Figure 2.7 Products sold, returned and the percentage returned for Wehkamp as a whole

This graph is based on the products sold and returned Wehkamp as a whole. An important notice one should take is that a product which is sold on the first day of the first week, physically returned on the third day in the third week, is added to the amount of returns of the first day in the first week. For consistency, it would be great to maintain this throughout this research. Since analyses regarding time required and productivity in a certain week are necessary, this is not possible. Another important point is that, in the data system of Wehkamp, a returned product has actually arrived at a customer first. Orders that are cancelled are excluded. An order that is cancelled by a customer before it was sent out is accounted as a cancelled order and not a returned product, nor is it accounted as a sold product. So a returned product in this research the product is actually received by a customer and returned to Wehkamp. Figure 2.4 is the exact same graph except that everything not stored and returned to the LSCZ is excluded. Next to Maurik this is a small amount of products that are for example a package deal with products from both warehouses, products directly from suppliers or products that come from repairs (see the category other, as in Section 1.4, the research Scope).

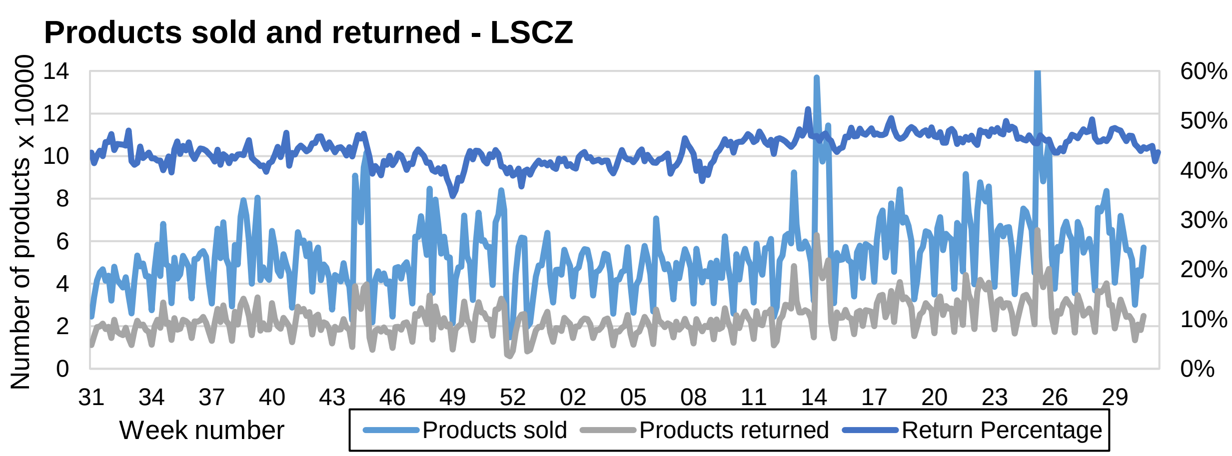

Figure 2.8 Products sold, products returned and the percentage returned for the LSCZ

Since fashion products are stored in the LSCZ and they account for most sales and returns there is very little difference between Figure 2.2 and Figure 2.3. As one might intuitively conclude from the general trend in both figures, there is a strong correlation between the amount of product sold and returned in one week. A Pearson score of 0.976 for Wehkamp as a whole and a Pearson score of 0.979 for the LSCZ to be precise. See Figure 2.5 for a graphical representation that shows an almost perfectly linear relation. This is due to the steps on both axes of equal relative size, based on the average percentage of returns in the past year. The two outliers in the upper right corner are weeks with an extremely successful promotion.

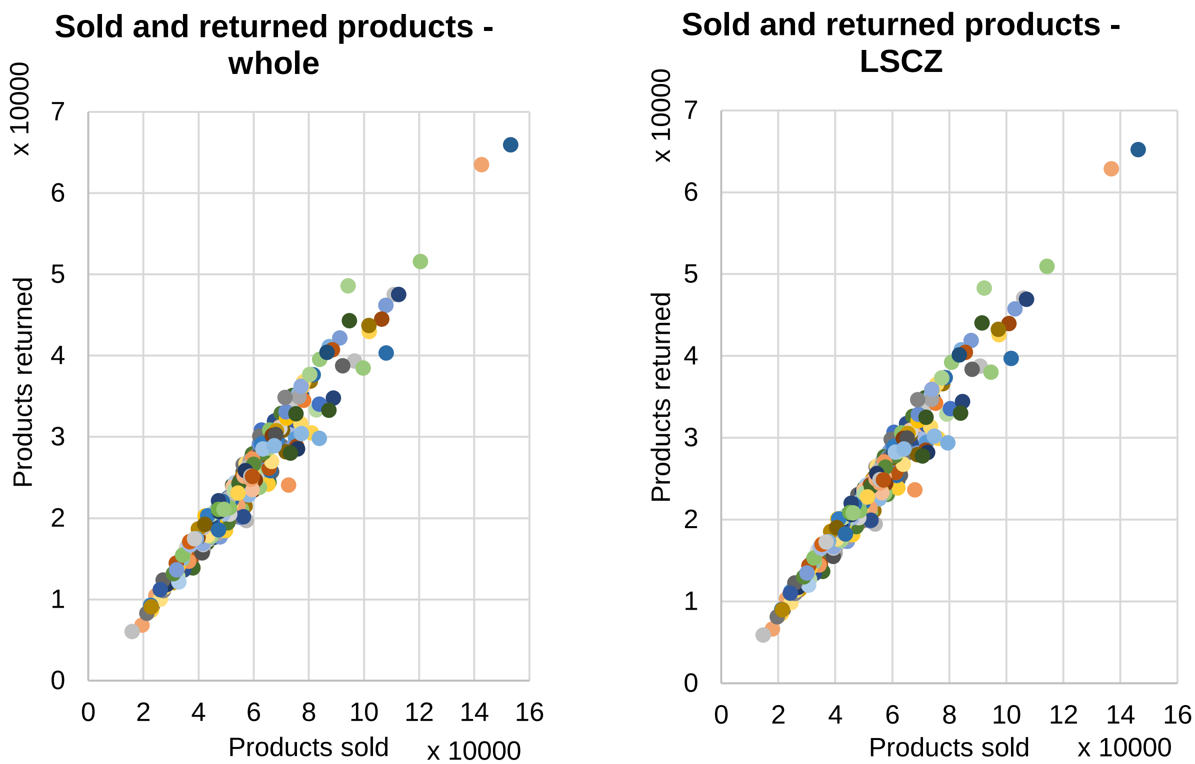

Figure 2.9 Correlation products sold and returned per week

Data of the previous three weeks cannot be used due to reasons explained above (how and when there is accounted for a return) plus the fact that a lot of product that might be returned for these weeks are simply not processed yet. The percentage of returns differs throughout the years, but an analysis shows that the difference between years is not extremely large. To go more in depth in this subject see Figure 2.5 and the trend throughout the last five years.

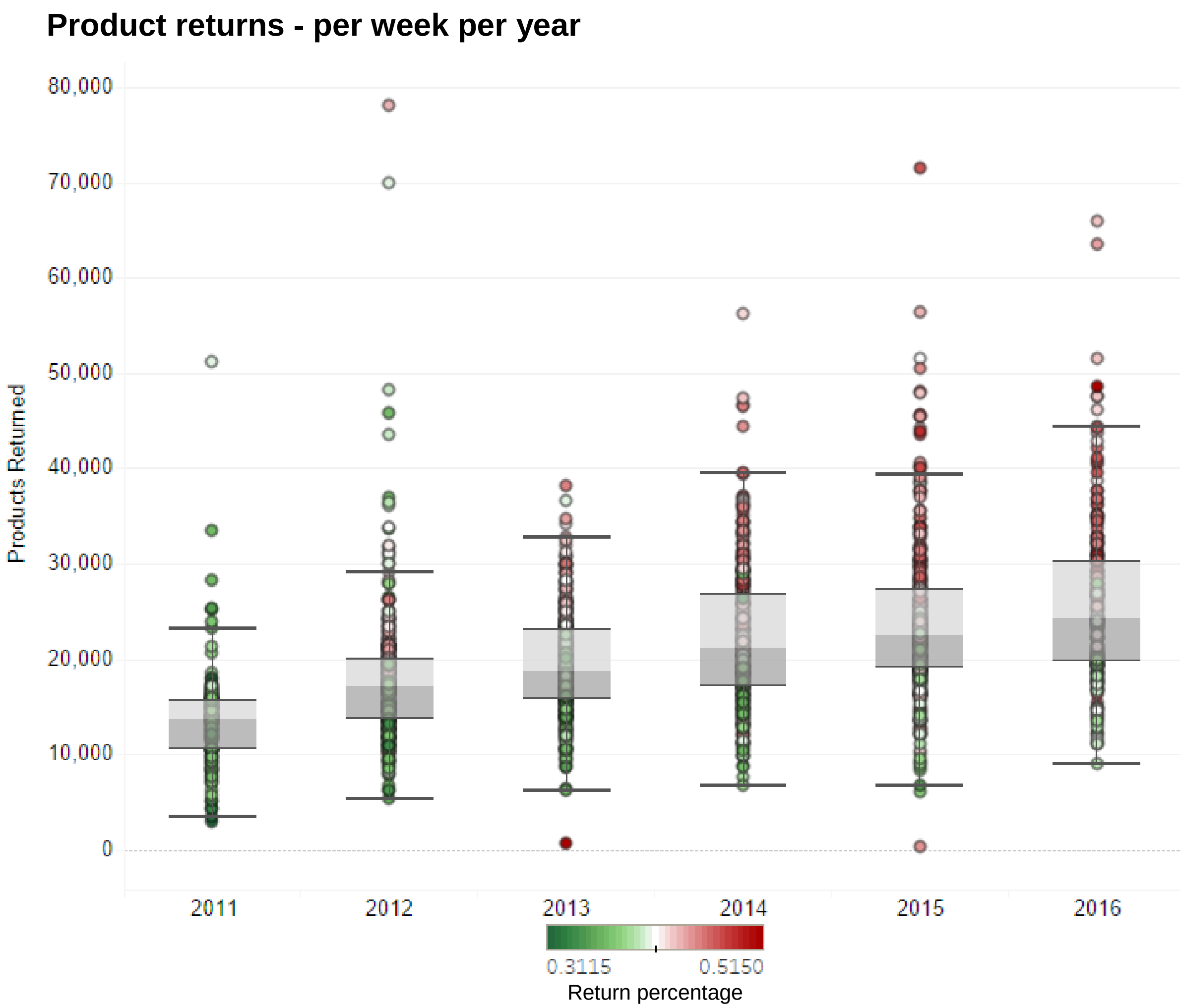

Figure 2.10 Product returns and return percentage of the past five years

Keep in mind that this analysis was in September 2016 and that the weeks with the highest percentage of returns are among the latest data taken into account. So, the boxplot of 2016 might look different when data of all weeks is used. Another notion is that due to a different allocation of products before the introduction of the LSCZ this representation is not completely representative, but the graph gives a decent representation of the trends concerning returns and the steady growth of sales. Now that some general aspects of Wehkamp and the LSCZ are introduced, this chapter will treat several topics in depth. The next section contains the analysis of necessary steps to process a returned product.

2.2 Analysis of return process

This section of Chapter 2 is devoted to the processing of returns in detail. A clear separation is made between the three phases. Those phases are based upon who still physically holds the product, which are: the customer, DHL and Wehkamp. These three actors separate this section and every phase consists of one or more steps. These steps are based upon the possible actions of the actors. This section will be concluded with an analysis of available data. An overview of all steps in the process, and a description of which actor can take a specific step is shown in Figure 2.7.

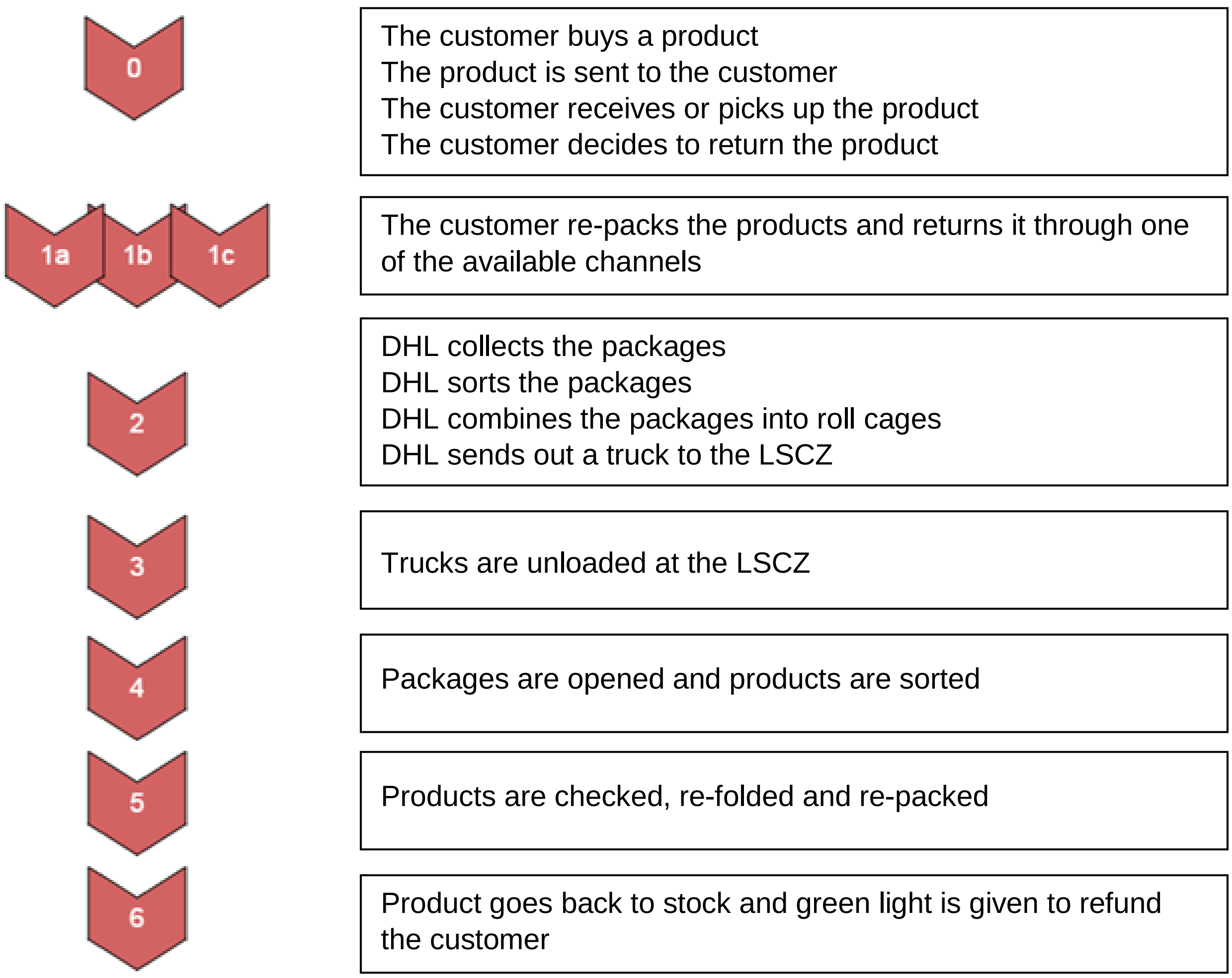

Figure 2.11 Steps a returned product goes through

2.2.1 Customer

Customers can return products in different ways. The options a customer has slightly differs per product and area a customer is located. For most of the product returns that originate from the LSCZ there are three options. Two of these options are specifically mentioned on the website. Regardless of the option a customer chooses, every product has to be repacked in the original bag and box it came, the invoice does not have to be included. These requirements are mentioned on the invoice as well as on the website. The three different options are the following:

1A - A customer can return a product through a DHL service point. No further action from the customer is needed than to deliver it to the DHL service point (see appendix B for an overview of DHL service point density).

1B - The second option is to make a pick-up appointment for one or more products. Such appointments are made through the Wehkamp website and require a customer to select at least one product to be picked up. A customer can however decide to return a different or more products than the one he or she selected. A customer can follow his or her package through a code provided by DHL. This can be done through the DHL or Wehkamp website.

1C - The final option is to give a product to a DHL deliverer when he arrives with other products. The deliverer carries blanc DHL tickets with tracking codes, of which the customer receives one to track his to be returned package. This is not a way of returning products that is advertised on the Wehkamp website, but still is used by customers.

Figure 2.12 Product return channels; service points, pick-up and swap

2.2.2 DHL

2 - DHL gathers all packages from the different streams in their distribution centres. Here products are sorted to ensure that products end up in the right location. An example of a product from the LSCZ that does not go to the LSCZ when it is returned is a defective electronic product under warranty. Although Wehkamp mediates in these cases, repairs are often done by the manufacturer or a third party. While sorting DHL takes care of Hanging goods, these are hung in roll cages that are not fully filled. All data DHL gathers is, although shown to customers through the Wehkamp website, not used by Wehkamp. The data shown to the customer on the website is only Wehkamp's presentation of data on the DHL website. DHL scans all boxes that go to the LSCZ, but it is unknown how many products a box contains. According to the contract, DHL should deliver every return to Wehkamp within 48 hours and Wehkamp has no indication that DHL deviates from these targets. DHL gives estimates during the day of how many roll cages with returns are expected to arrive at the LSCZ. This estimation only concerns trucks that arrive in the evening. There is no estimation or forecast for trucks that arrive at the LSCZ during daytime, from 8:00 to 17:00. Estimates concerning the evening also deviate quite a lot from reality, the actual number of roll cages might be more than 100% larger than what is estimated. DHL only started recently with providing these estimate and sometimes it is completely ignored and discarded in the LSCZ due to its bad performance. A decent analysis of this data was not possible and is therefore not included in this research.

2.2.3 The processing of returns within LSCZ

3 - When the truck with returned products arrives it will normally be docked at the specific docks in front of the storage area for product returns. The next step is to unload all roll cages and store them in this designated area. Roll cages are grouped together per day that they arrive at the LSCZ. This does not necessarily mean that all products have been returned by a customer at the same day since they might have been grouped separately by DHL. Roll cages are not scanned neither are the boxes they contain. These roll cages that are waiting are one of the variability buffers: the amount of work to be done.

4 - When the first shifts start (normally from 8:00 to 17:00) the sorting of products starts. Roll cages are transported towards the sorting tables. At the sorting tables big tickets and hanging goods, which do not enter the OSR, are taken from the roll cages by employees that transport roll cages. These products are gathered and processed separately. This is a small amount of the total number of products returned as said in Section 1.4 and Section 2.1. There are 18 different sorting stations available on the first floor of the LSCZ. Sorting stations can be operated by one or two persons per station. The boxes in the container are opened and the products taken out. A check takes place if the products are still packed in the see through bags with a label on them. If all products from a box are within such see through bag accompanied with a label, the product labels are scanned, a light above one of the three totes lights up and the product is placed accordingly. When a single station is operated by two persons, one person is responsible for opening boxes and checking for the required information, the other person scans and sorts. In Figure 2.9 we see an operator at a station scanning a product packed in a see-through bag ready to be placed in a tote.

Figure 2.13 Operator at a station

If the box with returned products becomes empty and all products are sorted, the box is thrown upon a line that leads it to a paper press. If not all products are within a see-through bag, the label containing the customer address from the box in included in the tote. To process such returns, which are not packed in the original see-through bag, is more difficult. Information can be retrieved based upon the label on the box or the invoice that often included in the box by the customer. Since either the label on the box or label on the see-through bag is enough to determine from which customer a product came, some customers return their products in random boxes or even those of other ecommerce companies. If there is no information at all the product is a “blind” and the product will be further processed without refunding the customer. This often results in a phone call to customer service from the customer after a few weeks.

5 – After sorting products end up in a tote and continue their journey to the OSR on a line moving them one floor up. Before they enter the OSR they reach one of the checking stations. The checking stations are divided over three different areas. Depending on their OSR category, products reach different areas. The areas are specialized for fashion, electronics and shoes. Per different area there are also a few more advanced checking stations which process products that cannot be processed at normal stations. An example is a product that is not packed in the original see through bag. A basic station can only look up the previous 15 products ordered. If the returned product is not among them, a basic station is unable to process the return.

Every single product is checked. It is taken out of the tote, out of its see through bag and compared with the label on the bag through a computer. If all is correct (product type, size, state e.g. no stains or bad smell) the product is re-folded, re-packed, the new bag labelled and product placed in a tote. A tote may contain different products or different types of the same product. Wehkamp prefers however that a tote contains only products of the same type, colour and size in one tote. This might be possible at the inbound of products, but it is certainly not for the returned products. There are some rules for what product combinations are allowed in totes in order to minimize the number of “miss-picks” in the outbound picking phase. The Warehouse Management System (WMS from now) handles this automatically by activating a light above the tote in which a product should be placed.

Products that cannot go back to stock due to defects that cannot be repaired are placed in a tote at the end of the table. Products that cannot be recognized after comparing them with the available information (label from the box or see-through bag), are placed in another separate tote at the end of the table, just as products that are sorted wrong which again has a separate tote. These totes are emptied by the employees who work on the respective parts of the process (e.g. "mistake tables", where products are tried to be linked to the corresponding order of a customer). All possible routings of a returned product summarized in Figure 2.10.

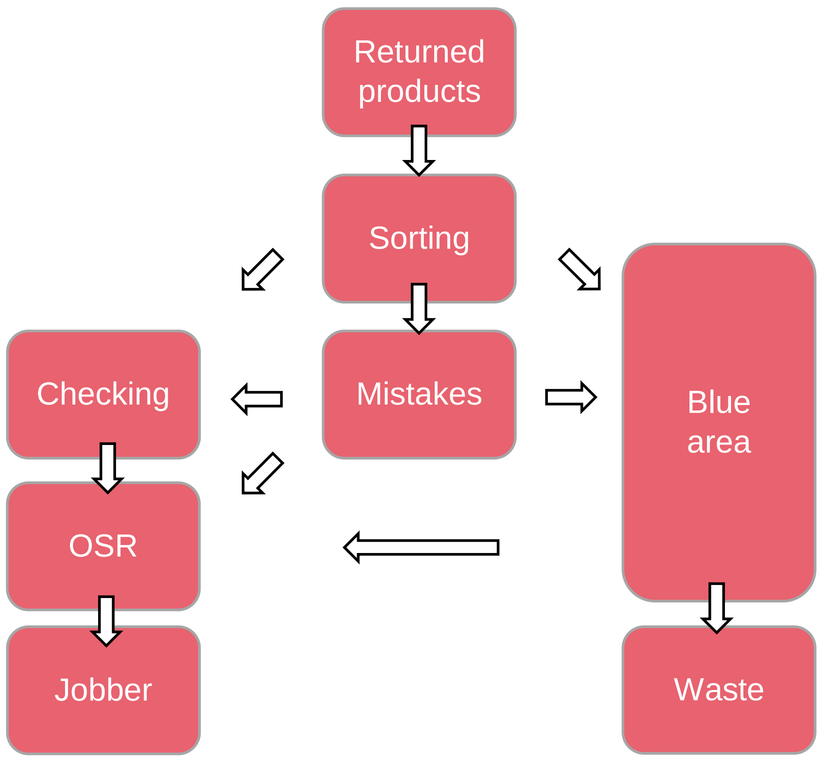

Figure 2.14 Possible routings in the LSCZ

6 - If a tote is full, it leaves the checking stations on a conveyor that leads them to the OSR. The WMS indicates if a tote is full, opposite to the sorting station, where the operator determines when a tote is full. When a product finally entered the OSR and this is registered by the WMS the green light is given to credit the customer and resell the product. In Figure 2.11 the OSR is shown without its side panels.

Figure 2.15 The OSR without its side panels

A small recap, customer returns mostly come in boxes, sometimes in plastic bags. This does not have to be the bag or box in which the product was sent to the customer. A product does have to be in the additional see-through bag in which single items are packed by Wehkamp. As stated this is additional packaging next to the bag or box that contains one or more products. Customers do not always repack products in these see-through bags. Wehkamp counts the amount of roll cages coming in, but does not know the exact number of boxes and bags, let aside the number of products they contain. This is estimated based on the number of roll cages processed, which is counted at the end of the day, and the number of products brought back to stock according to the WMS.

2.2.4 Analysis of time required

In conclusion of this section an analysis of the process as a whole is made. Every step takes a certain amount of time. To give some insight data is collected where possible to examine the amount of time required per step or between steps, starting with step 0.

0 - Order day, picking day and delivery day
An estimation of the amount of time that step 0 takes is made based upon the following three measures:

- Order day: The day that the customer orders the product.
- Picking day: This is the day that the invoice is printed. The invoice is printed just before the product is picked. Usually a product that is picked already has been through most of the necessary steps in order to be ready for delivery. Orders are ready for delivery within 30 minutes and most of this time is related to the OSR, especially when all three product

streams are processing high volumes. So this picking day moment is considered to be the moment that a product is ready for delivery.

- The initial delivery day: The day on which a product is planned to be brought to the customer. This does not guarantee that the product actually was delivered that day, a customer could not be home, a DHL driver might decide to try it again tomorrow or at a nearby service point. It is assumed that most of the time however this is the actual delivery moment.

There are several significant differences concerning for example destination type. Three different destination types are determined: Same address as registered, different address as registered and Service point. The orders delivered at a service point take longer to be returned. There is no reason that assume to this is due to different customer behaviour since same day delivery and next day delivery are only available for home addresses not for the service points. Overall the averages number of days picking, delivery and processing a return takes, for different years, is shown in Table 2.1.

Year	Picking	Delivery	Return processed
2011	0.48	1.76	12.87
2012	0.56	2.03	13.48
2013	0.39	1.83	12.01
2014	0.89	1.70	12.96
2015	0.71	1.51	11.45
2016	0.53	1.40	12.48

Table 2.1 Days until picking, delivery and return processed

All columns are inclusive of their predecessor, so delivery includes time to pick and processing a return includes picking and delivery. We conclude that picking is often done the same day, delivery takes one to two days on average and most returns are processed within 11 to 13 days.

For the sake of completeness also an analysis is made of the differences between the different week days (Figure 2.12 and Figure 2.13). The days in the Figure 2.12 are the days that the customer ordered the product. As you can see delivery became faster and Sundays slowly became as fast as working days. An order placed on a Saturday still takes approximately one day more to be delivered, as this is the day that the LSCZ is not operational. On Saturday the manufacturer of the OSR can do maintenance for example.

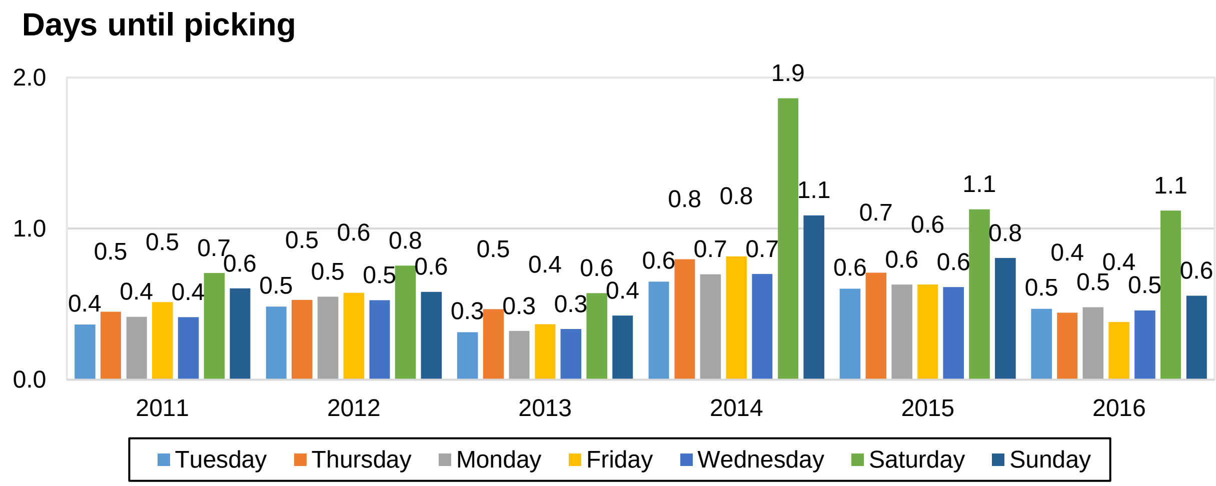

Figure 2.16 Days until picking

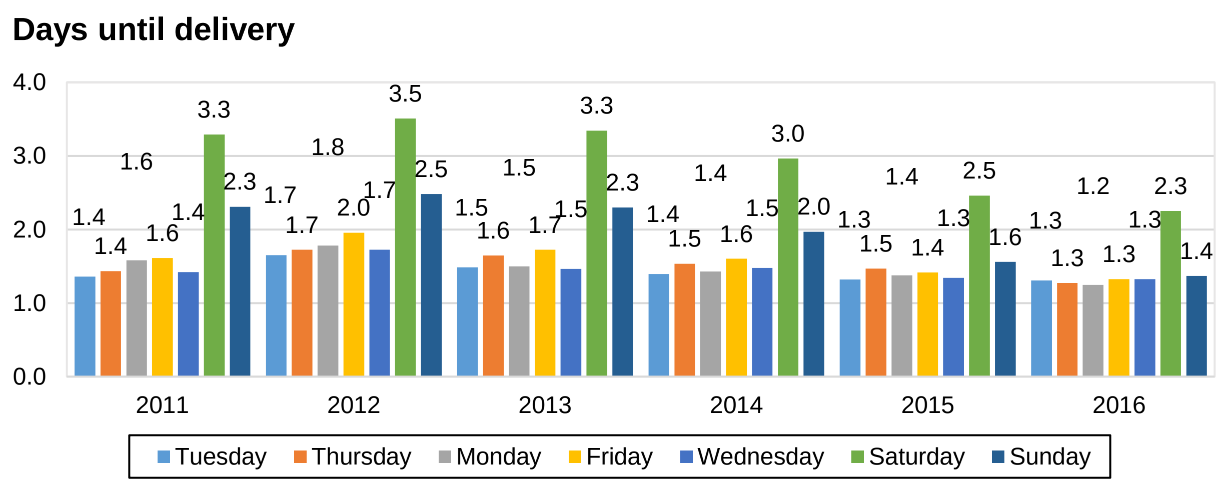

Figure 2.17 Days until delivery

We observe approximately the same patter in Figure 2.13, which is not strange since it includes the time required for picking as is shown in Figure 2.12.

1 & 2 - Wehkamp assumes that there is no discrepancy between DHL's promised and actual performance. Since DHL data, like scanning of boxes that contain return products, is not directly linked to customer order data in Wehkamp's data systems, the following analyses is made based upon the data that a product is processed by Wehkamp. No distinction in the graph is made between service points, same address or different address deliveries. The data used is that of distinct orders, which may contain multiple products of the previous year (2015 to 2016), all averages are weighted averages. The return lag, the time it takes to process a return as counted from the moment it is sold, is shown in Figure 2.14 per province (see appendix C for a separation based on municipality).

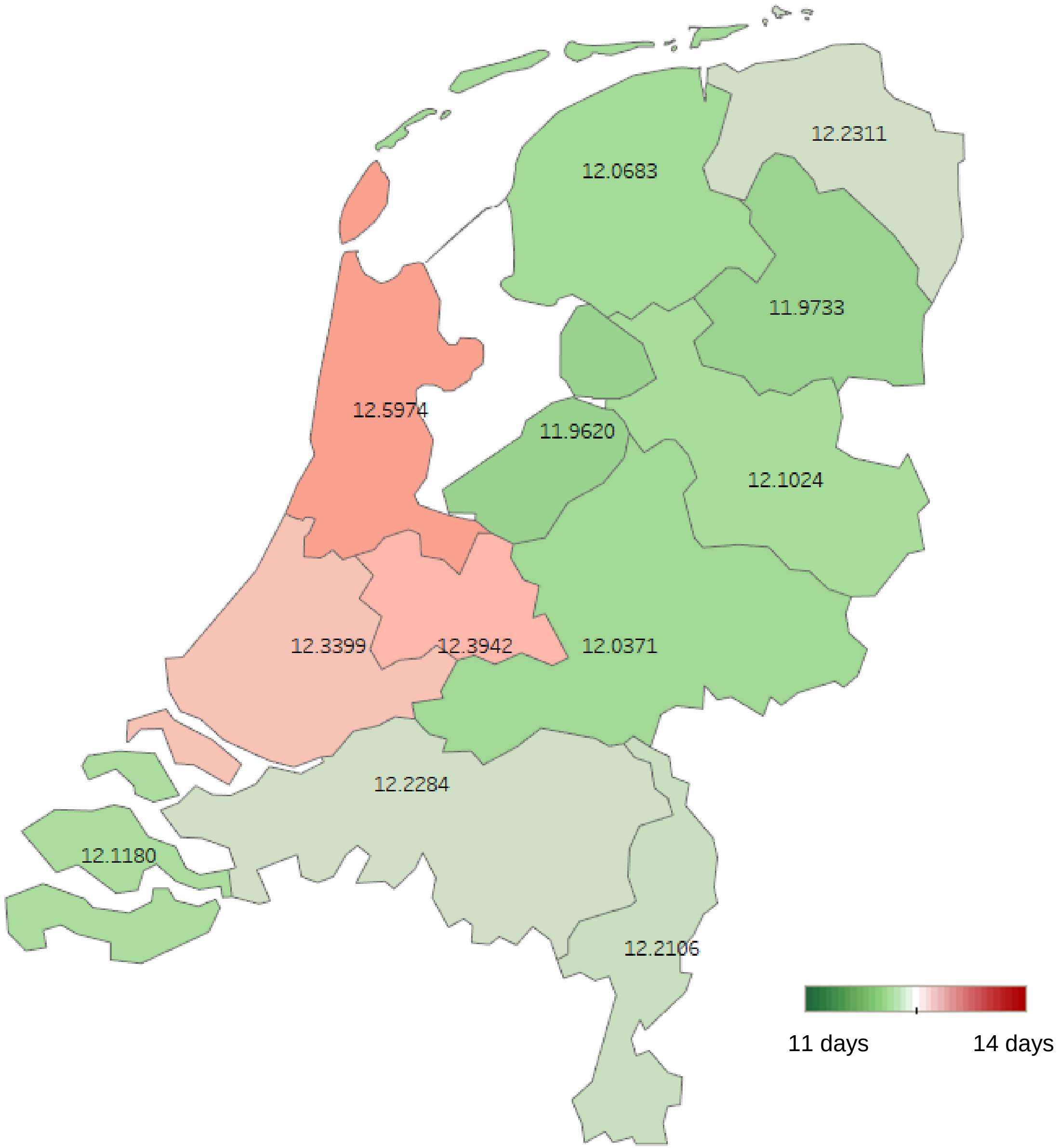

Figure 2.18 Average return lag per province

Figure 2.14 shows that average return lag per province is within limits of the two-day policy, there is approximately half a day of difference between the lowest average in Flevoland and the highest in Noord-Holland. It is of course possible that actual customer behaviour differs per province, but it might also have to do with the DHL policy. Since the differences are not extremely large and Wehkamp does not suspect discrepancies, it is assumed that indeed all products are returned within two days as is agreed upon with DHL, give or take some minor differences.

3 - The time required for the unloading is negligible, but there is some serious waiting time in the LSCZ. Wehkamp maintains an excel file that keeps track of different performance indicators, such as estimated waiting time. The excel file is the main source for this analysis, but has a few drawbacks. There was a period in time for example that not only roll cages were brought to Wehkamp but also bags, so called “Kiala bags”, that carried approximately 40 products. Also the size of the boxes changed with the introduction of the LSCZ and roll cages therefore carry a different amount of products on average. The average fill rate of a container, the amount of returned products per container, was estimated separately from these Kiala bags. Figure 2.15 shows this average fill rate and how it changed since the introduction of the LSCZ. The big gap in the line of 2016 represents the introduction of the LSCZ, since keeping track of data was difficult during these times. The amount of products per container dropped drastically in the LSCZ due to the boxes used, in return the average amount of roll cages coming in doubled. Arguably there are different possible causes for the increase in roll cages. Since the amount of processed products is practically the same, as Figure 2.16 shows, this is unlikely.

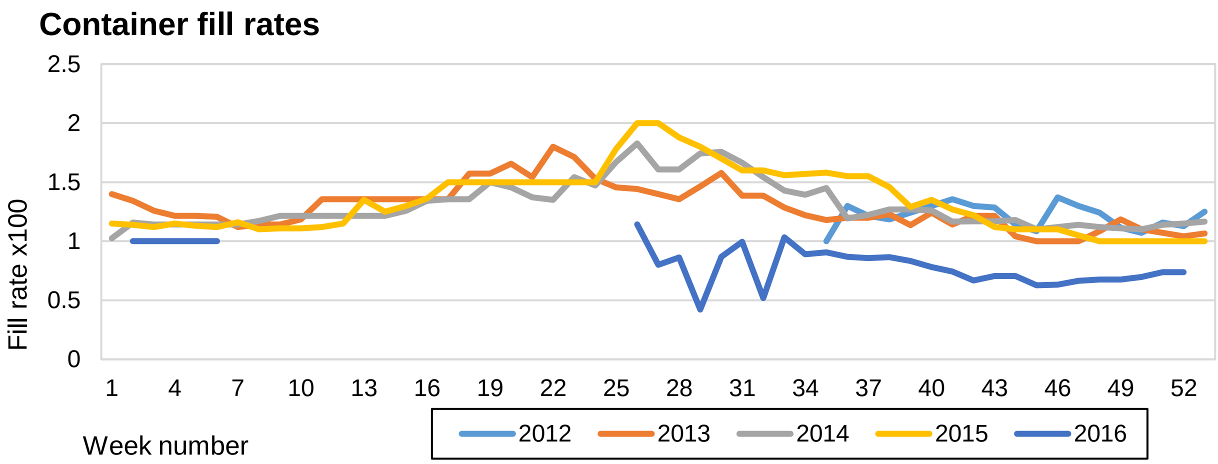

Figure 2.19 Container fill rates

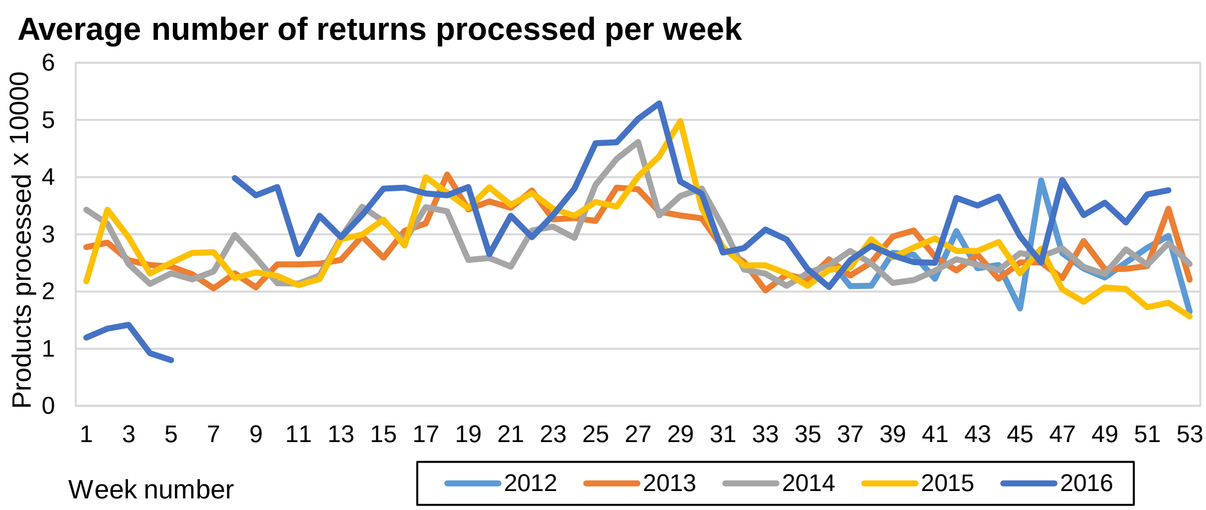

Figure 2.20 Average number of returned products processed

Although the total number of returns is higher in 2016, the relative difference in fill rate is larger and both cause more roll cages coming in to the LSCZ. Since product returns were separated over Kiala bags and roll cages in earlier years, the amount of roll cages coming in is not directly comparable between the current and pre-LSCZ situation.

The average length of stay before items are brought back to stock in the LSCZ is variable. Since boxes are not scanned when arriving at the LSCZ there is no certainty about the length of stay. Estimations are made within the LSCZ by dividing work to be done by the weekly average of roll cages processed per day, but this is not a trustworthy estimate. On this estimation will be elaborated in Section 2.6. To show that the amount of waiting roll cages is often higher than what comes in on a specific day refer to Figure 2.17, where weekly averages are shown.

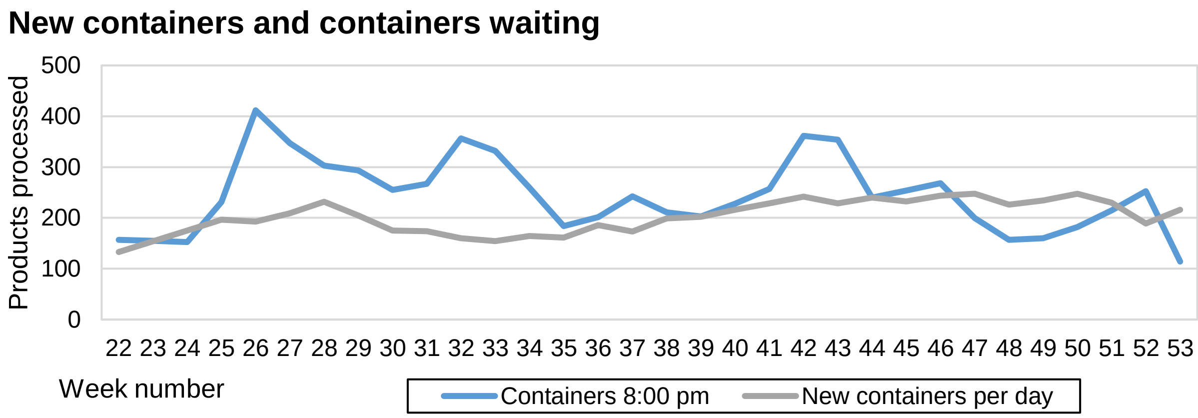

Figure 2.21 New and waiting roll cages

The amount of waiting roll cages can be twice as the amount of new roll cages in a given week. This suggests that a waiting time of at least three days applies to those weeks, without mentioning Saturdays since these introduce another day of waiting time.

A hidden benefit of the increased amount of roll cages might be a reduced waiting time at DHL distribution centres. A normal size trailer can hold up to approximately 50 to 60 roll cages and filling a truck takes less products when container fill rates are low. Therefore, waiting for a truck to be filled takes less returned products and therefore less time if the amount of product returns at least stays equal (assumed from Figure 2.16). Although this requires more transport to the LSCZ and more container unloading, it also means that the product returns come in smaller batches when regarding the number of products instead of number of roll cages.

4,5 & 6 - The time between sorting and checking depends on the amount of processing capacity at the checking stations, but is normally around 30 minutes. This is based on the observation of team leaders that a checking shift can start a maximum of 30 minutes in advance of sorting, when the conveyor is filled with totes. There can be concluded that it is a matter of hours for most products from the moment they are sorted until they are back to stock. Exceptions are products in totes that end up on the conveyor at the end of a shift. A tote with products can stay on the conveyor overnight, without any notification being send to the customer. This frustrates customers, especially during weekends which increase waiting times with at least another day. Wehkamp considers to scan every box that is sorted, to inform the customer that something entered the checking process. The scanning of individual products at the sorting area does not result in such update at this point in time.

Several analyses of the whole process
The “return lag” is interesting, since we can analyse it per day the product is sold and per year. The number of days it takes for a product to be processed from the moment it is sold is shown per weekday in Figure 2.18. The data in Figure 2.18 is that of five years.

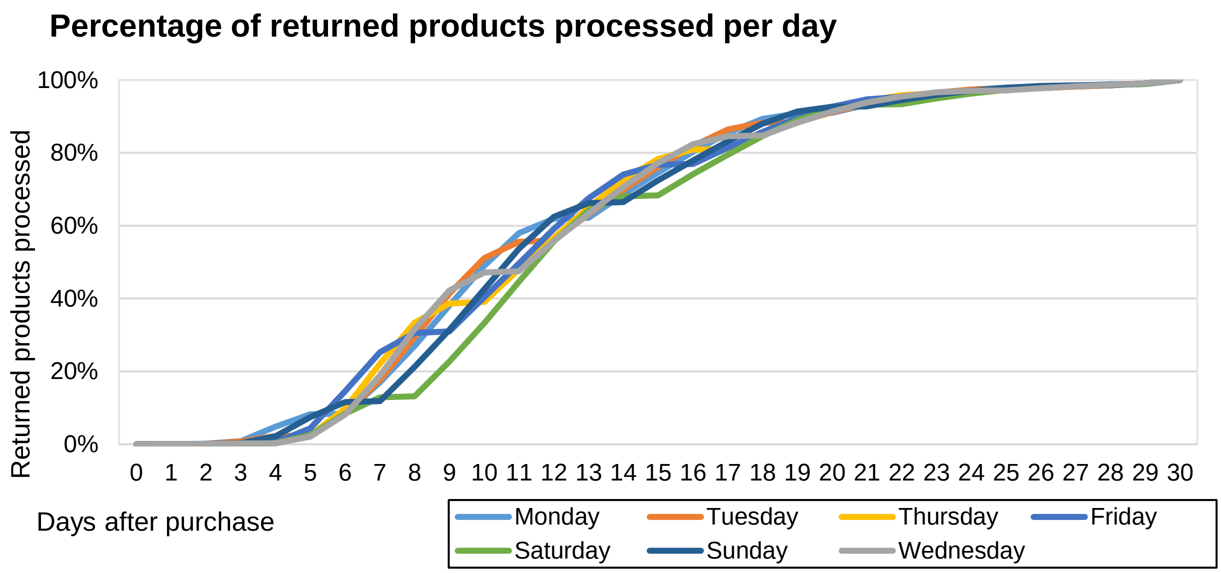

Figure 2.22 Percentage of returned products processed per day

One can clearly indicate the parts of the lines that are almost flat in Figure 2.18. These are caused by the lower amount of processing capacity on Saturdays and Sundays in previous years. Since a few months Sunday is also a regular working day, so in the future these flat parts will become smaller. There is no statistical difference in return lag per week day except for when the flat parts in the lines occur, since the different week days are a different number of days removed from the weekends. In Figure 2.19 we also see the return lag, but now separated per year.

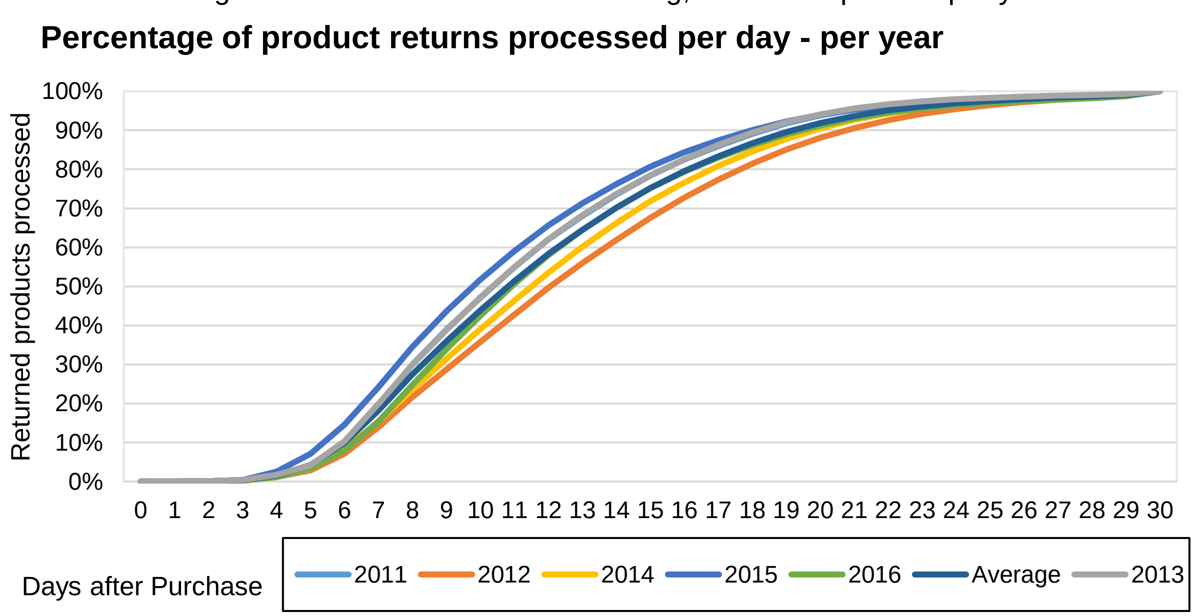

Figure 2.23 Percentage of returned products processed per year

We conclude from Figure 2.19 that, although there are differences in the time it takes to pick and deliver per different combination of year and weekday (Figure 2.12 and Figure 2.13), the differences between the years when looking at the entire return lag is rather small.

To conclude this section Table 2.2 presents an overview of how many days it takes before at least half of the returns are back to stock.

year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Day	11	13	11	12	10	11
Percentage	54,90%	55,94%	54,99%	53,52%	51,81%	50,63%

Table 2.2 First day after the purchase day that at least half of the returns is processed

So the average duration of step 0 until step 6, as are shown in Figure 2.7, is approximately 11 days. The following section will focus on the KPIs Wehkamp formulated for the processing of returns.

2.3 KPIs

KPIs are measured by different employees at different levels. A distinction is made between those at an operational level, available at a stand-up board, and those used by management. There are three operational level KPIs within the processing of returns, these also account for most other processes within the LSCZ, but are measured differently. Miss placements when sorting returns might be fixed easily at the checking stations while miss placements at outbound means that the wrong customer receives a product. Therefore, the descriptions below only apply to the processing of returns.

2.3.1 Operational KPIs

The three operational KPIs in order of importance are safety, quality and productivity. Safety KPI is measured in number of days since last incident. Incident does not mean accident per se, but could also be a dangerous situation. Wehkamp aims at continuously improving processes and creating the safest working environment possible. Currently there is no discrepancy between Wehkamp's expectations, targets and realisations regarding the aspect of safety.

Quality is the second KPI and is measured differently at different stations within the processing of returns. For the sorting stations a wrongly placed item can be "fixed" at the checking stations. Quality is most important at the checking stations since an item that is wrongly put back on stock, e.g. a product that is defect, ends up at another customer. This does not only concern mixed up products but also products that were unrightfully put back to stock, like stained products or bad folding for example. Quality in this sense is measured by sampling and rechecking. In order to perform these quality checks there are separate stations installed. Quality checking aimed at the sorting stations is placed just before the totes leave the ground floor. There are samples taken to see if the tote is not overfilled and that the right products are in the tote. For the checking stations on the first floor quality checking stations are placed before a tote enters the OSR. Quality check stations intercept totes, scan them and retrieve information about their contents. Quality checks whether the products correspond with their label, how the product is folded and if defective products went unnoticed (e.g. stains, smell, rips, tears or actual malfunctioning).

The final KPI, productivity, is roughly measured in throughput of returns per day within the LSCZ. The different areas have goals as a team depending on the amount of employees planned for a certain day. For management there is a dashboard of every employee indicating how much products are processed per hour. This dashboard is based upon items that indeed are brought back to stock. When the checking procedure is cancelled due to lack of information, a defective product or other reasons, there is no data recorded.

2.3.2 Management level KPIs

The dashboard used within the LSCZ is based upon data from the WMS. Several different data points are stored within the WMS. The number of products sorted and checked that go to the OSR for example, but also the hours worked by a person on a specific station. There are several specific pollutions in the WMS like for example:

- Too high productivity measured, caused by somebody who manually brings back a large number of products back to stock, without checking
- Extremely low productivity measured, employees that log their hours while training others
- Not logging hours while working
- Hours assigned to wrong workstation
- Product checking that does not result in bringing a product back to stock is not considered in productivity levels
- Cancelling an operation is not recorded

There are probably more examples of pollution. The important performance indicators measured are hours spent and products processed. Both performance indicators are measured for specific categories and individual persons e.g. sorting, shoes checking, electronics checking or fashion checking. Given these facts there is quite a detailed source of information, which will be used more extensively in different parts of this report.

In summary, management KPIs are mainly productivity and cost control. Due to data pollution and inconsistencies it is hard to keep track of individual performance on a specific day. Assumed is that the pollution of data has no influence on the measurement of someone's average performance over a long period of time. In short, the dashboard gives a general impression of performance under certain assumptions.

2.4 Personnel & Personnel planning

Based upon the operational forecast (described in Section 2.5) and the amount of work still to be processed Wehkamp plans personnel for the processing of returns. Every day the amount of roll cages that are to be processed and those that are processed is counted. The amount of roll cages that come in during the day is also counted. The amount of roll cages processed during they can be determined and is kept track of through the excel file, which is also a source in the previous section. Available through the WMS is the number of products processed that are successfully brought back to stock. By dividing the total number of products processed by the amount of roll cages processed on a specific day, Wehkamp has an estimate of how many products are in one container on average. Multiplying the number of roll cages with the average fill rate gives an estimate of the amount of work to be done.

Every Monday till Friday there is a day shift from 8.00 AM until 17.00 PM. Optionally there is a second shift when the amount of returns waiting to be processed is “structurally” too high. This is the night shift from 17.00 PM until 1.00 AM. This shift is more expensive for Wehkamp because of a compensation. Next to night shifts, it is also possible that returns are processed during the weekends, which is normally not the case. Most of the employees that process returns are contracted through an employment agency called Timing, as shown in Table 2.3.

Area	Timing hours	% timing row	Wehkamp hours	% Wehkamp row	% of overall total
Blue Area	2063	29%	5054	71%	6%
Big Tickets	194	23%	647	77%	1%
Hanging Goods	93	23%	314	77%	0%
Electronics checking	1260	55%	1022	45%	2%
Fashion checking	56418	92%	4639	8%	56%
Shoes checking	5298	71%	2206	29%	7%
Keyusers	342	29%	831	71%	1%
Mistakes	3842	61%	2430	39%	6%
QA	992	85%	178	15%	1%
Sorting	14382	84%	2833	16%	16%
Transport	2493	54%	2154	46%	4%
Total column	87376	80%	22307	20%	
Overall total	109684				

Table 2.3 Different ratios between activities and employers

As Table 2.3 clearly shows, by far the most employees are concerned with the checking of fashion products and within the category most employees are contracted through Timing. In Section 2.1 was mentioned that how an employee is contracted influence several aspects, of which one is how many days in advance they are planned.

Employees working directly for Wehkamp are planned first since they simply have to work the number of hours in their contract. Employees who are contracted by Wehkamp directly are informed about a new planning two weeks in advance. Employees contracted through Timing receive next week's planning (starting on Sundays) on Thursday this week.

An analysis of different employees is made based on their age, employer and experience at Wehkamp, but only experience showed a small structural result (Appendix D). As already mentioned, and shown in Table 2.3, sorting and fashion checking make up for the largest portion of hours and both consist mainly of Timing employees. The planning of these employees is also the part that has most influence on processing capacity on a specific day. Another important influence on processing capacity is the timing of the DHL trucks. Trucks with returns come in during the day, until approximately 00:00 at night. It is not often that a truck comes in 8:00 sharp, but a few trucks pass the LSCZ on their way to other destinations. These trucks carry approximately 50 roll cages. The rest of the trucks usually start coming in from 11:30. The buffer of work to be done is therefore kept at a minimum of approximately 20,000 products, to assure that there is something to do when regular shifts start. The productivity differs per area (sorting, fashion checking, electronics checking and shoes checking).

The productivity, products processed per hour, per employee in the fashion checking are, which is the checking area where productivity is the highest (for other histograms concerning productivity see appendix E), is shown in Figure 2.20.

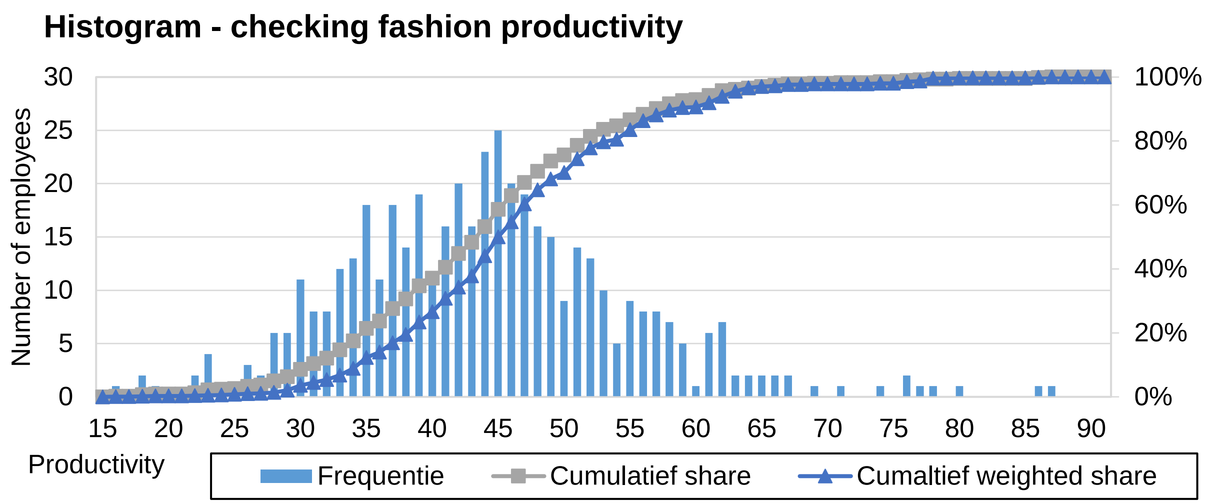

Figure 2.24 Histogram – checking fashion productivity per station

From this graphical representation we conclude that for every employee that is faster than average, a productivity of approximately 45 which is also the sample mean, there is also a slower employee. If there were two clear means, there might be a trick that employees learn or a certain type of employee that is faster or slower. There is no indication of such thing to be concluded from Figure 2.20.

Although this might not be the largest section in this report, its content has several important consequences, e.g. the estimation of work to be done and the number of days an employee is planned in advance. The following section will review the forecasting models at Wehkamp.

2.5 Analysis of different forecasts

Wehkamp forecasts returns for different purposes in different ways. There is a forecast for operational purposes based upon historic data and experience, which is updated every week. For the sales and marketing departments of Wehkamp there is a model in place that uses most recent data from both product, order and customer specifics to give a probability that a product will be returned, it is constructed by the data science department. From now on there will be referred to this forecast as the advanced forecasting model. Last but not least there is an expected return rate for every single product based on the lowest level of product history data available. A notion up front is that all these forecast returns on a product level, the amount of boxes is not estimated. The following paragraphs review the three different types of forecasts.

Operational forecasting model
The first forecast, the operational forecast, is made for the coming eight weeks and is reviewed on a weekly basis. The predicted returns are separated according to their product category, as described in Section 1.1, and per week day. The expected amount of returns is computed by multiplying the expected sales for the specific week with the average return percentage. The basis of the returns forecast is therefore the sales forecast. The sales forecast is "handmade", which means that more complex effects, like weather and specific promotions are easily accounted

for. Although this returns forecast is quite rough and does not incorporate the return lag as described in Section 2.2, or the fact that the percentage of product returns fluctuates (Figure 2.3), its performance is within a 20% bandwidth. A bandwidth represents the bounds that limit a variable's variation, when a forecast's bandwidth is 20%, it means that the forecast is at maximum 10% over or underestimating the true value. The performance of the forecast concerning product returns for the current week (week X), one week in advance (week X-1) and two weeks in advance (week X-2) is listed in Table 2.4.

Forecast	Week X-2	Week X-1	Week X
Std. Deviation	0.0903	0.0999	0.0844
Skewness	0.7314	1.1877	0.9361
Largest underestimation	0.8610	0.8720	0.9046
Largest overestimation	1.1745	1.2777	1.2132
Size 95% confidence interval	0.0822	0.0909	0.0769

Table 2.4 Operational forecast performance

The average in Table 2.4 indicates how much the forecast deviated from the actual amount of returns on average. There is no clear relation between the number of weeks a forecast is made in advance and the standard deviation observed. Standard deviations are little under 10% in Table 2.4.

The data is based on 21 different forecasts. The most notable is the fact that all three forecasts are skewed the same way. This has to do with the fact that the forecast's performance is measured against the number of products that are brought back on stock. If there is a large backlog at the LSCZ, the forecast can be spot on, compared to the data system. Actual performance can be totally different, but the forecast is not compared to the actual number of returned products that enter the LSCZ. This explains the relative large overestimations and skewness of the forecast. For the boxplots of this performance see appendix F.

Advanced forecasting model

Wehkamp's Data Science department constructed a forecasting model which aims to predict product returns. This model predicts returns on product order level. So for every product in an order, the model calculates a probability that it is returned. Multiplied with the price of the product this is the expected amount of turnover loss on product level. The goal of this forecasting model is to give a more realistic view on turnover and margins for the sales and marketing departments of Wehkamp. The model succeeds in its goal as the graph in Figure 2.19 shows its performance since the model went online. This forecast is made at the day that the orders were made and never adjusted with new information afterwards. It is a logistic regression model.

The model takes into account more than 100 variables among variables as:

- Product category
- Product subcategory
- Product specific return data
- Customer behaviour
- Customer gender
- Customer age
- Customer total number of orders
- Customer orders past few weeks

All data used is that of the past 52 weeks. When a new week starts the model recalculates the influences of the variables discarding the week that is now 53 weeks ago and taking into account last week. The forecast is accurate since its deviations from actual returns are small. The official bandwidth is 10% but actual performance is better. The downside of this forecast is that it cannot be made sooner than the order day of a product, which leaves little time to adjust planning. To be precise it leaves the return lag minus the time it takes to process the return. The latter is assumed to be one to two days on average.

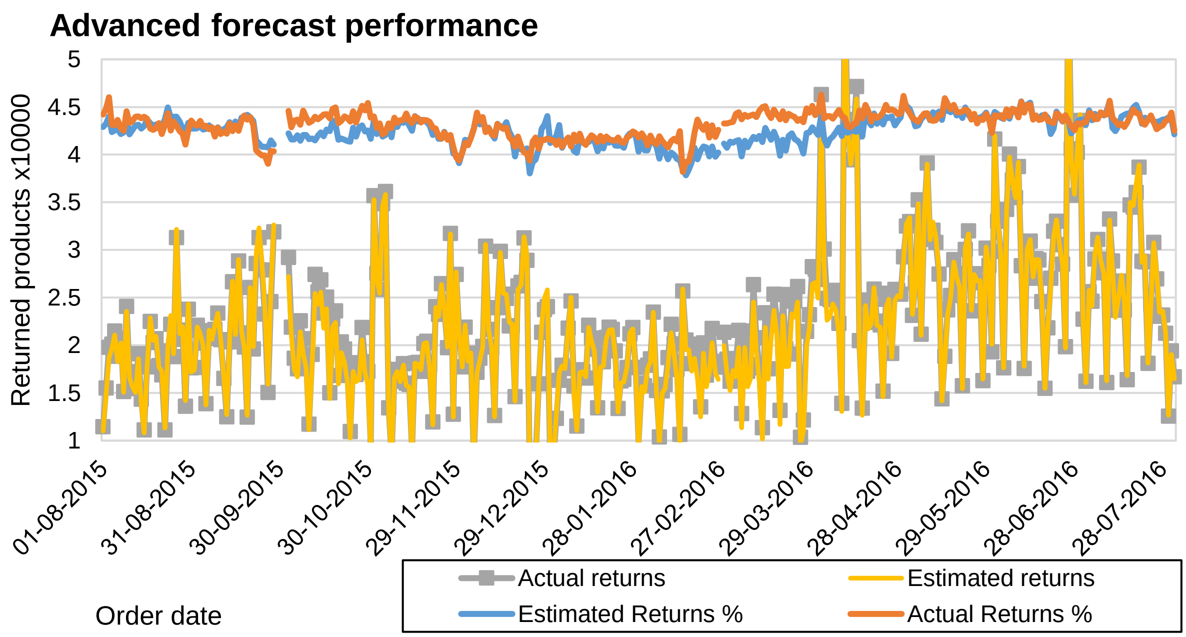

Figure 2.25 Advanced forecast performance

Empty points in data are result of issues, or the forecast not being run. On average it deviates less than two percent (taken actual returns as base score).

Expected return probability

Last but not least there is an estimation of the return probability of a product based on historical data, without further modelling. It simply divides the sum of sold products by the sum of returned products. The estimation is made as is shown in Appendix G. This forecast is therefore updated every time a product is sold or returned. The expected return probability of a product is present in Wehkamp's data sources. Analysing its performance makes no sense since this probability simply shows the current sold / returned ratio based on history. When only a limited amount of items is sold this model uses data of higher levels, like category, type or brand data. Its ideology is as follows: When no data on the lowest level is available, look up one level higher, e.g. if product specific information is not available, look at subcategory level. If there is some data available but not enough (100 sales), weight the available data relative to higher level data. This rough estimation is comparable to the percentage used in the operational forecast. The difference is that this estimation can be made based on the specific products rather than an average percentage per OSR or product category.

Summary of forecasts
The forecasts have different goals, horizons, restrictions and performance. Table 2.8 summarizes all this information to give a clear overview.

	Operational	Expected return	Financial
When is the forecast made	Once a week	Updated with every returned product, once per day	Once per day
When is it adjusted	Every week, so a single prediction is adjusted 8 times	With every sale and return processed	Incidentally when deviations are getting out of hand (structural bias). Not more than twice a year.
What information does the forecast provide	Total expected number of returns per week day	Expected return probability.	Summation over all orders regarding the probability that products are returned times the price of the product
Data source	History and predicted sales	based on product history and higher level category history	One year data of more than 100 variables
Type of model	Long term historic data combined with human expertise	Interpolation for individual probabilities, weighted averages to estimate total returns	Logistic regression model

Table 2.5 Summary of different forecasting models

2.6 Summary and relation to variability buffers

In the previous sections several aspects of Wehkamp are examined in detail. As a small summary of this chapter, this section reviews what can be learned from the sections above related to the variability buffers. The goal is to answer the second research question to reasonable extent with the data and information gathered in the previous sections.

2.6.1 Capacity

The amount of stations is only one part of capacity. The actual processing capacity is determined by the number of hours the stations are operated, as well as the productivity during these hours. Wehkamp regularly does not process returns outside the day shift on working days. Capacity utilization of materials, e.g. sorting stations, checking stations and the conveyor, is not high since a normal week has five shifts from 8:00 to 17:00. There is no particular reason not to utilize the rest of the time except for Saturdays, since maintenance is performed on Saturdays, and the higher wage of employees before 7:00 and after 19:00. Increasing workforce capacity during regular shifts is not always possible since it will require extra stations when all stations are already occupied. This is often the case in the fashion checking area. The most important capacity is therefore the processing capacity of the workforce, but having a larger workforce than necessary, to work multiple shifts for example, is costly and is believed not to enhance productivity. This is due to the fact that experience is the most important reason for employees to be fast or slow compared to factors as working directly or indirectly for Wehkamp and age. The results of the analysis made for experience can be seen in Figure 2.20. Processing capacity therefore mostly depends on who is planned and for how many hours. As long as only one shift is planned from 8:00 to 17:00 there is nothing buffered by capacity, since a large deal of time all stations are operated, nobody can shift from other activities towards the checking of returns.

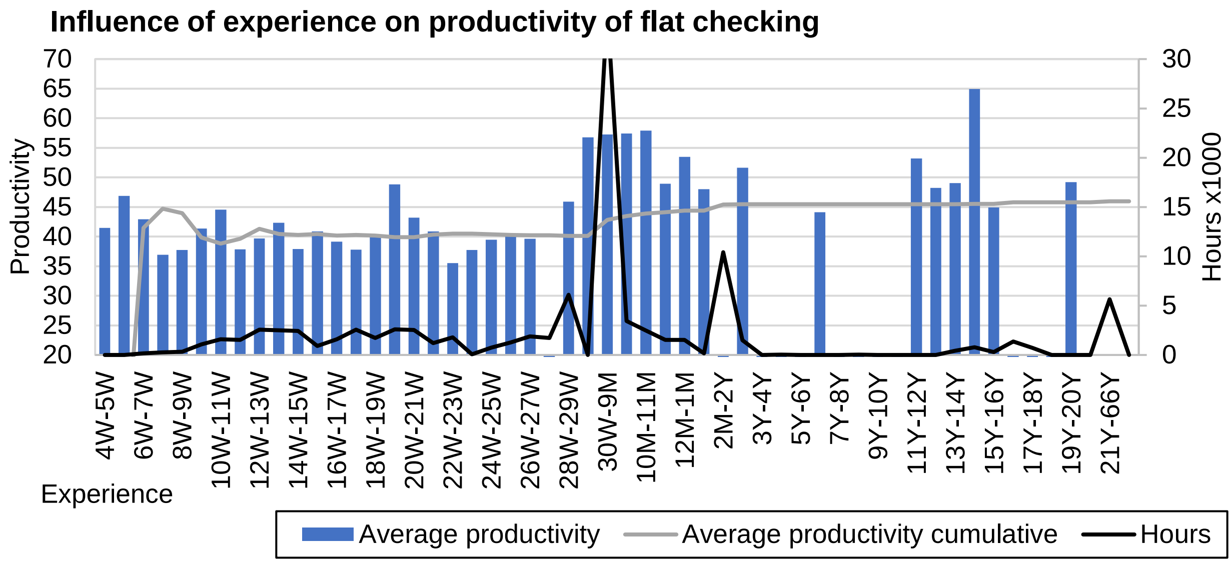

Figure 2.26 The influence of experience on productivity of fashion checking

In Figure 2.22 we see that the most hours (the black line) are worked by employees with 30 weeks to 9 months of experience. This has a logical explanation, since the LSCZ was in use for 9 months when the analysis in Figure 2.22 was made. When the LSCZ opened, a lot of new employees started working for Wehkamp.

2.6.2 Work to be done

The amount of work to be done is the amount of returns waiting to be processed, so that employee idle time is prevented. The target in the LSCZ is to keep approximately 20,000 items waiting in roll cages and fill the conveyor with sorted totes in order to prevent underutilization of checking stations. Since it is not exactly known how much products are in each container, how many roll cages to leave untouched is estimated based on the fill rate of roll cages in the past week. The fill rate is estimated based on roll cages processed (counted by team leaders) and products brought back to stock on a specific day. Causes of noise in this estimation are products that are processed that were in a tote on the conveyor at the end of the checking shift and products that were not brought back to stock. To account for these factors of noise the estimation of the fill rate is made based upon data of seven days. A side note is that the amount of work to be done buffered is not always a choice. In many cases, it is the mere pressure of new returns coming in that is greater than the number of returned products processed on that day, which causes an increase of this buffer.

An important observation is that, although there are several peaks regarding number of sales, most difficulties in processing returns arise around week 25 and resolve around week 35. Sales during this period is relatively higher, since Wehkamp sells a lot of bathing wear, while experienced employees also go on vacations. In this period, all stations are occupied during the first shift, which leaves no room for flexibility since no extra employees can be planned. During these weeks, the amount of work to be done builds up, see Figure 2.23, until night shifts are planned. This is shown in Figure 2.23 where the left axis represents the estimated number of product returns waiting in roll cages to be processed. This is what is meant by work to be done in this report. The average, estimated amount of work to be done in the LSCZ is shown in Figure 2.23, although this is a very rough estimate.

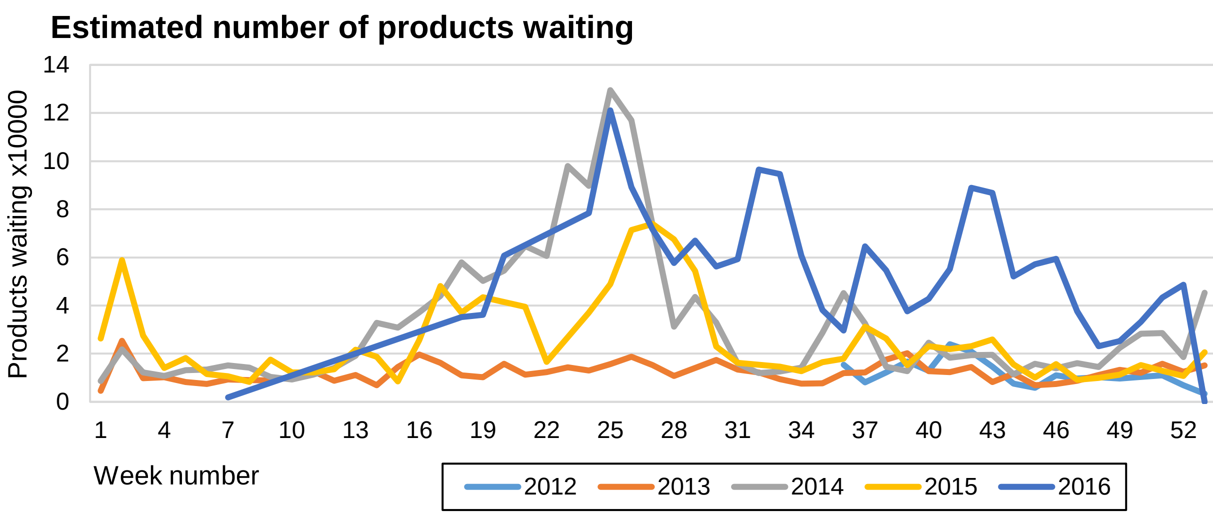

Figure 2.27 Estimated number of products waiting

As Wehkamp continues to grow in terms of sales and maintains approximately the same percentage of returns, the absolute number of product returns rises and also the number of products waiting grows. We can clearly observe this in Figure 2.23 as there are a lot more products waiting in the second half of 2016 compared to other years. Since most stations are occupied during day shifts, it becomes harder to control WIP with regular shifts only.

2.6.3 Time

There is a relative broad window in which the products that are returned should be processed. Officially this window is 14 days, but this period is sometimes exceeded. The time it takes to process returns fluctuates due to the fluctuation of amount of returns waiting to be processed. Usually after a product is sorted it will reach a checking station within half an hour, processing takes approximately one to one and a half minute and the process of bringing back to stock and synchronising data systems is a matter of half an hour up to a maximum of approximately three hours. The time related to the processing of returns is therefore practically zero compared to the time other steps take. The biggest problem concerning time required are returns that have to wait over the weekend, since this adds another day of waiting time. The time it takes depends mostly on two factors; first the numbers of products already waiting in the LSCZ and second the processing capacity the coming days. How best to balance this cannot be concluded from the current situation, but must be examined more in depth in the analytical model.

2.6.4 Workforce flexibility

Planning a varying number of employees, to avoid underutilization or not meeting the SLA, is one form of flexibility. Another is to plan and inform required workforce only a few days in advance. As said multiple times in this section, Wehkamp often operates a full day shift on fashion. Extra capacity is sometimes required, but is introduced by working overtime, night shifts or weekend shifts. Extra weekend shifts are no longer possible since Sunday is a regular working day for a few months now and on Saturdays maintenance on the OSR is done. No reliable information on how many employees switch activities, are send home or are re-planned is available. Currently there are not much worries about sending people home often since Wehkamp is mostly concerned with staying ahead of the large amount of returns. When the result of this report is for example that the amount of work to be done needs to be cut in half, sending people home due to low workloads might become extremely relevant, therefore it should not be overlooked. An aspect that is relevant regardless any other changes is the number of days people are planned in advance. Workforce flexibility comes at a cost, this might not be a monetary one, but it is surely paid by the workforce in the current situation. There are two options regarding this flexibility; minimize it to benefit employees or maximize its potential.

Since we cannot test different scenarios and examine certain relations between buffers and KPIs a model is used to answer such questions. Other questions that are also to be answered with the aid of simulation are related to the previous paragraph; how to maximize the potential of the workforce flexibility and what are the effects of planning more days in advance. The construction of this model starts in Chapter 5, but let us first continue with the available scientific sources in the next chapter.

3. Scientific literature review

The goal of the scientific literature study is to find applicable scientific knowledge for this research. The third research question in Chapter 1, which is to be answered in this chapter, is rather broad, therefore a section devoted to a scientific topic starts broad, describing the topic and explaining definitions. Later on in these sections focus on more the specific subtopics within a field and how these apply or can be applied to the processing of returns at Wehkamp. The literature questions described in Chapter 1 will be answered in the corresponding sections:

The scientific literature about simulation is not included in this chapter. As a reminder, the research question that is the reason for this chapter is:

3. What scientific sources are available?

The topic of simulation will be introduced in detail in Chapter 5, where also the first step of the actual study can be found. As in most of the chapters in this report so far, the first section of this chapter is an introduction. It describes the search approach, its structure and the boundaries of the search for scientific literature.

3.1 The general search process, its boundaries and structure

A preliminary search pointed out that there are different scientific fields that relate or might relate to the subject of this research. Examples are queuing theory, reverse logistics, supply chain management, forecasting and simulation. These subjects are all more or less related to the broader field of Operations Research (Informs, 2016). Most of these topics resulted in a question concerning scientific literature. Queuing theory however did not, which needs a justification. Although queuing theory is a great way to get insight in a system's queueing characteristics and overall performance, it requires a lot of effort construction and computation wise. Especially when a lot of stations have different productivity levels and time dependent scenarios are relevant. Next to that, queueing theory does not allow for more complex interactions on a system. For example: the effect of a planning policy where employees are sent home after 14.00, if the remaining work to be done is estimated to drop below 5000 products. Queuing theory is not suited to do analysis of such situations, while such time and system state dependent actions and policies are relevant to this research. Therefore, we do not take it into consideration in this research.

The remaining questions regarding scientific literature are twofold. First of all, general concepts, models and perspectives are required. For this part often is referred to books, literature reviews and more classical scientific work. A second necessity are scientific sources that apply to the specific case of Wehkamp. In the case of supply chain management, a combination of the general subject combined with characteristics like: ecommerce, commercial returns or product returns. For this latter category the specific search structure queries are recorded as the amount of available literature is rather large. Every search is done within three different sources, which are Scopus, FindUT and Google scholar. Big differences are found between these sources. When an article is not available through a specific search engine, a cross search is conducted. Often the number remaining articles is too high to filter based on abstract. Therefore, the following list is made which contains words and concepts that are excluded from the title of the peer reviewed articles:

- Chemical engineering
- Business 2 business
- End-of-life
- Financial products
- Medical
- Perishable products
- Batch blending (in manufacturing)
- Picker routing
- Marketing resource allocation

Descriptions and results of every single step that was conducted will not be shown in detail in this report. Let us continue with the first topic that we address in this chapter, which is that of planning.

3.2 Planning

Since planning is a part of the main research questions, it is one of the topics in this review. Although it is not actual manufacturing that takes place in the LSCZ, there are a lot of similarities and it is a form of processing products. Due to this fact, the scientific sources used below are related to “planning in manufacturing” or planning in reverse logistics.

A well-known planning framework is that proposed by Hans, Herroelen, Leus and Wullink (2003) which is an adapted version of the framework by De Boer (1998). The framework of Hans et al. (2003) is that in Figure 3.1. The hierarchical framework is designed for multi-project organisations. In the framework, there are three levels of planning time wise. The highest level, the Strategic level, considers the long-term decision that have to be made, in contrast to the lowest level which only considers short term decision making and planning called the Operational level. In between there is the Tactical level of planning which is maybe best defined as “everything in between”. Next to these three levels there are three different categories: Technological planning, Resource capacity planning and Material coordination. The framework is quite general and therefore applicable in many different situations, which has its pros and cons. Nuss, Sahamie and Stindt (2014) did an extensive literature research and concluded on an adapted version, specifically designed for reverse supply chains. They call it the Reverse Supply Chain Planning Matrix, see appendix H.

Given the subject of this research it seems more logical to apply the framework by Nuss et al. (2014). The problem with this framework is that it does not consider commercial and retail returns since they state that: "*these types of returns show a limited spectrum of planning problems*". Next to that, as a framework to determine the level of planning required for different alternative solutions, which can be considered projects, the framework by Hans et al. (2003) is more suitable than a framework solely focussed on reverse supply chains.

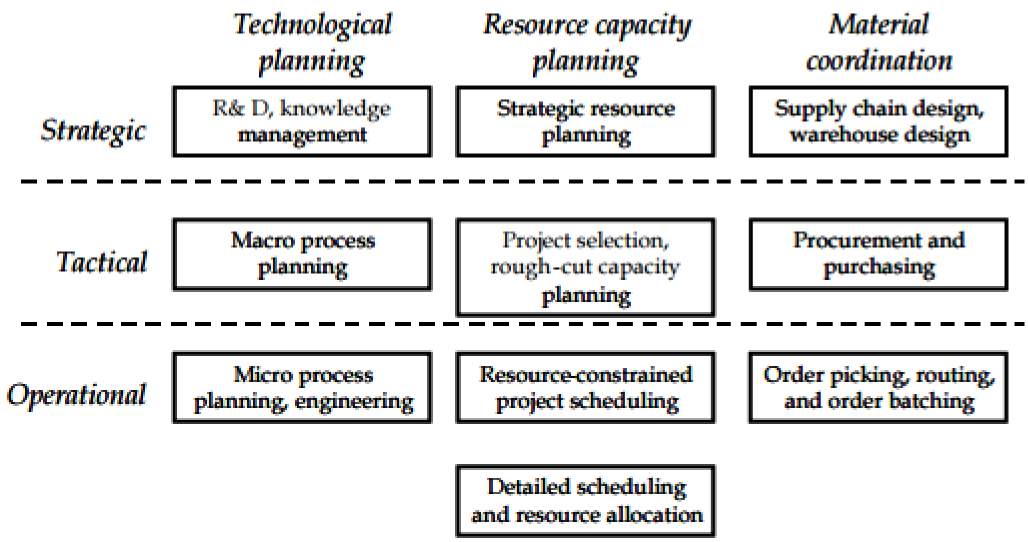

Figure 3.1 Planning framework by Hans et al. (2003)

Where the two remaining sections in this chapter have several paragraphs dedicated to the applicability of the found information, this section does not. The framework as described in this section is important due to the central research question and to determine what type of planning is required to implement the alternative solutions. The alternative solution are the subject of Chapter 4. We therefore close the topic of planning for now and continue with the subject of variability and its influence on processes.

3.3 Variability, and how to deal with it

Variability is an important aspect in the processing of returns and therefore relevant for this research. This section is devoted to variability, and concludes with a description of possible ways to cope with it. A lot of use is made of the book "Factory Physics" by Spearmann and Hopp (2008). The title is quite fitting, as the authors describe several relationships and "laws" which are often present in manufacturing and processing settings. The remainder of this section introduces the concept of variability, important performance aspects it influences and concludes with concepts that aid in coping with variability.

3.3.1 Variability and buffers

Variability can be described as the degree in which a variable deviates from a mean or base value. A formal definition given by Hopp and Spearman (2008) is the following: "*Quality of non-uniformity of a class of entities*". Discussions about variability and more specifically the closely related topic of randomness, go far back and resulted in fierce debates.

Although there are different views regarding these subject (see quotes Einstein and Bohr with regard to randomness) the results are the same: uncertainty regarding an outcome.

"God does not play dice"
Albert Einstein

"Stop telling God what to do with his dice"
Niels Bohr

A lot of processes have to deal with variability. Examples in manufacturing that are often subject to variability are: time between machine breakdowns, operator productivity, customer demand and arrival of materials. In order to analyse the effects of variability on the processing of returns in more detail a few concepts have to be introduced. A few concepts that are important in this research and influenced by variability are: throughput, work in progress, cycle time, utilization and service level. A short summary of definitions is given in the list below this paragraph. In this list use is made of the definitions and formulas given by Hopp and Spearman (2008). This summary is not comprehensive since only relevant subjects for this research are included.

Concept	Explanation
Throughput	Amount of products/objects output of a system per unit of time
Work In Progress	Amount of products between start and end points of a process (WIP from now)
Cycle Time	Average time between the moments an object enters a process and exits a process.
Lead time	Can be seen as the target or average cycle time given by for example management to a customer.
Service level	Service level can be described most generally in a manufacturing context as the probability that cycle time (which is random) is smaller than lead-time
Utilization	Utilization is the percentage of time a workstation is not idle due to lack of work to be done. Hopp and Spearman include the time required for setups, machine failures and other non-idle but also non-productive work time. Formula: utilization = arrival rate / effective production rate
Bottleneck rate	The rate at which the station that limits the whole system outputs products per unit of time. More formally this is the output per unit of time of the workstation with the highest long term utilization
Raw process time	Sum of the long term average process times of each station in the line
Throughput	Amount of products that are produced by a system or station per unit of time

Table 3.1 Concepts and definitions

Variability degrades system performance in one way or another which can be best described by the *"Pay me now or pay me later principle"* (Hopp and Spearman, 2008) which implies that one way or another, at a certain moment in time, variability leads to one of the following negative effects:

- Lost throughput
- Wasted capacity
- Inflated cycle times
- Larger inventory levels
- Long lead times or poor customer service

An example of how this pay me or pay me later principle occurs in reality can be found in *"The overtime vicious cycle"* which is described in appendix I. To cope with variability, buffers can be set in place. Hopp and Spearman, (2008) state variability buffering is done through inventory, capacity or time. The most important variability buffers at Wehkamp are mentioned in Chapter 1 (work to be done, capacity, time and workforce flexibility) are not all directly separable in these categories. The amount of work to be done at Wehkamp is actually a form of WIP and not inventory. Where inventory is often a buffer towards variable demand, in the case of Wehkamp this is somewhat different. Instead of providing more certainty to satisfy demand in time, as is often the case with inventory, the amount of work to be done is kept buffered to prevent low utilization of the sorting and checking stations. Comparing it with raw materials in a manufacturing setting is also just partly justifiable. Although raw material inventory might directly influence utilization, as is the case at Wehkamp's work to be done, raw material is normally not pushed as random as returns are at Wehkamp. Referring to it as a time buffer is also not valid since the WIP is not directly related to the required time at Wehkamp, due to processing capacity fluctuations. In search for applicable theory about improving this buffer there is referred to both inventory and raw materials management. The capacity and time buffers are more straightforward. Wehkamp has invested in a large amount of processing stations, which is an important capacity buffer, although it is not utilised fully as said in Section 2.6 The time required to process returns is sometimes rather large and can differ per routing. The last mentioned buffer of Wehkamp, as mentioned in Chapter 1, workforce flexibility, is not defined as a buffer by Hopp and Spearman, (2008). Flexibility has the following effect on buffering according to the authors:

"Flexibility reduces the amount of variability buffering required in a production system"

Must be said that in order to be flexible, Wehkamp has access to a trained workforce that is larger than the maximum number of workplaces at stations. One could say Wehkamp has invested in more workforce capacity and therefore the boundary between flexibility and capacity buffering is vague. Since these employees do not imply further cost, as long as they do not work for Wehkamp (in the case of timing employees) and the amount of workforce that actually works can be changed within days, without other than variable cost, it is therefore justifiable to consider it to be flexibility. The flexibility of the workforce is therefore twofold, not only can the processing capacity of the workforce as a whole deviate strongly, it can do so within a small period of time. The latter form of flexibility takes a toll on the workforce. Employees, and especially those contracted through Timing, only know a few days in advance when they are needed (see Section 2.4). Although this negative effect is not easily expressible in a quantitative value, it is not to be left unconsidered. Several statements indicate that there is paid for this flexibility in the sense of personnel turnover, which on its turn influences workforce productivity since more experienced employees are faster as can be seen in Figure 2.18. Since Timing employees can also be employed at other companies, they might prefer working at other companies due to more certainty. This causes

Wehkamp to lose access to skilled workforce and loses workforce flexibility. So although one can argue if the kind of workforce flexibility is actual flexibility or a form of extra capacity, it is undoubtedly true that there is paid for. There are other buffers in place at the LSCZ, like the conveyor that leads the totes to the second floor, or actual buffers that can hold up to six totes in front of two checking stations. Since these cannot be altered they are not mentioned in Chapter 1. The following paragraphs will address the quantifiable influences of the buffers on the system's performance, starting with an important relation also known as Little’s Law:

$$WIP = Throughput\ x\ Cycle\ Time$$

Little’s law implies that when throughput remains the same and WIP increases, cycle time must also increase. Cycle time is an important aspect for the processing of returns, since it is a customer’s main point of interest. Wehkamp has to deal with all concepts defined in the short list that is placed in the beginning of this section. One topic that needs some clarification is the subject of WIP. Hopp and Spearman (2008) identify five possible forms of WIP:

- Queueing
- Processing
- Waiting for batch
- Moving
- Waiting to match

All these forms of WIP occur at Wehkamp except for waiting to match, and actually all returns waiting to be processed can be seen as WIP. All the following examples are examples of WIP; queueing of roll cages, the processing of products at the checking stations, the first products in a tote waiting for it to be filled (waiting for a batch) and products moving on the conveyor to the next floor. All these examples of WIP are subject of variability. There might be different numbers of roll cages waiting, the processing might take more or less time and the conveyor fill rate might fluctuate between nearly empty to fully loaded within one day or even a few hours. Most of these forms of WIP do not influence the Cycle Time heavily. There is however one exception, which are the roll cages waiting to be sorted. Since after sorting it is a matter of hours on average until the product is back to stock. The cycle time in the LSCZ increases with every container waiting. The reason for this high WIP is that Wehkamp has near perfect utilization of the workforce present in the LSCZ. This is at the cost of a higher cycle time caused by the high WIP.

Regarding the other variability buffers described in Chapter 1 we conclude the following: Wehkamp’s workforce is relatively flexible at the cost of uncertainty for its employees, especially those contracted by Timing, and might even influence staff turnover and therefore productivity per person. The time required to process returns is sometimes quite large, especially in the case of more excruciating processes e.g. products that need to go through the blue area or mistakes stations and when WIP becomes large. The amount of “raw capacity” like processing stations and possible OSR and conveyor capacity is paid for in cold hard cash, but is not fully utilised at the moment. This does not cause any problems, and there are no real arguments to change this, taken into account the relatively low adjustability. Main targets for improvements are therefore the WIP, time and flexibility of the workforce.

3.3.2 Application of variability coping at Wehkamp

There are several specific options when coping with variability that can be applied to the case of Wehkamp. These possible applications are conceptually reviewed in this section. One option that is not examined in detail is buffering, since the buffers that are in place at Wehkamp already decrease performance and introducing more buffers is not likely to enhance performance. Most of the proposed applications are based on concepts by Hopp and Spearman (2008) and finalized with other scientific sources when necessary. This section will start with some more practical options and ends with more abstract forms of advice that are taken by heart in the construction of alternative solutions.

Increasing throughput

Often there is chosen to increase throughput daily or weekly when workloads are getting higher. There are several instruments through which throughput can be increased:

- More stations in order to allow more employees working during the day shift
- More shifts
- More working days
- Longer working days or overtime
- Higher productivity per station per hour

Increased throughput is often proposed as a solution to a large range of problems. An important question is what does an increased throughput solve? When a higher throughput during the day shift requires a higher amount of roll cages waiting to be sure that underutilization does not occur, cycle time is not likely to be reduced. Costs also do not decrease per se, except for maybe a higher productivity per station per hour, if this is achieved by improving employee's productivity. Wehkamp tested with a case where two instead of one person operate on a single sorting station. This diminishes most of the cost reduction provided by the productivity increase of the station, but still seemed to improve the productivity ratio with approximately ten percent. Planning more employees will only require more flexibility of the workforce. Last but not least increasing material capacity, e.g. amount of stations, will only decrease overall material utilization when work pressure during the year stays the same. In the case that the WIP remains the same and the probability of having a less utilized workforce increases, then increasing throughput indeed improves the coping with variability.

Visibility improvements

Hopp and Spearman (2008) describe that visibility improvements are a way of coping with variability. They describe three ways of increasing visibility, namely improve forecasting, reduce cycle times or improve scheduling. An improvement of scheduling or forecasting is quite specific per case, but the authors describe several generic options to decrease cycle times:

Reducing cycle time can be done as follows according to the authors:

- Reduce utilization by increasing effective rate at bottleneck, this can be done by increasing throughput as is mentioned in the previous paragraph
- Just In Time (JIT from now) manufacturing, in a manufacturing setting this practically means authorizing processing of jobs closer to their deadlines
- Setting safety stock, in this case having WIP to prevent lower utilization
- Setting order frequencies for purchased components

The last mentioned option is not applicable to this case, as it is aimed at manufacturing. An interesting combination of the second and third point might be setting a lower target for the work to be done and making sure that workforce capacity is aligned with truck arrival. This will effectively reduce the WIP and therefore reduce the cycle times. The benefit of improving the forecast and different planning policies will be examined with the aid of the simulation model described in Chapter 5.

Production control and Work In Progress

When it comes to the production control traditionally there are two separated categories of systems, the Pull and Push based systems. The processing of returns at Wehkamp is a typical example of a push controlled system, due to the fact that Wehkamp has simply no other choice than to receive the product returns and from then on they are work to be done or WIP. The only form of control that Wehkamp has to control the stream of returns is to sell less, which is of course no option. Something that might be applicable with small changes is the pull concept of CONWIP. A very general description of a pull system is that it authorizes production (Hopp & Spearman, 1990). In the case of CONWIP the idea is to have a constant amount of WIP, which can be achieved by a Kanban system for example (Hopp & Spearman, 1990). Wehkamp could structurally authorize extra production when WIP levels are getting out of hand, which also is a form of authorizing production to maintain a constant amount of work in progress or CONWIP.

Flexibility

Flexibility is another way of coping with variability. The concept of flexibility can mean different things in different situations. Where the previous section discussed whether having a flexible workforce is actual flexibility or an overcapacity of trained workforce, is a great example of this vagueness. In general, a good description is that of Upton (1994):

"Flexibility is the ability to change or react with little penalty in time, effort, cost or performance"

De Toni and Tonchia (1998) composed a literature review concerning manufacturing flexibility. They composed a scheme with six aspects in which several explanations of "manufacturing flexibility" as found in scientific literature can be classified. For an extensive overview see the full paper of De toni and Tonchia (1998) where every aspect is treated extensively. Flexibility which compensates for variability is what Wehkamp needs, but to what extent and in what form heavily depends on what is desired to be achieved. Flexibility is an important aspect of different alternative solutions and the effects of being more flexible. Since flexibility can be achieved in a large variety of ways, how this could be done is described in detail in Chapter 4. The results are again analysed in the simulation model.

Risk pooling

Risk pooling is often considered in the field of economics where financial product risks are "pooled" into one portfolio. A common example of risk pooling in Operations Research is the consolidating of a product stock into one location instead of multiple locations, in order to achieve the same fill rate i.e., number of products deliverable from stock, and service level with a lower safety stock (Cherikh, 2000). Absolute demand variability is then reduced, due to the fact that two demands that are consolidated, let's say X and Y are combined into Z, have a smaller variability than the sum of both individual variabilities (Gerchak & Qi-Ming He, 2001). The applicability of this effect is still being rediscovered resulting in more applications than simply combining demand. Examples applicable to this research are: cross-trained workforce (pooling workforce "demand") or a generic WIP instead of sorting (pooling all streams of WIP). For now, we will put this idea to rest as it requires serious restructuring and investments in the brand new LSCZ, but it might be interesting for Wehkamp to see how much of a productivity benefit is actually achieved at the checking station by sorting products according to their OSR category.

Optimality versus robustness
A final general remark is that there is a big difference between optimal and robust policies. Optimal policies and strategies mostly apply to a specific situation, which heavily depend on variability (Tan, 1998). It is important to consider robustness, and to determine the performance of a policy or strategy under different conditions. A solution for very different optimal policies under different conditions are dynamic policies. Different policies can be adopted for planning personnel, shifts or target setting of the WIP depending on the season for example. A radical example might be that during busy times, products are only checked on having the corresponding colour and then brought back to stock immediately. One could state that dynamically applying such policies depending on the amount of work, is actually a flexible policy.

All these applications are incorporated in more or less detail in the several proposed alternatives in Chapter 4, and the experiments performed with the simulation model as described in Chapter 6. The following section will review Supply Chain management starting with a broad introduction of the field and ending with specific applications possible at Wehkamp.

3.4 Supply Chain Management

The subject in this section is Supply Chain Management. First the subject will be introduced, followed by more specific concepts, namely Closed-loop Supply Chains and reverse logistics. Last but not least a section devoted to the application of theoretical knowledge finalizes this section.

3.4.1 Supply Chain management in general

Supply Chain Management (SCM from now) is not a new concept and many have discussed its exact definition. In this research the definition used in the book “Logistics and supply chain management” by Christopher (2005) is maintained:

“Supply chain management is the management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole”

The literature review of Power, which was made in 2005, found three articles that also contained the reverse logistics, service and recycling activities related to SCM. Although Power did not attempt to examine all literature available (only what is important and influential work in his opinion) it is notable that he found so little scientific work aimed at these aspects of SCM. Especially compared to the large amount aimed at more traditional, “forward supply chains”, topics. Must be said that others like Rubio, Chamorro and Miranda (2008) found a lot more, but still significantly less than reviews of “forward supply chains”. The last two decades the importance of reverse logistics has grown due to several reasons like ecommerce product returns, environmental awareness and governmental regulations (Govindan, Soleimani & Kannan 2015). This has caused a growth in the body of literature as well (see Appendix J).

Traditional forward supply chain literature often concerns the stream of products from raw material to final consumers, in more or less detail (Figure 3.2 and Appendix K). Most interesting for this research are reverse logistics, which considers materials, products and other resources that flow in the opposite direction (Power, 2005).

Figure 3.2 Different supply chains by De wit, Keebler, Nix, Smith & Zacharia (2001)

An important notion is that the reverse logistics aspect of SCM is often described in the context of closed loop-supply chains. Closed-Loop Supply Chain Management (CLSCM from now) can be defined as is done by Govindan, Soleimani and Kannan (2015):

"The design, control, and operation of a system to maximize value creation over the entire lifecycle of a product with dynamic recovery of value from different types and volumes of returns over time"

The difference between the "one direction only" view on supply chains and this definition is that, as an actor in a closed-loop supply chain, you also have to deal with products, components or materials which go up stream, come from different sources, are in different states and might have different values. In the most extreme case, in a fully closed-loop supply chain, manufacturers are responsible for their product from cradle to cradle. The closed-loop and reverse logistics side of SCM are most relevant to this research, therefore these subjects will be examined in more detail in the following section.

3.4.2 Reverse logistics & Closed-Loop supply chains

Reverse logistics are viewed in the context of these closed loop supply chains quite often due to the fact that, if a supply chain is partly or fully closed, this directly implies that there is at least some form of upward stream of products, components or materials. These objects that go upward in the stream, or as one could say: travel in reverse direction, is what the topic of reverse logistics is about. An example of a closed loop supply chain is a figure by Krikke, Bloemhof-Ruwaard & Van Wassenhove (2003) which can be found in the Appendix L. In the early years of the twenty first century an extensive analysis is made about reverse logistics by dutch researchers. They reviewed over 60 case studies concerning reverse logistics and acknowledge the difference between several types of product returns (Brito, Flapper & Dekker 2003). Later a book was written based on nine of these case studies by Flapper, van Nunen & van Wassenhove (2004). The book called "Managing Closed-Loop Supply chains", is accompanied by the complementary book. The second book, "Reverse logistics: A Quantitative analysis for closed-loop supply chains" (Dekker, Fleischmann, Inderfurth & Van Wassenhove, 2004), describes quantitative models related to these case studies. There are no models in the second book that are applicable to this research. In the first book however, one of the cases reviewed is the situation at Wehkamp in Dedemsvaart, which was the actual situation pre LSCZ. The authors described inventory management policies that take into account commercial product returns.

The authors of the first book divided the cases based on the type of product returns. Four different categories were distinguished by the researchers Flappen et al. (2004): Production related returns, distribution related returns, use related returns and end-of-life returns. Although this categorization might be useful in the context of conceptually reviewing cases, it is not very specific or clearly defined in order to make a clear operational distinction. In the second book another separation is made, which is maintained in this research:

1. Manufacturing returns
2. Commercial returns
3. Product recalls
4. Warranty returns
5. Service returns
6. End of use returns
7. End of life returns

This separation allows more specific boundaries between the several categories of product returns. What was hopefully already clear, the subject of this research are the commercial returns in a business to consumer (B2C) context.

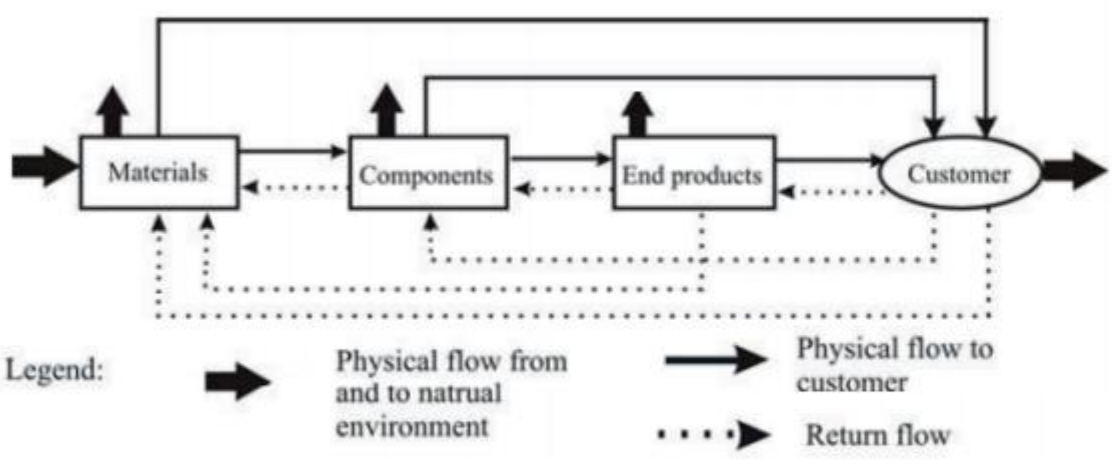

Figure 3.3 Closed loop supply chain by Flappen et al. (2004

Product returns originate from different actors and are destined to different actors. The Figure 3.3 represents the view of Flappen and his colleagues (2004) on reverse logistics streams through a typical closed-loop supply chain.

Such a closed loop supply chain comes with different activities depending on what stream of returns you consider. The sources of different returns streams are the following activities according to the authors:

- Production
- Distribution
- Use
- Processing
- Collection

Comparable lists are made, like the one of Guide, Harrison and Van Wassenhove (2003), although their list is a bit more specific concerning product acquisition and remarketing, the general idea is the same. A source where Wehkamp is not directly involved is production. The fact that production is not done at Wehkamp has great influence on the applicability of reverse logistic and SLSCM literature. Wehkamp does not produce products, which means that repairing, disassembling, managing spare parts, material planning, production planning and activities of such are not done at Wehkamp. Next to manufacturing related topics, even distribution and collection related topics like for example vehicle routing or activity allocation do not concern Wehkamp. This is due to the fact that DHL handles all distribution and collection related activities. Another activity that can be excluded is the one of use. Fashion clothing, shoes and even consumer electronics are not products that are returned to Wehkamp when they reach their End Of Life (EOL from now). In the Netherlands collection of EOL products is often done collectively and not specifically through the original retailers. This leaves the processing steps Wehkamp performs in order to bring a product back to stock, this is the most relevant for this research.

In search for more models, definition and theory, other sources exist than these two books. Rubio, Chamorro and Miranda (2008) reviewed most research that has been conducted on reverse logistics between 1995 and 2005. They concluded that there are three main areas of reverse logistics:

1. Management of recovery and distribution of end-of-life products
2. Production planning and inventory management
3. Supply chain issues in reverse logistics

Within these subjects the authors separated case studies, literature reviews, mathematical models, surveys and theoretical analysis. From the first subject, not much is applicable to the case of Wehkamp due to reasons described above (lacking the production activity). The second subject contains relevant topics like inventory management, but this is not considered in this research. The other part of the second subject, production planning, mainly focusses on producing in time to meet demand, which is also not aligned with this research's interest. Finally, the topic "supply chain management issues in reverse logistics" concerns those scientific sources that analyse new concepts and different level decisions related to the existence of a reverse flow. Thus, questions such as: the long-term behaviour of closed-loop supply chains, the role of IT, the impact of environmental regulation, the value of information sharing between actors, supply chain design issues and other important subjects are included in this area of reverse logistics.

In conclusion, the literature concerning CLSCM does not specifically focus on large amounts of relatively fast to reprocess commercial returns, as is the subject of this research. Topics like recycling, remanufacturing, production planning and resource allocation received a lot more attention. Other topics that are out of scope, but do relate to the situation at Wehkamp, there is even a case about the first topic at Wehkamp, are inventory management and pricing. Sadly, the inventory management as described in the case about Wehkamp is no longer used, product returns are no longer considered when managing inventory. This section ends the broad review concerning what reverse logistics and CLSCM literature contain and what specific subjects are useful to this research, but first the importance of the marginal value of time will be discussed.

3.4.3 Time and its marginal value

Now that it is clear what specific type of product returns and activities from SCM literature apply to Wehkamp, this section describes the importance of time and why most scientific theory focusses on reducing time required to process commercial returns.

Time is an important aspect regarding commercial product returns. What makes time so important is the fact that a lot of unsold products, especially concerning fashion, end up being sold to a jobber at the end of season. This requires the introduction of an important concept regarding product returns: The Marginal Value of Time, or MVT for short. The MVT of a product is a measure of the value a product loses per unit of time that it is actively sold. Although consumer prices might not change, the MVT theory assumes that a product loses value over time anyway. It can best be described by the Figure 3.4 (Blackburn, guide, Souze & Van Wassenhove, 2004).

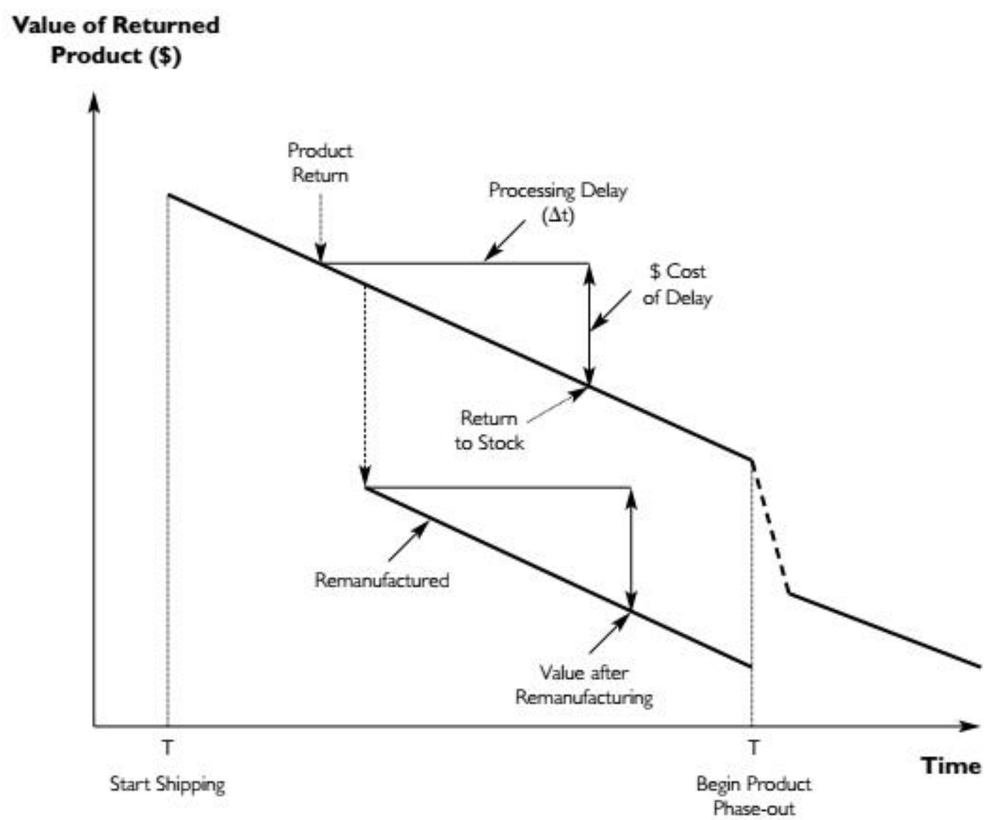

Figure 3.4 The marginal value of time, by Blackburn et al. (2004)

This MVT of a product is important since it directly relates the time it takes to put a product back to stock to a financial loss. Which should motivate companies to not only consider spent resources when looking at process efficiency, but also at the time the process takes. Important concepts in forward supply chains, which relate to time and timing of activities, like postponement, have not been examined in the context of reverse logistics (Blackburn, Guide, Souza & Van Wassenhoven 2004). Their applicability can also be questioned with logic due to the different characteristics of the situations. Like for example the fact that returns happen by the choice of customers, which is always a push and never a pull (see previous section). Waiting to process returns further or pulling instead of pushing them up the supply chain still means that there are returned products waiting somewhere, and waiting is a waste of time and according to the MVT theory also a waste of money. Next to important concepts also general rules differ from those applicable at forward supply chains. Fischer (1997) formulated, regarding forward supply chains, the following:

"Responsive supply chains are more appropriate for high demand uncertainty products and efficient supply chains are appropriate for low demand-uncertainty products"

This idea cannot be directly transferred to reverse logistics since there is no "demand" for customers to return products. Instead of certainty about demand Blackburn, Guide, Souze & van Wassenhoven (2004) indicate that, according to their research, the most influential characteristic of a returned product is its MVT. Regarding Fischer's statement they state:

"Responsive supply chains chains are appropriate for products with high MVT, whereas efficient supply chains are appropriate for products with low MVT"

Although one might not directly think of fashion products with regard to a high MVT, the MVT of fashion product is often quite high. Fashion products and shoes are seasonal products that have lifetimes of approximately three to six months and are afterwards sold to jobbers for much lower, often less than their cost, prices. This also accounts for electronics, although they might have a longer lifetime, the absolute value these products lose is even larger. The next paragraphs contain theory that describes how the processing of returns should be, from a reverse logistics and CLSCM perspective. These sources are found using the structured literature search as described in the introduction of this Chapter.

3.4.4 Application Preponement, Reason coding and Strategic partnership

The following paragraphs will reflect on how SCM theory can be applied at Wehkamp. Where this is a mere review of concepts, as in Section 3.2.2, actual proposed solutions are formulated in the Chapter 4.

Preponement

Blackburn and his colleagues (2004) recognize that in practice most reverse logistics in supply chains are aimed at efficiency no matter what type of return it concerns. This is often due to the fact that the processing of returns is seen as a mere necessity. Different type of product returns come as one stream where scrap, products that are as new and defective products are mixed. Processing such streams as a whole results in unnecessary delays for categories as commercial returns that are often directly re-saleable or a lot of excessive processing steps to conclude that a product should be discarded. To deal with this problem they came up with a new concept. Instead of forcing concepts known from forward supply chain into a reverse logistic perspective, they introduce "preponement". Preponement is comparable to the concept of postponement, as described by Lee and Tang (1997), in the sense that both strive for the same goal, which is financial benefit. Where postponement is beneficial due to the concept of late differentiation, in order to introduce risk pooling effects for example, preponement tries to achieve the contrary. Since risk pooling is not directly applicable, as returns are pushed by customers and different product categories simply need different treatments, the main idea of preponement is to minimize the amount of products that go through unnecessary processing steps.
This is done by identifying what steps are required as soon as possible, decreasing the amount of work to go through specific processes and therefore reducing cycle time (see Section 3.3 for the relation between WIP and cycle time).

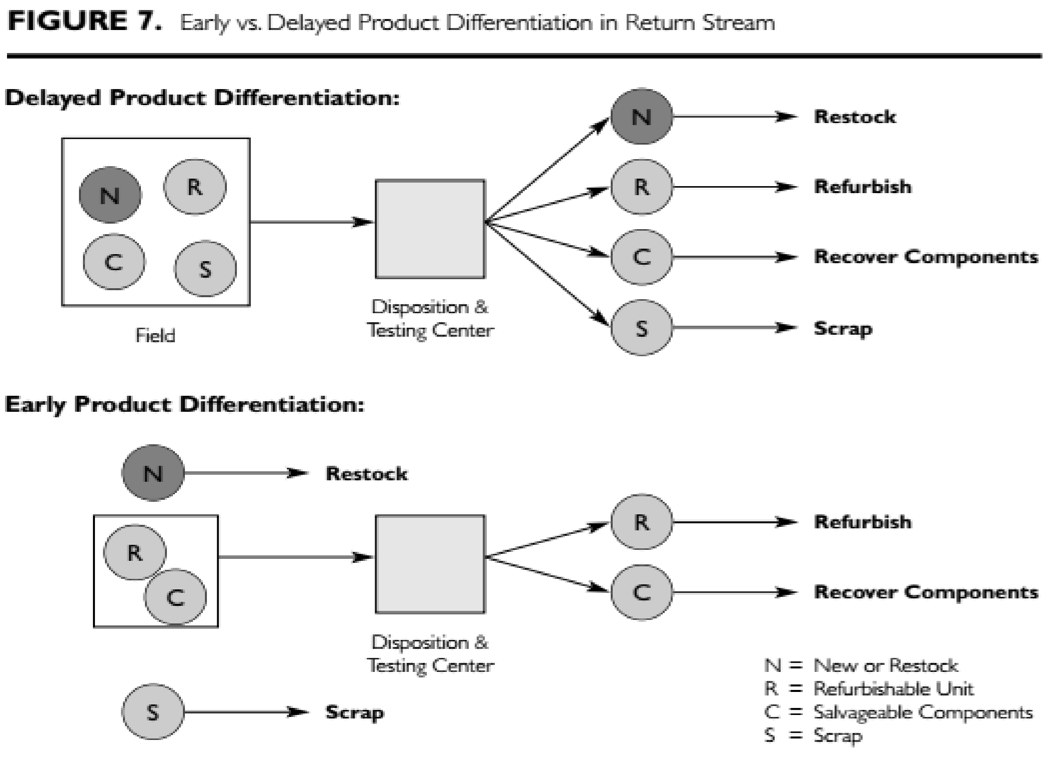

Figure 3.5 Preponement as described by Blackburn et al. (2004)

This is in line with reducing the delay for re-saleable products as much as possible to decrease their value loss, regarding the high MVT of Wehkamp's products. Next to the waste of time, when all products are treated in a mixed stream, the waste of unnecessary processing steps can be reduced by identifying certain categories early on and taking appropriate action. A clear overview of the differences between preponement and postponement is presented in a table made by Domagala and Wolniak (2013).

Postponement concept	Preponement concept
Usually it is used in forward supply chains	Usually it is used in reverse supply chains
Delaying individuation of products - the final shape is picking up only in the last stages in the manufacturing process and distribution	Making a disposition as early as it is possible
It allows a company to minimize unnecessary inventories of finished goods	It allows a company to recover the maximum value of returned products
It requires close cooperation between the chain participants	It requires close cooperation between the chain participants

Figure 3.6 Differences between post- and pre-ponement by Domagala and Wolniak (2013)

An important aspect is how to identify what sort of product return it concerns. This identification step is not always straightforward, but can and should be aided as much as possible. Blackburn and the other authors (2004) describe how technology can help in making preponement more efficient by simplifying the identification process. Regarding electronics one can imagine that it is relatively easy to track how a product has been used with the aid of diagnostic tools that are often already included by the manufacturer. Special equipment to aid preponement is not limited to laptops and smartphones, as it already exists in simpler products as power tools (Blackburn et al. 2004). The use of a "factory seal" can identify all boxes that are not even opened and can be as simple as a sticker (Blackburn et al. 2004). Either way, important is that the determination of the level of usage is simple, fast and inexpensive. Finally, Blackburn et al. (2004) have some recommendations for managers:

- Treat returns as perishable assets
- Elevate the priority of the processing of returned products
- Make time the essential performance metric
- Use time value to design the right reverse supply chain for different products
- Use smart technology to achieve speed at lower cost

Preponement can be applied at different levels in different ways at Wehkamp. A realistic approach would be to apply preponement within the LSCZ. The sorting stations in the LSCZ scan all individual returned products but only separate products based on their OSR category. The main goal is to sort in order to let the checking stations work on a less varying mix of returned products. For Wehkamp this is the most convenient place to apply a form of preponement. If there would be identified what is waste, scrap, EOL, needs repacking or can be directly go back to stock and acting upon this would seriously reduce the pressure upon the checking process. To identify scrap at first sight without opening the bag at the sorting station is unrealistic, but EOL products for example, which are sold to jobbers are now sorted, checked, brought to stock, retrieved from stock, picked and send to the jobber (see Figure 2.9). If the sorting stations simply returns a message that the product should be placed in a tote at the end of a stations, this saves Wehkamp a lot of unnecessary processing steps. Another simple option is to visibly seal a box or bag with a “factory seal”. If the seal is not broken, the product can be brought back to stock directly at the checking stations or more ideally at the sorting station. Identifying other categories like waste, e.g. clothes with stains which might not even be worth the checking, is harder to do fast. Reason coding or a predictive modelling might be beneficial to speed up this process and aid the identification of this category.

Reason Coding

A concept that might aid the early on identification of product returns is quality grading. Quality grading now occurs at the checking station after which there is directly acted upon this grading: a product goes back to stock, is discarded or is send for extra checking to mistake tables. Quality grading in mixed streams of product returns appears to be beneficial regarding value recapturing and cost reduction (Ferguson, Guide, Koca & Souza, 2009). Since efficiency is of utmost importance it is not realistic to do physical checks at the sorting station for example. An option that can be considered is giving customers the ability to give their return reason through a list of options called reason codings. Where other ecommerce companies demand several actions from their customers in order to return a product, Wehkamp does not. With reason coding is simply meant that a customer has the possibility to indicate why he or she returns a product through a list of options. Reason coding is highly dependent on the customers. If a customer is forced to fill in a form it is likely that he or she does not fill it in seriously and simply opts for the first checkbox. Wehkamp had a form that had to be sent back with a returned product on which was indicated why a customer returned the product. Since this was a paper form and the focus was (and is) to process returns fast, it was often simply discarded. Giving customers the possibility to give a reason for returning the problem, might help in identifying products with deviating sizes, or help Wehkamp with identifying defects at the checking station. Both deviating sizes and defects almost always result in a customer returning a product (Powers & Jack, 2015). The computer at the checking station could show the return reason, if there is any. Other beneficial effects of reason coding might also apply e.g. customers might appreciate the fact that they are involved in Wehkamp’s process of actively improving its processes. Potdar and Rogers (2012) even found that there is a different return lag depending on the reason of return, which may aid in the forecasting when specific returns come in.

Strategic Partnership & information sharing

The characteristics of the relationship between Wehkamp and DHL provide a strong basis for a more strategic partnership. Maloni and Benton (1997) state for example that there are several differences when looking at a discrete or relational oriented partnership, see Figure 3.7. Although the relationship between DHL and Wehkamp fits a lot of these criteria some, like visibility, are not always of the level they could be.

Discrete versus relational business strategies

Contractural	Discrete orientation	⇒	Relational orientation
Duration	One time		Long-term
Communication	Very little, just enough for the transaction		Complex, two-way sharing
Transferability (switch parties	Completely transferable		Extremely difficult to transfer
Management Support	Low		Extensive, sincere
Attitude	Soley profit-focus		Open, trusting, cooperative
Visibility	Low		High
Planning and Goals	Individual, short-term		Joint, long-term
Benefits and Risks	Individual		Shared, mutual
Problem Solving	Power driven		Mutual, judicious

Figure 3.7 Different supply chain relationships by Maloni and Benton (1997)

DHL provides a forecast to Wehkamp with how many returns are coming in that night, the actual amount of roll cages coming in might be twice or even three times as high. There is no forecast for products that come in during the day. Day to day visibility of incoming returns is for example still difficult. Available information, like returns collected, should be shared and monitored real time. This might not seem relevant for DHL but for Wehkamp knowing what is probably still to come, and if this is more or less than anticipated, can be the difference between having a night shift, overtime or sending employees home early. Monitoring the information available in the systems of DHL, since track and trace is available for customers, might benefit decision making in the LSCZ. Another option for a partnership like the one between DHL and Wehkamp is to let customers indicate what they want to return and apply another return address or code that is sorted differently by DHL. Sorting is done anyway by DHL and heaving different categories of returns to the LSCZ might result in easier prioritisation between return days or different return reasons. This can be done by letting customers indicate something on the label on the box for example, which is closely related to reason coding, by a small change on the label itself or a completely different return label depending on the MVT of the products. For outbound the LSCZ pre-sorts packages depending on their postal code to aid DHL, so it is legitimate to request the same of DHL. It would be ultimate preponement since you identify the required processing steps or priority directly when the customer decides to return a product. This way products that have stains or a bad smell can be identified earlier and can go directly to mistakes or even recycling after sorting, instead of going to a checking station first. Another option is to deliver roll cages of EOL products directly to the jobber. Especially at the end of a season it is a true waste to sort, check, re-stock, pick and send products which are not sold to consumers anymore. If DHL gathers these products they can be sent directly to the jobber. Products that are scrap can be directly send to recycling companies as well as products that are EOL but not suited for jobbers. There is research done to let customers even discard (or keep) products since returning them is more expensive than what the product is worth. This is not received cheerfully by customers and usually has a bad influence on the environmental image of the organization.

3.5 Summary and conclusions

In conclusion of this chapter we identify several concepts that might benefit the processing of returns in the LSCZ. This section briefly summarizes if, why and how concepts found in the previous sections are used in the remainder of this research. The concepts that aid the processing of returns according to the information in this chapter are:

- Increasing throughput
- Visibility improvements
    - Improved planning
    - Improved forecasting
    - Decreasing cycle time
- Production control
- Flexibility
- Risk pooling
- Optimality versus robustness
- Preponement
- Reason coding
- Strategic partnership and information sharing

Increasing throughput is not always the cure for every problem as described in Section 3.2, but heavily effects on performance indicators as cycle time. There are several ways to increase throughput and several other concepts that are described above also strive to increase throughput. The bare idea of increasing throughput will be tested through planning more workforce than is required according to the forecast. This will be examined in the simulation model, and might result in for example the advice to always plan 20% more than is forecasted in order to cope with variability.

Several visibility improvements can also be tested through simulation, like improved forecasts and improved planning. Since external factors like returns coming in the next week, can be predetermined in a model it is easy to incorporate an improved forecast and this will be one of the alternative solutions. Decreasing cycle time will not be a solution in Chapter 4, since this is to be achieved through other solutions like for example preponement and reason coding. Improve planning is also incorporated into an alternative solution that aims to maintain the same throughput with a lower average WIP, which also effectively reduces cycle time.

Production control and flexibility are combined into one solution. This has a practical reason since there is no possibility to control production on an operational level in the case of no flexibility. When the target is to keep WIP around 500 roll cages but there is no flexibility whatsoever in terms of reducing or increasing processing capacity there is no point in having the 500 container, target.

Risk pooling the stream of returns will not be an alternative solution since it requires structural changes to the LSCZ. A form of risk pooling that will be the basis of an alternative solution is cross training of employees. To what degree will be described in the next chapter.

Preponement and reason coding are both interesting topics. Preponement can be aided through reason coding, but there are other possibilities. The effective result of an alternative based on these two topics is to reduce work pressure on the checking stations. Since it is hard to predetermine the amount of products that can be identified early on, in order to prevent useless processing, the evaluation of such alternative is based on different scenarios.

The final topic that is used to generate an alternative solution is related to the information DHL might provide and having different agreements with DHL concerning the returned products. An example is what might happen to the process stability in the LSCZ when DHL is obligated to bring 20-30% of returns of a specific day before 15:00.

All these small paragraphs describe whether a topic or a combination of topics is the foundation of an alternative solution. The full conceptual description of such solution can be found in the following chapter.

4. Alternative solutions

The concepts found in scientific literature are the basis of the alternative solutions. This chapter describes these alternative solutions. Some concepts from literature are gathered into one solution, as is mentioned accordingly in the fifth section of the previous chapter. Every section will contain one specific solution, except for the final section which briefly reviews all solutions. The different solutions will be explained through the following points: a description, the concepts that are used, the requirements and cost, a description of how such alternative will be operationalized and its goals and the expected results. The operationalization is made before having any knowledge about the performance of an alternative. If an experiment with an alternative solution results in strange values or is no different from not applying any change, new values and ranges will be examined. This will be mentioned accordingly in the chapter that concerns the experiments, Chapter 6

The most important performance measures on which the different solutions will be judged are flexibility, WIP, cycle time, the pressure it puts on the available workforce and cost. These are summarized at the end of each section in the pros and cons. Robustness is also important but this will be tested through different scenario's while experimenting. The full operationalization and quantification of experiments that represent the different alternative solution is described in Chapter 6. The goal of this chapter is to answer the following research question:

> **4. What are the alternative solutions that can be formulated in order to balance variability buffers and process returns more efficiently?**

The alternative solutions are described in the same order as they are mentioned in Section 3.5, starting with increasing throughput.

4.1 Increasing throughput

Description

Wehkamp already conducted tests where two instead of one person operate a sorting station. The results of these tests were promising since productivity was 110% compared to the normal situation (i.e., two persons operating two stations). Although this saves cost, the actual bottleneck of the system are the checking stations. The throughput of these stations might be improved, by different policies like for example not checking bathing suites, or allow operators to bring a product back to stock immediately after a short visual check of the see-through bag. Since such changes to the processing of returns are aimed at the specific operation an employee performs and require extensive research on product level, these are not described in more detail. The expected result of such changes will be tested through simply running the simulation model at higher productivity levels. Next to increasing the productivity levels of individual stations, we test what an increase in overall throughput will do for the important performance measures. This will be done by planning an extra percentage of workforce.

Concepts used

- Increasing throughput (as described in Section 3.3)
- Planning different

Requirements and Costs

Depending on how much more hours are planned there is an increase in hours used. This will be reduced by the amount of employees that are send home early, since there should be lower utilization when structurally planning more employees than required. How this works out depends on the policy concerning sending employees home early. The operational process of improving planning differently does not enquire extra cost. For the increase of individual throughput improvements cost depend on how this is achieved, on which is not focussed.

Operationalization

Independent of other scenarios that can be tested in combination with this solution there will be three levels of planning more employees than anticipated with regard of current forecasts. Next to planning according to the forecast, there will be experimented with a 2.5%, 5% and 10% additional workforce planned. For the individual increase of productivity two additional levels will be tested for which will be a 2% and 4% increase in individual productivity of all sorting and checking operators.

Goal and expected results

By increasing throughput, individually or collectively at the bottleneck, the high peaks of WIP should diminish and therefore average cycle time decrease. This results in customers having their money back earlier. Expected results are that a small increase in productivity will benefit the processing of returns greatly. Due to the fact that planning to little workforce a few days in a row leads to a WIP that cannot be reduced easily over the course of weeks. Little “extra” capacity that is planned, knowing that there is planned to much should prevent WIP from getting out of control.

Pros and cons

KPIs	Score	Comment
Flexibility	+/-	Mostly depends on the policy concerning sending employees home
WIP	++	Planning more processing capacity than required will result in a WIP of 0 at the end of the day more often
Workforce	-	Available workforce will work more hours under lower pressure, but again the policy concerning sending employees home has most influence
Cost	--	Planning extra employees with the risk of lower utilization during the day is costly
Cycle time	++	Heavily reducing WIP and possibly planning extra processing capacity when required will do wonders concerning cycle time

Table 4.1 Pros and cons – increasing throughput

4.2 Improve Forecast

Description

The forecasting for operational purposes now performs within a certain bandwidth. This alternative solution is to improve the forecast of one and two weeks in advance, by making use of the financial forecast. Although the forecast is made on a weekly basis with a horizon of eight weeks, Wehkamp can respond relatively late, due to the amount of days an employee contracted through timing is informed. An ideal forecast would be:

- Real time monitoring of the three different streams at DHL
  - An improved forecast by DHL of what comes in during the day
- A short term, current week until two weeks in advance, forecast based partly on actual and expected sales, combined with return lag patterns aided by the financial forecast.
- Regular week to week forecast as is done currently

Instead of performing an individual forecast, the idea is to combine the benefit of having a strategic relation with DHL, being able to predict returns based on sales quite accurately and always having a quite robust long term forecast to fall back on. Such forecast covers the whole operational level of resource capacity planning as described by Hans and his colleagues (2003).

Concepts used

- Visibility improvement
  - Improved forecasting
- Strategic partnership
  - Information sharing

Requirements and costs

A tool is needed that is able to combine different types of information into one clear advice regarding required processing capacity. The cooperation is required of not only DHL but also other departments of Wehkamp to make information available. The creation of such tool can be done through the developments teams already present in both companies, the costs are therefore mostly in the hours they require for the development of such tool.

Operationalization

There will be two experiments besides the traditional scenario of a forecast performance within the approximately 20% bandwidth (see Section 2.5 or the glossary for an explanation of the term). The first experiment will be an improvement of the forecast resulting in a 10% bandwidth. The second experiment will be a perfect forecast where there can be planned while knowing exactly how many products are returned. Although the second experiment is not realistic, it should give insight in how much an improvement of the forecast benefits the performance of the processing of returns.

Goal and expected results
Improve overall forecasting of returns by combining three different streams of information. The improved forecast should aid in making better (short-term) planning decisions and therefore reducing the probability on heavily under or over planning the amount of workforce for the processing of returns. Since less over and under processing capacity occurs WIP should be easier to maintain stable.

Pros and cons

KPIs	Score	Comment
Flexibility	+/-	Does not change current flexibility
WIP	+	As there are fewer unexpected high amounts of returns WIP will get out of control less often
Workforce	+	Improving the forecast performance should cause a better fit between work pressure and processing capacity
Cost	+/-	Cost will not be influenced through improved forecasting since you require the same workforce capacity to process the returns and utilization is already high
Cycle time	+	Reducing the WIP that are roll cages waiting to be processed, should cause a decrease of cycle time given equal throughput (Little's law)

Table 4.2 Pros and cons – improve forecast

4.3 Improve planning

Description
Wehkamp has a relatively traditional planning concerning the processing of returns. Normally processing only takes place on Monday, Tuesdays, Wednesdays, Thursdays, Fridays and Sundays between 8.00 and 17.00. This is not optimal since maximum processing capacity is reached during these hours, while most trucks with returns arrive throughout the whole day, often starting around 11:30 until 00:00 at night. Trucks arrive in this time window since customers return their products during day time, through any of the available channels, plus there is some time required to transport the products. Next to that it does not allow for an increase in processing capacity by shifting workforce to fashion checking for example. This is due the fact that often all stations are operated. An idea would be to spread the processing capacity into two shorter shifts, or normal and short shifts in a specific ratio, although this might also differ per week day. Forecast performance does not differ greatly between the one week in advance and two weeks in advance forecast. Planning workforce earlier should therefore not actually harm performance. Only in the case that there is a high WIP build up within a few days, this cannot be compensated when planning more days in advance.

To compensate there can be a share of workforce that is planned more days in advance and a share that is planned like is done currently. Overall, planning workforce more days in advance should give employees more certainty, but several decisions need to be made, making planning more complex:

- How many days are employees planned in advance?
- Work one shift or more shifts?
- How many hours is one shift?
    - When do shifts start
    - When do shifts end

Working one early shift and one late shift might also be beneficial for the utilization certainty, requiring a lower WIP to remain for the next day. This is due to the fact that spreading processing capacity over the whole day results in a better aligned between returns coming in and processing capacity. This is comparable with working Just In Time (JIT). It also provides more options for flexibility since spreading processing capacity over a longer time period results in less moments that all stations in an area are occupied.

Concepts used

- Visibility improvement
    - improved planning
- JIT

Requirements and cost

Flexibility of the workforce is the most important requirement for this solution. Are employees willing to accept changes to the traditional shifts? This might be compensated for by planning employees more days in advance, giving employees more certainty. The cost of spreading processing capacity depends on what the actual starting and ending times of the shifts are. Normal wages apply from 7:00 in the morning till 19:00 in the evening. The scientific sources concerning planning, in Section 3.2, in Chapter 3 are not incorporated in this alternative since improving planning does not require a lot of planning ironically.

Operationalization

Next to the traditional hours i.e., from 8:00 to 17:00, there will be an experiment with two short shifts of equal length between 7:00 to 19:00. The traditional form of planning is done based on forecast performance and amount of roll cages waiting.

Goal and expected results

It should lower the number of products processed before trucks arrive. This should result in requiring lower WIP to ensure full utilization of the workforce. Lower WIP and processing returns directly after they arrive in the LSCZ reduces cycle time.

To compensate for different shifts employees can be planned more in advance. This should result in a hard to quantify benefit, a more satisfied workforce. Since the benefit itself is hard to quantify it is interesting how large its negative impact on performance will be.

Pros and cons

KPIs	Score	Comment
Flexibility	++	Depends on the experiment conducted, planning more days in advance with traditional shifts is bad for flexibility for example
WIP	+	The idea is to plan processing capacity more towards the moment that trucks with returns are coming in, reducing the WIP required to prevent underutilization the next day
Workforce	--	Changes to the regular 8:00 to 17:00 shift are anticipated to be received as positive by the workforce
Cost	+/-	As long as shifts stay within the 7:00 to 19:00 window cost will not increase
Cycle time	+/-	Depends on having a lower WIP or not, if the same WIP is necessary, there are no benefits for the cycle time and processing will only be done later

Table 4.3 Pros and cons – improve planning

4.4 Striving for a constant WIP

Description

One of the proposed improvements by Hopp and Spearman (2008) to cope with variability is to improve visibility by reducing cycle time, improve planning or improve forecasting, as incorporated in the alternatives mentioned in the previous sections. The reduction of cycle time can be achieved through different options of which some can and others cannot be translated to the specific situation of Wehkamp. Having processing capacity planned just in time for the truck to arrive (Section 4.3) and having an amount of work to be done stored that is just enough to guarantee full utilization would be ideal. This is comparable with other concepts like CONWIP, where the idea is to keep a constant amount of WIP through authorization of processing. Wehkamp receives product returns in batches and these are pushed not authorized, but striving for a WIP that is a fraction of the expected number of products to be processed tomorrow is also a form of keeping WIP constant i.e., a constant fraction of expected amount to be processed tomorrow. This is the balance between the certainty of full utilization and having minimal WIP. The most important question is how to achieve this constant WIP. Since the forecast's performance is a maximum of 10% off (20% bandwidth) a 10% increase and decrease of processing capacity will be required. This can be achieved by workforce flexibility e.g. sending employees home or working overtime. On a working day of seven to eight hours this would mean a reduction of 42 to 48 minutes or an extension of the same amount. In short: the amount of WIP that is required to guarantee full utilization is the estimated total processing capacity planned for tomorrow.

Concepts used
Concepts that are used and a basis for this solution are the following

- Visibility improvements: By having a structural target for the WIP, it will become more easily manageable
- CONWIP

Requirements and cost
Counting of roll cages is already been done and their fill rate is estimated. Planning made in advance as well as operational day to day planning has to be done differently to maintain a constant WIP, there has to be actively decided when to stop or continue processing returns. Next to additional “online” planning it would require a policy concerning what to do when WIP grows to large. After an initial reduction of the WIP there should be no further cost implied than in the original situation, except for maybe additional night or weekend shifts in order to maintain a low WIP.

Operationalization
Two different experiments are conducted while striving for a constant WIP. First striving for a WIP that fully covers the processing capacity of the next day and second striving for a WIP that covers half of the processing capacity planned for the next day. The experiments will be conducted without extra flexibility.

Goal and expected results
Minimize cycle time in the LSCZ by reducing WIP to the minimal level that still ensures utilization with a specific (high) certainty. This is beneficial for customers and regarding the MVT of products, since they are ready to be sold again earlier.

KPIs	Score	Comment
Flexibility	+/-	This alternative does not positively influence flexibility, but will probably benefit greatly from flexibility
WIP	+	Especially the second experiment is expected to effectively reduce average WIP
Workforce	-	Depends on how the constant WIP is achieved, uncertainty concerning working hours will have negative consequences
Cost	+/-	Only overtime will effectively increase cost
Cycle time	+/-	If average WIP drops this will positively benefit cycle time, but the experiments might also result in having lower WIP peaks and a higher average

Table 4.4 Pros and cons - CONWIP

4.5 Risk pooling

Description

Wehkamp clearly chose to benefit from the advantages of more specialised checking practices by sorting the stream of returns early on. The negative effects of these sorting practices are:

- More variability overall concerning returns coming in
- More variability in the different forecasts
- More steps i.e., the whole sorting process itself, required to bring back a product to stock
- More variability in required workforce

The idea of this alternative solution is to enable workforce to shift from sorting, electronics checking and shoes checking to fashion and back. Initially nobody that is planned to check fashion will shift to the other stations, if results indicate that this might be beneficial it can be considered. Next to risk pooling this is a form of flexibility or cross training employees.

Concepts used

- Flexibility
- Risk pooling

Requirements and cost

Invest in more training and more work instructions due to higher varying streams of products operators have to deal with. Operational planning becomes more complex due to extra decision making and required monitoring.

Operationalization

The experiment will allow for different numbers of employees to switch from sorting, shoes checking and electronics checking towards fashion checking. Some restrictions do apply, such as that WIP for other areas should not explode and that it is there can never be more employees working in the fashion checking areas than there are stations available. The first experiment will allow for a maximum of one person per area to shift towards fashion checking, the second will allow two and the third experiment will allow three employees to switch to fashion checking per area.

Goals and expected results
Reduce the overall variability of the stream of returns by combining all different OSR categories.

KPIs	Score	Comment
Flexibility	+/-	This alternative improves the flexibility of the processing of returns
WIP	+/-	No specific influence on WIP, effects are unclear in advance
Workforce	+/-	More diverse job, but requires extra practice
Cost	-	Cost of extra training or allowing for lower productivity due to multiple learning curves
Cycle time	+	Same as for WIP unclear in advance

Table 4.5 Pros and cons - risk pooling

4.6 Preponement and reason coding

Description
Preponement and reason coding are both practices that aim to reduce the pressure on the checking stations. This is especially relevant for the checking stations that handle fashion products since the pressure on these stations and shifts is the highest. Preponement by simple stickers that identify if a bag was opened or not will reduce pressure with the percentage of unopened returns. How high this percentage is, is not known. Preponement could also be used to identify items that are not actively sold to customers any more. When such product is returned, it can be sorted differently, with the goal to prevent unnecessary checking and repacking of the product. Reason coding might be beneficial when the checking stations look for defects, but since it is not applied at this moment it is also unknown how this might be beneficial and how many products this concerns. Earlier and more successful detection of defect might reduce customer dissatisfaction and absolute number of returns, while easier detection reduces work pressure at the checking stations. A form a preponement that identifies if a product can be brought directly to stock without stickers and other physical aids, might be achieved through computer learning solutions. A bathing suit does not wrinkle as a cotton blouse. Other influences like the season, the current work pressure, the specific customer and reason coding might be great additional predictors that aid in the decision to check a product or directly bring it back to stock.

Concepts used
Concepts that are used and a basis for this solution are the following:

- Preponement
- Reason coding
- Increasing throughput: By applying reason coding the operator at the checking station might detect defects easier, which reduces required checking time. This reduction of processing time only applies to defects, so the effects are limited.

Requirements and cost
The installation of machines that enable preponement through for example stickers is expensive. Suiting the current WMS to enable the presentation or relevant information provided by customers

(reason coding) also requires additional investments and a serious amount of time. A data science solution is accompanied with a lot of risks and uncertainties, and model construction would cost a lot of time.

Operationalization

Concerning preponement we test for different percentages of EOL and items that can be brought back to stock without checking. We test for 1%, 2% and 3% this can be considered as quite careful as we do not want to harm overall quality of returns checking and there are no reliable sources for how much preponement can safe. For reason coding we expect a productivity increase for every helpful reason coding of 30% at checking and expect an amount of 2%, 4% and 6% of all returns to be accompanied with such coding. This totals to six individual experiments.

Goals and expected results

There are two clearly different goals. The first goal is to lower the amount of products that have to go through checking unnecessary and the second is to aid this process by making it easier to find defects by the use of reason coding in order to reduce the required time. How high the amount of unopened packages is, is hard to estimate but empirical research by Stock and Mulki (2009) indicates that, especially for fashion, it might be rather high. In the case that two different colours of a product are ordered and the first one does not fit, a customer is logically inclined to directly return both. Concerning reason coding, Wehkamp is rather sceptical due to the experiences in the past. Since the whole operational aspect has changed and giving this possibility through the website instead of a separate form, so making it optional, is something which is strongly recommended to consider. Wehkamp could then automatically filter on messages that indicate defects to come through at the checking tables. Again the effects of such changes are unknown and can only be estimated or pilot tested. Since pilot tests are no options at this point in time, possible effects are tested through simulation.

KPIs	Score	Comment
Flexibility	+	This alternative solution is not aimed to improve flexibility nor to limit it
WIP	+/-	Changes to the WIP are not caused by this alternative solution
Workforce	+	The employee operating a checking station is aided to make his job easier
Cost	--	Implementing this solution is very expensive due to the several investments required
Cycle time	+/-	Cycle times become smaller when a reduction of checking time is achieved

Table 4.6 Pros and cons - reason coding and preponement

4.7 strategic partnership

Description

This alternative solution is based on two aspects. First the agreement with DHL that returns are brought to Wehkamp as soon as possible. No matter in what quantities. Second that there is perfect information sharing concerning the amount of packages that is taken in by DHL. The latter offers no actual benefits for Wehkamp as long as there is no operational decision making or flexibility. This is not the most realistic alternative it can be therefore considered as a test case for what the influence of DHL is on the performance of the processing of returns.

Concepts used

- Strategic partnership
- Information sharing

Requirements and cost

Unclear since this alternative would require completely different operation from the side of DHL and there is no insight in cost involved with the returns being delivered by DHL

Operationalization

Shifting the average of truck arrival from 20:00 to 18:00, 16:00 and 14:00. A second influence that is only interesting when there is operational decision making and flexibility is having a good estimate of how many returns are coming in today (95% certainty).

Goals and expected results

The earlier the trucks with return arrive, or at least enough trucks to provide enough returns to fully utilize processing capacity in the different areas, the less WIP is required. Lower WIP while remaining the same throughput will actively bring down cycle times.

KPIs	Score	Comment
Flexibility	+	Although this alternative solution might heavily benefit from extra flexibility it does not create it
WIP	+/-	This main reason to have a different agreement with DHL is to reduce WIP, but there should also be planned accordingly
Workforce	+/-	Workforce is not significantly influenced by the described changes of
Cost	?	Implementing this solution is very expensive due to the several investments required
Cycle time	+	By planning such that a lower WIP is required, cycle time will also be reduced

Table 4.7 Pros and cons – strategic partnership

4.8 Summary

This sections summarizes the different alternative solutions in one table. With regard to the table we can say that all alternatives score relatively bad on cost. This is because the value of customer having their money back sooner and the MVT of products is not taken into account. Since this would be pure speculation

Alternative	Flexibility	WIP	Workforce	Cost	Cycle time
Increase throughput	+/-	++	-	--	++
Improve forecast	+/-	+	+	+/-	+
Improve planning	++	+	--	+/-	+/-
Strive for a constant WIP	+/-	+	-	+/-	+/-
Risk Pooling	+/-	+/-	+/-	-	+
Preponement and reason coding	+	+/-	+	--	+/-
Strategic partnership	+	+/-	+/-	?	+

Table 4.8 Summary

The strategic partnership option will not be examined for three reasons, next to it not being very promising. First of all, it is unknown if DHL data is actually real time or delayed. If data is delayed this reduces the benefits of real-time monitoring of returns coming in. Second it does require a lot of investing, not only in time but also a lot of coordination between DHL and Wehkamp. Finally, since there is no research conducted about what time during a day customers return their products this cannot be incorporated into the simulation model and therefore not tested accurately. The next chapter introduces the simulation model through which we test the different alternatives that are described.

Second risk pooling is not examined. Since rearranging the operational processes of the conveyors is not an easy task, nor one that Wehkamp can execute without the aid of KNAPP we already discarded this option in Chapter 3. Cross training employees is also not considered any further since it is not aligned with the decision to contract most employees through Timing and its expected results are not very promising.

5. Simulation Study

This chapter describes the simulation study. Simulation is chosen instead of other tools, like queuing theory, for reasons described in Section 3.1. The first section describes the initial framework used in this simulation study. This framework, holding the necessary steps to construct a simulation model and conduct a simulation study, originates from the book written by Averill Law (2014). Next to the framework this chapter also contains the three necessary phases as described by Law. Only the final step of the last phase, presenting the results, is not included in this chapter, since it is the subject of Chapter 6. The content of the sections in this chapter are based on the steps in the phase of the framework and are as follows:

The steps described by Law are in no way a guarantee for a good simulation study, but do provide a logical structure to follow. The first section describes these steps and simulation in general.

5.1 Simulation in general

This section describes the necessary steps in a simulation study as defined by Law. Law describes three different phases, with their own set of steps. One of the issues specifically mentioned in the book written by Law, is to choose the suitable type of simulation, on which will be elaborated further on in this section. Other theory, like how to determine the number of runs, will be addressed in sections that correspond with the topic.

5.1.1 Steps in a simulation study

In order to guarantee a valid simulation model a certain set of steps is followed in this research. These steps are based on the book of Averill Law (2014) in which he describes how to conduct a simulation study. Next to this book, there is made use of another book called "*Simulation using ProModel*" by Charles Harrell (2011) and several papers written by Averill Law in different years.

Law describes three main phases while conducting a simulation study. In this report slight alterations are made to the original description by Law, that fit this research. These three phases and the subjects they hold in this report are as shown in Figure 5.1.

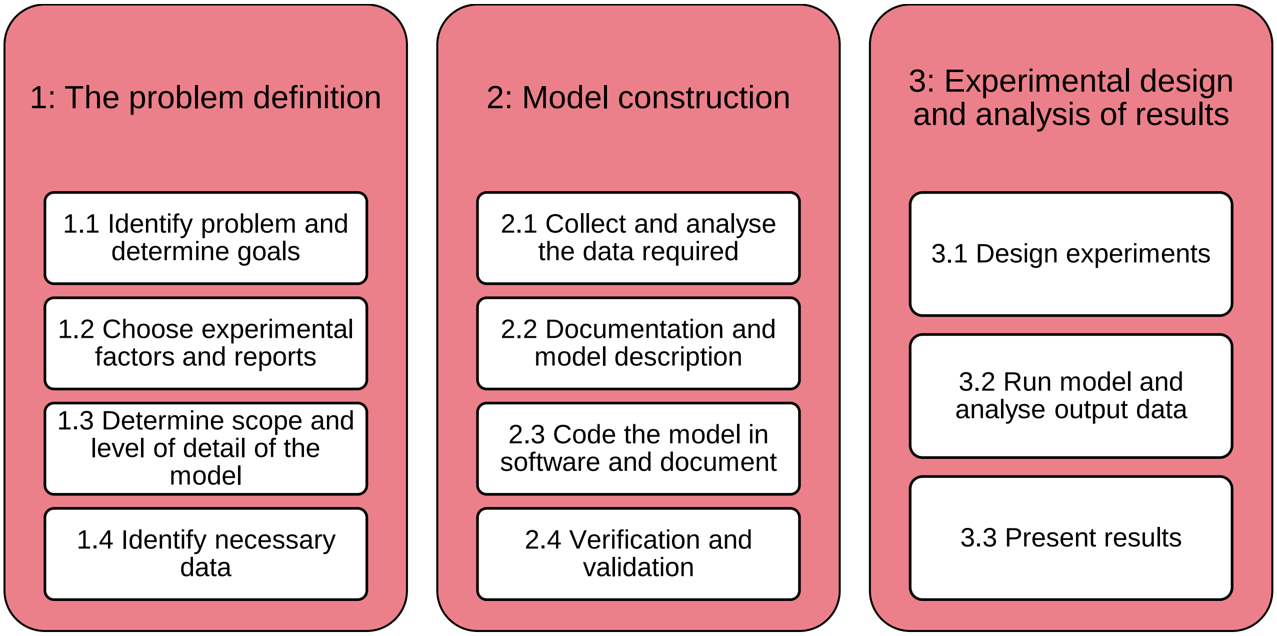

Figure 5.1 Phases and steps in a simulation study by Law (2014)

For the full, more specific description of every step and the critical aspects of a simulation study see Appendix M. There are two iteration points described by Law (2014), these iterations, although of most importance in practice, are not described in this report. The two iterations concern the check if the conceptual model is valid and the check if the programmed model is valid. If there can be concluded that one of these is not valid, there restarted at one of the previous steps. Those iterations are not described in this report. The steps defined by Law (2014) apply to several types of simulation studies. An introduction to simulation in general and the different sorts is given in the following paragraphs.

5.1.2 Different types of simulation

Different types of simulation exist. Law (2014) and Harrel (2011) state that a simulation model can and must be classified along three different dimension. The three different dimensions are static or dynamic, stochastic or deterministic and discrete or continuous.

Static or dynamic simulation model

Static and dynamic in the sense of time, not location. Where static is *"a representation of a system at a particular time, or one that may be used to represent a system in which time simply plays no role"* (Law, 2014). So in short: a simulation model that is independent of time. Examples are Monte Carlo simulation to determine expected yield of a set of stocks or bonds, which is considered static. A dynamic simulation model does depend on time e.g. the state of the system might change over time. The latter type of simulation model is most suitable for the analysis of an operation over time, like manufacturing and service systems (Harrel, 2011). Next to that interventions might depend on time, which makes static simulation models unsuitable (comparable line of reasoning as in Chapter 3 why queuing theory is not reviewed). Processing of returns can be seen as a manufacturing system, the simulation model used in this research is therefore a dynamic model.

Stochastic or deterministic simulation model
Stochastic, also called probabilistic, simulation models produce outcomes that are (to a certain degree) random. Every “run”, i.e., simulating a predetermined amount of time with predetermined settings, within an experiment has different random numbers. Due to this randomness, a single run only gives an indication of the actual system's performance. With stochastic simulations it is often wise to conduct multiple runs of the same experiment in order to get a more trustworthy view of the system's performance. Deterministic simulations produce the exact same outcome under the same conditions (states) regardless of how many time the model ran. This is best illustrated by the figure of Harrel (2011), which is Figure 5.2. Since this research concerns variability the model is a stochastic simulation and therefore multiple runs of the same experiment are required. This requires stochastic input, which is described in Section 5.3.

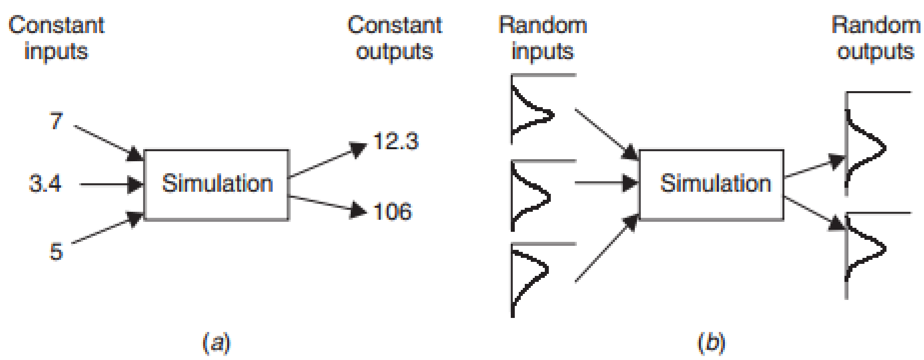

Figure 5.2 The difference between stochastic and deterministic simulation by Harrel (2011)

Continuous or discrete simulation models
The meaning of continuous and discrete in this context does not differ that much from their definitions in mathematics and statistics. In the context of simulation, continuous or discrete is related to time and how is dealt with state changes of variables over time. Again a figure of Harrel (2011) is used to illustrate the difference between discrete and continuous simulation models, Figure 5.3. In the case of continuous simulation models variables change continuously through time. Discrete simulation models change at a specific moment in time, then remain the same until the next change. This allows such models to jump in time from event to event. What is most suitable for a specific simulation study depends on the goals of the study and most simulation software offer the possibility to do both interchangeably. The big advantage of discrete simulation models is that one does not have to simulate the full timespan continuously, since only the moments in time that variables and states change are relevant. Examples of such moments are: shift starts, shift ends, processing is finished, new product arrives etc.

For this research Discrete Event Simulation (DES) modelling is used, which is dynamical, stochastic and discrete. Since this is the last of the three dimensions, we continue to the next section. It will start with the first phase described in the framework by Law (Figure 5.1).

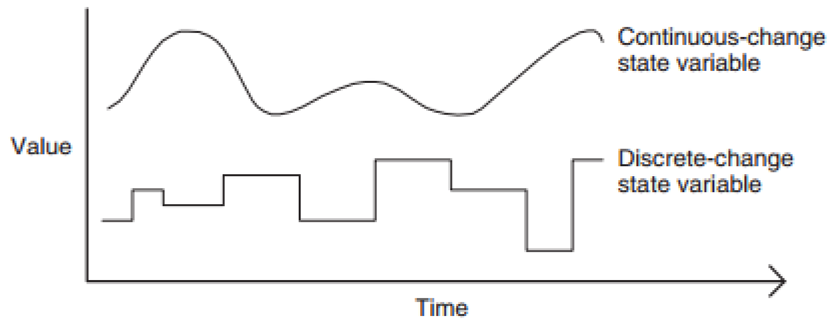

Figure 5.3 The difference between continuous and discrete simulation by Harrel (2011)

5.2 Problem identification and goals

This section contains all steps and subjects that belong to Step 1.1 of the simulation model construction framework. It is the first step of the study as a part of phase 1. The problem identification, goals and restriction are the first two topics in this section, followed by the scope and level of detail. Last but not least there is final section of this chapter which describes the necessary data.

5.2.1 Problem identification, goals and restrictions

Since large parts of the problem identification are already covered in Chapter 1, this section only summarizes several important points. Also, the differences between the general description, as they are noted for the general research in Chapter 1, and the simulation study are mentioned.

Wehkamp has to deal with a lot of returns. Processing all these returns in agreement with the SLA cost efficiently is very challenging. Within the processing of returns there are different variability buffers. It is unknown how the buffers interact and difficult to predict how changes affect them and overall performance. In order to stay ahead of the large number of product returns Wehkamp wants not only to get insight in these interactions, but also be in control of these buffers. Experimenting with different policies and alternative solutions concerning these buffers should provide insight in an optimal balance between the buffers and the KPIs. Wehkamp aims to minimize time required to process returns. The model should also provide insight in how much the proposed alternative solutions in Chapter 4 could benefit the processing of returns.

There are some restrictions to the model. First of all, all products must be processed. This might not seem to be a problem, but it has serious consequences regarding the level of detail. To model every single possible action at a checking station is impossible and infeasible due to the high amount of different unmeasured actions and high amount of products per year. A product might be fully checked at a checking station only to be discarded. Products that are not brought back to stock are not added to the total of processed products by the WMS. Another restriction is the fact that capacity cannot be increased any further. The available checking stations cannot be reassigned to a different stream of returns. Another very practical restriction is that most software used for simulation studies, like Plant Simulation, do not handle big tables files and high amounts of Moveable Units (MUs from now) very well. A possible solution is to aggregate individual products; this is mentioned by Law (2014) in his book. On the subject of aggregation will be elaborated further on in this section.

5.2.2 Experimental factors and reports

This section is devoted to the experimental factors, which are input, and reports about outcomes which is the output. Important experimental factors are the targets for the variability buffers and how to cope with deviations from these targets, which is operational decision making and planning. If the processing of returns takes more than two weeks at a specific time during a run; what is supposed to happen? Is there a night shift enabled to deal with the high amount of returns? Or do the (virtual) customers have to take the hit, and wait longer? How this is exactly modelled is a very important aspect on which will be elaborated on later in this chapter in Section 5.6 and concerns how workforce is planned.
Concerning the experimental factors, we conclude that we need to be able to conduct experiments to gain insight in possible benefits of the described alternative solution (Chapter 4) and insight in buffer interaction and relation to KPIs, as this is research question 2. The required experimental factors for the different experiments are:

- Planning policies
- Forecast performance
- Productivity levels
- Operational flexibility
- DHL behaviour

We want to know the performance of the system given a specific set of input parameters. We therefore define several performance measures, which are output of the model. Since a lot of the employees related to the processing of returns, e.g. team leads, key users and employees that transport roll cages are left out of scope, it is hard to estimate the actual cost or cost savings. Planning an additional shift is much more expensive than only an increased wage for those directly involved in the processing of returns. Due to this reason, none of the performance measures is expressed in a monetary value since it would not be a fair representation of the actual situation. We focus on waiting time for customers and hours required, while keeping an eye on flexibility, pressure on the workforce and hours spend during night shifts, through the following performance indicators:

- Processing time in the LSCZ
- Required resources; regular hours and night shift hours
- Amount of work to be done also called WIP
- Pressure on the workforce

Although the number of days a person is planned in advanced is input, it is also a performance aspect. Planning more days in advance provides more certainty for employees, while planning later gives uncertainty. Other aspects that can be considered as “putting pressure on the workforce” are working shifts with different start and ending times or the possibility of being send home early.

5.2.3 Scope and level of detail

This section briefly describes what is inside the scope of the model, what is outside the scope and the level of detail. Starting with what is inside the scope.

Inside the scope:
The sorting of returns and the checking of returns are the two most important processing steps in the simulation model. Next to these two processing steps the buffering of roll cages before sorting and the buffering on the conveyor that transports totes one level higher is also within the scope. Planning, forecasting and DHLs behaviour are also within scope. Planning is an important instrument to implement different experiments, whereas forecasting is only used as input for the planning process, but also inside the scope.

Outside the scope:
As said in Chapter 1 problems with the OSR, as well as other equipment failures, are out of scope. Employee sickness or not showing up are also excluded. In such cases the station which this person should operate is often operated by somebody else. Since Timing has a large pool of employees one can imagine that there might be someone available on short notice with experience at the LSCZ. Another option is that someone who would normally do other work, which can be postponed, operates the station. An example might somebody who would normally do quality checking. The subject of sickness or no shows is therefore left out of scope. All supporting personnel (team leaders, transporting roll cages to the sorters, key users, quality checking) are left out of scope. In a normal shift these functions are fulfilled, but when there is a night shift some can be postponed until the next day shift. There is no easily distinctive policy concerning this topic when it comes to extra shifts. Training of new employees causes lower average productivity and is not identifiable or possible to model individually. Therefore, it is taken into the average productivity levels. Since “mistake stations” can also process returns regularly, they are taken into account in the average productivity analysis. Finally, it is assumed that when a truck arrives the roll cages are directly available for the sorting stations, since transporting them to the sorting station is only a matter of seconds.

Level of detail:
Processing time is determined by the productivity levels at the checking stations and items are processed per tote. No distinction is made between different operations performed at the checking station. Individual products are not modelled, but aggregated in totes. Employees are not modelled individually, but represented by the availability of stations. Breaks are taken into account in the hours that are logged to the WMS, so productivity levels exclude breaks and this data can be used without biasing. Actual breaks are incorporated in the simulation model.

5.2.4 Necessary data

Wehkamp has a lot of data available, which can be used in the model. Since the model is stochastic available data must be fitted into distributions. For specific data, which cannot be estimated, assumptions have to be made, these can be found in the same section.

Available data:

- Products processed per station
- Hours spent on a checking station
- Products sold per OSR category
- Products returned per OSR category
- Products returned to the LSCZ
- Forecast performance
- Products per box
- Products per container

Not available but collectable or to be estimated:

- Number of totes on the conveyor
- Products per tote
- Times trucks arrive
- Number of roll cages trucks carry
- DHL behaviour

A lot of data is already presented in Chapter 2. The following section, Section 5.3, will describe how this data is used and fitted in to distributions. Let us continue to that section.

5.3 Data collection and analysis

This entire section describes the necessary data and how it is represented in the simulation model. Next to the actual modelling, the used data is of crucial importance since it determines how well the model represents reality. This section consists of two parts, the first describes what is done with available data and the second describes collected and estimated data.

5.3.1 Available data

The available data discussed in the following part of this section are productivity, sales and returns and the forecast performance

Productivity

To calculate productivity both products processed and hours spent per station are required. Data containing hours spent and items processed are available in the dashboard that tracks performance in the LSCZ (Chapter 2). For sorting there was a lot of testing with either one or two operators per station and with scanning every product or simply sorting without scanning, if all customer information is present. Therefore, there will not be concluded on sorting productivity per station, since mixed policies are used. Since processing capacity of the sorting area relatively easily matches the total processing capacity of the checking stations, this research will only advise on how much processing capacity should be present. How exactly this amount of processing capacity is achieved is up to Wehkamp. An important note for the productivity of the checking area is that a lot of employees started at the LSCZ when it opened. There might still be an ongoing increase in productivity. Here is not directly accounted for in the model, but scenarios with higher individual levels are also examined as Section 5.6 describes. Let us now continue with the productivity data for fashion, shoes and electronics checking, a graphical representation of data can be found in the histograms of Appendix E.

The data is tested to fit a normal distribution according to Chi-square goodness of fit test. The number of bins are determined by taking the root of the number of available samples and all bins have equal expected frequencies by using an inverse normal distribution. The averages, standard deviations, Chi-square scores and more can be found in Table 5.1.

Type	Mean	Standard deviation	Chi-square	Degrees of freedom	Critical value (α = 5%)	Assumed normal distribution
Fashion	44.119	10.670	18.845	17	27.587	Yes
Electronics	26.604	8.035	4.968	3	6.251	Yes
Shoes	33.247	6.249	12.765	7	14.067	Yes

Table 5.1 Checking productivity distribution fitting

As can be seen in Table 5.1 Shoes, Electronics and Fashion checking productivity levels are assumed to be normally distributed with corresponding mean and standard deviation, according to the Chi-square goodness of fit test with corresponding degrees of freedom (number of bins minus three in the case of estimating a normal distribution). Technically speaking there is not proof that they are not normally distributed. No correction for outliers was required in all cases. Electronics checking does not look normally distributed graphically, but this can be due to the lower amount of data. The Chi-square test however shows that there is no reason not to assume normality. There is chosen to use a normal distribution instead of using historical data, in order to introduce more variability in the entire system and due to the nature of the type of simulation chosen (Section 5.1). We continue with the sales and returns data.

Sales and returns

Data on sales and returns is available for many different years. Wehkamp not only keeps growing, practices in the LSCZ are also ever changing. Due to this ever-changing situation, only latest data is used; 60 weeks of data until the week 52 of 2016 to be precise. A collection of 60 weeks is chosen since this is the run length. This run lengths allows for an eight-week long warm-up period in which WIP can be build up. To test robustness, we examine three different types of sales and returns.

- Historical data
- Generated sales and actual return probabilities
- Actual sales and generated return probabilities

The first type is the most straightforward, simply using historical data about how many products are returned. For the other two scenarios, the sales and return probability data is fitted into distributions. How this is done is explained in the next paragraphs. An important notice is that returns are not delayed by transportation in the model. This non-optimal solution is chosen due to the bias in the data of when a sold product is returned. This data is smoothened by the processing capacity and fluctuating WIP in the logistic centre at the time of return (full description in Section 2.2). The data only tells us when a product was sold and when it was brought back to stock, no specific information about when a customer returned the product.

To maintain the trend throughout the year, weekly averages concerning sales are maintained. The differences in sales per weekday are used to introduce variation. Deviation of single weekdays from weekly averages (per week day) are resembled as normal distributed variables according to the values in Table 5.2, these are all Chi-square tested versus a critical value of 24.996. Since all days have the same number of samples and therefore same number of bins, we subtract three from the number of bins to get the degrees of freedom; 15.

Weekday	Average	Standard deviation	Data discarded	Chi square
Sunday	0.997	0.161	4.60%	11.611
Monday	1.095	0.204	0.70%	9.434
Tuesday	1.026	0.125	4.20%	9.064
Wednesday	1.142	0.148	6.13%	19.417
Thursday	1.072	0.138	3.45%	15.050
Friday	0.987	0.114	4.59%	20.290
Saturday	0.655	0.087	6.13%	24.319

Table 5.2 Average deviations from weekly average sales per weekday

Weekly sales averages are based on sales from week 45 in 2015 until week 52 in 2016. The fourth column concerns the amount of data that is discarded due to abnormalities or general outliers. With histograms is graphically checked for abnormalities. All data has a skewness lower than one and, as we can see in Figure 5.4, tail thickness is approximately symmetrical.

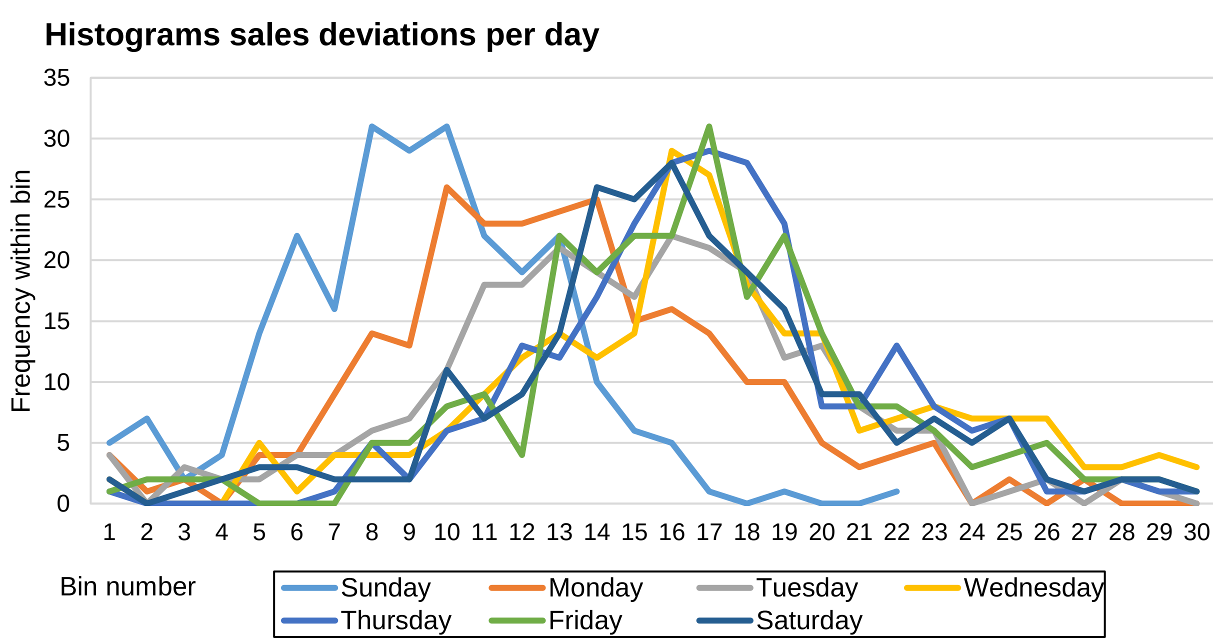

Figure 5.4 Histograms sales deviations per day

For the returns that result from these sales, we use actual return probabilities of corresponding weeks and days. These actual return probabilities and generated sales are the second type of returns.

The model is also able to generate new return probabilities, for a third scenario. These probabilities are based on mean return probabilities and observed standard deviation of the past 60 weeks. Return probabilities are relatively stable, as in Table 5.3, therefore introducing variability in the number of sales has more effect than a different percentage of returns.

	Electronics	**Fashion**	**Shoes**
Mean	0.121	0.499	0.494
Standard Error	0.002	0.003	0.003
Median	0.124	0.506	0.498
Standard Deviation	0.018	0.021	0.020
Minimum	0.076	0.448	0.450
Maximum	0.149	0.526	0.537
Count	60	60	60
Confidence Level (95.0%)	0.005	0.006	0.005

Table 5.3 Return percentages per OSR category per year

To recap the three types of product returns are: historical returns, generated sales with actual return percentages and actual sales with generated return percentages.

Now that we have returns we still do not know when they come in the LSCZ. Therefore, the number of roll cages that arrives at the LSCZ is analyzed, assumed that there is no difference between weekdays concerning container fill rates. There is no reason why boxes or roll cages have a higher fill rate on Monday compared to Saturday. An analysis of how many roll cages come in per day of the last half year in the LSCZ (week 21 2016 to week 51 2016) can be found in Table 5.4.

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Average number of products	335.727	360.033	461.833	431.367	387.267	395.414
Standard Error	19.312	26.562	19.141	27.014	20.156	19.766
Median	334.5	339	453	446.5	391.5	383
Standard Deviation	90.580	145.488	104.839	147.963	110.397	106.444
Minimum	162	165	220	110	207	232
Maximum	626	689	647	789	718	636
Count	22	30	30	30	30	29
Confidence Level (95.0%)	40.161	54.326	39.148	55.250	41.223	40.489

Table 5.4 Roll cages with returns data

This data is checked for correlation between subsequent days as shown in Table 5.5. The right column is corrected for weekly averages to remove any possible trend(s). From Table 5.5 we conclude on no real correlation between subsequent days based on this data, which pleads for the conclusion that DHL does not heavily influences the amount of returns coming in per week day. If DHL would for example choose to only send out full trucks, we might have observed negative correlation between the amount of returns of subsequent days.

	Actual Roll cages							**Corrected for weekly Average**					
	Sun	Mon	Tue	Wed	Thu	Fri		Sun	Mon	Tue	Wed	Thu	Fri
Sun	1	0.28					Sun	1	-0.25				
Mon		1	0.21				Mon		1	-0.14			
Tue			1	0.29			Tue			1	-0.32		
Wed				1	0.66		Wed				1	0.25	
Thu					1	0.59	Thu					1	0.01
Fri						1	Fri						1

Table 5.5 Correlation between subsequent weekdays

Based on the data in Table 5.4 the ratios between different weekdays are calculated. The data in Table 5.4 is corrected for weekly averages which results in an index number. If this number is 0.8 for example it means that the specific day receives 20% less returns, on average, compared to the weekly average per day. Standard deviations are also calculated and the data is tested for normality.

To introduce variation, even in the case of an historical amount of returns, variation in the number of product returns coming in is introduced. This is done by a variable number of roll cages that enter the LSCZ per day of the week. The number of roll cages per weekday is fitted into distributions. Product returns per week depend on one of the three described types of returns. Variation per day is introduced by variating number of roll cages that enter the LSCZ. Since the data represents the actual amount and variation of product returns coming in to the LSCZ, this results in a more realistic variation than a fluctuating number of product returns or sales that depend on the moment in time. This is the normalized data in Table 5.4 multiplied with the average fill rate.

Number of products per box is based on sales data of 1.5 years from the first of January 2015 till week 32 in 2016. Average of 3.34 products per box and a standard deviation of 0.32, rounded on two decimals. Products per container is based on data about fill rates in the LSCZ, which is already shown in Section 2.2.4, Figure 2.14 and assumed to be approximately 80. No further estimations are made since available data is small due to serious changes after the introduction of the LSCZ. With these two estimations boxes per container and products per container are generated in accordance to available data. Employees have more breaks than is required by Dutch labor regulations and if there is experimented with different times for the shifts, the same ideology as in the current situation is maintained. On a normal day from 8:00 to 17:00, there are two small breaks and one big break. Small breaks take 15 minutes where large breaks are 30 minutes.

Forecast performance
Forecast performance is as described in Section 2.5, Table 2.6 and Appendix F. Apparently planning different weeks ahead did not influence forecast performance a lot, although this is not very likely. We take an average performance bandwidth of 10% planning the day before the next week, 12% planning one week ahead and 14% planning two weeks ahead. Although this does not correspond with data, it is expected to be a more likely scenario. It also allows for measuring of how forecast performance influences the performance of the processing of returns. Testing the same bandwidths, but different standard deviations, is believed to give too little variation in LSCZ performance and therefore no insight in the relation between forecast performance and LSCZ performance.

5.3.2 Collected and estimated data

This section is relatively smaller since better data or estimates were simply not available. Since there are less details to discuss, descriptions are shorter. The following topics are in the next few paragraphs.

- Number of totes on the conveyor
- Products per tote
- Number of roll cages trucks carry
- Times trucks arrive

Totes on the conveyor
The amount of totes that can be on the conveyor is estimated by dividing conveyor lengths through the length of one tote plus the "in between totes" space. A tote is approximately 60 centimetres long plus an extra 10 centimetres of space in between the tote and its successor or predecessor. All lengths in the simulation model are enlarged with factor 1.5 to provide for more clear animations. Conveyor lengths in the model are therefore 1.5 times as large as they are in the actual situation. To adjust for this increase in length, the speed of the conveyor is also 1.5 times as fast.

Products per tote
The number of totes is based on sampling via one of the quality control stations. These stations are placed directly after all sorting stations and directly after all checking stations. They are normally used to do quality checks of the sorting process or re-folding for example. In this research use was made of these stations to sample how many product one sorted tote contains. See the data below for three hours of counting how many returned shoes fit in one tote.

Shoe boxes per tote	2	3	4	5	6
Frequency	6	44	60	17	1
Percentage of total	4.69%	34.38%	46.88%	13.28%	0.78%

Table 5.6 Shoe boxes per tote

The data in Table 5.6 results in an average of 3.7. Number of products per tote is not fitted into a distribution but actual observed percentages as in Table 5.6 are used. For electronics this number is a lot harder to estimate since number of totes per day is a lot lower and processing one totes can take from one minute to half an hour. The fill rate of a tote containing electronics is therefore assumed to be approximately 80. The amount of fashion products per totes differs less and is assumed to be 13 products on average with a standard deviation of 5.1.

Number of roll cages trucks carry

The number of roll cages is 45 to 60 as a trailer can carry approximately that much, depending on what kind of truck. DHL prefers to send full trucks to the LSCZ to minimize transport cost and therefore not much variability is expected, although this is based on empirical evidence through interviews in the LSCZ.

Times truck arrive

In the morning several trucks from DHL arrive from different DCs carrying little amounts of roll cages. These trucks are on their way to Dedemsvaart to retrieve excessive materials, but since they pass the LSCZ on their way, they already bring some roll cages with returns. Approximately 40 to 60 roll cages with returns are delivered at the LSCZ before 8:00. Then the trucks with returns start coming in at around 11:30 until 00:00 that evening. In the model, product returns that are available for the LSCZ on a specific day do not necessarily arrive at the LSCZ. This depends on the stochastic variation per returns coming in per weekday. A single run with the exact same number of returns on a specific week day might still result in different amounts of returns coming in at the LSCZ. The distribution that determines when trucks deliver their return is a beta distribution with beta is two and alpha is tested for with three, four and five, since this fits the empirical evidence best and there is no other record what so ever. This distribution is shown in Figure 5.5. As base setting in the experiments the distribution with Beta 3 is used.

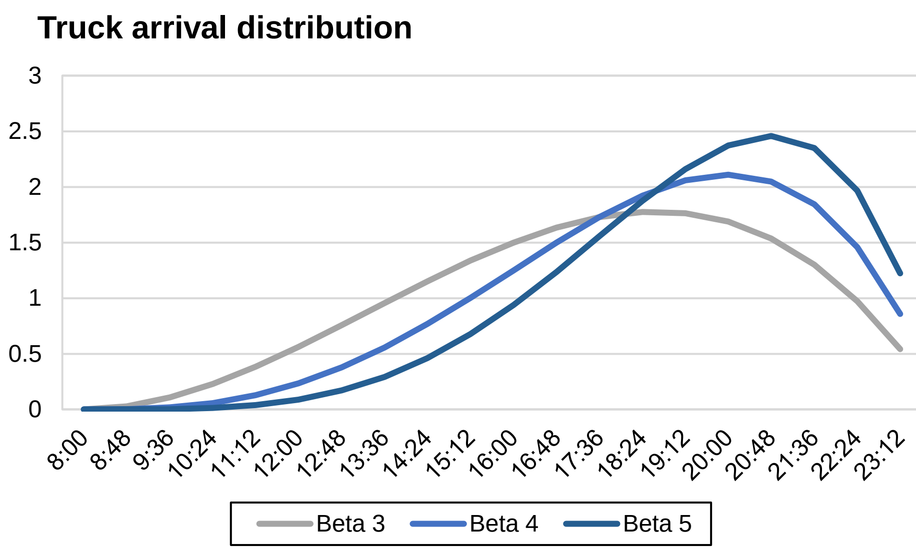

Figure 5.5 Truck arrival distribution

5.4 Documentation, model description and model coding

This section combines the description of step two and three of phase 2. This is done to reduce redundancy and increase readability. The model should contain the parts of the processing of returned products as described in Section 5.1. To clearly identify the boundaries between several aspects of the process, these will be constructed as individual units. The units fulfil the following main tasks:

- The receiving of roll cages
- The sorting process
- The transport of totes
- Fashion checking
- Shoes checking
- Electronics checking
- Storing totes in the OSR

These areas, their main function and the data required are the subject of this section. Let us first consider the mechanics in the model that are not directly handling products but have most influence on overall performance. These aspects are:

- Parameter setting
- Planning
- Forecasting
- Performance measurement

Parameter setting

All the predetermined data and information is stored in a “Control centre”. The Control centre contains not only numbers and figures but also certain parts of code that can realign shifts when starting and ending times change per experiment. It can also generate completely different numbers of sales and returns for a following run or experiment. All numerical information that is required for an individual unit to function is retrieved from the Control centre. This is done to ensure that a parameter change for a new experiment applies to every part of the model. Productivity of a station is determined by a formula that refers to the control centre for example. A short summary of data and parameters that can be found in the control centre is the following (Standard Deviations is abbreviated to SD):

- Sales means
- Sales SD
- Return probability means
- Return probability SD
- Products per box
- Products per box SD
- Boxes per container
- Boxes per container SD
- Roll cages per truck
- Roll cages per truck SD
- Productivity per station mean
- Productivity per station SD
- WIP target
- Over planning level
- Generated or historical sales
- Generated or historical returns
- Instant truck arrival
- Starting and ending times shift
- Effective shift lengths
- Planning performance

Although the control centre might seem a logical place to keep track of performance, this is not the case. For no other reason than to ensure that only parameters are in the control centre, there is only data retrieved from it, never stored to it.

Planning
Planning is done in a separate coding blocks for the sorting and checking areas. Different experiments are conducted through different planning policies. Different planning types are referred to by their number in this report, as in Section 5.6. The most straightforward example of a planning policy is simply planning all workforce that is required to process the forecasted amount of returns. As an example of coding in Plant Simulation see Appendix N, reassembling the most straightforward planning type. This planning type simply plans all required workforce as forecasted. There are a lot of flaws in planning like this. The sorting and checking area will not be balanced for example. This is due to the stochastic variables of productivity and the rounding of numbers, causing WIP in between sorting and checking to become larger than the conveyor can handle or having low utilization of checking workforce when too little processing capacity is available at the sorting area. Other problems are for example not considering current workloads or the possibility that nobody is planned at a specific checking area. The latter only applies for the electronics checking area due to a very low amount of returns for that area. Not to mention problems like having different shift lengths for the first and second shift and what to do when a policy advises to plan a night shift with only one person operating a station. As becomes clear from these examples, how stations are planned is at the core of the model and is restricted by a lot of practical limitations. Different planning policies will be tested as experiments, to determine their representation of reality. Normally this would be done while validating the model, but since this is such an extensive process it is described as an experiment on its own.

Forecast
Opposite to planning, forecasting is relatively simple. Since returns are determined at the initialisation of a run we can easily ensure that the exact forecast performance is achieved on average in the model. See appendix F for the specific forecast performance, which is also described in Chapter 2. A deviation of actual returns is forecasted that corresponds with historic forecast performance is generated in advance of the planning of workforce.

Performance Measurement

All performance measurement is done on the "MainFrame". Different tables are in place for sorting, fashion checking, shoes checking and electronics checking per run. At the end of an experiment data from these tables is combined into a table that summarizes all data into one row per run. When all runs of an experiment are finished, all data is combined into one row for the specific experiment. Figure 5.6 graphically represents these steps. Next to these tables that measure performance, there are tables that help validating the model. These tables keep track of truck arrival, utilization of workstations and forecast performance, to check for abnormalities during validation.

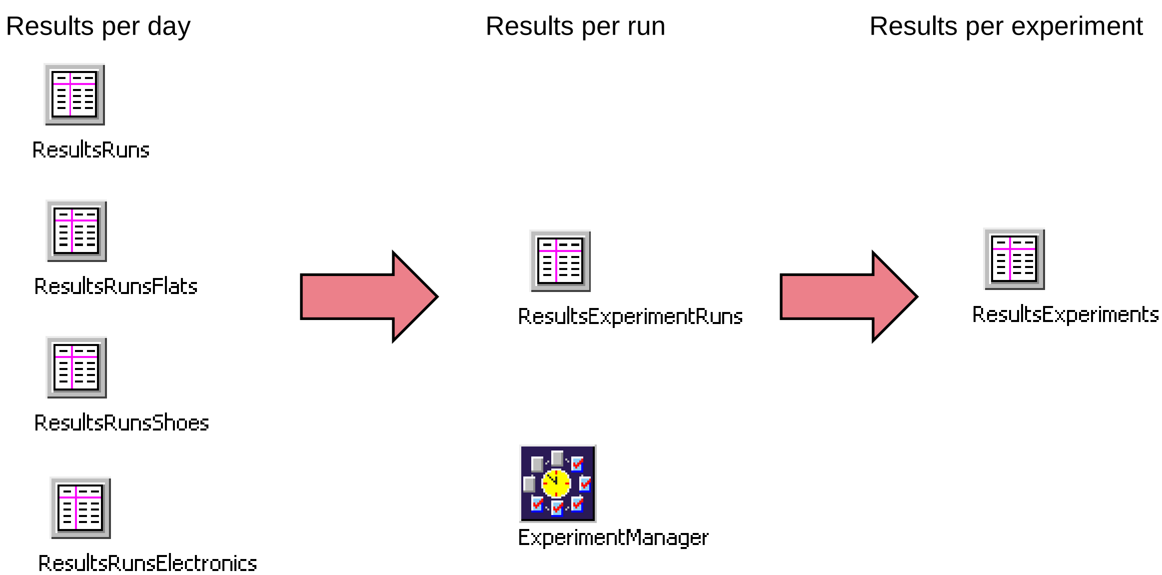

Figure 5.6 Processing of results

The table "ResultsRuns" contains general information and sorting related performance of the following types:

- How many products returns are generated today
- How many roll cages came in
- How many roll cages were waiting at the start of the first shift
- How many roll cages were left after the first shift
- The number of sorting hours used
- The number of sorting hours forecasted to be necessary
- The time the last container (if this is the case) went to a sorting station
- The number of times a sorting station was not utilized
- The first moment in time a sorting station was not utilized fully
- The items the sorting area processed
- The effective productivity achieved in the sorting area

For the checking areas, approximately the same data is gathered and how many products waiting in the specific area (in buffers and on the conveyor). This concludes the description of most units that have an overhead function. Let us now continue to the different parts of the model that process returns. As they are shown in Figure 5.7, which shows the actual model as in Plant Simulation.

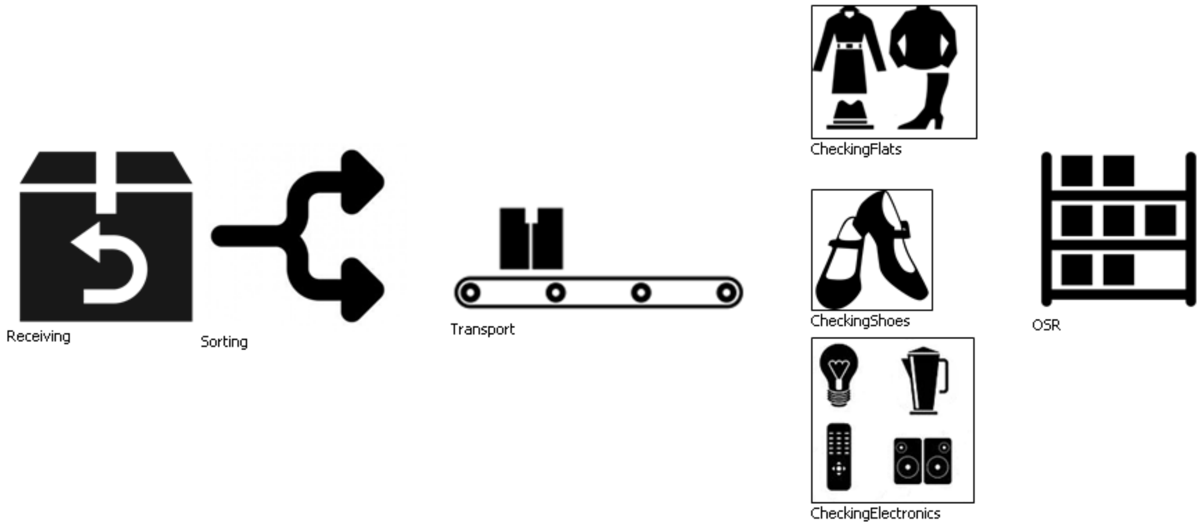

Figure 5.7 Overview of the model in Plant Simulation

Receiving
The receiving area is where returns are randomly combined into roll cages, since returns belong to different OSR categories and are also generated separately they are combined based on their weighted average with some variation. This is not an actual step in the processing of returns but a prerequisite for this model. These roll cages are stored as numbers in a table and do not exist in the model until a truck brings them to the LSCZ. Trucks with returns arrive in the receiving area and the roll cages are then stored in a buffer zone.

Sorting
In the LSCZ the area where roll cages are received and the area where products are sorted, are located next to each other. When one of the 18 stations in the sorting area is active, roll cages are pushed to it from the buffer are. Products that are in boxes are sorted per OSR category (shoes, electronics or fashion) in a tote. Totes are put on the container when they are full and when one tote is colliding with another, the second station to put a tote on the conveyor waits one second and then retries to put the tote on the conveyor. The buffer of roll cages and sorting area as it is modelled, is shown in Figure 5.8.

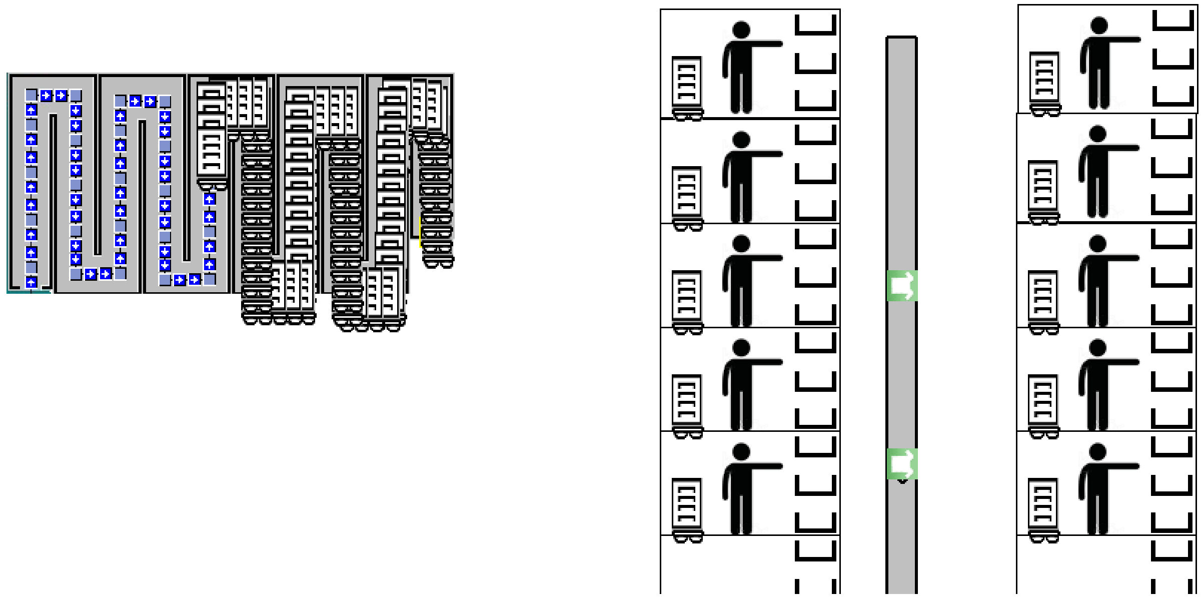

Figure 5.8 Roll cage buffer and sorting area

Transport

From the first conveyor in the sorting area, totes continue their way one floor up towards the checking areas. This is done through a series of conveyors. Once a tote reached the next floor it is continues its route to the checking area in accordance to the OSR category of the products it roll cages. Totes cannot pass each other on a single conveyor. Figure 5.8 shows the route of totes on their way to the checking areas.

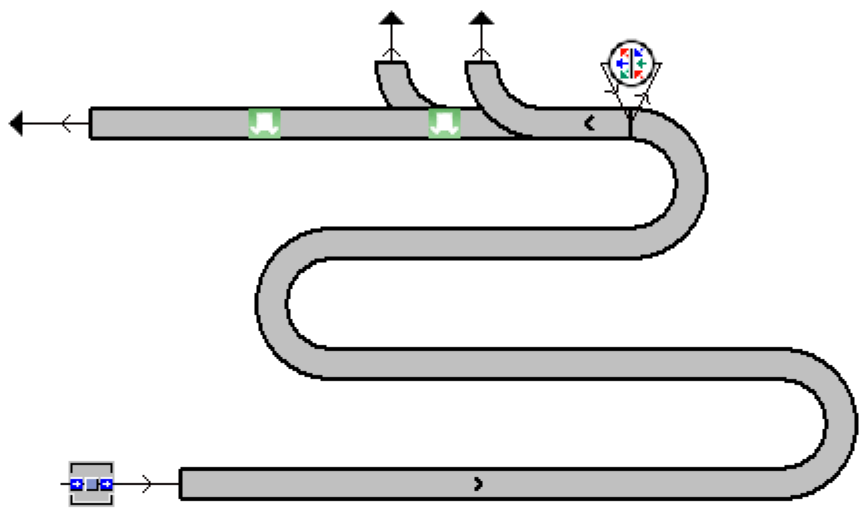

Figure 5.9 Transportation of totes

Checking

All three checking areas contain of the same parts. Every two processing stations share one buffer, whereas one station works on one tote and the shared buffer can store up to six totes. There is a conveyor that flows throughout the whole are area which also function as a buffer in the case that all individual buffers are filled. Totes are divided based on current buffer levels, where buffers that contain least totes are prioritized for the incoming tote. In the case that all buffers are full, a tote is placed on the conveyor with the least number of totes already waiting in the case of fashion checking, since this is the only area that consists of two conveyors. The status of a station is active or inactive, and inactive stations will not process totes. If a buffer is connected to two inactive stations, it will store no totes. Totes stay in the checking area overnight, in breaks and between shifts. Stations that have a preceding buffer that contains totes will be used as much as possible the next day, and totes that are left at inactive stations will be re-divided among active station and buffers. It is unclear how this process takes place in the LSCZ. Leaving totes in inactive station while other stations are processing results in an extreme waiting times for the products in such totes. The model therefore re-divides such totes. If a tote cannot continue because its destination is occupied, it is blocked and turns orange in the model. See Buffer 8, in the bottom right corner of Figure 5.10, for an example of a blocked tote.

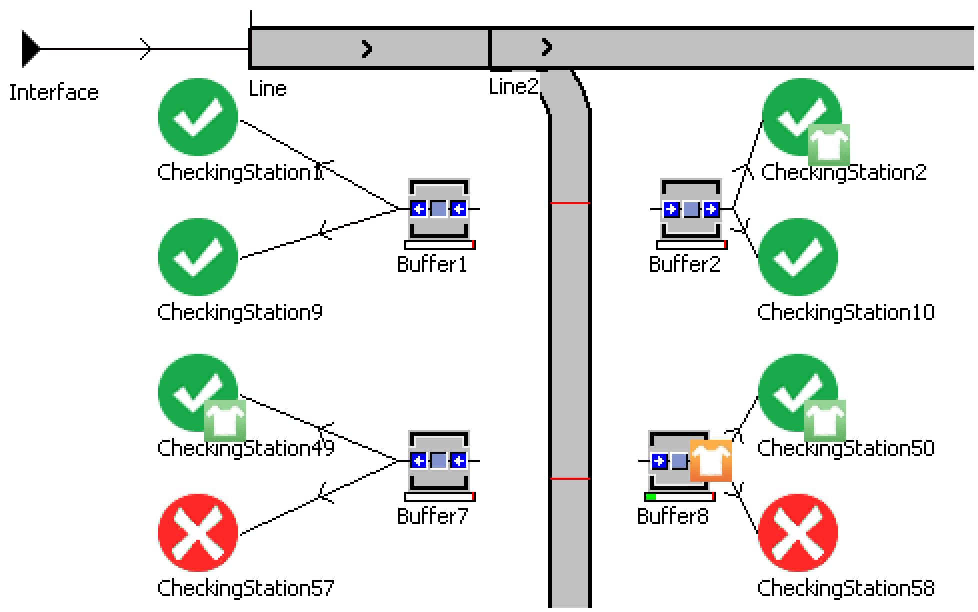

Figure 5.10 Fashion checking area

5.5 Verification, validation and run length

This section describes three topics of which two are more or less related. Verification is a prerequisite for validation. If a model is not verified, does not run without bugs for example, it is hard to validate. Verification is not a specific part in this section. It will be treated briefly in the small paragraph below, after which we will continue with the validation and run length.

The model is verified to run without bugs under all different combinations of experiments and always generate output that corresponds with the limits of the model. It never plans more stations than are physically present, never forecasts negative workloads, productivity levels are always above zero and WIP is minimally zero. As the model is verified, let us continue with the validation.

5.5.1 Validation

A first validation step that is conducted is a three-hour evaluation of the model with the Process Engineer in the LSCZ. A second way of validation is to check the models output. To check if the output of the model corresponds with reality, we examine several aspects. If the collected data and distributions that are input for the model are correct, the results of these tests should be in accordance with reality. The output of the model are compared with data gathered from their real-life counter parts, as they are described in Chapter 2. This output is presented to several Intelligence and Data science specialists at Wehkamp. Further validation is done by comparing output of the model with actual data. The two outputs that are examined are actual productivity, as measured by dividing products processed and workforce hours used, and products processed specifically. Since productivity depends on products processed, we first examine products processed and afterwards actual productivity. Actual productivity is different from the input productivity in the sense that when workforce is not fully utilized, actual productivity will be lower. Actual productivity will never be higher than input productivity, but high WIP can prevent lower than 100% utilization.

Products processed

The three different types of sales and returns, as described in Section 5.3, are used as input, while the number of products that is processed in each week is compared and is output. From Figure 5.11 it becomes clear that generating completely new sales do not follow the same trend as actual sales. The average number of products processed per week differs less than 3%, which is caused by the variation that is introduced per different weekday and variating buffer levels.

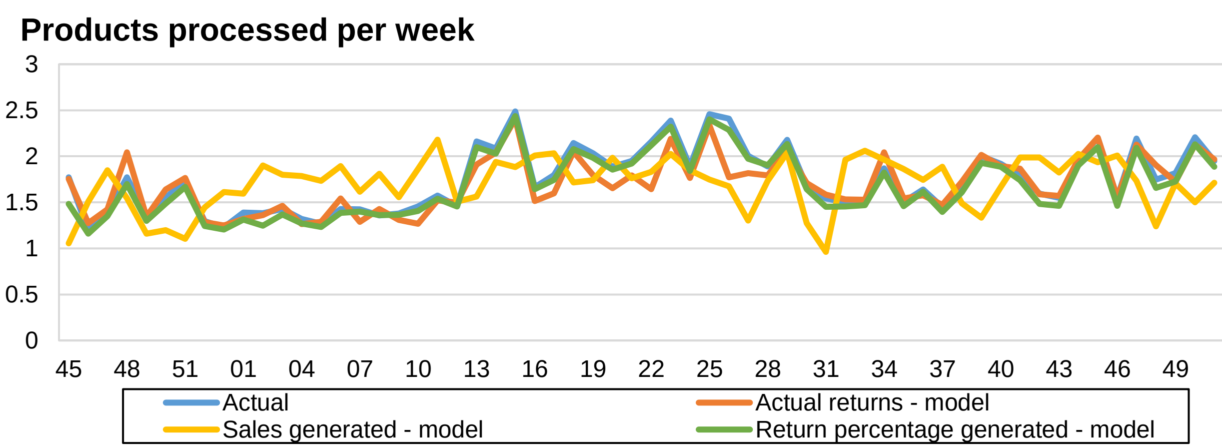

Figure 5.11 Products processed per week in the simulation model

Actual returns numbers from the model (includes variation per weekday) results in almost the same number of products processed per week, as well as a generated return percentage. As we assumed in Section 5.3, generating return percentages does not introduce a lot more variation. We can conclude from Figure 5.11 that all types represent the historical amount of returns to some degree, where generated sales ignore normal trends throughout the year.

Productivity

To measure actual productivity, there must always be work to be done. There cannot be any excessive processing capacity since this would result in lower utilization and unfair measurement of productivity. The validation of productivity is therefore done with exactly the workforce that corresponds with the forecasted workloads, while forecast has a 100% accuracy. Returns are also directly delivered to the LSCZ, although this is of course far from a realistic scenario, it is beneficial in testing the productivity in the model. Sorting throughput is enough to provide all checking stations that are active with new products, every day. The results of such experiment can be found in Figure 5.12.

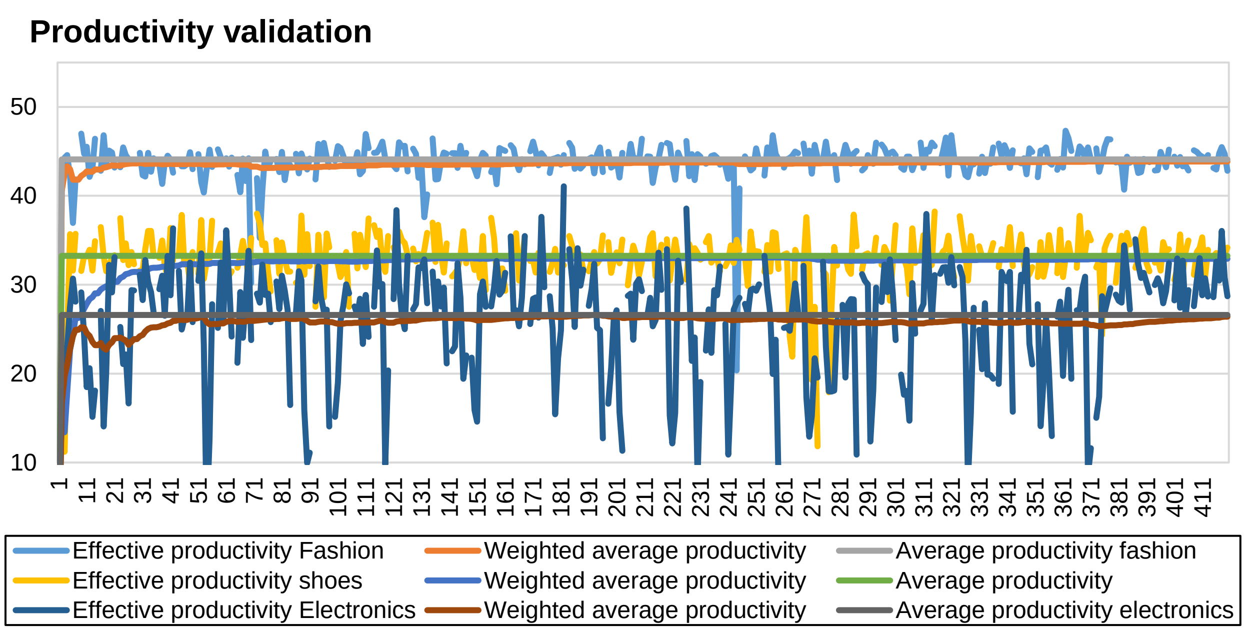

Figure 5.12 Productivity validation

Since there was no WIP build up in the beginning of the run, there is low utilization in the first few simulation days and therefore low productivity. This can clearly be observed in Figure 5.12, where the weighted average lines stabilize after approximately 40 days. All weighted averages correspond with the average productivity levels determined in the data collection step and therefore productivity in the model is validated. To compensate for the fact that there is always the possible of having lower than 100% utilization we could increase input productivity, but since differences are small we do not consider this option any further.

5.5.2 Run length

As run length a period of 60 weeks is chosen. The most important point is that there is never a moment that zero roll cages remain in the LSCZ due to WIP build up in the beginning of a run. This is exactly the case when the model is starts. In the eight weeks of warm-up period WIP can be extremely high (larger than 1500 roll cages) and within the same period also approach a very low amount, depending on which policy and experiment are used. The warm-up period can therefore probably be smaller, for example when using methods like MSER (as described by Law, 2014) to determine its total length. This is not necessary since a warm-up period of eight weeks leaves us with exactly one year of data. This makes results more easily comparable. With a functioning and validated model, we continue to the design of experiments.

5.6 Design of experiments

The experiments that are conducted have three goals. First; to find a realistic base planning model that represents the current situation. As described earlier in this chapter, it is not straightforward to construct a planning policy that represents the experience based planning as is exercised currently. We need to measure the performance of alternative solutions against the current situation, which is why we need a planning model that represents it. Second; to answer the research question concerning the influence of the buffers, planning and forecasting on the entire process. Third; to test the different alternative solutions as described in Chapter 4.

5.6.1 Current situation planning model

The first set of experiments aims to find a planning policy that represent the planning method that is currently used. The following different planning policies for the checking stations are tested:

1. Plan workforce to process the forecasted amount, no further restrictions.
2. Plan workforce to process the forecasted amount plus a 1% “over planning” (excess processing capacity).
3. Plan workforce to process forecasted amount plus a 1% “over planning” percentage and at least one station per area.
4. Plan workforce to process the forecasted amount and over plan 5% if the conveyor has totes waiting on it.
5. Plan workforce to process the forecasted amount of returns, over plan 5% if the conveyor has totes waiting on it, but only plan a second shift when at least 60% of the checking stations are required that second shift.
6. Over plan 15% workforce when last week’s number of remaining roll cages was higher than 500 on average. Only plan a second shift when at least 60% of the checking stations are required.
7. Over plan 15% when last week’s number of remaining roll cages was higher than 500 on average and if this is not the case over plan 5% if the conveyor has totes waiting on it. Only plan a second shift when at least 60% of the checking stations are required.

At first different forms of planning for the sorting area were considered. This is not considered since there is only one workable option, which is to balance its throughput with that of the checking areas combined. Experimenting with different planning policies for the sorting stations resulted in impossible situations like extremely low utilization of checking stations, sorting stations, thousands of totes waiting to get on the conveyor and more unrealistic situations. Therefore, there is only one policy used for the sorting area which is to plan a workforce equal the processing capacity of that of the checking areas combined.

All parameters in the base planning model are based on preliminary experimenting and estimations. To review all this experimenting would extensively increase the amount of experiments without adding to this research.

5.6.2 Forecast and variability buffer influence

The second research question is hard to answer without the simulation model. To find the answer to the question, we examine the influence of variability buffers by the following experiments.

Time and WIP
Time and WIP are described as different variability buffers in Chapter 1. A high WIP does not necessarily mean that there is a lot of waiting time for example. In the LSCZ however the influence of the actual processing time is so low compared to waiting time caused by high WIP, differentiating between time and WIP makes no sense while conducting experiments. Results would be that time is for more than 90% related to WIP since throughput (remember Little's law in Chapter 3) cannot be increased heavily by Wehkamp, due to a limitation of physical stations for example. We therefore only consider different experiments that consider WIP, since it is our main tool of influence on the time required to process returns. Bringing down WIP fast, means requiring less time to process returns while having a large amount of WIP , means longer waiting times.

Flexibility
Flexibility is in this case the amount of workforce that can be planned extra on a specific day or in a specific week. Other forms of flexibility are not examined, like switching between different checking areas or between checking and sorting for example. We experiment with flexibility of 0% to 20% in steps of 5% when the conveyor is over 90% full at the beginning of a shift. Next to this form of flexibility we examine the same levels and steps (0% to 20% in steps of 5%) for when the number of roll cages waiting is over 500 in the previous week.

Capacity
The only form of capacity that can be influenced is processing capacity. Actual processing capacity is a result from how much workforce is planned and how much they process per hour. Increasing capacity is therefore simply increasing the number of employees planned or increasing individual productivity, which is already an alternative solution. Conclusion for this variability buffer will be drawn results of experiments that represent such changes as are described in the following paragraphs.

5.6.3 Alternative solutions

There are the different experiments as they are already operationalized in Chapter 4. A short summary of those experiments and the different parameter values is:

- Increasing throughput
  - A 2.5%, 5% and 10% additional workforce planned.
  - Individual increase of productivity will be tested for which will be a 2% and 4% increase in individual productivity of all sorting and checking operators.

- Improve forecast
    - Bandwidth of 20% (normal), 10% and 0%, to check for the benefits of a possible improvement of the forecast.
- Improve planning
    - Planning two shorter shifts, with operating times from 7:00 to 13:00 and 13:00 to 19:00
- Strive for a constant work in progress
    - A WIP that covers tomorrows processing capacity
    - A WIP that covers half tomorrows processing capacity
- Preponement and reason coding

    1%, 2% and 3% work influenced by preponement reducing processing time by 30%.

As different types of experiments are defined, to find a representative base planning model, to examine the influence of the variability buffers and to examine different alternative solutions, the next chapter will be divided in three sections based on these topics.

6. Results

The sixth chapter is completely devoted to the results of the experiments that are described in Section 5.6. The different sections of this chapter are separated based on the different types of experiments.

The first type of experiments, which is the subject of Section 6.1, is to conclude upon a base planning model that represents the current situation. All experiments are reviewed based on several performance indicators. These are:

- hours used
- productivity
- number of roll cages waiting
- number of products waiting
- required hours in more expensive shifts (night shifts)

When there is no difference between experiments on one or more of these performance indicators they are left out of consideration. When this is the case it will be mentioned. Another important note is that productivity levels are compared to the column average to make differences more clear. The coming section reviews the results of the experiments aimed at finding a representative base planning model.

6.1 Base planning model

To find a base planning model which represent the current situation, we tested seven different policies that are described in Section 5.6. In this section the main findings are discussed and the most notable points are summarized in the end of this section.

6.1.1 Finding the base planning model

Information about how many products are buffered between sorting and checking is not very interesting since yearly averages (minus warm-up period) are always the approximate maximum the conveyor can hold, as is actually in the LSCZ, guaranteeing utilization even at the beginning of a shift. Only sorting and fashion information is shown since shoes and electronics checking areas perform approximately the same as fashion checking. There is one difference and that is that the workstation utilization for these two types of returns is a lot lower. Since the number of product returns and stations is a lot lower, variation is averaged out less, which leads to a lower utilization. Where expected returns for fashion are approximately ten times larger as the expected returns for shoes and more than 100 times larger than expected electronics returns, the ratios between the available number of stations is completely different: 72 fashion checking stations, 13 shoes checking stations and 5 electronics checking stations.

Although productivity is less while checking these returns, not that much lower to compensate for the large difference. This also accounts for the other experiments, lets now focus on the base planning model specifically of which the most relevant results are shown in Table 6.1 and Table 6.2.

Planning policy	Sorting hours	Sorting hours (index = average sorting hours)	Average roll cages waiting	Productivity sorting (index = average productivity)	Hours fashion	Hours shoes	Hours electronics
1	45218	0.985	1778	1.004	203365	25793	11267
2	45859	0.999	1188	1.003	205702	26123	11915
3	45859	0.999	1188	1.003	205702	26123	11915
4	46904	1.022	609	0.990	209462	27244	12403
5	44142	0.962	2502	1.009	197017	26026	11870
6	46621	1.016	537	0.996	208347	26876	12159
7	46746	1.018	511	0.994	208475	27187	12333

Table 6.1 Results of base planning experiments 1

As Table 6.1 shows, the hours planned do not differ greatly between the different planning policies. This is due the fact that productivity levels are the same on average and all experiments process the same number of products. We also observe this in the other experiments in Section 6.2 and Section 6.3. The only difference in hours planned is caused by over planning, which is excess processing capacity that often results in not fully utilising available workforce. Influence of different productivity levels, due to the stochastic variables that determine productivity (Section 5.3) is believed to be small, since the large number of hours evens out most variation, see Section 5.5.

In Table 6.1 we observe several other facts, as we expected the number of hours used does not differ a lot (third column Table 6.1). The relation between WIP and utilization becomes clear by comparing the number of buffered roll cages with the effective productivity, which are positively correlated throughout the results. Although by planning responsively, i.e., not always any secondary shift in policy six and seven, this effect is reduced. Putting a restriction of nearly full utilization on secondary shifts reduces the number of secondary shifts at the cost of high WIP. This is diminished when accounting for actual work pressure (policy five versus policy six and seven).

This can be concluded from Table 6.2 where the four columns to the right represent the average number of stations planned in shift 2, per day, for the different planning policies.

Planning policy	Fashion Shift 2	Electronics shift 2	Shoes shift 2	Sorting shift 2
1	11.803	0.357	0.322	2.404
2	12.721	0.514	0.408	2.623
3	12.721	0.514	0.408	2.623
4	13.875	0.598	0.574	2.885
5	8.779	0.377	0.112	1.761
6	12.892	0.450	0.281	2.619
7	12.798	0.470	0.290	2.605

Table 6.2 Results of base planning experiments 2

Planning policy two and three do not differ at all, which indicates that other than expected, there is always at least one person required, even for electronics checking.

6.1.2 Summary

Regarding a base planning model to compare the alternative solution with we conclude that:

- We prefer planning policy six and seven due to their better fit with reality; not only because of their good fit with the actual situation concerning restrictions, but also the average number of roll cages waiting.
- Overall the required number of hours does not differ a lot as due reasons described above; it only differs when lower than 100% utilization occurs in an experiment. This is caused almost exclusively by planning excess capacity. Data of an eight-week long warm-up period is discarded, and therefore all data represents the system in a state that already has a stable level of WIP. Planning without excess capacity therefore does not result in lower than 95-100% utilization.
- Approximately the same number of hours in secondary shifts is required when there are no restriction in place. Only when accepting extremely high WIP, like in planning policy five, hours worked at night can be reduced with approximately 40 to 50%. This is unrealistic, since it requires the LSCZ to process returns too late on a structural basis.
- An average of around 500 to 550 roll cages is an average of 30,000 to 40,000 products waiting in the LSCZ. Which is comparable with the actual situation in the LSCZ of the last six months of data analysed, as shown in Section 2.6.
- Effective productivity does not differ a lot, and corresponds with input on average. Lower than 100% utilization therefore does not occur a lot in the model. According to the employees interviewed in LSCZ, this corresponds with the actual situation.

We chose policy seven as a base planning model since not only its output, but also its restrictions best fit reality.

6.2 The influence of the forecast and variability buffers

In the very first chapter of this report, the second research question is to analyse the influence of the different variability buffers. Although some influences can be concluded from the previous section and Chapter 2, this section will structurally examine their influence through experimenting with the simulation model. The question that is to be answered:

> **2. What causes the underperformance of KPIs and the need for large variability buffers?**

We will try to find the answer to this question by complementing our knowledge previously found with the different experiments that are described below.

6.2.1 Influence of the forecasted number of product returns

The forecast that concerns the number of products returns in the current situation is within a 10 to 20% bandwidth. As is shown in Section 5.3 there is variation in the amount of returns coming in, which is most likely caused by customer and DHL behaviour. The current forecast does not regard this behaviour, and this would be a strange requirement. Since this would require to estimate when customers are going to a service point. This can be different on an hourly basis due to rain for example. Estimating such factors as the weather three weeks in advance, is not a realistic demand, the performance bandwidth of 10% is reasonable. To find out what the influence of the forecast is, experiments are conducted with different bandwidth in which the forecast performs. The forecast performance is altered in the experiments while planning is done according to planning policy seven. Results are shown in Table 6.3.

Bandwidth	Sorting hours	Average roll cages waiting	Sorting productivity (index = average)	Hours fashion	Hours shoes	Hours electronics
0	46394	516	1.002	207208	26971	12334.8
10	46434	519	1.000	207126	27142	12316.2
20	46485	526	0.998	207413	27220	12253.2

Table 6.3 Results influence forecast

The results in Table 6.3 are surprising at first sight. While the forecast is assumed to have great impact, having a larger or smaller performance bandwidth does not seem to influence hours used or the number of roll cages waiting. This can be explained by the average number of roll cages waiting, which evens out most variation caused by the variation in forecast performance. Next to the number of roll cages waiting, the roll cages that come in early in the morning also prevent low utilization. These two factors assure utilization while planning more employees when WIP is getting out of hand, or conveyors are full (planning policy seven) guarantees good performance concerning WIP.

To examine the effect of forecast performance without this level of flexibility, we conduct the same experiment with half the flexibility available; having 2.5% flexibility when the conveyor is full and 7.5% when the number of roll cages is higher than 500. The results are shown in Table 6.4.

Bandwidth	Sorting hours	Average roll cages waiting	Sorting productivity (index = average)	Hours fashion	Hours shoes	Hours electronics
0	45408	1165	1.014	202932	26349	12060
10	45610	1064	1.014	203913	26341	11981
20	45722	1001	1.013	204532	26408	11950

Table 6.4 Results influence forecast with half the flexibility

In Table 6.4 we see that productivity is higher when the amount of flexibility is cut in half and higher when the forecast would improve. This is caused by the higher WIP, which is never compensated for by accidentally forecasting more than expected in the case of a perfect forecast (bandwidth of zero). We observe a large difference between Table 6.3 and Table 6.4 due to the reduction of flexibility, but still no real difference between the different bandwidths within experiments with the same amount of flexibility. In conclusion, improving the forecast will not result in large improvements when high amounts of WIP are allowed or flexibility is available to compensates for forecast performance. The WIP effectively buffers the variability in forecast performance, and improving forecast performance is only relevant when the average WIP is decreased or having less flexibility. Improving the forecast was possible solution, but we do not examine it any further since this experiments shows that its benefits are rather limited.

6.2.2 Influence Time and WIP

To test for the influence of time and WIP, we experiment with different amounts of allowed WIP before processing capacity is increased. Since WIP has most influence on time required to process returns, we do not examine processing time individually. Surprisingly, we see in Table 6.5 that an average WIP of 295 roll cages seems to be minimal, although we aimed for no waiting roll cages at all. The reason this WIP is still so high after setting the target WIP on zero, is that the number of waiting roll cages is measured before the shift starts in the morning. So, while the remaining number of roll cages at the end of the shifts on the previous day might be zero, roll cages can come in until 0:00 and before shifts start in the morning, resulting in this average of 295 roll cages waiting. Next to that, we observe once more that a higher WIP results in higher utilization. Reducing the average number of roll cages from 780 to 295 costs us approximately an extra 7.5% hours (as calculated from the average hours per day at sorting required in this experiment).

Roll cages waiting target	Sorting hours	Average roll cages waiting	Sorting productivity (index = average)	Fashion hours
0	49415	295	0.958	220544
100	48937	317	0.967	218414
200	48051	367	0.984	214406
300	47479	420	0.994	211745
400	47022	460	1.003	209725
500	46746	526	1.008	208475
600	46382	565	1.013	206852
700	46246	608	1.016	206263
800	46103	672	1.018	205561
900	45990	734	1.019	205047
1000	45914	781	1.020	204750

Table 6.5 Results setting different WIP targets

The most important notion we should make from the results in Table 6.5. is that average WIP will always be approximately 300 when working until 17:00, so setting lower targets only marginally improves waiting time, while reducing utilization and therefore requiring more workforce hours.

6.2.3 Influence Flexibility

To examine the influence that workforce flexibility, i.e., planning more workforce on short notice as described in Section5.6, has on performance several experiments are designed. Combinations of flexibility experiments were not conducted. All experiments that concern flexibility are done with other parameters on their standard levels. Table 6.6 shows the results for different levels of flexibility that apply when the conveyor is full on the previous day.

Conveyor flexibility	Sorting hours	Average roll cages waiting	Sorting productivity (index = average)	Hours fashion	Hours shoes	Hours electronics
0	46669	549	1.010	208531	26839	12194
0.05	46847	526	1.006	208850	27184	12387
0.1	46992	469	1.002	209132	27561	12508
0.15	47325	438	0.996	210438	27910	12619
0.2	47715	408	0.987	211879	28318	12781

Table 6.6 Results influence conveyor flexibility

We observe that 20% flexibility does not result in a 20% increase in hours, this is not surprising since there is not always called upon the flexibility. This is due the fact that the conveyor is not always full at the end of a shift. We observe a 2.2%, 1.6%, 5.5% and 4.8% increase in hours used for sorting, fashion checking, shoes checking and electronics checking when comparing 0% to 20% flexibility. The relative increase in hours for shoes checking and electronics checking is larger since planning one extra station has more influence upon the total hours used. We now conduct the same experiment, but change the flexibility when the number of roll cages becomes too large. This form of flexibility does not put any extra pressure on the workforce since it regards the number of roll cages of one week ago.

Container flexibility	Sorting hours	Average roll cages waiting	Sorting productivity (index = average)	Hours fashion	Hours shoes	Hours electronics
0	43416	3281	1.008	194252	25321	11510
0.05	45099	1547	1.007	201676	26145	11986
0.1	46405	694	1.000	207304	26787	12224
0.15	46847	526	0.995	208850	27184	12387
0.2	47250	466	0.990	210926	27328	12399

Table 6.7 Results influence roll cage flexibility

Having no flexibility whatsoever concerning the number of roll cages waiting requires more buffer space than is available in the LSCZ and results in extreme waiting times. Having 5% flexibility on a weekly basis is also too little, but from 10% and more we observe a realistic situation. When comparing Table 6.6 and Table 6.7 we must also conclude that flexibility based on number of roll cages waiting has far more influence on the entire system's performance. Recap that in Table 6.6 the level of roll cage flexibility is 15%, as that is its base level. Next to the fact that whether conveyors are full or not does not imply that there are a lot of products waiting to be processed, balancing sorting and checking processing capacity completely removes the relation between workload and the conveyors being full. We conclude that flexibility on the same day, based on whether conveyors are filled up, does not outperform flexibility per week based on roll cages waiting.

6.2.4 Summary

To answer the main research question, we need to answer several other research questions. Answering one of these questions is postponed until this section, namely research question 2, since analysis through simulation aided in finding the answer to research question 2.

2. What causes the underperformance of KPIs and the need for large variability buffers?

From all previous paragraph in Section 6.2, we conclude that:

- High WIP in terms of roll cages waiting is required to ensure high utilization of available workforce. High utilization of available workforce is a necessity to process returns (cost) efficiently.
- The forecast does not have a large influence upon the performance of the processing of returns, since WIP buffers for the variation in the forecast. However, the forecast as it is now is not the main reason Wehkamp needs a large WIP, but utilization is.
- Variation concerning the amounts of returns coming in seems to be simply part of commercial product returns. There is no evidence that this is caused by DHL. This variation is mostly buffered for with WIP and the possibility to process more returns than come in on a specific day, i.e., increased processing capacity to avoid extreme waiting times by the introduction of night shifts.
- Having a lot larger processing capacity mostly relies upon the flexibility of the workforce, since they are required to work night shifts during busy times. There is actively called upon this flexibility, but night shifts are worked at increased wages so Wehkamp rather avoids working at night.
- Flexibility and maximum processing capacity during regular hours are restricted by the maximum number of processing stations available. When all processing stations are occupied, which occurs frequently, it is hard to increase processing capacity without working during the night.

Forecast performance does not cause the need for large variability buffers. Having some form of buffer, for the variation that accompanies commercial product returns, is a simple necessity. Variability buffers seem to be part of processing commercial product returns efficiently. If variability buffers must be as large as they are currently, is hard to tell from these analyses. The alternative solutions might show that this is not the case.

6.3 Alternative solutions

All alternative solutions are tested through their operationalisations described in Chapter 4. In this section, all experiments are done without interference of other experiments, and again other parameters are set at their base level as they are described in Chapter 5.

6.3.1 Increase throughput

We examine the solution of an increased throughput under the circumstances that are introduced in planning policy seven. The excess amount of processing capacity that is planned does not regard the extra amount planned through flexibility measures. This would mean that both “stack” and actual excess capacity is higher than intended. In the case that we plan an excess processing capacity of 5% for example, while also planning an extra 15% due to high WIP this can be done two ways. We can add an extra 5% to the original processing capacity and subsequently another 15% based on the original intended processing capacity. The second option is to first increase the intended processing capacity with 15% or 5% and afterwards increase this new number with the remaining percentage. We choose the first option, where flexibility and excess capacity planned do not amplify each other. The experiments are an additional 2.5%, 5% and 10% workforce planned and an individual increase of productivity with 2% and 4% as shown in Table 6.8.

excess processing capacity	Individual productivity increase	Sorting hours	Average roll cages waiting	Sorting productivity (index = average)	Hours fashion	Hours shoes	Hours electronics
0%	0%	46847	526	1.010	208850	27184	12387
2%	0%	47261	445	1.003	210853	27304	12469
5%	0%	47930	376	0.992	213791	27806	12651
10%	0%	48981	299	0.972	218376	28455	12892
0%	2%	46811	522	1.010	206068	26629	12139
0%	4%	46823	518	1.013	203311	26228	11999

Table 6.8 Results of increasing throughput

Planning an excess capacity of 10% increases the total number of required hours by 4.5% as compared to not planning any excess capacity. This is because WIP buffers for this excess capacity, since the number of roll cages waiting is reduced by approximately 50%. This reduction of roll cages waiting results in fewer times of planning additional workforce through flexibility, i.e., not passing the 500 roll cages waiting limit, and therefore a smaller than 10% increase in hours used. Planning like this has a downside that is not specifically shown in the table. A lot of the excess capacity requires secondary shifts and is therefore expensive. Planning an excess capacity of 10% results in an increase of 15% in required hours during the second shift. This also explains why the average number of roll cages waiting is this much lower: employees work late more often, resulting in fewer roll cages waiting the next morning. Since the number of roll cages is lower every morning the number of roll cages waiting is often lower than 500 and therefore the flexibility when the number of roll cages waiting exceeds 500 is not necessary as often. Since WIP is hard to control and planning an extra percentage of workforce does not increase hours used with that percentage, not even mentioning the possibility of sending people home, the results are rather good.

6.3.2 Improve planning

There are multiple advantages to improving planning. Shifting the processing hours to a later moment on a specific day reduces the chance of lower utilization while maintaining the same WIP, since there is a larger probability of trucks coming in while still processing. Another advantage is that, since there are more hours during daily shifts, less stations need to be occupied while processing equal amounts on specific days. This allows for more flexibility, shifting employees from sorting to checking or outbound to checking and many other options. This is not always possible now, since employees cannot shift to checking when all stations are occupied. The results of this experiment are shown in Table 6.9.

normal shifts	Container buffer target	Sorting hours	Average roll cages waiting	Sorting productivity (index = average)	Hours fashion	Hours shoes	Hours electronics
1	500	46766	526	0.987	208850	27184	12387
2	500	46105	626	1.018	207656	26332	12025
2	400	46345	545	1.013	207939	26527	11973
2	300	46573	480	1.009	208885	26657	12064
2	200	46872	411	1.003	211530	26871	12123
2	100	47327	350	0.994	213655	27105	12168
2	0	48139	264	0.977	217230	27541	12324

Table 6.9 Results of planning different

Shifting processing capacity to a later moment on a specific day, we would expect a lower average number of roll roll cages waiting for all experiments except for the first in Table 6.9. When we compare Table 6.9 with Table 6.5 we can conclude that although less hours are used, WIP is higher in Table 6.9. There is a logical explanation for this surprising result which is the fact that the model cannot handle a third shift. The normal situation, where the two relatively large shifts consist of one day-shift and one night-shift, the two shorter shifts are both during day time and therefore do not require an increase of wage. The two shorter shifts cannot be expanded with a third one in the model, although the hours in a day would allow for a third shift. Note that this is a specific limitation of the simulation model and results in Table 6.9 are therefore quite impressive. Planning two shorter shifts completely diminishes the extra cost incurred with night shifts, while performing at a comparable level. This is clearly shown in Table 6.10 where the first experiment is the base model and the others represent two short shifts with different roll cage buffer targets.

normal shifts	Container buffer target	Fashion Shift 2	Electronics shift 2	Shoes shift 2	Sorting shift 2
1	500	12.839	0.470	0.290	2.613
2	500	38.032	2.202	4.823	8.444
2	400	38.249	2.193	4.858	8.488
2	300	38.440	2.210	4.882	8.530
2	200	38.742	2.220	4.921	8.585
2	100	39.131	2.229	4.964	8.668
2	0	39.786	2.257	5.044	8.817

Table 6.10 Results of planning different, hours per shift

While planning traditionally we need an average of 16 people per work day to work the night shift, while there are no night shifts while planning two shorter shifts. The four right columns of Table 6.10 represent the employees per second shift per day. In the case of the first row this means working during night shifts. For all other rows we would see the exact same number for the first shift as the second shift, since they are of equal length, and do not imply working during the night.

6.3.3 Strive for a constant WIP

A constant WIP as percentage of available processing capacity is hard to achieve because WIP influences processing capacity and vice versa. We examine the results of the experiment Section 6.2. more in depth, Table 6.5. Looking at the available processing capacity of all stations for example we conclude that we have approximately 30,000 to 35,000 items on a regular eight-hour workday. With an average fill rate of 75 items per container, around 400 to 500 roll cages should be enough to guarantee for a full shift to never have a utilization lower than 100%. Looking at the results of our experiment we see in Table 6.5 that setting our target between 400 and 1000 roll cages only 1.7% difference in productivity, while aiming for 0 and 400 results in a difference of 3.9% and still having 300 roll cages waiting on average. The problem with this solution is that although we have a goal and we can try to achieve this goal through planning, we never know how much comes in the remainder of that day. Striving for 500 roll cages seems to be a sweet spot where customer waiting time is and utilization are at a decent balance on average. In those specific cases that low utilization does occur, there is always the possibility to send employees home to guarantee a 100% utilization. No matter how high the target WIP there is always the possibility of having lower than 100% utilization.

6.3.4 Preponement and reason coding

The experiments that were designed in Chapter 5 described preponement and reason coding as 1%, 2% and 3% of all returns coming of which processing time is reduced by 30%. This is one of the more straightforward experiments in coding and executing and the results are shown in Table 6.11.

Preponement	Sorting hours	Average roll cages waiting	Sorting productivity (index = average)	Hours fashion	Hours shoes	Hours electronics
0%	46847	526	1.000	208850	27184	12387
1%	46746	526	1.000	208453	27169	12314
2%	46758	525	1.000	208549	27180	12348
3%	46743	525	1.001	208475	27171	12326

Table 6.11 Results of preponement and reason coding

Where a possible reduction of 0.9% of necessary hours should be possible for the 3% preponement experiment, we observe almost no significant reduction. This indicates that although processing items requires less hours the effects are rather limited. An important note is that while planning, the advantage of preponement and reason coding is not considered. This could have explained why effects are so limited, but we would at least expect average WIP to be a bit lower while planning the same number of hours. Even stranger is the fact that there is no linear relation between preponement percentage and roll cages waiting nor hours used. Results are random and preponement is not very promising when planning is not adjusted to it.

6.4 Conclusion

All different alternative solutions are discussed individually in Section 6.3. This section briefly compares them, to find the answer to research question 5:

5. What specific solution should Wehkamp consider?

Simply increasing throughput is by far the easiest to implement alternative. An increase in workforce planned by a certain percentage does not imply that actual hours used is increased by the same amount. Increasing processing capacity by simply planning more workforce has a very positive effect upon WIP at the cost of a limited number of extra hours. Problem is that most of the regular days all stations are occupied and night shifts are less flexible since they are often full shifts to reduce the overhead cost (team leaders, key users etc.). We observe that increasing individual productivity is beneficial to both WIP and hours required, while having no specific negative influence on flexibility required. The most difficult thing to increasing individual productivity is the fact that it is not straightforward how to achieve this. Preponement and reason coding did not result in such benefit. Other options like introducing extra training is expensive, uncertain and creates an even bigger gap between experienced and in-experienced (untrained) workforce. Striving for a constant WIP does not always result in achieving the target goal since there are uncertain factors that influence WIP. The best option is to improve planning and divide regular working days in two shorter shifts. This option simply has most benefits:

- More processing hours per day, an effective increase of 31%
    - a lower occupation level of all work stations, which leaves room for switching between activities
    - increased throughput per regular shift
    - Lower maximum demand for returned products from the sorting and checking area, as it is divided over more hours
- Less night shifts required, in the model a reduction of 100%
    - A full reduction of extra cost introduced by working during night times
- Lower average WIP without the loss of utilisation, a reduction of 9% on average.
    - Process returned products until 19:00 enables Wehkamp to process more products that came in on that specific day so lower WIP overnight, which results in a smaller waiting time for customers.

These benefits are unmatched by the other alternative solutions and therefore planning two shorter shifts is the best solution.

6.5 Discussion

The weaknesses of these results mostly lay in limitations of the simulation model. Like the fact that in the model people are not send home. When utilization is 99% on average it would mean the number of times employees are send home early is kept quite small. Incidentally being send home a few minutes early is something every worker is willing to accept. So how important is a small increase in utilization, if it can be easily compensated for by sending people home? Second, the model is not able to plan a third shift, while this could lower the average WIP even further, it could also cause lower utilization on average. What the actual effects are is pure speculation and one of the weaknesses of this research, although if it would harm performance severely, there could simply be chosen not to plan night shifts. So, night shifts could only benefit the best solution even further. Another weakness of this model is that WIP is expressed in number of containers waiting. This is done with a none changing fillrate (number of products per container) since this has no real influence on the performance, but it is not a correct representation of reality. A final question to ask is: how trustworthy is historic data for a company like Wehkamp? Although most data is extensively analysed, it does not give any certainty about the future. Finally, there is not experimented with a mixture of alternative solutions, nor is there experimented with dynamic policies that change throughout the year. Such experiments could be very interesting and a simulation model is more than suited to test mixtures of policies throughout a year or run. Due to a limitation in time and the already quite large size of this report any further testing is not conducted.

7. Conclusions and recommendations

After all analyses, intermediate summaries and conclusions, we arrive at the final chapter of this report, Chapter 7. It consists of three sections. The first section draws conclusions regarding the main research question, after which the second section contains the recommendations and last the final sections discusses the possibilities for further research.

7.1 Conclusions

In the first chapter of this report a main research question is stated. It is the following question:

How to process product returns efficiently, now and in the future, by balancing variability buffers and through planning aided by forecasting?

The main research question can be decomposed into several parts. We begin with the variability buffers. This research started with the idea of four different flexibility buffers. The four variability buffers as stated in Chapter 1 are:

- Work to be done (WIP)
- Capacity
- Time
- Workforce flexibility

After the context analysis, we concluded that time is directly related to WIP, since the largest part of time required to process returns consists of waiting time. This amount of waiting time is caused by returned products waiting to be processed. The amount of waiting time is so much larger than processing time, that it is in no way relevant to reduce actual processing time. Reducing waiting time is done by reducing average WIP and therefore examining time individually is irrelevant.

Leaving us with the variability buffers flexibility, capacity and work to be done (WIP). Total processing capacity, in terms of processing capacity per hour, is however limited by the number of stations, productivity of employees and working hours per day. We do not consider adding new processing stations, which leaves with the option to increase the number of working hours or productivity levels. Looking at the results in Section 6.3, we observe that increasing throughput by planning extra workforce or increasing individual productivity, both have positive effects on the average WIP and therefore the time required. As discussed in Section 6.4. both have their cons, as an increase in individual productivity is hard to achieve and increasing collective processing capacity requires more workforce to be planned, often during night shifts. Increasing processing capacity further is therefore also limited. Setting a lower target WIP is only beneficial to a certain degree, due to the nature of the arrival of product returns. The most important downside of a lower WIP is that it causes lower utilisation, but WIP is the only easily controllable, more or less unrestricted, variability buffer. To what extend a lower WIP is worth lower productivity is up to Wehkamp, but having more containers waiting than can be processed in two days is never justifiable. In the end setting a different target WIP only has marginal impact and is always a trade-off between waiting time and productivity. So, instead of focussing on the variability buffers, Wehkamp should consider to improve its planning methods. We will review the solution of planning differently later, but let us first continue with the forecasting part of the main research question.

This research also intended to examine the possibilities for a different form of forecasting, but the simulation study pointed out that this has almost no effect. Next to having no effect, one can argue that it is impossible to achieve a (much) better forecast. There are several reasons for the limited effect of an improved forecast, as stated in Section 6.2, but most importantly due to:

- The average amount of WIP is large enough to buffer for deviations in forecast performance
- Although the forecast might be improved concerning how many returns come in, when these returns come in depends on customer and DHL behaviour, which is just as relevant

Predicting customer behaviour on the level that enables one to know when products are returned, would require an accurate forecast of the weather or traffic congestions and more three weeks in advance. This is simply impossible.

The best alternative solution by far, is to improve planning by working two shorter shifts during day time. It offers a wide range of benefits such as increased flexibility due to a lower occupation level of workstations, possibility to increase throughput without extra cost of night shifts and lower average WIP by processing until a later moment on a given day. Even without the possibility to schedule a night shift, such policy almost performs just as well or better on all performance aspects compared to regular planning. The downside is that workforce must accept such drastic changes. When looking at the results from the experiments as conducted in Section 6.3, setting a target WIP of 300 results in a lower average WIP, a lower number of total hours used, higher utilization and zero night shifts, compared to the current situation. This is an amazing result with a potential to be improved even further.

As one might have concluded already this research did not result in a decision support tool, as was described in the objectives (Chapter 1). This is due the fact that improving the forecast is believed to have little impact on the processing of returns and would therefore not be useful. Another part that is relatively left untreated is robustness. The reason to leave robustness out of all experimenting is that while conducting preliminary experiments robustness was directly related to the amount of processing capacity available. When the number of returned products increases the amount of night shifts and hours used increases, which is shows little difference between every experiment.

Concerning the forecast and buffers to variability a final notion must be made. Since the introduction of the LSCZ more products are packed in boxes instead of plastic bags. This reduces the number of products per roll cage, as boxes cannot be compressed as bags, and therefore increases the number of roll cages. Since variability in number of roll cages coming in per day remained constant compared to the situation pre-LSCZ, but these roll cages hold less products on average, variability relative to average amount of products returns is smaller. This effectively smoothens the returns coming in per day. Downside is the fact that this requires almost 50 to 75% more space to keep the same amount of WIP waiting, but the forecast performs better under these new conditions of less variability in amount of product returns per day. Wehkamp should account for the reverse effect when there is chosen to pack more products in bags instead of boxes.

7.2 Recommendations

As described in Section 6.4 the best solution is to improve planning and divide regular working days in two shorter shifts. This option simply has most benefits:

- More processing hours per day, an effective increase of 31%
  - a lower occupation level of all work stations, which leaves room for switching between activities
  - increased throughput per regular shift
  - Lower maximum demand for returned products from the sorting and checking area, as it is divided over more hours
- Less night shifts required, in the model a reduction of 100%
  - A full reduction of extra cost introduced by working during night times
- Lower average WIP without the loss of utilisation, a reduction of 9% on average.
  - Process returned products until 19:00 enables Wehkamp to process more products that came in on that specific day so lower WIP overnight, which results in a smaller waiting time for customers.

There is however one very big negative side to this solution, which is the fact that in order to successfully implement such solution, the workforce has to agree with this change in working times. When you regularly work eight hours a day, from 8:00 to 17:00, going to shorter shifts from 7:00 to 13:00 or 13:00 to 19:00 might be perceived as a quite negative change. While there a no problems legally, such changes could result in an unmotivated workforce. There might be however something to offer the workforce in exchange. Since the forecast performance, as analysed in Section 2.5, did not show large deviations in performance per week performed in advance, Wehkamp must consider to inform workforce, or at least a part, more weeks in advance in turn for working these non-traditional hours. Providing more certainty for their workforce in exchange for these non-traditional working times. Something more advanced Wehkamp should consider is having three shifts. The two short shifts plus the traditional shifts, since there is a lower occupation of stations this is very well possible. Wehkamp could offer those working the short shifts certainty more weeks in advance while informing the part of workforce that works the traditional times like is done currently (Section 2.4). To shortly summarize what is crucial for Wehkamp:

- Introduce “non-traditional” shifts and working times
- Create support among workforce for changes in working times
- Maintain the same forecast performance to inform (a part of) the workforce more weeks in advance

Since the scientific fields that relate to these prerequisites do not share a common ground with those in this research and the solution could be implemented by Wehkamp within minutes ignoring this advice, there is no further description of how to implement the solution. A final note that leads us to the following section is that Wehkamp could consider a dynamical planning policy. In such policy, traditional working times are planned during periods where low amounts of products returns are expected and the two short shift policy can be introduced during busy times.

7.3 Future research

Let us end this report with several interesting topics for further research. Wehkamp is a fast developing and energetic company, a great place to do research. An excellent opportunity to do examine the following topic: Wehkamp has a unique position within the ecommerce market given the fact that Lacent, which handles payments and offers credit to customers, is part of the same holding. This is not common, but offers the possibility to introduce more financially related options for customers. Wehkamp can consider to offer credit or money back to their most loyal customers the moment they return their package. It is required that they indicate what specific products they want to return, but this would be enough to refund the customer before processing the return. Next to the technical implications, it is of course important to weight the benefits of giving these customers their credit or money against the risks, but if there is one company suited to make this call, it is Wehkamp. Such solution would be the ultimate data driven, customer friendly alternative and a great topic to do research about.

Another topic that is interesting for research, which lays a bit closer to the topic of this research is that of risk pooling. Wehkamp actively sorts the different product returns in three possible categories to benefit from more specialized checking personnel per category. As stated the ratio between the different areas do not match the ratio of returned product. Especially electronics checking is subject to strong variability, which is not evened out by the large number of products that fashion checking area handles. A very interesting topic of research would be if Wehkamp benefits from sorting and specialized checking areas, or if it is only decreasing performance and it would be wise to simply unpack and process all products, regardless of their category.

Finally, and most importantly, there is the possibility to examine a mixture of planning policies during the year, as mentioned in the last paragraph of the previous section. Since product types, sales and returned products differ a lot during different seasons and during summer a lot of employees go on a holiday there might be great differences between what is the optimal planning policies for a specific season. This might even increase the benefits of improving the planning of workforce even further.

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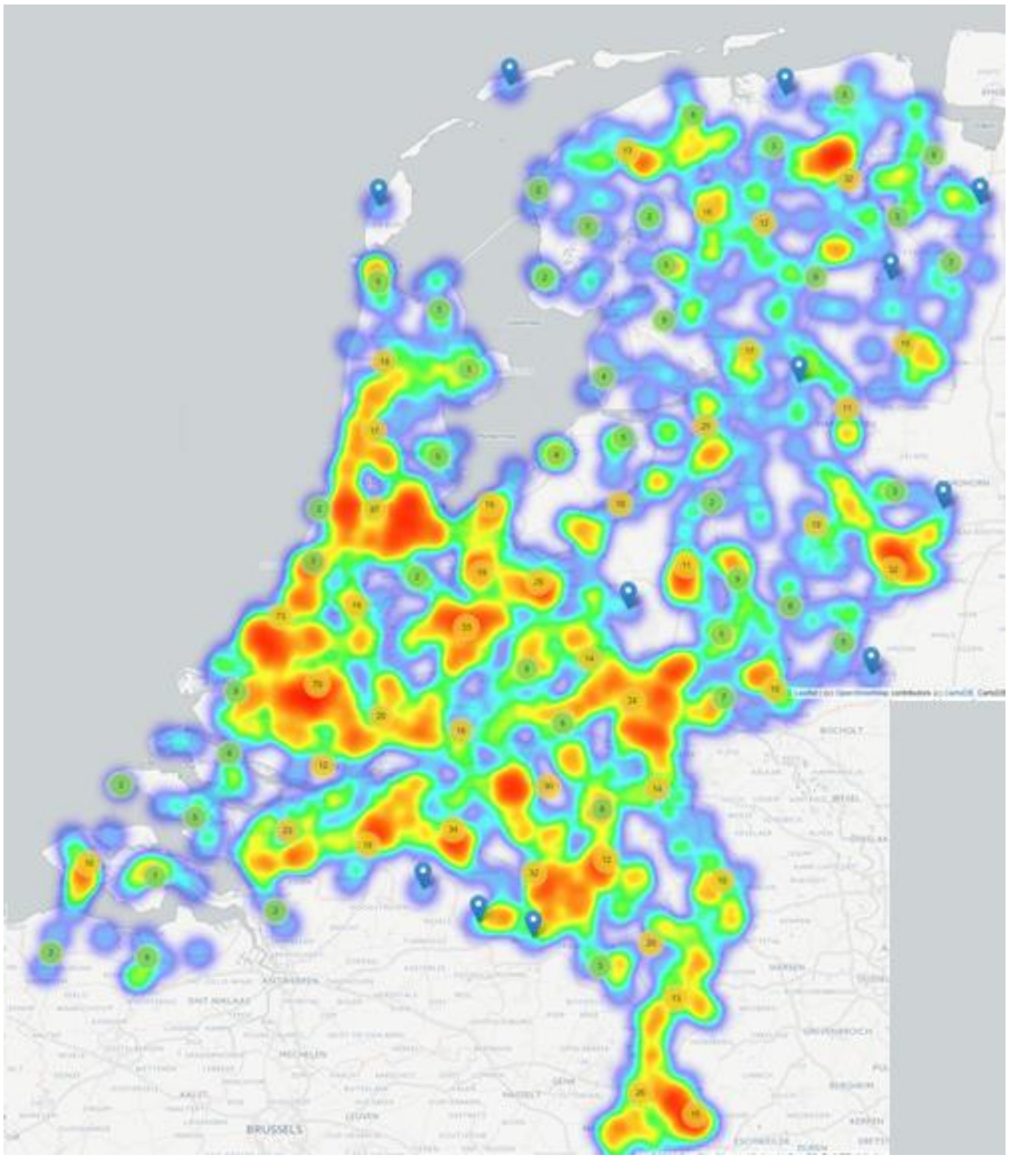
Appendix

A. Customer panel scores

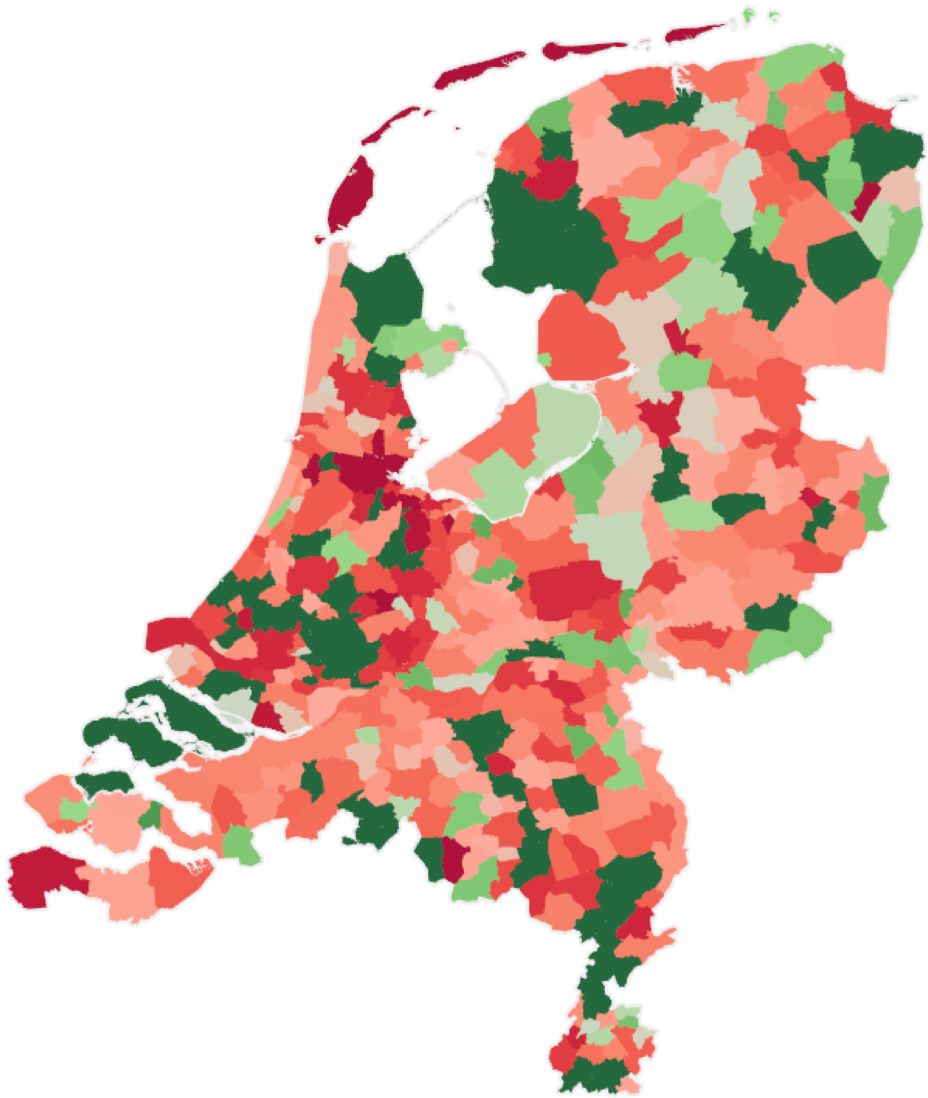
CSAT_Retourneren	CSAT	std	N	Ntot	Penetration
Wehkamp	8,08	1,72	839	1079	78%
Zalando	8,11	1,24	258	368	70%
Coolblue	8,32	1,54	104	384	27%
Bol.com	8,16	1,31	193	465	42%
H&M	7,41	1,72	299	367	81%

First column: CSAT_Retouren	Company name
Second column: CSAT	Customer appreciation returns
Third column: std	Standard deviation of score
Fourth column: N	Total customer responses
Fifth column: Ntot	Total customers asked to respond
Fifth column: penetration	N divided by Ntot

B. DHL service points

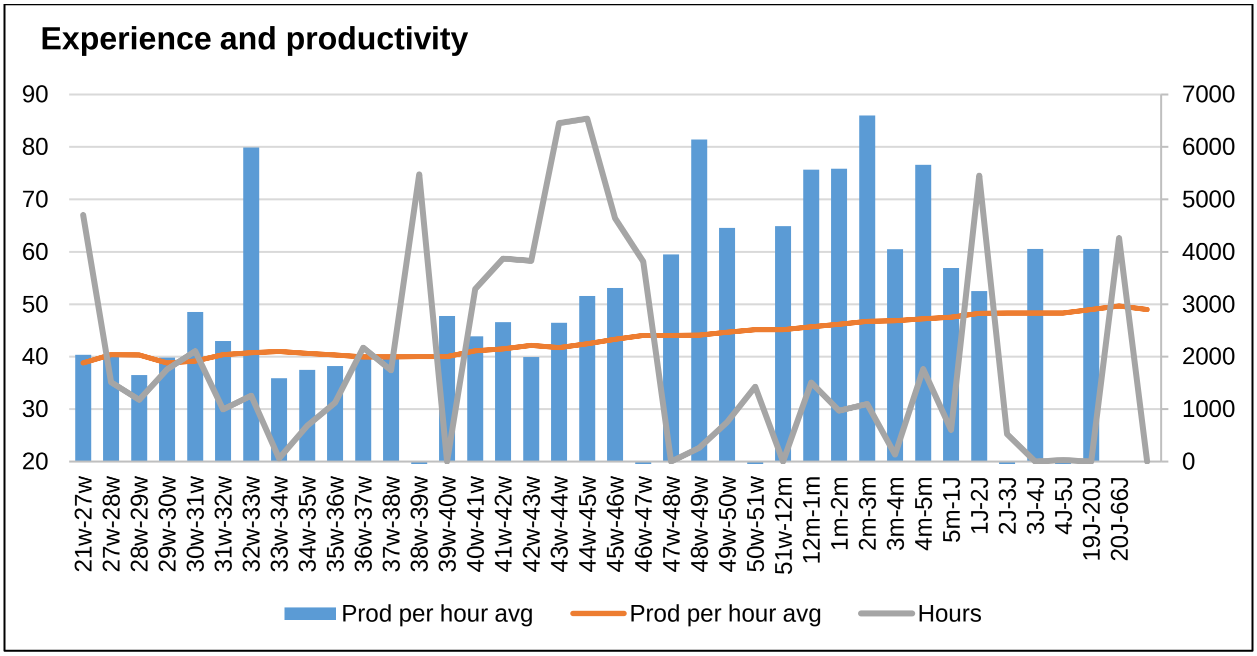


C. Municipality return lag

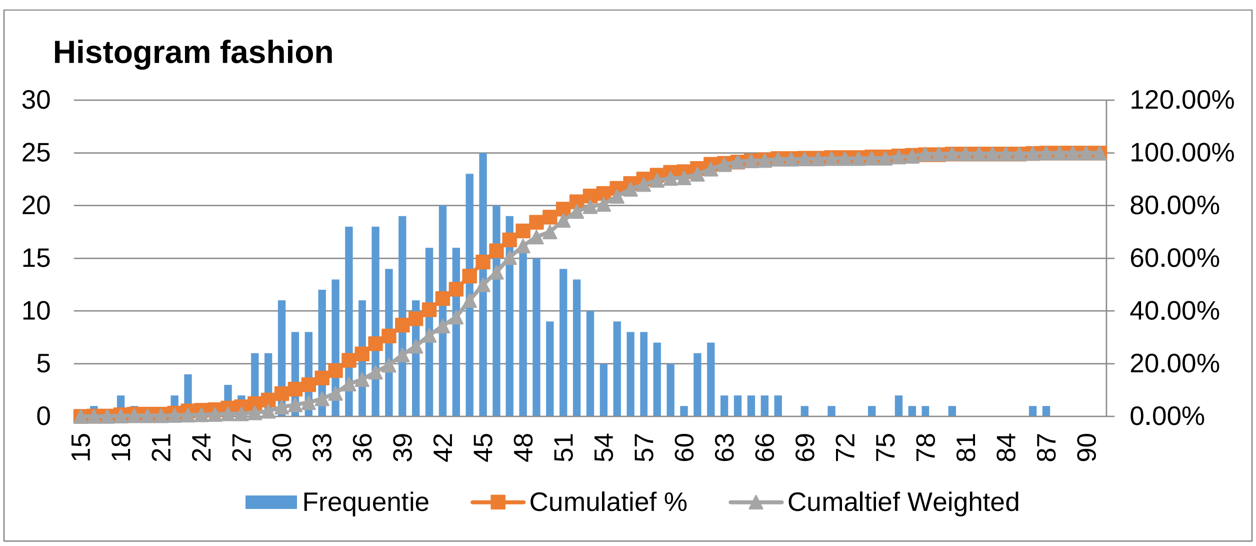


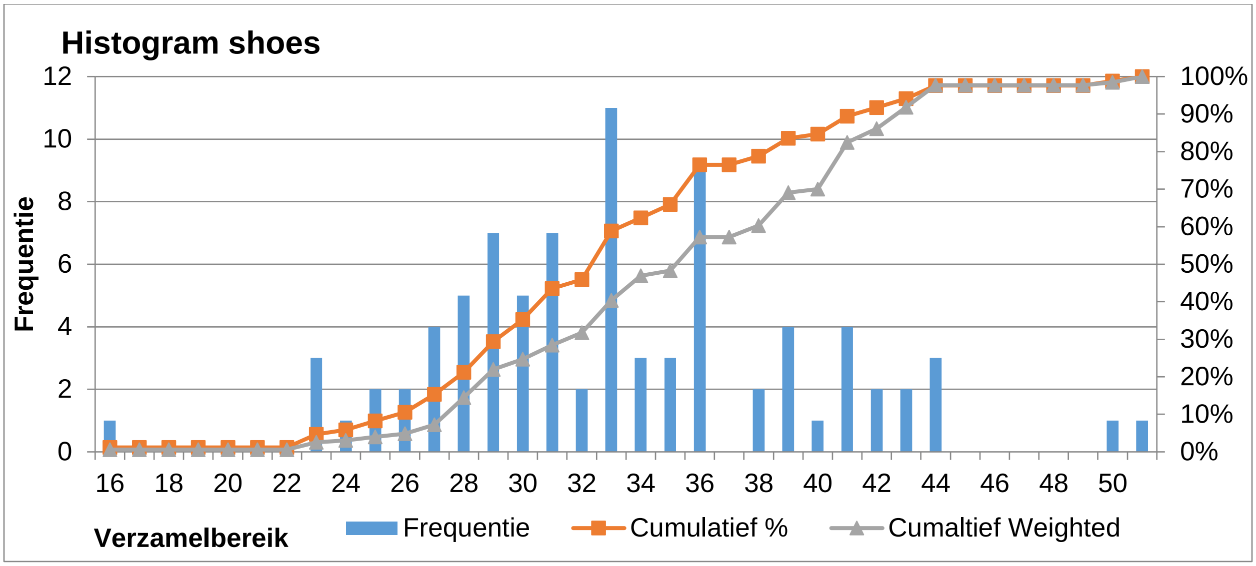
11 days to 13.5 days until a returned product is processed.

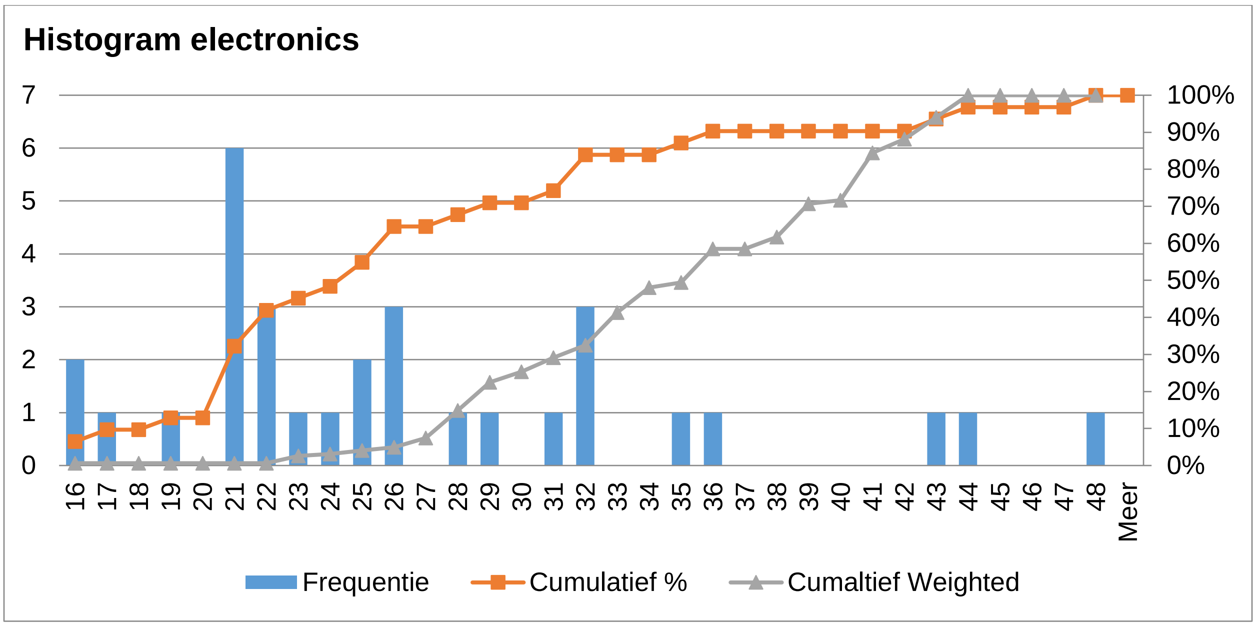
D. Experience analysis



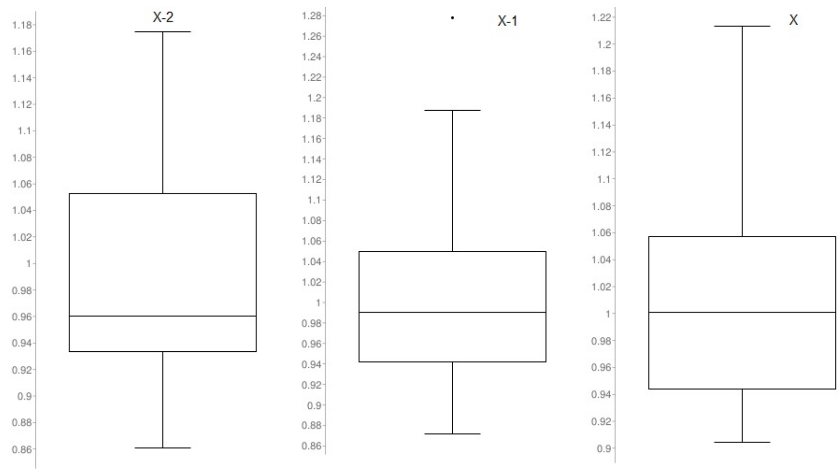
E. Productivity histograms




Histogram shoes
Frequentie
Verzamelbereik
Frequentie
Cumulatief %
Cumaltief Weighted


Histogram electronics
Meer
Frequentie
Cumulatief %
Cumaltief Weighted

F. Forecast performance boxplot



Forecast performance per week made in advance

- Left plot two week in advance
- Middle plot one week in advance
- Right plot forecast of current week (given on Monday)

G. Historical return probability estimation

Analyseperiode:

Vandaag - 365 dagen t/m vandaag - 21 dagen

Berekening verwacht retourpercentage

#	Niveau	Voorwaarde	Ja	Nee	
1	Artikel	Verkocht aantal >= 100?	Ja, Retour / Verkocht	Nee, naar 2.	
2	Artikelgroep + Merk	Verkochtaantal >= 100?	Ja, Retour / Verkocht	Nee, naar niveau 3.	
3	Hoofdartikelgroep + Merk	Verkocht aantal >= 100?	Ja, Retour / Verkocht	Nee, naar niveau 4.	
4	Artikelgroep	Verkocht aantal >= 100?	Ja, Retour / Verkocht	Nee, naar niveau 5.	
5	Hoofdartikelgroep	Verkocht aantal >= 100?	Ja, Retour / Verkocht	Nee, naar niveau 6.	
6	Subcategorie + Merk	Verkocht aantal >= 100?	Ja, Retour / Verkocht	Nee, naar niveau 7.	
7	Subcategorie	Verkocht aantal >= 100?	Ja, Retour / Verkocht	Nee, naar niveau 8.	
8	Categorie + Merk	Verkocht aantal >= 100?	Ja, Retour / Verkocht	Nee, naar niveau 9.	
9	Categorie	Verkocht aantal >= 100?	Ja, Retour / Verkocht	Nee, naar niveau 10.	
10	Hoofdgroep + Merk	Verkocht aantal >= 100?	Ja, Retour / Verkocht	Nee, naar niveau 11.	
11	Hoofdgroep	Verkocht aantal >= 100?	Ja, Retour / Verkocht		
Aanvullend op bovenstaande tabel geldt wanneer een artikel 10 of meer keer besteld is (en minder dan 100) dan geldt de formule in kolom *					
*	Verkocht artikel aantal >= 10 en < 50	(retour [Niveau] / Verkocht [Niveau]) + 0.25 * ((retour Artikel / Verkocht Artikel) - (retour Niveau] / Verkocht [Niveau]))			
	Verkocht artikel aantal >= 50 en < 75	(retour [Niveau] / Verkocht [Niveau]) + 0.50 * ((retour Artikel / Verkocht Artikel) - (retour Niveau] / Verkocht [Niveau]))			
	Verkocht artikel aantal >= 75 en < 100	(retour [Niveau] / Verkocht [Niveau]) + 0.75 * ((retour Artikel / Verkocht Artikel) - (retour Niveau] / Verkocht [Niveau]))			

H. Planning matrix by NUSS

	Product Returns Management	Reprocessing Operations	Remarketing / Reintegration
STRATEGIC PLANNING	**Product and Source Selection:** Fleischmann et al. (2003), Guide and van Wassenhove (2001), Srivastava and Srivastava (2006)	**Recovery Option Selection:** Fleischmann et al. (1997), Kiesmüller et al. (2004)	**Market Selection and Segmentation:** Debo et al. (2004), Debo et al. (2005), Ferguson and Toktay (2006), Ferrer and Swaminathan (2006), Ferrer and Swaminathan (2010), Guide and Li (2010), Webster and Mitra (2007)
	Acquisition Strategy: Agrawal et al. (2012), Aras and Aksen (2008), Guide and van Wassenhove (2001), Guide et al. (2003b), Klausner and Hendrickson (2000), Majumder and Groenevelt (2001), Östlin et al. (2008)	**Recovery Technology Selection:** Debo et al. (2005), Fleischmann et al. (1997), Fleischmann et al. (2001)	
	Collection Strategy: Aras and Aksen (2008), Beullens et al. (2004), Kara et al. (2007), Kiesmüller et al. (2004)	**Eco-Design:** Agrawal et al. (2012), Chung and Wee (2008), Geyer et al. (2007), Tibben-Lembke (2002)	**Remarketing Strategy:** Agrawal et al. (2012), Atasu et al. (2008b), Guide and Li (2010), Oraiopoulus et al. (2012)
	Reverse Network Design: Aras and Aksen (2008), Barros et al. (1998), Cruz-Rivera and Ertel (2009), Fleischmann et al. (1997), Fleischmann et al. (2001), Fleischmann et al. (2004), Gomes Salema et al. (2007), Gomes Salema et al. (2010), Jayaraman et al. (2003), Listeş and Dekker (2005), Min and Ko (2008), Quariguasi Frota Neto et al. (2008), Schultmann et al. (2010), Walther and Spengler (2005)		
TACTICAL PLANNING	**Backflow Forecasting:** Srivastava and Srivastava (2006), Toktay et al. (2000), Toktay et al. (2004)	**Reverse Production Planning :** Dobos (2003), Dobos and Richter (2004), Fleischmann et al. (1997), Gotzel and Inderfurth (2002), Guide (2000), Inderfurth (2004), Inderfurth et al. (2004), Kenné et al. (2012), Mahadevan et al. (2003), Minner and Lindner (2004), Richter and Dobos (2010), van der Laan and Salomon (1997), van der Laan et al. (1999)	**Demand Planning:** Bakal and Akcali (2006), Dobos (2003), Guide et al. (2003b), van der Laan and Salomon (1997)
	Backflow Channeling: Debo et al. (2004), Fleischmann et al. (2003), Jayaraman et al. (2003), Meade and Sarkis (2002), Savaskan and van Wassenhove (2006), Savaskan et al. (2004)	**Inventory Control and Dual Sourcing:** Dobos (2003), Dobos and Richter (2004), Ferguson et al. (2009), Fleischmann and Kuik (2003), Fleischmann and Minner (2010), Fleischmann et al. (2002), Fleischmann et al. (2003), Inderfurth (2004), Mahadevan et al. (2003), Minner (2001), Minner and Lindner (2004), Richter and Dobos (2010), Teunter and van der Laan (2004), Toktay et al. (2000), van der Laan and Salomon (1997), van der Laan et al. (1999), van der Laan et al. (2004)	**Remarketing Pricing / Transfer Pricing:** Atasu et al. (2008b), Bakal and Akcali (2006), Debo et al. (2005), Ferrer and Swaminathan (2006), Ferrer and Swaminathan (2010), Guide et al. (2003b), Liang et al. (2009), Majumder and Groenevelt (2001), Toktay and Wei (2011), Webster and Mitra (2007)
	Acquisition Pricing: Bakal and Akcali (2006), Galbreth and Blackburn (2006), Guide and van Wassenhove (2001), Guide et al. (2003b), Klausner and Hendrickson (2000), Liang et al. (2009)	**Reverse MRP:** Fleischmann et al. (1997), Gotzel and Inderfurth (2002), Inderfurth et al. (2004), Mukhopadhyay and Ma (2009)	**Channeling: –**
OPERATIONAL PLANNING	**Transportation Planning:** Beullens et al. (2004), de Brito and de Koster (2004), Schultmann et al. (2006)	**Sorting and Grading:** Ferguson et al. (2009), Galbreth and Blackburn (2006), Guide et al. (2003a), Teunter and van der Laan (2004)	**Redistribution Planning: –**
	Return Handling and Inspection: de Brito and de Koster (2004), Guide et al. (2003a)	**Reprocessing Scheduling:** Guide (2000), Guide et al. (2003a), Inderfurth et al. (2004)	**Demand Fulfillment: –**

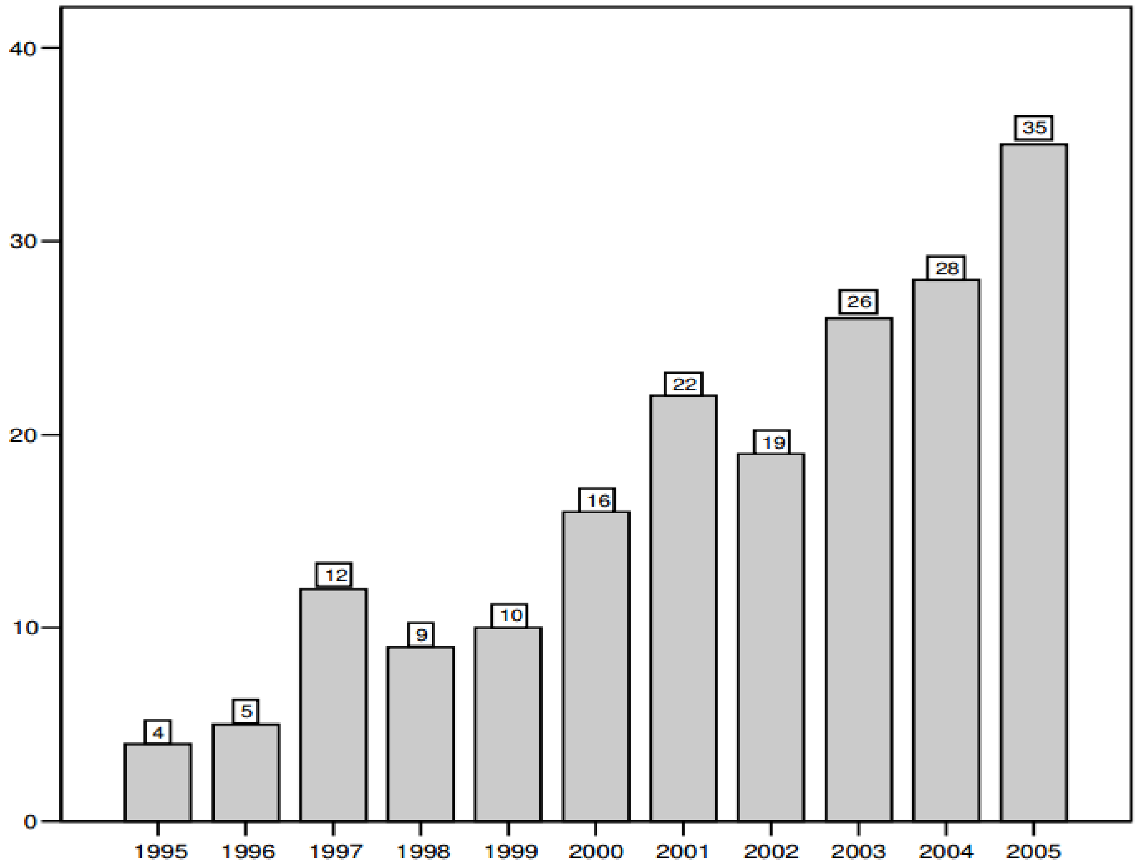
I. Viscious cycle of overtime

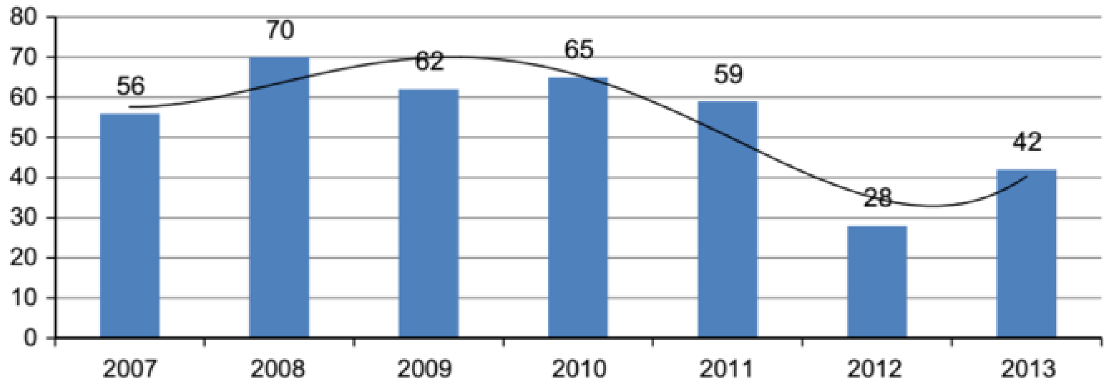
Common type of behaviour is the "overtime vicious cycle," which goes as follows:

1. Plant capacity is computed by taking into consideration detractors such as random outages, recycle, setups, operator unavailability, breaks, and lunches.
2. The master production schedule is filled according to this effective capacity. Release rates are now essentially the same as capacity. 6
3. Sooner or later, due to randomness in job arrivals, in process times, or in both, the bottleneck process starves.
4. More work has gone in than has gone out, so WIP increases.
5. Since the system is at capacity, throughput remains relatively constant. From Little's Law, the increase in WIP is reflected by a nearly proportional increase in cycle times.
6. Jobs become late.
7. Customers begin to complain.
8. After WIP and cycle times have increased enough and customer complaints grow loud enough, management decides to take action.
9. A "one-time" authorization of overtime, adding a shift, subcontracting, rejection of new orders, etc., is allowed.
10. As a consequence of step 9, effective capacity is now significantly greater than the release rate. For instance, if a third shift was added, utilization dropped from 1,00 percent to around 67 percent.
11. WIP level decreases, cycle times go down, and customer service improves. Everyone breaths a sigh of relief, wonders aloud how things got so out of hand, and promises to never let it happen again.
12. Go to step I!

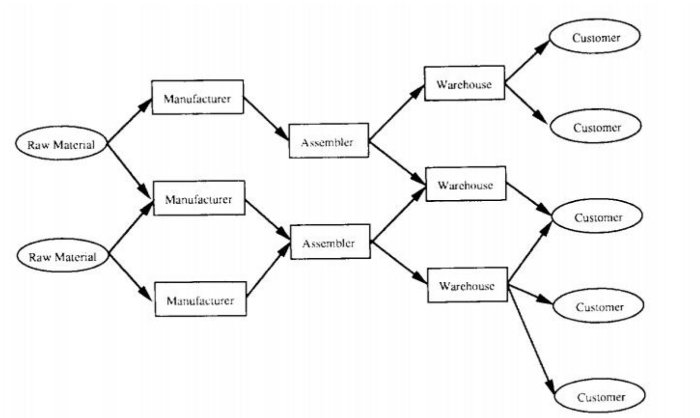
Relationship between CT and utilization

J. Amount of supply chain literature



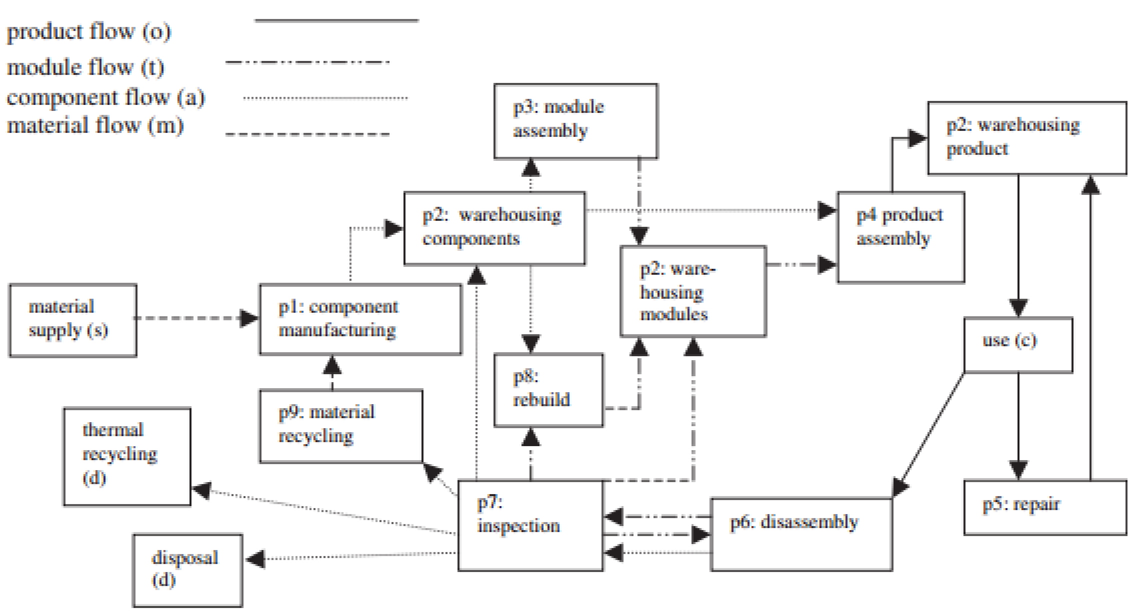


K. Multi actor supply chain



* *Generic supply chain by Thomas, D. J., & Griffin, P. M. (1996). Coordinated supply chain management.European journal of operational research, 94(1), 1-15.*

L. Closed loop supply chain



Krikke, Bloemhof-Ruwaard& Van Wassenhove (2003).
Concurrent product and closed-loop supply chain design with an application to refrigerators.

M. Original steps LAW

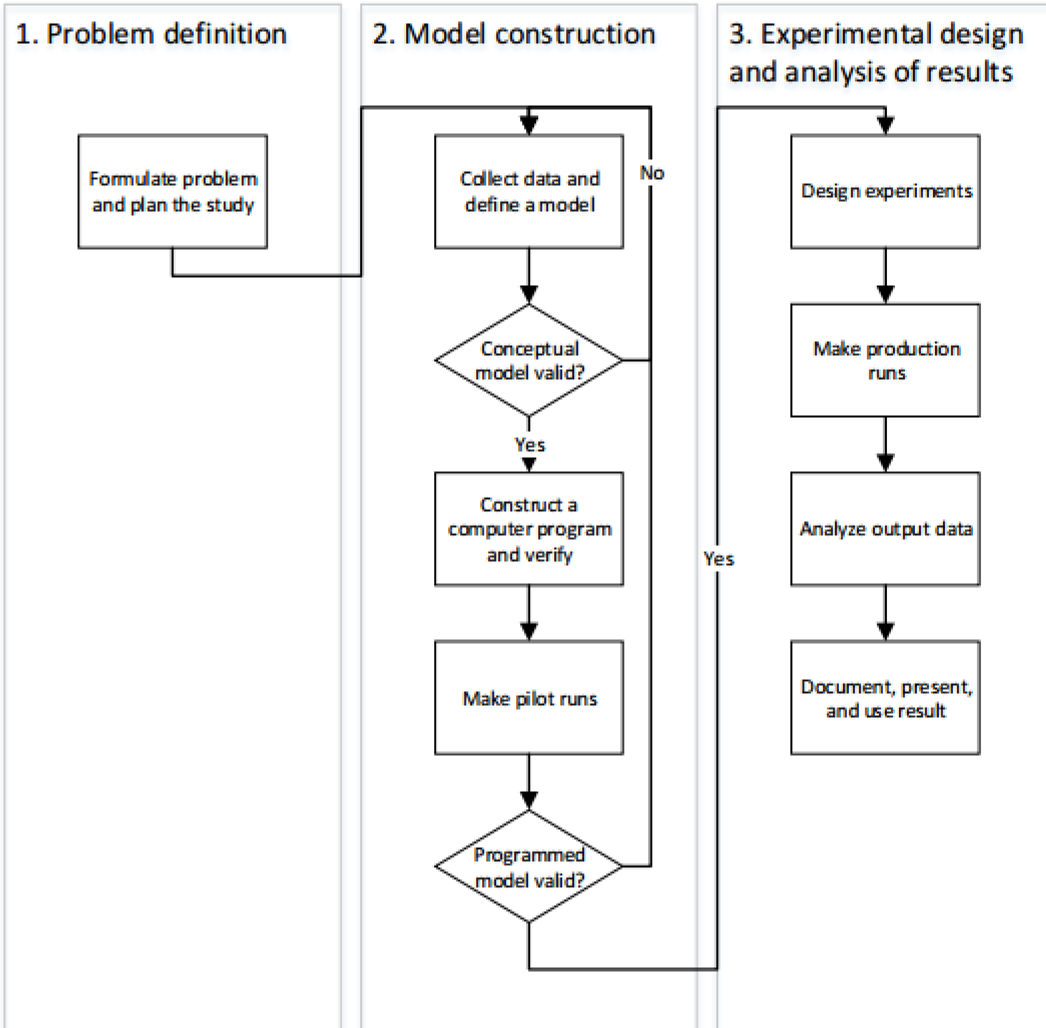


Figure 16 – Steps of a sound simulation study, adopted from (Law & Kelton, 2000)

Step 1: Formulate problem and plan the study

- Identify problem and determine goals
  - Problem identification
  - Determine goals related to the problem
  - Restrictions
  - Further: timing,visualization/interaction, run times
- Choose experimental factors and reports
  - Experimental factors: input
    - Identification: # staff on different stations, working hours, # rooms, # equipment, prioritization rules
    - Ranges
    - Combinations of experimental factors
    - Sensitivity analysis

    - Reports: output
        - Performance indicators: waiting times or length of stay
- Determine scope and level of detail of the model
    - Scope: What has to be modeled
        - Whole company, business unit, department… (boundaries)
    - Level of detail:
        - E.g., incorporate employee sickness, equipment failure?
        - Level of aggregation?
- Collect and analyse the data required
    - Data needed for:
        - Input simulation model
        - Model validation
    - Data categories
        - Available
        - Not available, but collectable
        - Not available and not collectable
- Make a project specification
    - Samenvatting van bovestaand icm. cost estimate en time planning

Step 2: Model Construction

- Collect and analyse the data required
    - Collect all data required
    - Analyse data
    - Fit data
        - Fit data into usable distributions or use historical data
        - Validate assumptions concerning data
- Documentation: Describe model
- Programming: Code model in software
    - Programm
    - document
    - Pilot run
- Verification & Validation: Check model implementation and validate results

Step 3: Experimental design and analysis of results

- Design experiments
- Make production runs
- Analyze output data
- Present results

N. Pseudo code

```
First turn all available station off, for every checking unit.
For i:=1 to 3 loop                                                    loop over all 3 units
    Shift1Planned:=0;                                                 set variable 0
    Shift2Planned:=0;
    TargetArea:=Areas[1,i];                                           set target area i

    For j:=1 to NumberOfStations loop                                 Loop over all stations
        StationActive:=false;                                         Set station inactive
    Next;
Next;

Now determine how much should be planned for today
If PolicyType = 1 then                                                Check PolicyType
    CheckingHoursRequired:=ForecastedReturns/Productivity;
    CheckingStationRequired:=CheckingHoursRequired/ShiftLength;
    Plan(CheckingStationRequired);
End;
```