G. de Haan

Improving and adapting the upstream supply chain of an e-grocer during fast growth

A case study at Boni and Picnic

TU Delft

PIC NIC

Boni

Improving and adapting the upstream supply chain of an e-grocer during fast growth

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By

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1508180

in partial fulfilment of the requirements for the degree of

Master of Science

In Mechanical Engineering

at the Delft University of Technology,

Committee chairman:	Dr. ir. R. R. Negenborn
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This thesis is confidential and cannot be made public until June 18, 2022.

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Specialization:	Transport Engineering and Logistics
Report number:	2017.TEL.8147
Title:	**Improving and adapting the upstream supply chain of an e-grocer during fast growth**
Author:	G. de Haan

Title (in Dutch) Verbetering en aanpassing van de opwaardse bevoorradingsketen tijdens snelle groei van een online supermarkt

Assignment:	Masters thesis
Confidential:	yes (until June 18th, 2022)
Initiator (university):	ir. Mark B. Duinkerken
Initiator (company):	ir. Frank B. Gorte
Supervisor:	dr. Rudy R. Negenborn
Date:	June 26th 2017

Abstract

Since online shopping was invented in 1979 there has been a major shift in the way people shop. More than 40% of the clothing and footwear and more than 35% of the home electronics are bought online in the Netherlands. Grocery shopping in the e-commerce market. This, and the fact that over 92% of the Dutch population has access to internet implies that there is a huge market gat for e-grocers. Predictions are made that the market share of e-grocers will grow from the current 2% to at least 5% in 2025.

At the moment the e-grocery market is dominated by traditional supermarket who also delivery online shopping as a service to the client, the so called click-and-mortar concept. Currently 55% percent of the market is owned by AH followed but not yet threatened by other supermarkets like Jumbo and Spar. In August 2015 however an online-only supermarket, a so called pure player, opened named Picnic. Because of the fact that they are a pure player gives them confidence that they can compete in this market. Since the opening of Picnic has grown to just above 9000 orders per week in January 2017 when the maximum capacity of the first fulfilment centre was reached. The aim of Picnic is to continue a with a growth of around 5% per week which comes with a lot of challenges, starting with the fact that a new fulfilment centre had to be opened in February 2017. The ambition of Picnic is to deliver high service to the customer with lowest price guarantee which means the processes at the fulfilment centres should run as efficient and as smooth as possible.

In literature there is a lot to be found about supply chains in general and more specific about e-grocer supply chains. It has become clear that there are several pit falls for e-grocers to recon with. First of all there last-mile delivery is relatively very expensive. Furthermore, over investment in automation, weak negotiation power, customer acquisition and low ordering frequency are reasons why online grocers have failed in the past. Unfortunately, there is little known about the effect of fast growth on the supply chain, let alone the effect on the supply chain of an e-grocer.

In order to give a well-founded advice in how to improve the upstream supply chain of Picnic while adapting to the fast predicted growth, the following research question is defined:

How can the additional costs due to disturbances of an upstream supply chain of an e-grocer be reduced while accommodating expected rapid future growth?

To answer this question a research methodology is developed consisting out of five steps: literature research, analysis of the current process, design (synthesis of the two previous steps) , assessment and conclusions and recommendations.

From the literature research and the analysis it can be concluded that the process in the FC consist out of seven steps: the inbound, receiving, replenishing, picking, storing, consolidating and shipping. In a happy flow all of these processes work without disturbances ergo, all the items are delivered at the FC and are on the shelves as expected. This would mean all the order lines would be shipped completely. When something goes wrong extra costs are involved and it has been researched what can be done to reduce these additional costs. It has also been found that the rush order process is highly inefficient and store picking is relatively expensive.

It has been found that there are eight root causes which lead to unexpected shortages in the FC: un-orderable products, shortage at supplier, delivery failure, receiving's mistake, unexpected clearance, non-fifo picking, quality buffer and stock mismatch. These unexpected shortages have either no consequence (other than a stock adjustment) or a rush order, store pick, substitute or a cancelled order line, of which respectively no consequence is the most desirable and cancelled order line is the least desirable effect. After an extensive data analysis it was found that delivery failures had the most negative impact on the processes in the FC, followed by stock mismatches and non fifo picking. Also, the rush order process appeared to be highly inefficient since it is designed for picking much larger amount of items and the store pick procedure is relatively expensive.

The results from the analysis phase have led the creation of five design alternatives: reduction of delivery failures (RDF), improvement of insight in the FC (IWI), direct delivery (DD), different store pick procedure (DSPP) and an improvement of the rush order process (IRP). Here the reduction of delivery failures is chosen because of the clear advantages for both the supplier and the e-grocer. Improvement of the insight in the FC is wanted since the consequences of an stock mismatch are relatively often a substitute or a cancelled order line which are highly unwanted. Since the performance of the supplier is so essential for the e-grocer,

the alternative of (partly) direct delivery instead of using the DC of Boni as a buffer, is also taken into account. Improving the rush order processes and changing the store pick procedure are chosen as alternatives since both processes were labelled as inefficient so there is room for improvement. The different alternatives are shown in Table 1.

Table 1: Summary different alternatives

Design alternative	Effect	Investment
RDF	Reduction of delivery failures	Team of experts on improvement
IWI	Improvement of warehouse insight	Extra employee to count articles on the shelves
DD	Plausible worse performance of direct delivery	Unavoidable due to fast growth, no investment costs
DSPP	Store pick less articles	Judgement call supervisor, no investment costs
IRP	More efficient rush order picking	Extra work to merge receipts for pickers

These alternatives are subsequently assessed using a Monte Carlo simulation with as input the root cause distribution of the different alternatives. This input resulted in a distribution of effects which were subsequently the input for an extra costs calculator. These extra costs per day (and per order) were used as a key performance indicator to compare the alternatives. Furthermore as an input the predicted growth scenario 5% per week was chosen. The results can be seen in Figure 1 and Figure 2.

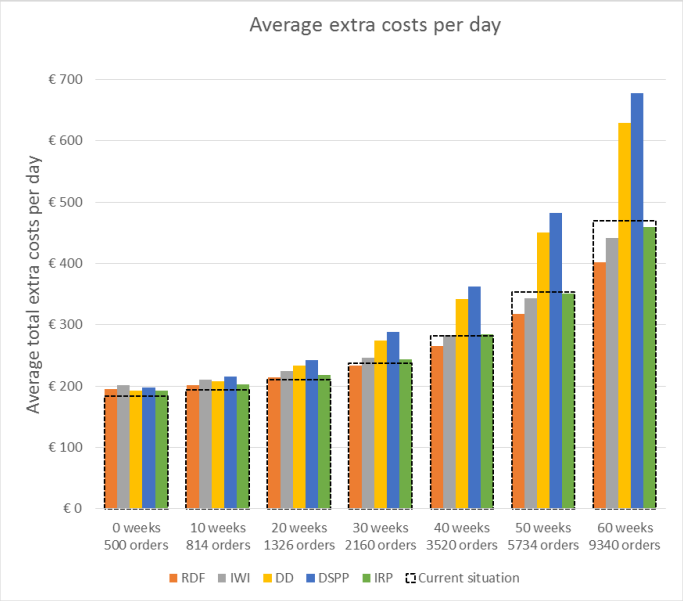

Figure 1: Average extra costs per day of the different alternatives

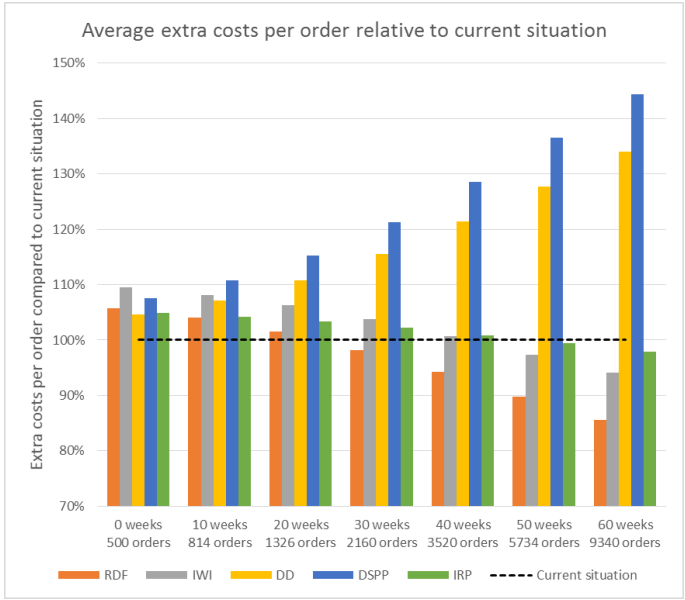

Figure 2: Average extra costs per order of different alternatives

First of all it can be seen in both figures that all alternatives initially lead to more extra costs. This is due to investments needed to enable the different alternatives. In Figure 1 the influence of the performance of the supplier can be clearly seen. A reduction of delivery failures leads ultimately to relatively lower costs in contradiction to the worse performance of direct delivery. Changing the store pick procedure results in extra substitutes and cancelled order lines which that leads to extra costs as shown in Figure 1. The influence of improvement of insight in the FC is better shown in Figure 2 where at low order amounts the extra costs to enable the extra insight outweigh the advantages. At higher order amounts above 3500, extra costs are saved compared to the current situation. The same goes for improvement of the rush order process.

It can be concluded from the research that the reliability of the deliveries are essential for the performance of the FC. Therefore it is recommended that both the supplier (Boni) as Picnic look for solutions in reducing the amount of delivery failures. Furthermore, when direct delivery is necessary because of the limited capacity of Boni, clear performance deals should be made with the suppliers which ought to be checked, automatically if possible. Here the delivery performance of Boni can be used as benchmark.

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Abbreviations

AOT	Ahead Of Time
BBD	Best Before Date
CU	Consumers Unit
DC	Distribution Center
DD	Direct Delivery
DPF	Dispatch Frame
DSA	Delft System Approach
DSPP	Different Store Pick Procedure
e-FC	electronic (commerce) fulfilment center
FC	Fulfilment Center
FiFo	First in First out
IDEF-0	Integration Definition for Function Modelling
IRP	Improve Rush order Process
IWI	Improve Warehouse Insight
JIT	Just In Time
LU	Logistic Unit
PC	Picking Cart
PN	Picnic
PIM	Product Information Management
POM	Purchase Order Management
PO	Purchase Order
PTA	Peak to Average
PVF	Potatoes Vegetables Fruit
RC	Roll Container
RDF	Reduce Delivery Failures
SCM	Supply Chain Management
SKU	Stock Keeping Unit
TU	Trading Unit
UoM	Unit of Measure
WoI	Waiting on Inventory
WMS	Warehouse Management System
XD	Cross Docking

Definitions

Ambient temperature zone	A fixed temperature zone for products that need to be kept in an ambient environment
Brick and mortar	The physical presence of an organization or business in a building or other structure
Chilled temperature zone	A fixed temperature zone for products that need to be kept in a colder environment
Consumer Unit	A single piece unit which can be bought by the customer
Corax	A WMS at Picnic
E-grocer	Grocer which sells products online directly to the customer
E-worker	Typical Picnic van that is used to make the deliveries at the clients
Fulfilment center	Distribution center where items are collected, stored and prepared for the customer
Locus	A WMS at Boni
Order completeness	Factor that indicates in how far the order includes all items ordered by the customer
Pick cart	A moveable storage unit for pickers during picking rounds (consists out of 12 totes)
Tote	A box where the products of the client are put into, consists out of three bags
Timeliness	Factor which indicates on-time readiness for shipment
Trading Unit	Unit containing one or more CUs which can be bought from suppliers

1. Introduction

Since online shopping is invented in 1979 by Micheal Aldrich [1] there has been a shift in the way customers shop. Now more and more people can access the world wide web (currently 92% of the Dutch population [2]) online shopping seems to be the future. Especially in the last few years there has been a dramatic increase in the online sales where companies have mainly focussed on slow moving, non-perishable goods. Traditional supermarkets like Albert Hein (since 2012) and Jumbo (since 2014) try to profit of this trend by offering online shopping as well. Although this is a major change in the way people do their grocery shopping the main focus of these supermarkets are still their old-school supermarkets. This is one of the reasons why the total market share of online grocery shopping is still only 1.1% in the Netherlands [3] of which more than 50% is in the hands of AH. The market share of online grocery shopping would grow up to 5% in 2025 if the growth continues at the current rate. This growth could however go faster if more competitors enter the market like Picnic or AmazoneFresh, according to 'het financieele dagblad' [3]. This new way of grocery retailing comes with other logistics, requirements and challenges. In this report the challenges in the supply chain with the expected fast growth of Picnic are discussed and a proposition is done on how this could be best handled.

1.1. Picnic

Picnic is the first 100% online grocery store in the Netherlands and is founded in August 2015. The aim of Picnic is to have zero emissions and waste reduction and still be competitive compared to conservative grocery shops and other online grocery shops. This is done by not only low pricing of the products but also be offering a delivery free of charge. This means that there is a huge challenge in, among others, improving the distribution process to reduce supply chain costs in order to continue to compete with other competitors. Picnic is now conveniently located in Nijkerk next to a distribution center (DC) of Boni (a traditional supermarket chain) and Picnic has a deal so Picnic has a priority position. The reason Picnic needs to make a deal with a company like Boni is because of its connection with the SuperUnie which is able to purchase goods for low prices because of high quantity orders. Picnic is currently active in Almere, Amersfoort, Leusden, Soest, Maarssen and Utrecht. Picnic grows rapidly and has the ambition to expand to other cities as well.

1.2. Boni

Boni is a supermarket chain which is founded in 1972 by Klaassen with its headquarters and distribution centre (DC) in Nijkerk. At the moment the supermarket chain consists out of 42 branches. These branches are generally located in the middle of the Netherlands with a few exceptions. Boni is one of the 13 members of the purchasing organization Superunie. Superunie arranges deals with a lot of different suppliers of these supermarkets in order to give them a stronger market position in comparison to when they would purchase individually. The name Boni comes from Latin which can be translated to 'bonus' or 'of the good'. The main focus of Boni is therefore offering food at a low price with extra attention to the quality of fresh products.

1.3. Problem statement

In the past a large amount of online grocery stores have failed due to various reasons [4]. Although they showed high potential with rapid growth figures, they made mistakes like too early automatization or had a weak purchasing position. Picnic thinks it has learned from these other online grocery stores and expects to be able to accompany the rapid growth along with matching company strategies. Because of the rapid growth of Picnic its impact on the DC of Boni is growing along with it. In order for Picnic and Boni to keep being competitive to other (online) supermarkets it is important that the supply chain is continuously improved during this rapid growth of Picnic. Currently (October 2016) the first fulfilment center (FC0) of Picnic has outgrown the biggest supermarket of Boni has a capacity which is even 50% bigger. Furthermore Picnic is opened a new FC (FC1) which is supposed end up being 5 times as big as the first FC (FC0), so Picnic can supply the demand of the customers. This means that the current supply chain to Picnic also has to undergo major changes in order to keep working efficient.

Besides the fact that maintaining or improving a supply chain during fast growth Picnic (as any other online grocer) has another problem. Their order reliability has to be higher than a brick and mortar supermarket. The reason for this is that when a client is at a supermarket and something is unavailable, the client is able to choose a replacing product there and then. This is not possible for an online supermarket, once a customer has ordered a product it is supposed to be delivered. For this reason clients are only able to order products that are in the Picnic inventory or are orderable at the supplier by Purchase Order Management (POM). Unfortunately from this point forward many things can still go wrong. In order to tackle the problems at the FC insight is needed in the root causes of the occurring problems and the way these problems are handled.

1.4. Research goal

The aim of this assignment is to research how an upstream supply chain of an online supermarket can improve its reliability and keep working efficient during fast growth. This then has to result in giving Boni and Picnic an advise in how they should adjust the supply chain from Boni to Picnic in the future. After this is done more generic conclusions, about maintaining and improving the upstream supply chain during fast growth, should be drawn.

1.5. Research questions

The research goal is met by answering the following research question and its subsequent sub-questions.

How can the additional costs due to disturbances of an upstream supply chain of an e-grocer be reduced while accommodating expected rapid future growth?

This research question can be divided into several sub questions:

- Literature: what is already known about the supply chain of online supermarkets?
  - What is known about online supermarkets?
  - What is known about (upstream) supply chain management?
  - How can supply chain adapt during fast growth?
  - What key performance indicators exist in literature?
- Analysis: how do the current processes look like at Picnic?
  - What are the processes in the FC of Picnic and how are these related?
  - What are the key performance indicators at the FC of Picnic?
  - What are root causes of unexpected shortages in the warehouse and how are these related to its effects?
- Design: How can possible design alternatives be constructed and evaluated?
  - How can the supply chain costs be calculated?
  - Which design alternatives are feasible?
  - What variables are linked to the disturbances in the supply chain?
  - How are these variables related to each other?
- Assessment: How do the alternatives perform compared to the current situation and each other?
  - Is the experiment applicable to the processes at Boni and Picnic?
  - How do different design alternatives influence the KPIs of the upstream supply chain?
  - What conclusions can be drawn from the model?

1.6. Research scope

This research focusses on the upstream supply chain of Picnic. More specifically, the research scope stretches over the delivery of suppliers at the FC of Picnic until the order lines are ready to be shipped from the FC to the different hubs, see Figure 3. This is done because there are two clear disconnection points at the inbound and outbound of the FCs of Picnic. As can be seen, the vast majority

of the products that are available at Picnic is ordered via Boni. The reason for this, in short, is that by purchasing goods via Boni the purchase price is a much lower.

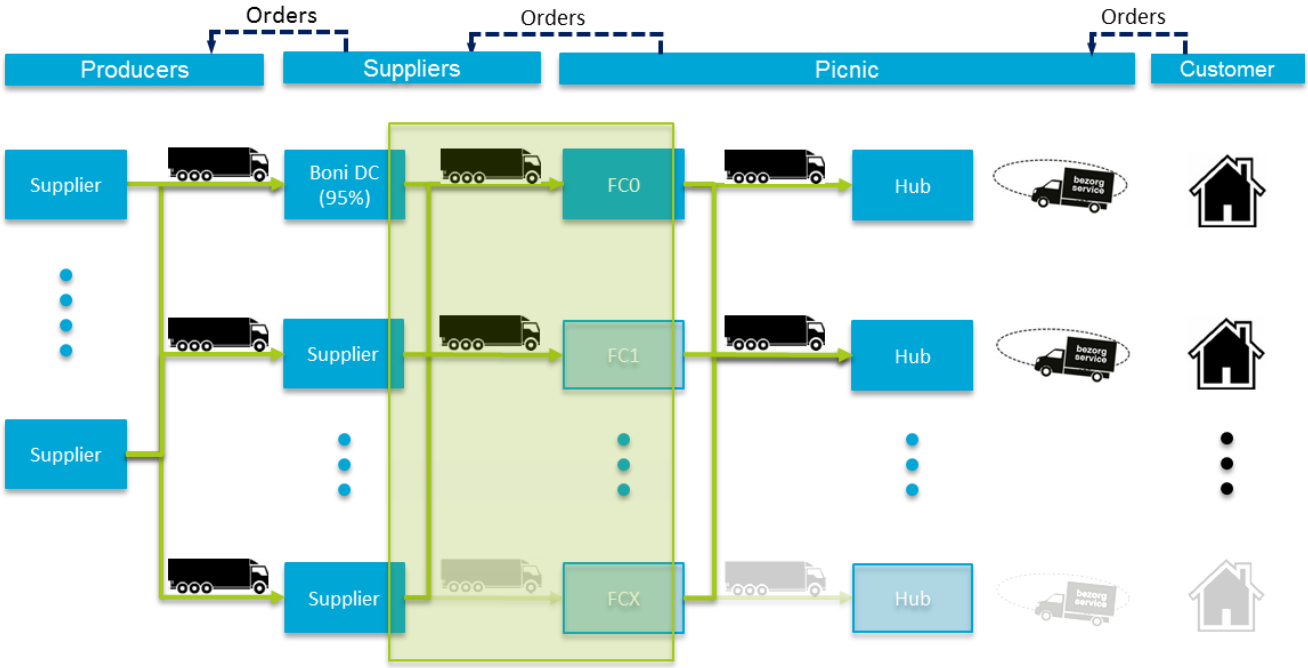


Figure 3: Schematic representation of the research scope

Furthermore since there are a lot of different suppliers and products the scope is narrowed to fresh products. The reason for this is that the quality of the fresh products highly depend on the efficiency of the supply chain. Therefore, a good organized supply chain for fresh products is very important for both Boni as Picnic. Another reason is that for products with an high best before data (BBD) often are delivered by deliverers where Boni has sophisticated deals with which makes it difficult make a decent framework. In Figure 3 the research scope is shown schematically. As can be seen the orders from the customers to Picnic and the orders from Picnic to Boni are not within the scope of the research. These are considered as a given. Once these orders are known the desired input and output of the FC is known which means that an analysis of the problems in the FC can be done.

1.7. Methodology

In order to give a well-founded advice a methodology is developed as can be seen in Figure 4. In the exploration phase the focus is mainly in the literature research. Here the available literature will be summarized and with that, the knowledge gap of which is little to nothing known. Then in the analysis a description will be given about the current situation at Boni and Picnic and the connection with the found literature. The analysis is done by mapping the flows important flows of an upstream supply chain. This can already result in some quick solves in the current supply chain from Boni to Picnic. Furthermore mapping this supply chain is needed to give an advise in how the supply chain to a new Picnic fulfilment center (FC1) should look like. In the analysis the daily processes at Boni as well as at Picnic are also explained. The analysis phase end with a root cause analysis of the unexpected shortages in the FC and the effect these root causes have. In the design phase a simulation model is proposed which can simulate the results from the root cause analysis. Then the some feasible future alternatives can be tested is this simulation. In the last phase the conclusions and recommendations are given.

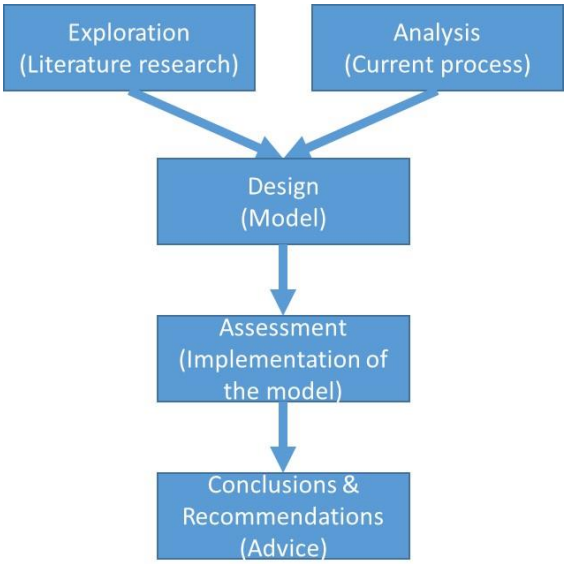


Figure 4: Methodology of the report

1.8. Document Structure

This report starts with a brief introduction about the companies Picnic and Boni at which a case study has been done, after which the problem statement, research goal, research scope and the methodology are explained. In the next chapter the available literature about online supermarkets, supply chain management and improvement strategies is discussed. In the chapter 'Analysis' the current processes at online supermarkets and their suppliers is explained. This eventually resulted in a design which can give inside into the influence of root causes of inventory problems at an online supermarket and its effects. Out of the analysis different alternatives arise which could solve problems at the fulfilment centre (FC). These alternatives are put in a simulation and are assessed in chapter 5 in order to see what the effects are. In 'Conclusions and Recommendations' an advise is given to Boni and Picnic along with any recommendations for future research.

2. Literature

In this chapter the available literature about online grocery shopping and supply chain management (SCM) is discussed. First a short introduction is given about the history and the current situation of the online supermarket along with an introduction of SCM. Subsequently some improvement strategies of supply chains are explained along with key performance indicators (KPIs) to measure these improvements. Furthermore a general overview of the processes in online shopping are given.

2.1. Supply chain management

In this section a part of the available literature about supply chain management (SCM) is discussed. SCM is the synchronization of a firm's processes with those of its suppliers and customers to match the flow of materials, services and information with demand. There is a lot known about SCM and there is a lot written about it therefore this is not nearly complete but merely and introduction to it. E-commerce on the other hand is relatively new which makes it, also from a supply chain perspective, a less researched area. Last but not least the literature about SCM for fast growing organizations is been discussed.

2.1.1. The supply chain

According to the book "Operations management: processes and supply chains" [5], a supply chain is the interrelated series of processes within a firm and across different firms that produces a service or product to the satisfaction of customers. Or even more specifically, it is a network of service, material, monetary and information flows that link a firm's customer relationship, order fulfilment and supplier relationship processes to those of its suppliers and customers. A difference can be made between supply chains for services and manufacturing. Supply chain design for a service provider is driven by the need to provide support for the essential elements of the various services it delivers. On the other hand manufacturing supply chains have the purpose to control inventory by managing the flow of materials. This often means that the supply chain of a manufacturer looks a lot more complicated than that of a service supply chain where the supplier are in more direct contact with the service provider. Online grocery shopping can be seen as a service provider.

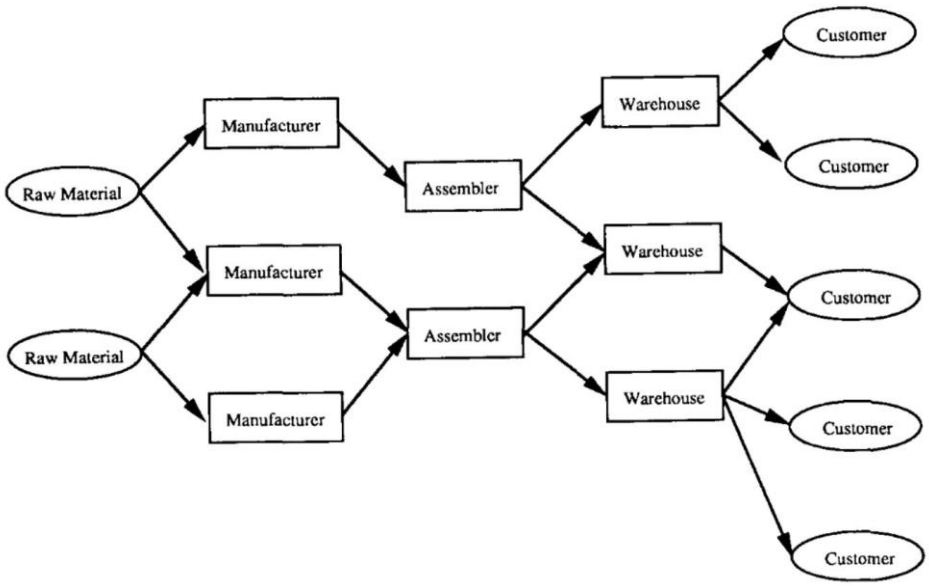


Figure 5: Schematic of a generic supply chain

The supply chain can be divided into three stages: procurement, production and distribution. These stages are often not managed separately which led to big buffers in the form of warehouses. Historically, organizations tended to focus on making the individual stages more efficient. This was clear in a sense that every stage consisted out of assembly, storage and distribution but, thanks to for

example globalization, also not very cost effective. It became more and more important that these different stages where managed in such a way that there was better coordination between the stages, hence supply chain management. In *Thomas et al* [6] a review is made about the existing coordination between the different stages in a supply chain, see Figure 5. Although SCM was relatively new at the time (1996) the idea of coordinated planning was already pretty old. In the 60's the multi-echelon inventory and distribution systems started but they didn't focus on coordinated production and distribution scheduling which needed a lot of up to date data. Obviously is this day and age these data can be made available. Although there isn't a general accepted definition of SCM *Garret* [7] summarises SCM as follows:

- Integrating and managing the sourcing, flow and control of materials
- SCM covers the flow of materials to suppliers through to customers
- There are potentially many suppliers and customers
- Synchronising of materials received, processed and despatched to customers
- Simultaneously achieving good levels of customer service and low costs for the company

This can all be divided into upstream and downstream which means: the flow of material into the organization (upstream) and the flow of materials from the organization to the customers (downstream).

2.1.2. Inventory

One of the most important parts of the supply chain is the inventory. Although the performance of a number of suppliers determines the services to a firm and on the other hand the performance of the firm determines the service to the customer, the flow of material determines the level of inventory. The level of inventory influences the entire company needs to be closely monitored at all times. There are several reasons to keep the inventory level as low as possible but this can have some downsides as well. Therefore it is important to know which reasons one can have to lower the level and which reason to raise the level of inventory.

Reasons for small inventory

The main reason for keeping the inventory at a low level is that the inventory represents an investment. One of the reason for a small inventory is the cost of capital. The cost of capital refers to the opportunity cost of making a specific investment. It is the rate of return that could have been earned by putting the same money into a different investment with equal risk. For this reason when an investment is done the company wants to make profit out of the product as soon as possible. Another reason is storage and handling costs. Inventory takes up space and it needs to be moved from time to time. The building a company rents costs money and therefore also the space in it. Furthermore movements takes up man hours and sometimes machinery and costs therefore money. The last main reason for low inventory levels are the taxes, insurance and shrinkage. The costs of taxes and insurance are higher when the inventory levels are high at the end of the year. Shrinkage can be loss of inventory in several ways, it can be stolen by employees or customers, it can lose its value due to model changes, engineering modifications or unexpected low demand and lastly the risk of damaging the goods raises when the products are in the inventory for a longer time.

Reasons for large inventory

One of the most important reasons is customer satisfaction. When the inventory is too low the change of a stock out is higher. This means that some of the clients will have to be disappointed which means that these clients might look for their service elsewhere. For this reason many companies give discounts when a backorder is needed but this is obviously not preferable. Another reason to keep inventory at a higher level is that sometimes the ordering costs are a lot lower when the ordering amount is higher. A supplier rather delivers a full truck than a half full so it gives discounts for higher quantities. This can outweigh the disadvantage of a high inventory level. This also goes for the outbound where a full truck is more efficient so higher inventory levels are accepted. Sometimes a new item is introduced which involves set up costs. These set up costs are unrelated to order size which creates pressure to make or order a large supply of items. Labour and equipment utilization is very important since it is value adding to the product. With a large inventory the chance of employees or equipment standing still is a lot lower which would otherwise be a lot of unnecessary costs.

2.1.3. Internet driven supply chain

In the paper from *Hesse* [8], the implications of e-commerce on the conventional way of freight transport and logistics are discussed. The general thought at the time (2002) was that electronic transfer of information would lead to more efficient transport operations by cutting out unnecessary transactions and avoiding redundant traffic flows. Thanks to the electronic exchange the logistics market would be transparent and allow for optimal organisation and allocation of transport services. But the real situation seems to be much more complicated than that. One of the main differences is that internet driven purchases have the downside of having to deliver the goods directly to the customer. This so called last mile delivery is relatively very expensive. On the other hand costs can be saved because of the reduced number of members in the supply chain as can be seen in Figure 6. A big difference in the supply chain though is that for e-commerce the picking and home deliveries is a (extra) part of the supply chain.

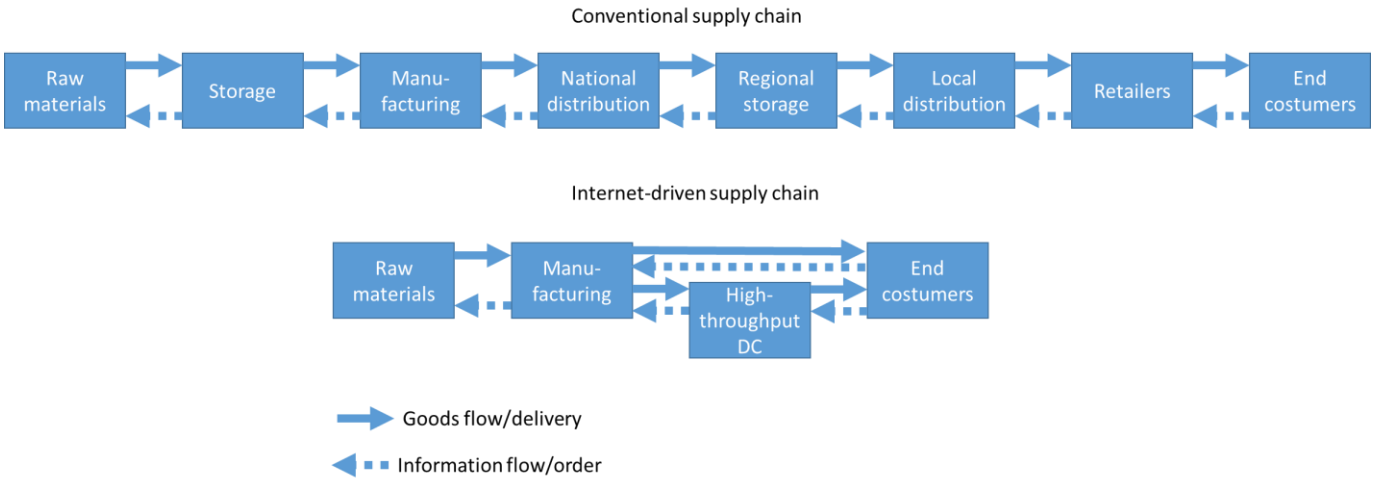


Figure 6: Conventional and internet driven supply chain

2.1.4. E-grocery supply chain

The upstream supply chain of e-grocers does not defer much from conventional upstream supply chains in the grocery retailing market as described in section 2.1.1. On the other hand the downstream supply chain is very different. *Theirry Vanelslander et al* [9] has given a comparison between commonly used e-commerce supply chains for fast moving goods. The most used supply chains are: pure player – van delivery (Figure 7), pure player – parcel delivery (Figure 8) and click and mortar – van delivery (Figure 9). Here pure players are retailers that are only active in the online segment. For the first type of supply chain, pure player – van delivery, the picking takes place in a specially designed DC where after the delivery is done by vans which drives to the 'shoppers'. Pure player – parcel delivery is a little bit different since there is an extra hub in play. This extra hub can be an existing parcel deliverer like UPS which makes the last mile delivery. The advantage is that the density of the customer of such a third party is higher which makes the last mile delivery relatively cheaper. The click and mortar – van delivery is increasing in popularity since many existing retailers also want to profit from the online market. The idea is simple: somebody orders something online and a picker goes into the shop to pick the items after which a van makes a round with all the orders. This process of picking is done between the normal customers in the supermarket. Obviously these are not the only ways an online grocery can work, but these (or a combination of them) are the most common.

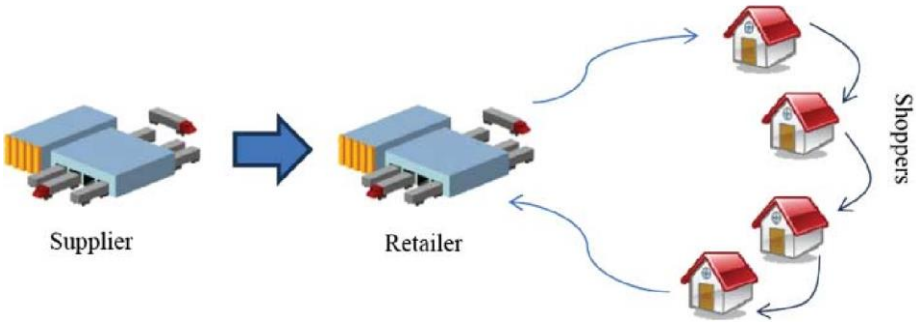


Figure 7: Pure player – van delivery

In the paper of *Vesa Kämäräinen and Mikko Punakivi* [4] about developing cost-effective operations for the e-grocery supply chain some improvements of the internet driven supply chain are given. Although the number of members in the supply chain is reduced there are still several problems in the supply chain to overcome in order to be able to make profit in e-grocery. One of the important items in the paper is that focussing on specific operations in the supply chain is not effective so the focus should shift to the overall effectiveness of the supply chain, as mentioned earlier in *Thomas et al* [6]. In addition to this e-commerce and thus also e-grocers have to problem of order picking and last-mile-delivery which are huge expenses plus the fact that in groceries there is a big demand variation which makes the puzzlement for a stable supply chain more difficult. Although this seems pretty obvious many e-grocers, for example Webvan and Streamline, where not able to overcome these obstacles and went bankrupt.

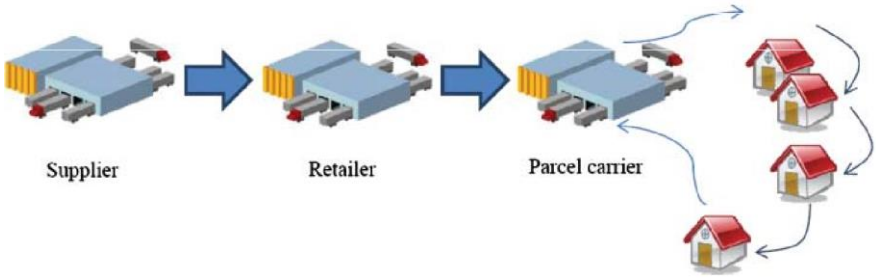


Figure 8: Pure player – parcel delivery

Figure 9: Click and mortar – van delivery

According to the paper of *Kämäräinen* the most important areas of improvement are at the receiving end of the customer and the process of picking. An example of improving the picking process is by (highly) automate the process. One of the most basic type of picking is store-based picking. This has the advantage that it is very easy to implement when a brick-and-mortar business is available. The big downside is that when the online-business grows the efficiency decreases and the pickers are walking in the way of the

customers at the store. Therefore another possibility is to pick straight from the DC or FC. This is on the other hand a bigger investment. Picking can also been done highly automated which increases the picking speed, decreases the labour costs and uses the available space more efficient. The problem is that this only works from a certain amount of orders per day, which is between 5,000 and 10,000 orders per day. The last mile delivery can be done in two ways: the delivery is done within a certain time frame which is agreed on with the customer or by delivering in an installed delivery box. The problem with delivery within a time frame is that the deliverer has to drive back and forth in order to fulfil the appointment. Therefore a delivery box can decrease the costs dramatically. The downside is that the delivery box has to be installed which can be an inconvenience for the customer and obviously there are investment costs involved. This seems straightforward but still e-grocers make a lot of mistakes in these areas, according to *Kämäräinen* the most important reason e-grocers failed are:

1. Over investment in automation of picking
2. Expensive home deliveries
3. Weak negotiation and purchasing power with suppliers
4. Customer acquisition
5. Low ordering frequency
6. Lack of services

2.2. Supply chain improvement strategies

In the course of time a lot of supply chain improvement strategies are developed. Some are very alike and other differ a lot from each other. In this section the most important ones are explained and discussed. According to "Operations management" [5] the US food industry estimated that poor coordination among supply chain partners wastes around $30 billion annually. Another research by *Gustavsson et* al [10] shows that up to 5% of the perishable goods can spoil during the distribution face. One of the reasons that came forward is that managers have no understanding about the nature of the demand for their services or products and cannot design supply chains to satisfy those demands. One thing a manager is ought to know is the difference between efficient supply chains and responsive supply chains. An efficient supply chain is best implementable where the demand is highly predictable, such as a post office. Typically the contribution margins are very low and thus is the efficiency of the supply chain very important. Responsive supply chains on the other hand are designed to react quickly in an uncertain environment where firms have to frequently introduce new services and products in order to stay competitive. Because the company often doesn't what is going to be ordered the margin on the products is much higher. In this kind of supply chain the focus should be less on efficiency and more on reaction time.

First of all one can improve operations within the supply chain, but sometimes the entire supply chain design has to be changed in order to get descend improvements. Naturally, changing the entire supply chain is more effort but sometimes the best option. In Figure 10 (adapted from "Operations management" [5]) the difference between these two is shown in a graph. First of all, in a supply chain efficiency curve it can be seen that in the beginning investments lead to big rise in the supply chain performance, whereas later the performance isn't rising that much anymore with the same investment costs. In Figure 10 the red dot represents an inefficient supply chain operation. The idea is that all of the operations are as close as possible to the supply chain curve and therefore there is an area of improvement (the orange field). The field shows that the operation can be made more efficient by reducing the costs or improving the performance or a combination of both until the efficiency curve is reached. Important to notice is that the operations cannot cross the curve due to the supply chain design. Therefore if more drastic improvements are needed the entire design has to be changed which moves the supply chain curve down (reduce costs) and/or to the right (improvement of performance).

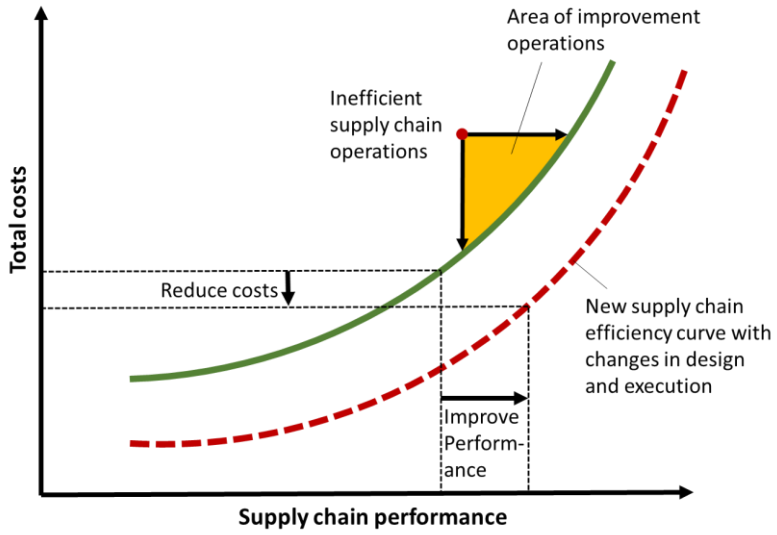


Figure 10: Supply chain improvement opportunities

2.2.1.Lean manufacturing

One of the most famous ways of improving a supply chain is to design a 'lean' system. The company at which this improving strategy started was Toyota which is described in, among others, "The machine that changed the world" [11]. The goals of lean a lean system is to eliminate types of waste, produce services and products only as needed, and to continuously improve the value-added benefits of operations [5]. These eight types of waste are transportation, inventory, motion, waiting, over production, over processing, defects and underutilization of employees, see Table 2.

Types of waste	Definition
1. Transportation	Excessive movement and material handling of product between processes.
2. Inventory	Excess inventory hides problems on the shop floor, consumes space, increases lead times and inhibits communication.
3. Motion	Unnecessary effort related to the ergonomics of bending, stretching, reaching, lifting and walking.
4. Waiting	Wasteful time incurred when product is not being moved or processed.
5. Over production	Manufacturing an item before it is needed, making it difficult to detect defects and creating excessive lead times and inventory.
6. Over processing	Using expensive high precision equipment when simpler devices would suffice.
7. Defects	Quality defects result in rework and scrap and add wasteful costs to the system in the form of lost capacity, rescheduling effort, increased inspection and loss of customer good will.
8. Underutilization of employees	Failure of the firm to learn from and capitalize on its employees knowledge and creativity impedes long-term efforts to eliminate waste.

Table 2: Types of waste according to lean manufacturing

According to lean manufacturing the key to continues improvement is *kaizen*. It means that not only you have to know the types of waste which can exist in a manufacturing system, but also understand that excess capacity or inventory hides underlying problems with the processes that produce a service or product. In Figure 11 this is visualized as a lake full of water and rocks. Here the water represents the inventory and the rocks the waste which are hidden by the water (or inventory). When the inventory is high enough there is no risk of hitting the rocks. Nevertheless this is very costly and therefore it is better to lower the inventory. This has as a consequence that also the rocks in the lake have to be taken care of, or in other words the underlying problems have to be solved as well.

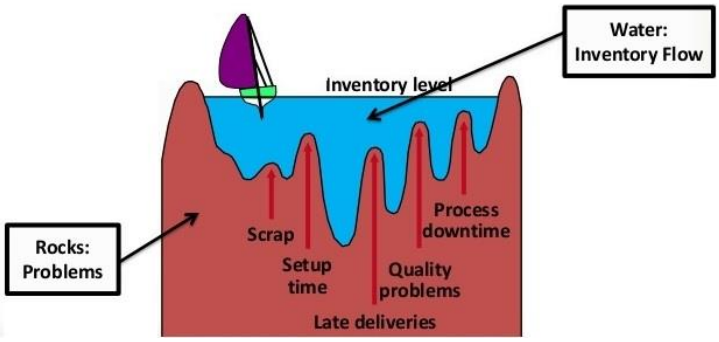


Figure 11: Representation of Kaizen

As can been seen lean manufacturing is applicable to the entire process at an organization. For supply chain considerations there are two important points in lean manufacturing: close supplier ties and small lot sizes. Because lean systems operate with low levels of capacity slack or inventory, firms that use them need to have a close relationship with their suppliers. Supplies must be shipped frequently, have short lead times, arrive on schedule and be of high quality. For this clear contracts can be made about all of these things. This is not only in the benefit of the company but also for its supplier. Close cooperation between the company and its supplier through better communication enables more efficient inventory planning and delivery scheduling by suppliers, thereby improving supplier profit margins. Therefore, according to lean manufacturing, the customer shouldn't see its supplier as an adversary but rather as a partner in business. An example of how this can work is by assigning an in-plant representative, an active member of the purchasing office of the customer. Another way of improving the supply chain is as mentioned before using small lot sizes. Here a lot is a quantity of items which are processed together. First of all small lots have the advantage of keeping the inventory level low. Furthermore a small lot is processed a lot faster through the system the bigger lots. An additional benefit is that when a defect is discovered only a small lot needs be examined which saves a lot of time. Last but not least, small lots help reducing overproduction. A disadvantage is that the setup of the process frequency is obviously higher. Another disadvantage is that with small lots the chance that employees or machines are not working because of delay or absence of a next shipment is higher. This is an extra reason for the customer and the supplier to communicate well with each other.

2.2.2. Agile supply chains

More and more people are getting excess to the internet and with that globalization rises. This means harder competition where the customer expect innovative product features, greater speed, more product variety, dependable performance and high quality. As mentioned before because of the changing circumstances it is important to maintain or improve the supply chain. According to *Basu et al* [12] there are next to lean manufacturing two other types of supply chains improvement strategies with their own spearheads. These 'standard' supply chain types can be used as a target point. These types are known as traditional, lean and agile.

- Traditional is known for:
  - Protection of the market, aims for leadership
  - Forecast driven
  - Higher emphasis on customer service than cost
  - Inventory held to buffer fluctuations in demand and lead times
- Lean characteristics are
  - Integration upstream with suppliers and downstream with customers

  - High emphasis on efficiency
  - Aims for minimum stock holding
- Agile noted for
  - Flexibility and speed in coping with innovative products and unpredictable demand

It needs to be noted that most supply chains are some kind of hybrid of these models but nevertheless in most of the situations in a supply chain one of these types is the best solution and therefore it is important to know their differences. Since lean and agile supply chain are often seen as improvement of the traditional, the difference between these two needs to be understood. *Naylor et al.* [13] defines agility as: "(…) using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace. Leanness means developing a value stream to eliminate all waste, including time, and to enable a level schedule." In Figure 12 the difference is shown schematically. Here can be seen that agile supply chains work best in less predictable environments where demand is varying and variety is high. On the other hand lean supply chains work best when the volumes are much higher and the environment is relatively predictable.

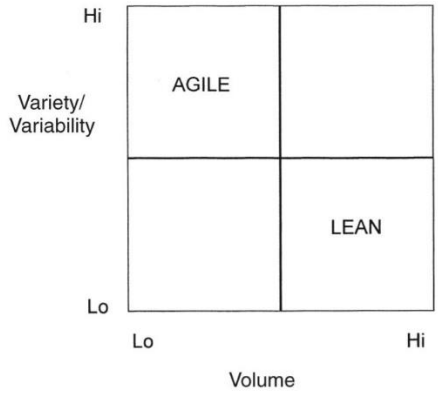


Figure 12: The difference between lean and agile 1 [14]

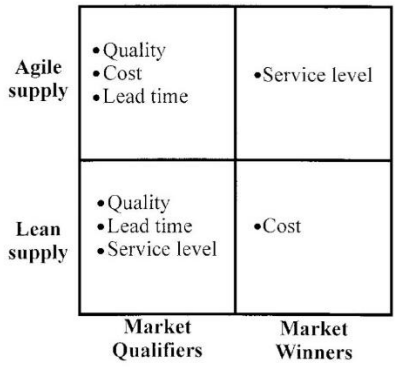


Figure 13: The difference between lean and agile 2 [15]

The traditional and lean supply chain have already been discussed and therefore in this section the emphasis will be on agile supply chains. According to *Christopher et al* [16] agility is achieving a rapid response on a global scale to constantly changing markets. This rapid response is not only reacting on the changes in volume demand but also in variety. Therefore Christopher thinks four characteristics are indispensable for an agile supply chain:

1. Market sensitive
2. Virtual
3. Process integration
4. Network

Market sensitive means that that the supply chain is capable of responding to real time demand. Most companies are forecast driven which means they rely on the data they collected from before. An agile supply chain is rather demand driven or in other words, it listens to the markets voice and responds directly to it. Being virtual means that data is shared using technology like the internet which in essence creates a virtual supply chain of information. This leads to process integration where the client and the supplier work together to make a certain product. This way the entire supply chain can be improved which is good for all the parties involved. This is also a spear head for lean manufacturing as mentioned on page 20. Taking this a step further creates a network. There is growing recognition that individual businesses no longer compete as stand-alone entities, but rather as a supply chain network. This means that working together with their partners instead of their suppliers or customers becomes more and more important in order to be able to keep competing with the competitors.

2.2.3. Hybrid strategies

Hybrid strategies, or 'leagile strategies', can be appropriate is certain situations. This is the case when for part of the products the demand is predictable and stable whereas for other products the opposite is true. A good example of a leagile company is Zara, a Spanish fashion company. An important part in this supply chain is the fact that Zara keeps a real-time record of the products they're selling. This way the company can deliver the products at the stores in a very lean way in the first instance, but when a certain product shows to be very popular, the company is quick to react. The next step is then to produce the popular product extra, which is normally more expensive, to react appropriately to the demand of the customers. In the case of Zara, the cloths are normally produced in countries like China, but when the demand in West-Europe is high a factory in Spain makes sure the demand is met.

2.3. Key performance indicators of the supply chain

For companies to measure the performance of SCM the key performance indicators (KPIs) are of great importance. These KPIs can have to do with the suppliers, delivery performance, inventory and customer-service, but in the they all relate to customer satisfaction. In the literature survey of *Gunasekaran et al* [17] an attempt is done to develop a framework of these KPIs measuring the strategic, tactical and operational level of performance of the supply chain. In this section the most important ones are discussed.

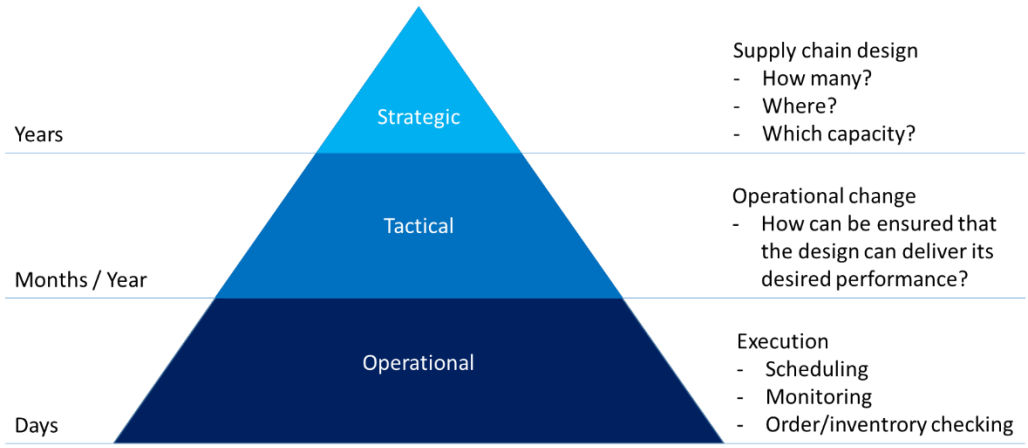


Figure 14: Decision making for supply chains on a strategic, tactical and operational level

2.3.1. Strategic

There are several strategic KPIs but the ones that are most important for an starting online grocer are listed below. Most of these KPIs have a lot to do with other comparable KPIs.

- Total supply chain cycle time
- Order lead time
- Level of customer perceived value of product
- Range of product and services
- Rate of return on investment
- Buyer-supplier partnership level
- Level of supplier's defect free deliverers

One important KPI is the total supply chain cycle time which has a lot to do with the order lead-time. The order lead-time is the time it takes from the order placement of a customer until the arrival of the product at the customer. This is a clear measure which has great influence on the customer satisfaction. The order lead-time can be subdivided into several other KPIs:

$$\textit{total order lead-time} = \textit{order entry time} + \textit{order planning time} + \textit{order sourcing} + \textit{finished goods delivery time}$$

Here the order entry time is the time it takes for an order placement to be converted into useful information, or in other words, how long it takes for the company to know which services they have to deliver. This order entry time can come from a direct order

from the customer but also be shortened through forecasts so the company can prepare for future orders. The order planning time is the time it takes to make, schedule and communicate the tasks. After this the order actually has to be assembled, ordered or withdrawn from the warehouse, 'the order sourcing'. In the end the goods have to be delivered at the customer which combines to the total order cycle time.

The level of customer perceived value of product is of importance for the customer satisfaction. When the value isn't high enough, the customer may go on its own to the supermarket in order to prevent buying products of low quality. The range of products and services also has to be comparable to brick-to-mortar supermarkets. The rate of return of investment is an important KPI when big investments are done in order to work more efficient for example. The buyer-supplier partnership level is difficult to measure but it comes down to how well the buyer and supplier can work together in order to both benefit from the partnership. One of the KPIs that has to do with this partnership is the level of supplier's defect free deliverers.

2.3.2. Tactical

The tactical KPIs have more to do with what happens inside the company. This means that there is also a more direct solution to the KPIs that might be too low for the standard. Some of these KPIs are:

- Accuracy of forecasting techniques
- Order entry methods
- Planned process cycle time
- Supplier ability to respond to quality problems
- Delivery reliability

On the floor the process often starts with forecasting. This in order to start the rest of the process even before the orders come in. The accuracy of these techniques heavily influence the efficiency of the rest of the process. High accuracy means small adjustments against low accuracy which leads to high adjustments. A forecast model is comparable the an order entry method. A good order entry method converts customer specifications into useful information along the supply chain. With this information the process time can for example be planned, this compared to the actual process time is an valuable KPI. When there is a disturbance in the supply chain because of quality problems this can be handled efficiently or not at all. When the ability to respond to this problems is high this can lead to a higher delivery reliability which is a good measure for customer satisfaction.

2.3.3. Operational

According to *Gunasekaran et al* [17] the last category of KPIs in the supply chain is 'operational'. Some of these KPIs are listed below:

- Capacity utilisation
- Total inventory as
    - Incoming stock levels
    - Work-in-progress
    - Scrap level
    - Finished goods in transit
- Supplier rejection rate
- Frequency of delivery
- Driver reliability for performance
- Quality of delivered goods
- Achievement of defect free deliveries

In companies often big investments have to be done in order to make the process more efficient. Although these investments might seem like a good idea at the time the utilization of the capacity is a good KPI to keep track on. When there is a gap in the usage of capacity it is an opportunity to improve the supply chain process without doing any big investments. There is also a thing as using too capacity in the form of inventory costs. According to *Harrington* [18] inventory is where the biggest cost is hidden in most

businesses today. Although it seems like it is a buffer to be able to cope with uncertainties, it can also be the reason of an increase in lead time. Another way of looking at operational performance is by researching the deliveries of the company. The customer can appreciate for example more delivery possibilities but also the reliability of delivery which is partly being determined by the driver reliability. Furthermore ones an item is delivered the quality or achievement of defect free deliveries is a good measure which is correlated to customer satisfaction.

2.4. The online supermarket

When looked into the history of the retail industry a few important events happened that changed the way of the retail industry entirely. The original retail shop was a place where the clients came and the clerks made the orders for every clients. In 1916 Piggly Wiggly was the first self-service grocery store [19]. The clients had to pick their products themselves and for the first time which made packaging and brand recognition suddenly very important for manufacturers. Fifty years later in 1963 Carrefour opened their doors to the first modern day hyper market. The idea of such a market is that everything can be found under one, big roof. This was again a huge step in terms of efficiency, space utilization, productivity and cost management. The next big step was again a few decades later when Jeff Bezos saw that the online superhighway was a perfect platform for to sell bulk items like books and amazon.com was born. Although apparently online shopping was a success for bulk items, online grocery shopping had a rough start. The companies that started to sell groceries online grew too quickly, which seems to be a good thing, but where not able to keep the customers satisfied. Despite this rough start it seems that online grocery shops will eventually be an important part of the grocery retail industry. Companies like Ocado [20] in England seem to grow steadily and slowly conquer a significant part of the market. In terms of market share online grocery shopping in England is ahead of online grocery shopping in the Netherlands. The trend of growth of online grocery shopping in the UK can be found in Figure 15 (from Kantar World panel [21]).

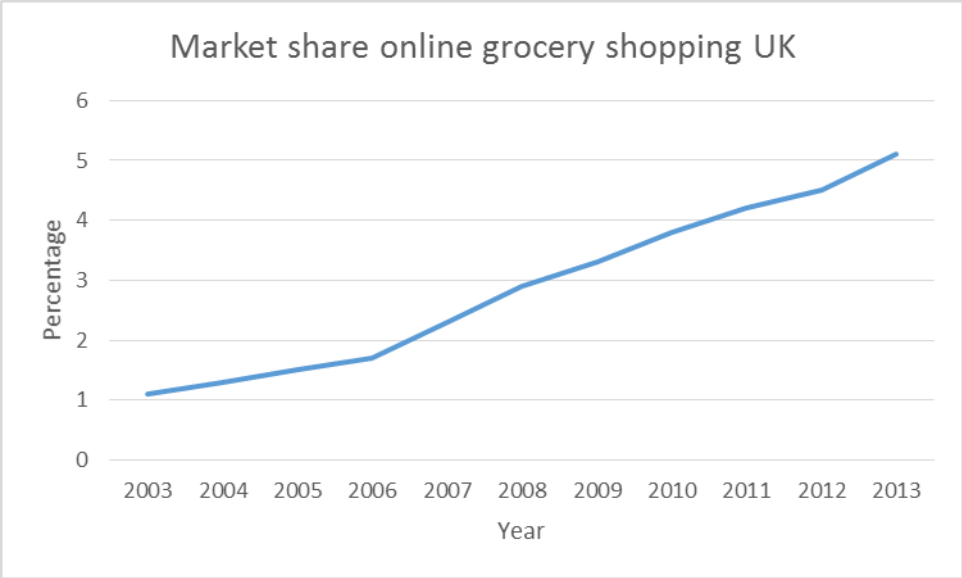


Figure 15: Market share online grocery shopping in the UK

This close to linear growth in the UK is one of the reasons that 'het financiele dagblad' [3] thinks that the market share of e-commerce in grocery shopping will be around 5% in the Netherlands in 2025 (as mentioned in the introduction), since the growth in the Netherlands will most likely look almost the same as in the UK. In a research conducted by *Syndy* [22] the market shares of grocery retailers in the Netherlands in 2014 is estimated, see Figure 16. It can be seen that there are a significant amount of companies which invest in e-grocery. In 2014 the Albert Heijn had the largest share of the market with 53% but has a lot of competitors whom also want to capture their share of the pile. The market share of online grocery retail as a percentage of the total grocery retail market was at that time 1.5%, which would mean that the Netherlands is 9 years behind on the United Kingdom.

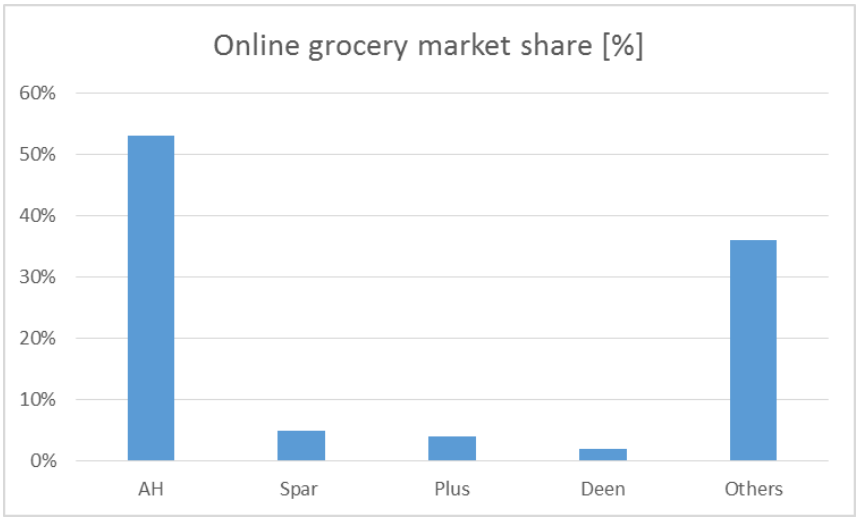


Figure 16: Market shares and revenues of online grocery retailers in the Netherlands (2014) [22]

According to McKinsey & Company [19] the future of (digital) retail can be split into 7 steps or trends:

1. Continued rise of e-grocery attackers: although the last mile delivery is very expensive more and more companies are trying to sell groceries online whom all improve the process bit by bit until the entire process is profitable.
2. Thinking differently about the box: conservative grocery shops try to redefine themselves in response to the threat of the online shops, this way the line between online and offline will get blurry.
3. Increasing importance of online marketing: since in the digital world there is a lot more possible than just e-commerce, companies will focus more and more on online marketing.
4. Sophistication of personalization and CRM: companies are starting to get the hang of how to handle all the personal data which results in more personal advertising.
5. Advances in self check out and digital wallet: retailers are trying to find a way for a more efficient customer check out which would look something like the customer has its digital wallet (mobile phone) and scans all its products which he or she has to pay on the way out. This leads to more efficient shopping in a conventional supermarket and produces personalized data from each customer
6. Digital dashboards: because of the use of apps by the customers there is much more real time data available where the retailer can profit from.
7. Dynamic pricing: thanks to the digital real time data for both e-commerce and physical shops the pricing can be dynamic so customers can wait for low prices and retailers can adjust their prices according to real time supply and demand

Here it McKinsey & Company does not specify whether online shopping will eventually will be compatible with physical shops or not, the main idea is that both online shops as physical shops try to profit from the digital age by getting to know as much as possible about their customers and real time sales. Whether or not online shopping will continue to be profitable for companies depends on if they can keep their customers satisfied even though conventional retailers also make use of the digital age.

2.5. The processes of online shopping

There is a tight interaction between the customer, the online supermarket and the supplier. How these actors are generally related can be seen in Figure 17. Here the customer initiates actions at purchase order management (POM) which on its turn orders the desired amounts of items at the supplier. The supplier then delivers the goods at the online grocer which can sort and deliver the items to the clients. During these actions some mistakes can be made like placing an incorrect order by POM, making a delivery failure or a mismatch between the virtual and the physical stock.

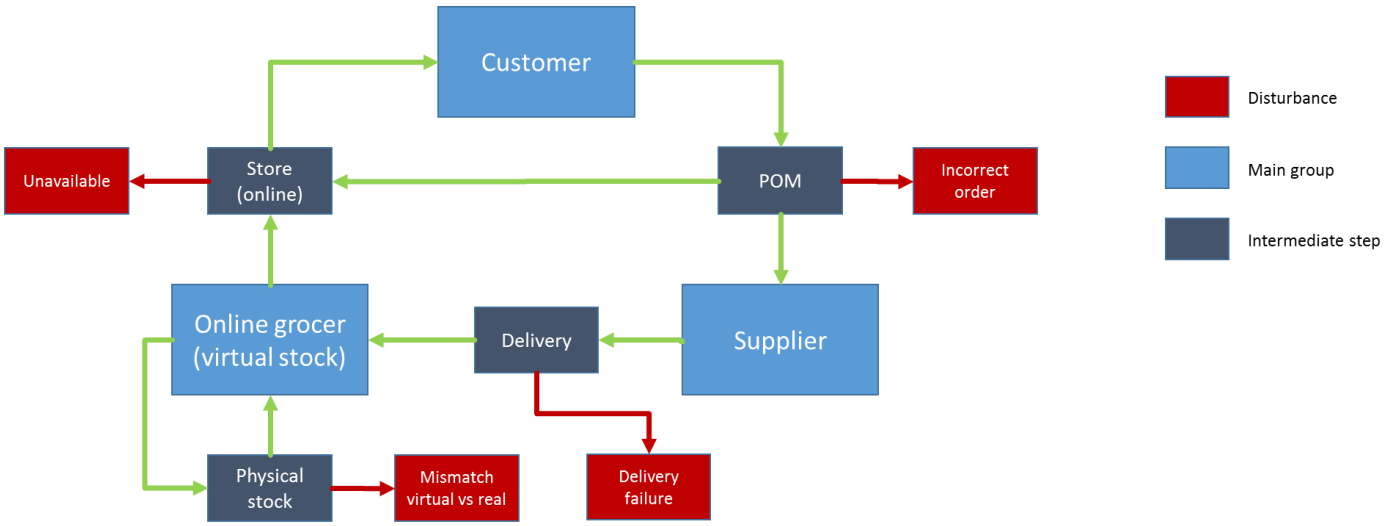


Figure 17: Interactions between customer, supplier and the online grocer

2.5.1. Customer

The customer is initiates the entire process. Typically the customer logs in on a website or an app on the phone where he or she can make an order. The customer is able to order the different items from the virtual store. The availability of a product depends on what is in the virtual stock and what is orderable by Purchase Order Management (POM). This means that when there is a mismatch in the virtual stock or POM thinks it's able to purchase something but can't, the customer is able to order something which can't be delivered.

2.5.2. Purchase order management

POM is one of the most important parts of an online grocer. POM has to make sure that enough products are ordered on time so the online grocer has it in the inventory when needed. The trick of POM is to balance between having products in store but also make sure not to much inventory space is used and avoid loss of products because of BBD. For this an order prediction is needed which is often some kind of algorithm that based on past sales can make a prediction. These predictions normally need to be checked for exceptions.

2.5.3. Supplier

There are a lot of different kinds of suppliers, even though it seems that the only thing that has to happen is transporting a good from producer to the fulfilment center (FC) of the online supermarket. First of all there is direct delivery (DD). DD means that the product is transported directly from the producer to the FC. Within DD there are two possibilities: the transporter drives only to one producer or makes a round and visits several producers. The second one is more common since most of the times it is more efficient. Another possibility is that an 'intermediary' is enabled. This is normally a distribution center (DC) where the products are delivered, potentially stored, and distributed to several locations. The advantage of this is the size of the DC which means that full trucks arrive at the DC and full trucks leave the DC. Within the DC there are again two different types of product handling: the product can arrive and be stored where after it is picked and transported, and the products can be cross-docked which means it arrives, is unloaded and directly loaded into another truck. Products are often stored in the DC when the BBD is higher and cross-dock is often used for fresh products.

2.5.4. Delivery

The delivery of products is straightforward. Most suppliers check whether they were able to fill the truck according to the orders. Along with the delivery sometimes a receipt is send, a so called ASN. This makes checking the completeness of the products during receiving easier since not every missing product has to be searched for.

2.5.5. Online grocer

The online grocer consists out of one or more FCs and hubs. In Figure 18 the basic process at an online grocer can be seen. This process can be divided into the inbound, replenishment, picking, consolidating and the outbound. These processes are normally actuated by a warehouse management system (WMS). In the WMS all the information about the products is stored and which products have to undergo which process. Employees therefore get the assignments from a WMS.

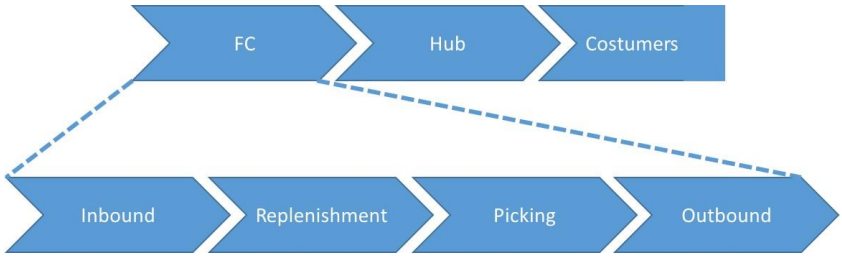


Figure 18: Basic process at an online grocer

Inbound (FC)

Every day several trucks arrive at several times of the day (normally in the evening or early in the morning) to deliver all kind of products. Typically the products are packed in trading units (TUs) and these are stacked on roll containers (RCs) or pallets. At the inbound the completeness of the delivery is checked. Besides the financial motivation this is done in order to be able to perform adequate actions in time so the delivery failure has as little as possible influence on the rest of the process.

Replenishment (FC)

Once the products are received they have to be replenished. Depending on the product there are different ways to handle them. Big fast moving bulk products can be replenished in the RC or pallet they're delivered in. The advantage is that the handle time is very low, on the other hand picking might not be ideal since it is still pact in TUs. Other products are unpacked and normally filled on the shelves following the first in first out (FiFo) principle. The main reason for this is that this prevent products to stay in stock until their BBD is over. To avert that replenishment and pickers are in each other's way, replenishment is normally at the other side of the shelf. This has as an extra advantage that the FiFo principle is automatically executed.

Figure 19: Picking

Picking (FC)

Picking is getting the products from the shelves in the right box for clients. This is a very labour intensive process since it is done per item. Mostly this is done by hand but there are systems that can do it (semi-) automatic. The picker gets the assignment from a WMS and puts an item in the write box. Since it is one of the most labour intensive process it is essential that picking is done efficiently. Therefore the products on the shelves are normally located in such a way that the picker first picks the heavy products so they end up on the bottom of the boxes.

Outbound (FC)

Ones the products are picked and put into boxes they're moved to the outbound. Mostly these boxes are somehow stacked in so called dispatch frames (DPFs) which enables them to be moved easily into the truck. This process has to be monitored very carefully since the filling trucks with wrong DPFs is disastrous for the entire process.

Hubs

Most online grocers have hubs. A hub enables the transhipment of client specific boxes from trucks to smaller vans. This is needed for several reasons. The most important one is that it simply costs too much to drive with a truck to every single address. Moreover when the delivery is in a crowded area a smaller mean transport is required. The process at an hub is in basis quite simple: trucks unload their goods which are then transhipped into a van. This van is then send to drive a specific round to deliver the order at the clients.

Online store

Every online grocer has a different form as an online store but they all have the same goal: making it as easy as possible for clients to place orders. The availability of the products in the store depend on what is in the virtual inventory and what can be purchased by POM. The number of possible purchases of the client is the number of items of a particular article in the virtual inventory plus the number of possible orders of POM. Furthermore the client has to enter the location at which he or she want to get the order delivered. Then, mostly depending on the location, the client can choose a timeframe in which the order is delivered.

2.6. Conclusions of literature

Since customers these days make more and more use of online retailers there is a huge business opportunity in the online grocer market. Figures [21] show that in the UK the market share of online grocers has grown close to linear for the last 10 year. Assuming this will also happen in the Netherlands a big gap will be filled by online grocers in the upcoming years. Therefore several existing supermarkets try to invest in this area but also new players are trying to penetrate the market.

In order to make a successful entrance in the market, an efficient supply chain is vital. Although this supply chain has many similarities to the traditional supply chain, the internet driven supply chain has some major differences. First of all a lot more is known of the demand of the customer since the data can be collected of the online orders. Secondly, an online grocer has to deliver at the homes of the customers which results in having to reckon with an expensive last mile delivery. There are several ways on how the online grocer can build up their supply chain but history has learned that they all have the same pit falls: over investment in automation of picking, expensive home deliveries, weak negotiation power, customer acquisition and low ordering frequency [4]. These are therefore the main reasons why many online grocers have failed in the past.

There are several supply chain improvement strategies, out of which the lean supply chain [11] might be the best known. Improving the supply chain using the lean way of thinking means focussing on reducing the waste. Here waste is divided along eight types: transportation, inventory, motion, waiting, over production, over processing, defects and underutilization of employees. Although this makes sure the supply chain works efficient this is not always the best improvement strategy. Agility is for client satisfaction also an important performance measure which makes hybrid improvement strategies [16] highly wanted in the online grocer market. To be able to measure the performance of the supply chain, key performance indicators (KPIs) are useful. These KPIs can be divided into strategic, tactical and operational [17] which measure respectively the performance over years, months and days.

Looking more closely at the general processes at an online grocer it can be concluded that there are three major actors involved: the customer, the supplier and the online grocers itself. The customer initiates the process by placing an online order where after the online grocer orders at its supplier what is needed. These items then have to be collected and delivered at the online grocer, which on its turn picks the groceries and distributes them along the customers. During this process several disturbances can occurs like incorrect order at the supplier, delivery failures or differences between the virtual and physical stock.

Although a lot is known about the general processes of an (upstream) supply chain and how it works for an online grocer, little is known about how such a supply chain can be maintained and improved during fast growth of the company. Furthermore, a root

cause analysis in warehouses is done often but the possible effects of growth in different scenarios is not found in the literature, let alone for e-grocers. This results in a literature gap where this report focusses on.

3. Analysis

In this chapter the processes at an online supermarket will be analyzed. The goal of the analysis is to get an understanding about the processes within Picnic and Boni. This is first done by looking at the system as a black box after which the IDEF0 [23] and the Delft System Approach [24] is applied in order to look at the processes within this black box in more detail. Then the root causes of unexpected shortages are explained along with what currently happens when such an unexpected shortage occurs. The distribution of these root causes and effects of unexpected shortages is researched in section 3.5 after which the KPIs and the results of the data collection are given.

3.1. Overview of the Picnic process

As mentioned before a general overview of the Picnic process is given by the IDEF0 approach and a PROPER-model. In the next section these approaches are also used to view at the process in more detail.

3.1.1. The IDEF0 approach

In order to get a general idea of the whole system the IDEF0 approach [23] and a PROPER-model [24] give a good insight in what happens at Picnic. The IDEF-0 A0 only shows the input, output, controls and mechanisms of the system, whereas the processes within the box are omitted. In Figure 20 the IDEF-0 A0 is shown where can be seen that the goal of Picnic is to convert a customer's order and the incoming articles into a shipped order (or home delivery). The orders of the customers can only be placed online via an app or the website. The data of these orders is subsequently directly available for Picnic so instant action is possible. The end product of Picnic is the home delivery of the ordered goods of the customer. Every process within Picnic is supposed to help one way or another in the transformation of a customer's order to a shipped order.

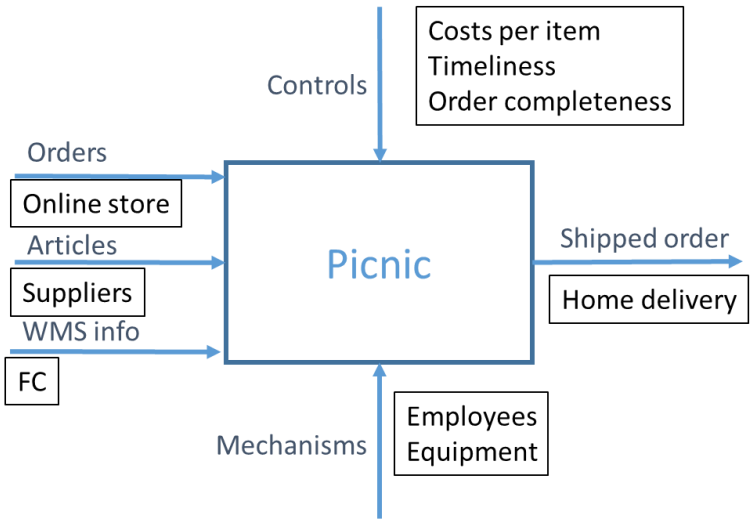


Figure 20: IDEF0 A0 overview of the supply chain of Picnic

Although the end goal of the process is converting the inputs in output(s), a lot more comes to it. The IDEF0 diagram shows not only the input and the output, but also the mechanisms used for the system (bottom arrow) and the controls (upper arrow). The most important controls or KPIs of the system are the costs per item, timeliness and order completeness. Since Picnic has to be competitive towards other players in the e-grocery market, they charge no delivery expenses and they have a lowest price guarantee. This means that in the entire system the processes need to work as efficient as possible to make the concept feasible. Another selling point of Picnic is the fact that they have a 20 minute time window in which they guarantee delivery. This has as a consequence that the processes in the system have to co-operate on a very high level to make this possible. A difficult issue in this is that some perishable goods need a very short lead time to maintain low losses in the system, which is a big problem in food supply chains [25]. Last but

not least the order completeness has to be as high as possible to keep the customers satisfied. These are not the only controls of the systems but definitely the most important ones.

The most important mechanisms in the system are currently the people working on the floor which are among others the supervisor, flow operator and the pickers. The supervisors and the flow operators task is mainly to make sure that the processes on the floor are running smoothly and when something goes wrong they have to find a suitable solution. The pickers task is the get the products in the right tote and put the totes in the DPFs so they're able to get shipped.

3.1.2. The PROPER model

There are several ways in which the black box from the previous section can be decomposed. In this research the Delft System Approach (DSA) is chosen [24]. In DSA the analysis of industrial systems and supply chains can be done using a PROPER model (PROcess-PERformance-model). A PROPER model shows the interrelations between three aspects: the material flow, the order flow and the resource flow (Figure 21). The dotted line in the figure represents the black box from the previous section.

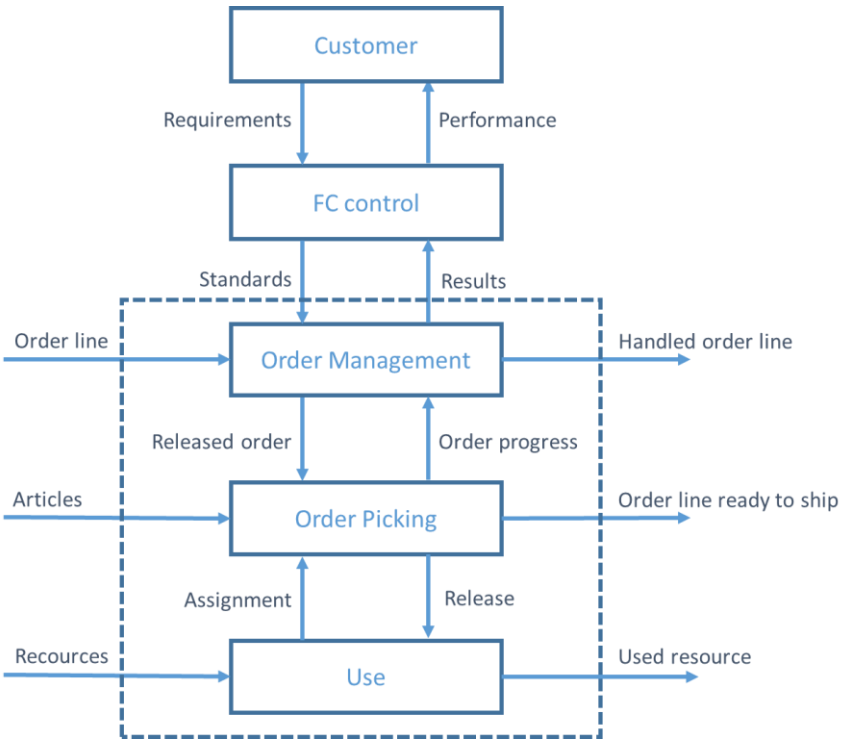


Figure 21: The PROPER model

Every flow in the PROPER model is transformed. In the material flow the articles are transformed into an order line that is ready to ship. The process behind this transformation is order picking. The same goes for the order flow where order lines are transformed to handled order lines by order management and the resource flow where resources are used for the order picking process. Furthermore from Figure 21 it becomes clear that there is an interaction between the different transformation processes there is an interaction. Order management releases order to order picking which on its turn returns information about the process of these orders. The resources are used in the process of order picking where the employees and totes for example are assigned to do something whereas they are released ones the job is done. Another important layer in the PROPER model is the FC control. The FC control determines the standards for the FC and check whether these standard are achieved. These standards do not come out of nowhere, but are distracted from the needs and requirements of the customers who expect a certain performance level from the company. Here the most important performance indicators are timeliness of the order and the order completeness.

3.1.3. Current situation at Picnic

In this section the order line flow, the article flow and the resource flow are briefly explained. This should give a better insight in what happens in the FC of Picnic.

The order line flow

The amount of orders that need to be delivered in a typical week fluctuates a lot per day (Figure 22). Normally the peak days are on Monday and Friday where the limit of the FC (a bit over 2000 order per day) is currently reached. The workload on the rest of the days is clearly a lot lower which results in a peak to average of around 30%. Some other characteristics that differ greatly per day are the amount of items, SKUs, items per order and SKU per order. These can be found in Table 3. Here can be seen that although the amount of orders on Monday is higher than on Friday, the amount of items and SKUs is significantly higher on Friday. Whereas Picnic would rather have a more evenly spread amount of orders, items and SKUs per day over the week, the behavior of the customer is very difficult to change. Most customers tend to make an order on Monday so they have groceries at home for the rest of the week. The same goes for Friday where people would like to see the cabinets full so they can enjoy the weekend.

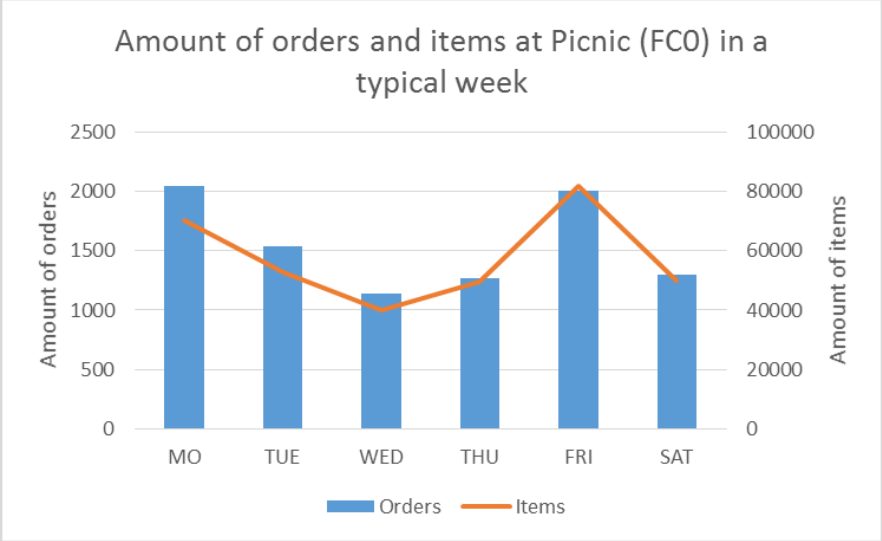


Figure 22: Graph of the average amount of orders per day (week 5, 6, 7 and 8 in 2017)

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Orders	2049.8	1541.0	1140.8	1266.3	2005.8	1297.5
Items	70554.3	52618.8	400886.3	49719.3	81844.8	50001.5
SKUs	4507.5	4367.0	4195.0	4379.8	4670.8	4730.0
Items per order	34.4	34.1	35.1	39.3	40.8	38.5
SKU per order	2.2	2.8	3.7	3.5	2.3	3.6

Table 3: Average amounts of orders, items and SKUs per day from week 5, 6, 7 and 8 (2017)

The article flow

First of all it is important to know that the fulfilment center (FC0) of Picnic is located very close to the distribution centers (DCs) of Boni, see Figure 23. The DCs of Boni provide around 95% of the inbound of Picnic, the rest is ordered at small suppliers whom deliver directly at the FC of Picnic. The articles are mostly shipped from DC1 with the exception of the articles from BVA which are directly delivered from the BVA DC. At this FC all the articles are received, stored, picked and shipped to the different hubs. Subsequently the totes (filled with the articles) are disturbed from the hubs to the customers using so called E-workers.

The articles are ordered at Boni on basis of the customer orders that already known and an algorithm that predicts the expected extra customer orders. Once a certain article is ordered at Boni, Picnic assumes the product will be delivered and can therefore sell it to a customer. In a happy flow where everything goes as it should go, the articles are the delivered, received, split into different aisles, replenished, picked and stacked into dispatch frames.

Unfortunately many things can go wrong. When an article is not delivered, damaged or the inventory information of Picnic is not accurate, one or more order lines need to be cancelled unless a solution can be found. For this reason the products are counted during receiving and an automatically generated list of missing products is made. This results in another list of products whereof it is known that a solution needs to be found. These solutions can be in the form of a rush order, store pick or a substitute. A rush order is sent to Boni which comes down to an extra delivery. The downside of this is that is highly inefficient since the order is normally relatively small. A store pick means that an employee drives to a supermarket nearby and buys the product directly at the store. Not only is this very inefficient but the prices of the products at the store are a lot higher than when bought from the Boni DC. The last solution is find a very similar product to the order line, a substitute. This substitute is normally given away for free since it is not what the customer had ordered. If non off these solution work, the order line has to be cancelled.

The resource flow

The resources used in the FC of Picnic are first of all the employees. These employees are scheduled by the supervisors and can have many different tasks like picking, replenishing, receiving and more. These tasks are explained more elaborate in the next section. These employees are only able to fulfill their tasks with some other resources like the totes, bags, picking carts (PCs), roll containers (RCs) and dispatch frames (DPFs). Every one of these resources are used somewhere in the process and the supervisor is supposed to control the process in such a way that when these (prepared) resources are needed, they are available.

Figure 23: Plan of the DC's of Boni and FC0 of Picnic

3.1.4. Growth ambitions of Picnic

The historical growth of Picnic is analyzed so a descent prediction can be done about the future development of the amount of orders, items and SKUs per day. In Figure 24 amount of orders per day is shown as a moving average over 6 days from the 16th of May 2016 until the 20th of February 2017. Here is can be seen that the goal of Picnic (which is to grow 5% per week) is met, with exception in the summer and Christmas holidays. Furthermore the maximum capacity of FC0 has been reached half of January which has slowed the growth a bit. It can be argued that if Picnic is able to minimize the peak to average, FC0 is able to process a lot more orders per day, but with the current behavior of the clients this is not possible. Nevertheless, Picnic has shown that in normal circumstances the company is able to grow 5% per week.

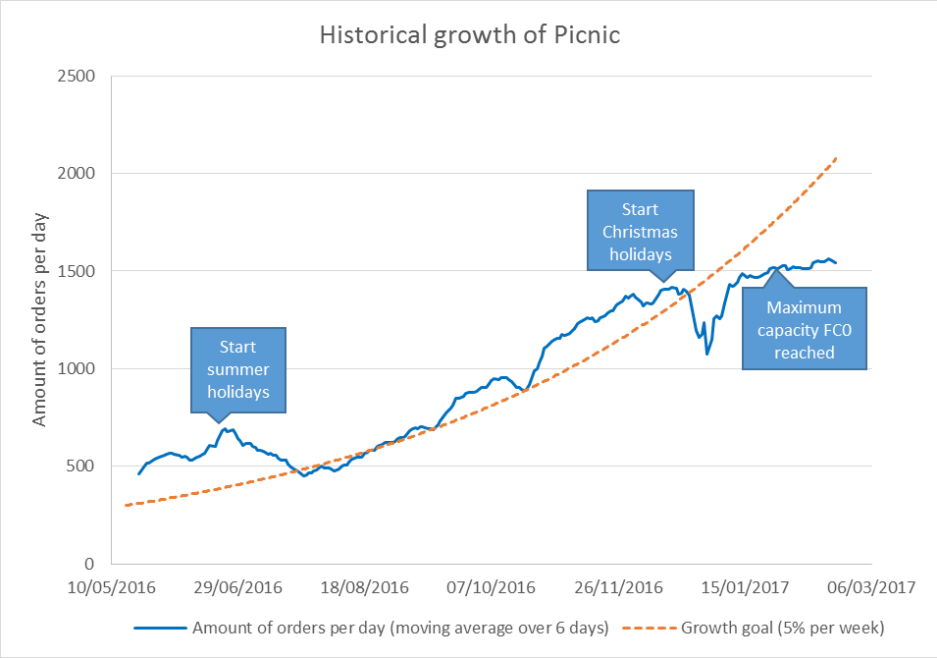


Figure 24: Historical growth of Picnic (16th of May 2016 until the 20th of February 2017)

In Figure 25 the predicted peak day growth of Picnic is shown. Here also been seen that the maximum capacity of FC0 is reached according to the growth team of Picnic, and in week 8 of 2017 a new FC will be opened. This new FC (FC1) will enable the desired growth of Picnic until a maximum amount of order at a peak day of 5000, where after a new FC (FC2) needs to be opened.

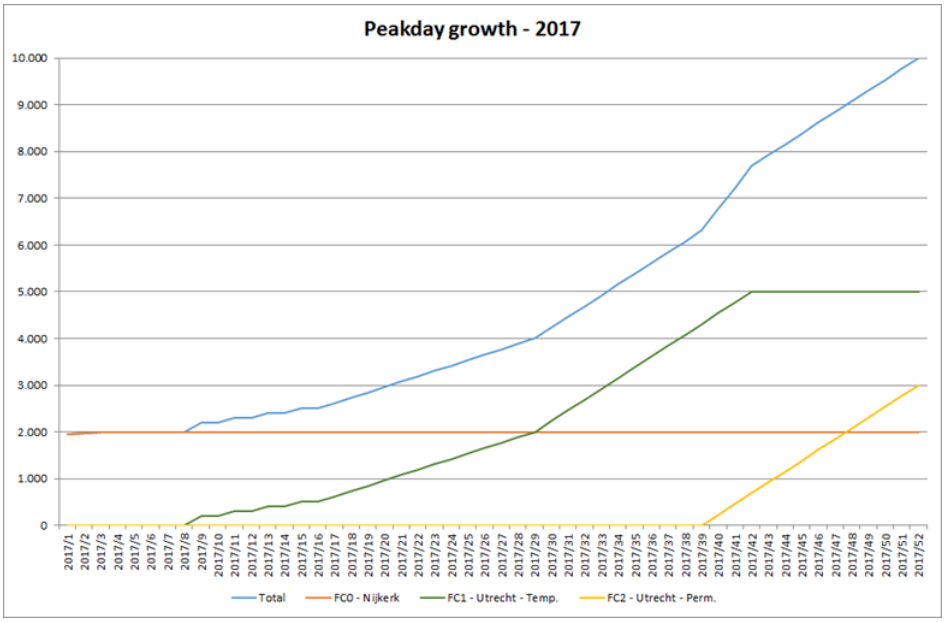


Figure 25: Predicted peak day growth of Picnic

3.1.5. Current situation at Boni

The DC's in Nijkerk are the only DC's of Boni and therefore has to provide for 42 Boni supermarkets in the Netherlands and Picnic. Since the number of items which is sold per day at Picnic is comparable with the biggest supermarkets of Boni the impact of Picnic on the DC in Nijkerk is relatively big. Keeping in mind that Picnic's ambition is to grow more than 5% a week this impact is only going to increase.

In Figure 23 the different DC's of Boni can be seen. In DC1 there are only articles that are conserved in an ambient area in contrast to DC2 which is the chilled zone. DC2 can be divided in the area where the temperature is around 3°C and a 'tropic area' where the temperature is around 13°C. The reason for this is that some products have different ideal temperatures in which they are best conserved. DC3 is the packing area where all the paper and plastic is send to in order to sell for recycle, furthermore the bottles and crates with a deposit are send here and then distributed to the producers. DC4 is relatively new and is, just as DC1, an ambient zone but here are mostly slow movers. At the Boni BVA ('Boni Vers Ambacht' which means Boni Fresh Craft) most types of meat are processed, stored and distributed. As can be seen in the picture FC0 of Picnic is located very close to all these DC's but the most important DC is DC1 since after picking at Boni the trucks leave from DC1 to FC0.

In Figure 26 a schematic overview is given of the supply chain to and from Boni. First of all it is important to know that Boni is part of the 'Super Unie' group. The 'Super Unie' is a wholesale purchasing cooperative between 13 supermarkets in the Netherlands. The idea is that by buying goods as a collective their market position is stronger and therefore purchase of goods is a lot cheaper. Furthermore since they buy as a collective it is possible to have a DC in Haaften from which the goods can be distributed to the DC's of the supermarkets. Another advantage is that since the supermarkets are working together they can share trucks in which goods are transported. This means that when some producers deliver at different supermarket DC's, one truck can collect everything at this producers and can supply multiple DC's of supermarkets or even deliver straight to the supermarkets themselves.

Picnic can be seen as one of the supermarkets of Boni since the supply method is largely the same. In Figure 26 it can be seen that a part of the goods that come from the DC of the Superunie or the producers go to the DC of Boni, but another part is going to the 'cross dock' (XD). When goods are delivered at the DC of Boni the goods are stored in the DC. But when the throughput time is very short is sometimes is much more efficient to move the goods from the inbound straight to the outbound, this is called XD. Typically this is done with goods with a relatively short expiration date like bread. The reason this is still done at the DC of Boni is that the goods have to be divided over different trucks to go to different supermarkets.

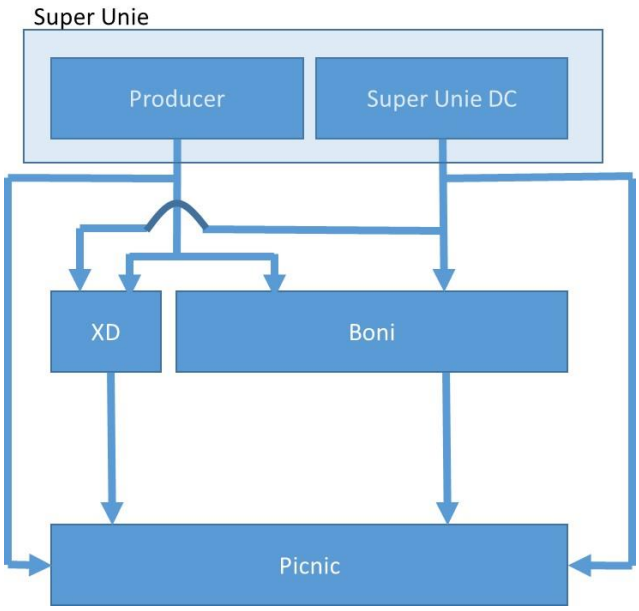


Figure 26: Schematic overview of the supply chain through Boni

The process at the DC's of Boni is pretty straightforward as can be seen in Figure 27. The process start by receiving all the goods. Most goods then have to be stored which is done during replenishment. For this the employees have to scan the article, which is mostly conveniently packed in trading units (TUs), after which a program gives them a location to which the product has to be brought. Then at arrival at the location the employee gets asked one of the three pin codes at that location, if he or she names the right code he or she can drop the TU. Order picking is done exactly the other way around, the employee gets a location, names a pin code and he or she picks the TUs from the shelve and its done in a roll container (RC) or on a pallet. These RC's are picked up by other employees and brought to the shipping area. Another possibility is that the lead time of the products is so short (for example bread) the products aren't stored at all, but shipped immediately which is called cross docking.

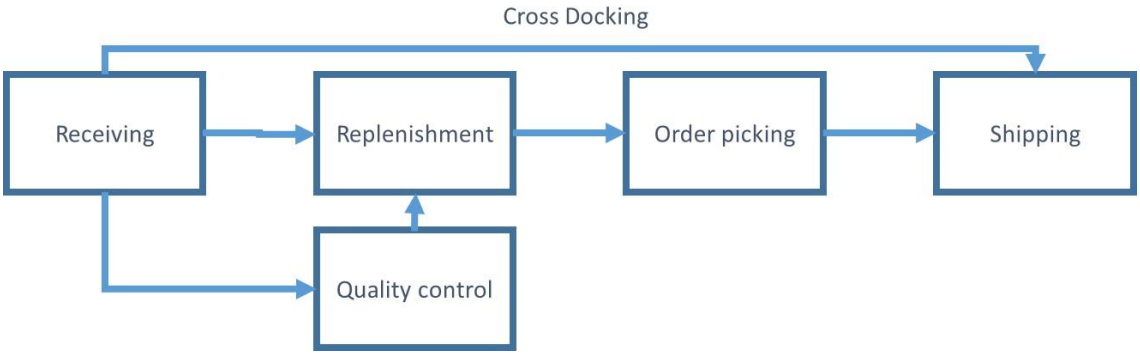


Figure 27: Flow chart of the process at the DC's of Boni

3.1.6. Transportation between Boni and Picnic

As been said before the DC of Boni is currently located next to FC0 of Picnic. This means that the transportation is very short in distance but nevertheless very time consuming. Although the distance is very short the transport is still done by trucks since the docking stations are made especially for trailers which have to be transported by trucks. These trucks, along with their drivers, are outsourced to a third party whom handles everything. Since trucks are quite limited in their movements it takes relatively much time to drive away but even more time to put the trailer in the right docking station at FC0. Furthermore when a driver is too late for some reason this takes up relatively much time which can be very unpleasant for Boni as well as for Picnic since they are both on a tight schedule. Therefore Picnic and Boni are both learning employees to drive a tractor which is especially designed to transport trailers. These tractors are not allowed to drive faster than 50 km/h but this is not problem at all since the distance is so short. When some employees can transport the trailers themselves Picnic and Boni won't be dependent anymore from a third party.

3.1.7. Current situation at the hubs

From FC0 the totes are transported in DPF's to several hubs. At these hubs the DPF's are stored in the inbound area. Once the DPF's are ready to be transported to the clients the DPF's are loaded into the E-workers. The driver then drives to the clients in a predefined order which is determined by planning software. At every client the driver gets an instruction about which totes are for that particular client which he or she then has to scan as an extra check. After delivery the driver gets a new address to go to and the process repeats itself.

3.2. Detailed view of the Picnic process

In the previous section a PROPER model is used to give a good overview of the system of FC0. In "The Delft System Approach" [24] it is also explained how the system can be showed in more detail. Instead of looking at the system consisting out of three major processes that convert orders, products and recourses into handled order, delivered products and used resources, these processes are opened up as well. According to DSA the three major processes can be divided into plan, source, make and deliver blocks. Here 'planning' balances resources with requirements and establishes plans for the supply chain. The 'source' takes care of the supply of stocked, made-to-order and engineer-to-order products. 'Make' concerns the actual execution of the make-to-stock, make-to-order and engineer-to-order production. In the end, 'deliver', covers the last phase, where the product of the prior processes is prepared for the next process.

The detailed PROPER model of FC0 is shown in Figure 28 where some of the same elements are shown as in Figure 21. The order lines that enter the system consists out of a certain number of articles, a delivery time and a hub where the order line needs to be send to. From this information the order management system (OMS) creates a plan which makes sure that the orders are received correctly, a picking plan is made and the order are released to the master planning process (MPP). Once the order are released the warehouse management system (WMS) can start planning so the ordered articles are received, replenished and picked correctly which results in a filled dispatch frame which is ready to be shipped. For these processes the supervisor makes sure that the resources

are used correctly and are prepared at the time they are needed. As soon as these resources are ready to be used they are assigned to a certain job. After this job is done the resources are released in order to be used again or to leave the system as used resources.

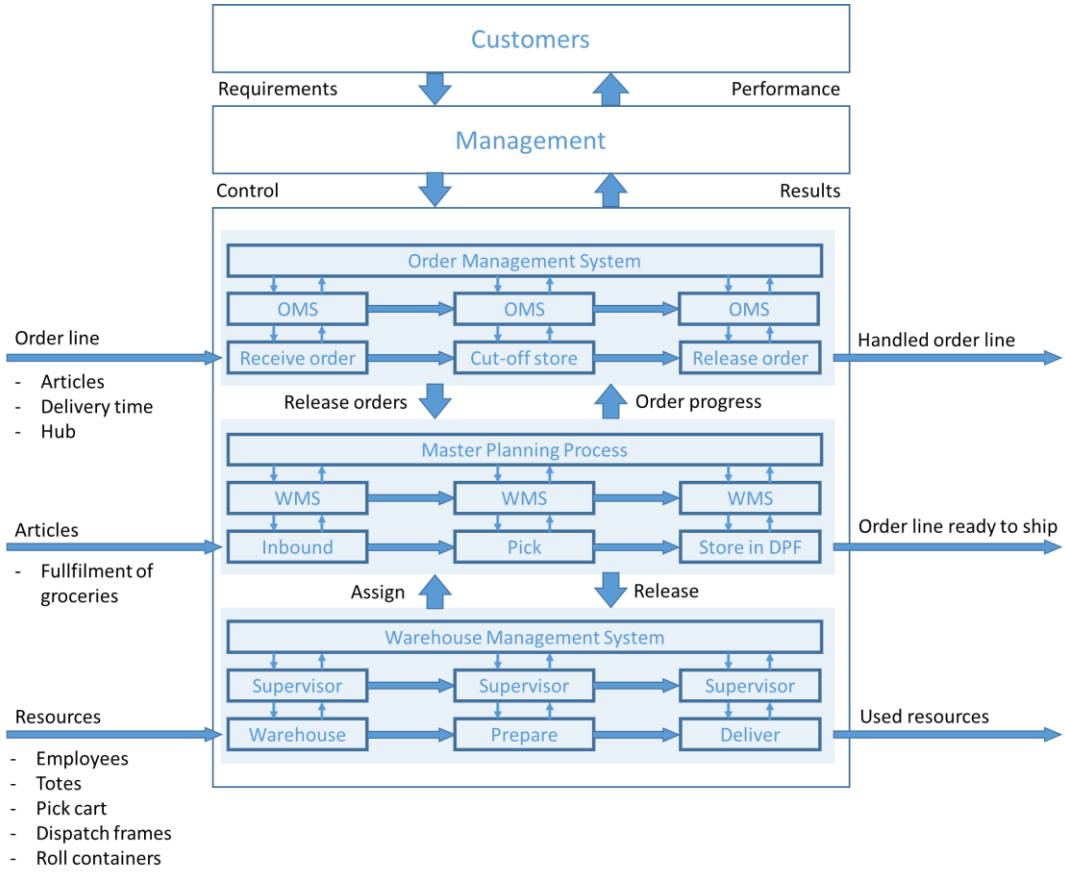


Figure 28: Detailed PROPER model of the processes at Picnic

3.2.1. Detailed explanation of the processes at Picnic (FC0)

When zoomed into the process at Picnic the process can be divided into several activities, see *Figure 29*. These activities are on chronological order the inbound, receiving, replenishment, picking, consolidating, storing and shipping of the articles. Every one of these processes should add something in transforming the ordered articles at the supplier to an order line that is ready to ship. A more complete overview is made in Figure 30 where an IDEF0 overview of the processes in FC0 is made. The supervisor and the flow operator keep a close eye on the entire process and captains have the task to manage the individual processes.

Figure 29: Process at Picnic (FC0)

Inbound (A1)

The inbound are the articles that are delivered at the FC from the Boni DCs. The amount of articles depend on the amount of confirmed orders for the upcoming day and a forecasting model used by order management. Every day several trucks arrive at FC0 to deliver all kinds of products on different times of the day. Normally these trucks arrive in the evening around 6 o'clock and most trading units (TUs) are packed at roll containers (RCs).

Receiving (A2)

Ones the products are delivered, the RCs are divided along the right aisles. Some other deliveries, for example bread, arrive in the morning or at different times of the day. The process then remains the same. The majority of the trucks however has to keep arrive in the evening so the other processes at the FC are interrupted as little as possible. An important part of receiving is to check whether all the products are delivered. For this a receipt is used where all the expected articles are listed. If products aren't received this is communicated with the order management (OM) so a solution (if necessary) can be found.

Replenishment (A3)

Once the products are received and divided along the different aisles they can be stored in the shelves by replenishers in either the ambient zone or the chilled zone. This is done by moving the RCs into the stacking area where the products can be filled. Most of the stacks are ordered in such a way that they can be filled from one side and the products can be picked from the other side. The stacker scans each product after which the stacker fills in the amount of items, he or she then gets a location after which the stacker can fill that position.

Picking (A4)

A shopper, or picker, walks with a picking cart (PC) filled with 12 totes. Every tote is coupled at a fixed position on the PC which enables a WMS program (Corax) to make a fill plan for every tote. Since all the products are measured beforehand (weight and dimensions) the program can plan everything in such a way that all the totes are filled for 75%. The program also makes sure that once the shopper is coupled to a PC, the shopper gets the assignment to pick items in the right order so he or she only has to walk through the picking area once. The shopper gets a location from Corax after which he or she scans the product at that location, the program then gives the tote number and the picker can put the product in that tote. After the tote is also scanned by the picker the next location is given by the program. When a product is not present on the shelve although the WMS thinks it is present, the picker informs the supervisor or flow operator that there is an unexpected shortage. The supervisor or flow operator then tries to solve this problem with either a rush order, store pick or a substitute. When none of these options is possible the supervisor can decide to cancel the order line.

Store (A5)

After all the totes are ready the totes are stored in dispatch frames (DPF's). These DPF's are very similar to PCs but are more conveniently shaped so the trucks can be filled more efficient. The WMS Corax lets the picker know at which location the totes have to be stored in the DPFs and where the DPFs have to be located.

Consolidate (A6)

Although theoretically every product should be in the shelves during the picking rounds, this is not always the case. When this happens the pickers can mark the item as 'shortage' and continue his or her picking round. The totes that are not filled completely then are stored in the consolidation area where the totes can be filled completely. The items that weren't in the shelves can be found in the buffer shelves, replaced, store picked or rush ordered.

Ship (A7)

The last step of the process is that the DPF needs to be shipped in the truck. This is done by the truck driver. Because of the way the DPFs are stored the truck driver only has to push them into the truck without messing the sequence up.

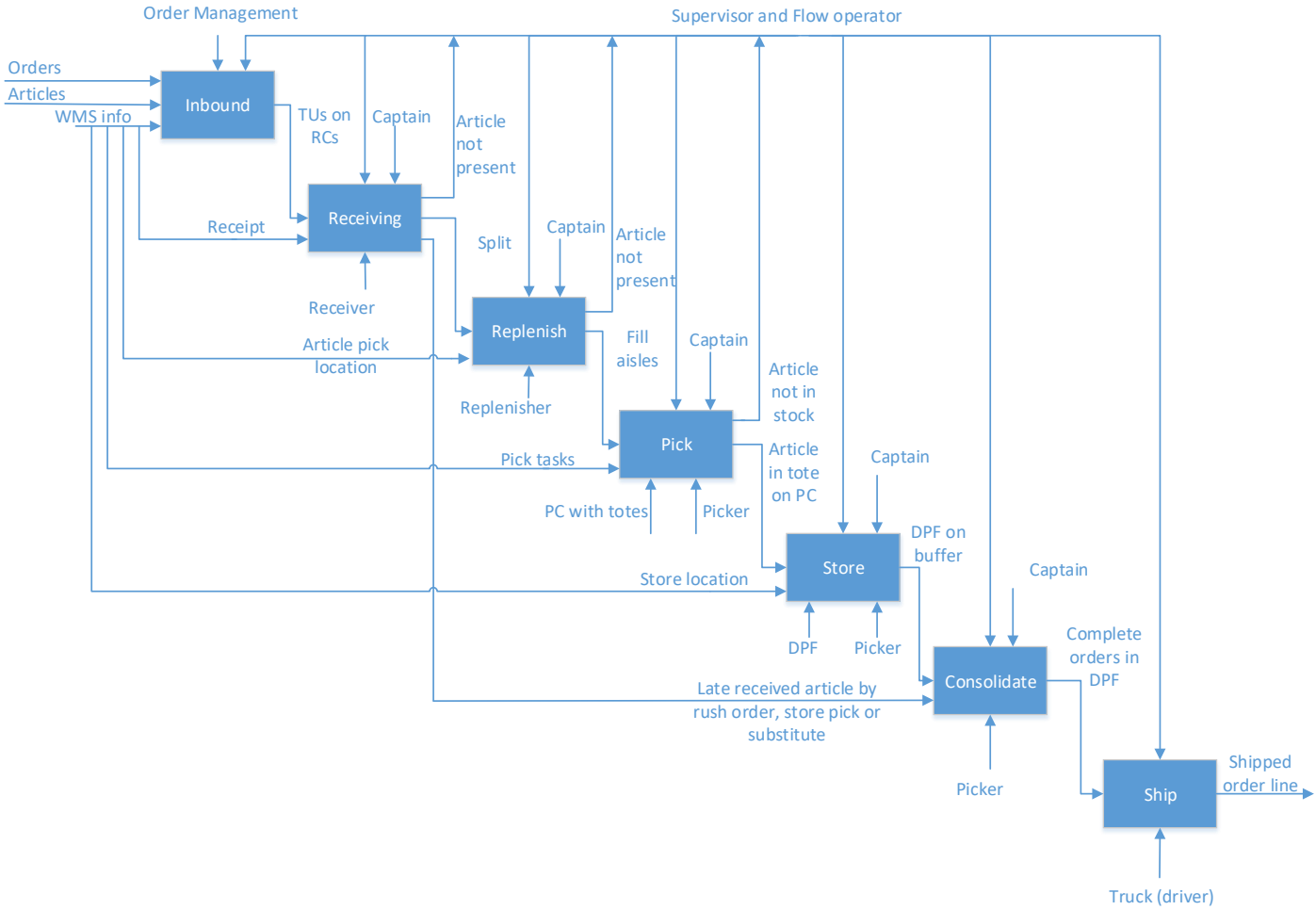


Figure 30: IDEF-0 A1-A7 overview of the processes at the FC

3.3. Root causes of an unexpected shortage

First of all it is important to know what a problem actually is. A problem arises when the stock is lower than initially expected. Ideally there are no mistakes in the process. This means that purchase order management (POM) orders just enough and in time, the supplier delivers everything on time so the products that are needed for the clients are always available in the FC. Furthermore software keeps perfect track of the products that are received and while the products are in the shelves nothing can happen to them. Unfortunately this is not always the case. During several interviews [26] possible root causes of problems came forward which are shown in an Ishikawa diagram [27] in Figure 31. Here the root causes are divided into four main groups: Supplier, management, process and personal. The supplier is responsible for the delivery of needed products, the management, supervisors and flow operators, are responsible for keeping track of the processes and making decisions when needed. The processes are supposed to be designed in such a way that mistakes are (almost) impossible to make, but also to be efficient as well. The personnel is the human factor in the processes which means the human errors comes into the frame.

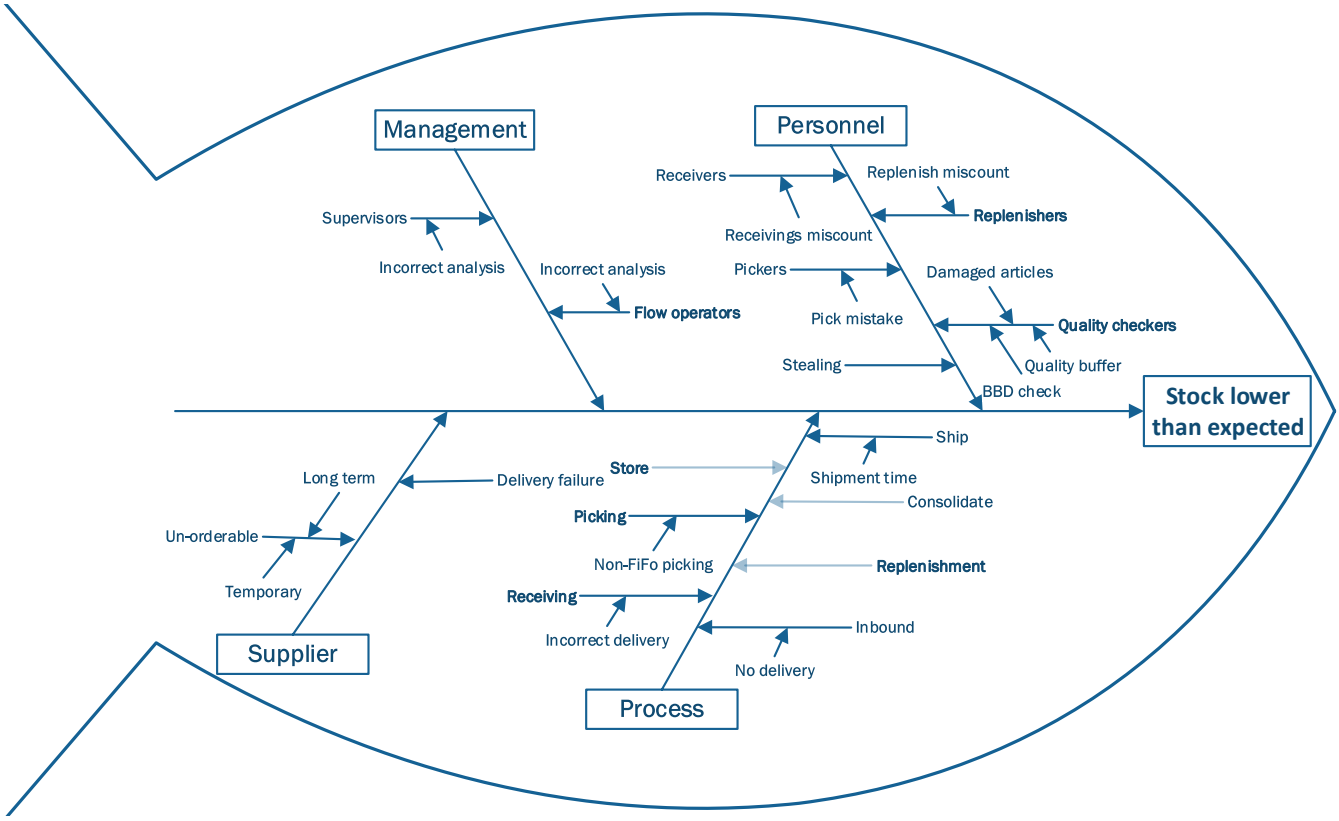


Figure 31: Ishikawa: cause and effect diagram

Although the root causes from Figure 31 are all present in the FC, they're not all of equal importance. An example is that the flow operator can make an incorrect analysis. Although it is possible it almost never happens since most of the tasks of the flow operator are automated which minimizes the amount of mistakes that are made. Furthermore some of the root causes can be put onto one pile: when an article is un-orderable at the supplier this automatically means that there is no inbound. Other root causes are impossible to trace, like stolen goods, and are therefore combined under the title of stock mismatch. After the interviews and a week analysis on the floor the root causes groups from Table 4 came forward as the most important ones. The reason that the root causes are ordered in groups is that it is often difficult to find the actual root cause, but the different group causes are more easily to retrace.

In Table 4 delivery failure means that when POM has ordered a certain item but the supplier was in the end unable to deliver the item. Sometimes this means that the supplier is able to deliver part of the total order and sometimes nothing at all. Another possibility is that an item which normally would be orderable at the supplier is unexpectedly not orderable. When the company has already sold the items before it was ordered, which often happens, that can lead to a stock shortage in the FC. Unexpected clearances often happen with fresh goods with a short BBD. Normally a someone in charge of quality checks to products during receiving and when the products are in the shelves. Ones the quality of the products is not acceptable, the product gets cleared. When POM assumed that these products were able to sell, a stock shortage is again possible. When products with a short BBD are on the shelves the idea is that the oldest products have to be picked first. This to make sure that they don't leave the FC too late. Sometimes pickers don't pick FiFo which results in products with a too short BBD on the shelves wherefore they have to be cleared. Although most of the employees are of good nature, sometimes employees steel certain products. Obviously they do not update this into the database which results in an unexpected item shortage. To make sure there is insight in the products availability in the warehouse, regular stock counts are done. This is done because other disturbances might have caused that the available data is not up to date anymore. Although this can resolve a lot of mistakes, this is still done by humans and humans make (count)mistakes. Arguably there are more disturbances then named here but these are the most important ones.

Table 4: Root cause groups

Root cause group	From Figure 31:		
	Category	**Primary cause**	**Secondary cause**
Un-orderable	Supplier	Un-orderable	Long term Temporarily
Delivery failure	Supplier Process	Delivery failure Inbound	- No delivery
Receiving's mistake	Process Personnel	Receiving Receiver	Incorrect delivery Receiving's miscount
Unexpected clearance	Personnel	Quality checker	BBD check Damaged article
Non FiFo picking	Process	Picking	Non-FiFo picking
Quality buffer	Personnel	Quality checker	Quality buffer
Stock mismatch	Personnel	Picker Replenisher Stealing	Pick mistake Replenish mistake -

3.4. Unexpected shortage effects

When a problem occurs it might lead to the needed search for a solution. This is not always the case since sometimes the stock is simply big enough to cover the disturbance. If this is not the case a solution has to be found. These solutions are definitely not wanted since first of all they disturb the normal process and secondly they come with extra costs. At Picnic, when the stock is lower than expected, the flow chart from Figure 32 is applied.

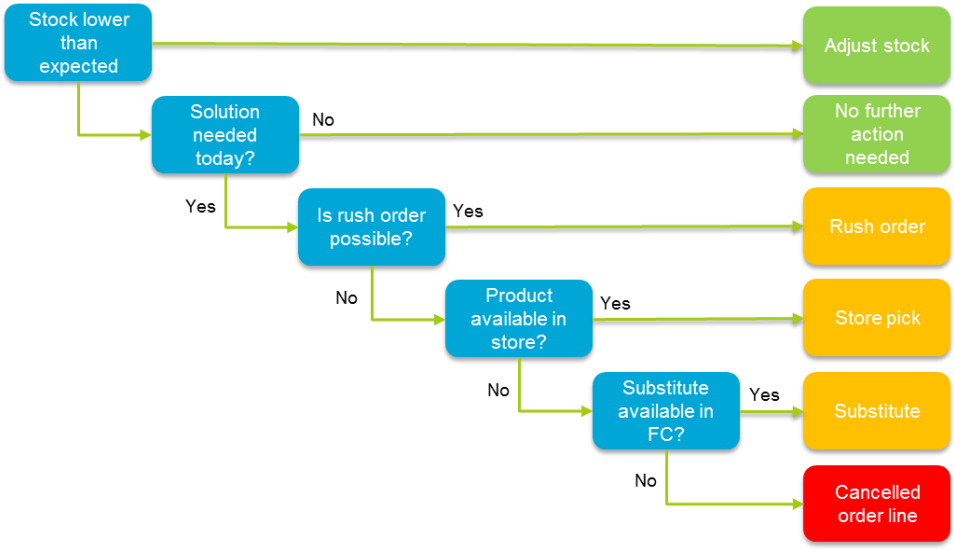


Figure 32: Flow chart when an unexpected shortage arises in the FC

A rush order is done when possible. This normally means that an employee searches for shortages in the FC for that particular day and looks whether it is still possible to order these at the supplier. This has to be done early in the day because otherwise there is simply not enough time to ship the articles and replenish them after receiving. If a rush order is not possible an online grocer can as an alternative go to a nearby supermarket and buy it there. This is not only very time consuming (and thus expensive), the products also have a relatively high purchase cost. Furthermore not all products are possible to buy at a local store since the

products can be very specific. Another solution can be that the customer gets a substitute which is very alike to the product he or she ordered. Although this seems to be a very good solution, normally this product is sold with a discount which also makes it an expensive solution. When the above mentioned is not possible the disturbance can unfortunately result in a cancelled order line. This means that a customer doesn't get one or more products from his or her order. This is highly unwanted since this has a huge effect on the customer satisfaction.

3.5. Collecting data

To gain insight in the disturbances in the FC, many data has to be collected. These data can be divided in the root causes of problems and the solution of the problems. Furthermore it is important to know the relationship between these root causes and their effects.

3.5.1. Collecting data root causes

Product un-orderable

Sometimes it can happen that an article in not orderable at the supplier. This can happen because of a bad harvest which lead to a shortage, disagreement between the supplier and its supplier or something else. Either way it is not possible for Picnic to order a product although they actually want to have it. If Picnic knows this in time they are able to remove the product from online store and it has not consequences. Unfortunately when some clients already ordered the product a solution has to be found.

Finding which products were not orderable is relatively easy since the purchase orders (POs) are available. In these POs the proposed amount (determined using an algorithm of POM) can be compared with the actual order amount. When the order amount is 0 it means that the product was not orderable at Boni. The reason Picnic orders the amount of 0 is because they have insight in what they can and what they can't order at Boni.

Delivery failure

When an article is ordered Picnic assumes the product will be delivered. This because according to the data given by Boni the product should be available. Although most of the times this information is right it can happen that something went wrong. Most of these disturbances are comparable to the disturbances at the FC of Picnic described in this section. One extra reason is that the information given at Picnic about the inventory of Boni is updates once every two hours. This means that in that time another supermarket of Boni can also have placed an order which means that some articles are double ordered. The problem with delivery failure is that compared to an un-orderable product the time to find a solution is shorter.

Since during receiving all the incoming articles are counted and communicated with Boni a good estimate can be made about which articles are delivered and which not.

Receiving miscount

As mentioned in the paragraph above the delivered articles are counted during receiving. After this is done this is communicated with Boni whom on their turn react on this. A significant part of the articles that were previously considered to be not delivered were in fact delivered (at least according to Boni). Although it is never completely clear which company is to blame (Boni can have shipped to little or nothing of the articles or Picnic has made a simple miscount), these articles are all considered as a receiving miscount.

It can happen that after these products are miscounted an inventory shortage comes up. Although this might not be the case, according to the WMS this is, since the products were never received. Therefore some of these products will be rush ordered, store picked or substitutes when this would actually not be needed. Per day the receiving report needs to be checked in order to find out with which products this happened.

Unexpected clearance

During a normal day employees on the floor constantly check the quality and the BBD of the products. When a product is found that is either damaged or has the wrong BBD, this article is removed from the FC. This is done by the employee using a scanner which is in contact with the WMS Corax. Every task that is done by the employees is saved which means that these tasks can be retraced.

Although this seems quite straightforward it is important that only right tasks are taken into account. This is possible using a sophisticated filter to look for the correct tasks.

Non-FiFo picking

For perishable products it is important that they're picked in a first-in-first-out manner. From some products this is done by filling the isles from behind and picking from the front, but this is due to space issues not always possible. Either way the possibility exists that the picker picks an item that has a longer expiration date then another item on the same shelve. The WMS then thinks that the wright item is picked, but a picker on the next day find the item with the short expiration date which is then unsalable. This means a sudden stock change occurs which has to be dealt with.

When something like this happens a stock change has to be made in the WMS Corax which is a task that can be traced. Then when these tasks are found the tasks concerning items without an expiration date and normal count tasks need to be filtered out. If this is done the items where non-fifo picks have occurred are found.

Quality buffer

When the quality checker do not trust the quality of the product they can decide to undertake action. This can mean that a rush order is placed or later on the day a store pick. Another possibility is that a product is qualified as unsalable and a substitute given away to the client. These actions are reported so can be traced.

Stock mismatch

An important disturbance is the stock mismatch. Although it is highly unwanted to find this as a root cause of for example a rush order, it is impossible to not take this into account in the data analysis. The reason for this is that there are too many untraceable reasons why the stock count is wrong. One reason for example can be that an employee stole an item or maybe simply miscounted. A way to make sure the stock count is correct is to check the stock regularly. Currently every shelve is checked once every 20 days. Although this is a good way to make sure the stock count is correct this is a labour intensive job and therefore costs a lot of money. On top of that it is not a guarantee that the stock checker doesn't make a mistake during his or hers check round.

3.5.2. Collecting data consequences

During the day the flow operator continuously updates a file named 'availability cockpit'. In this file the flow operator is able to see the current state of the products need to be shipped that day. Furthermore he or she sees whenever there is a problem with these products. If there is a problem the flow operator decides how he or she want to solve this problem. This is all entered in the availability cockpit from which the data of the consequences can be collected.

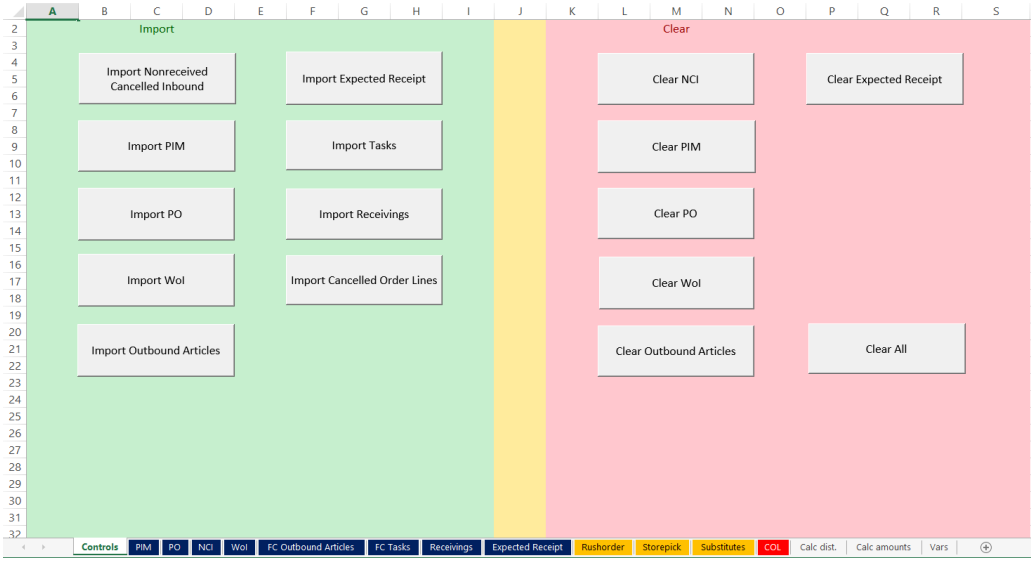


Figure 33: Data collection for the root cause analysis

These data needed for the root cause analysis have been uploaded every day in an excel-file (Figure 33). The file then automatically checks for every sold product that day if something special happened to it (rush order, store pick, substitute or cancelled) after which a possible root cause is searched. A few products cannot be analysed automatically since not all data is available or the analysis is simply too difficult. For these products a manual test is done keeping in mind the conclusion of the flow operator on the floor. This results in a few hundred lines per day for every products which includes what happened to the product on that particular day. These lines are then uploaded in a data collection file which then creates the graphs which are discussed in the next section, Results.

3.6. Key performance indicators

The extra costs resulting from the root causes are a very important KPI for the different design alternatives. Although this is a good measure to compare two options, there is no boundary to which the costs per item has to hold. This boundary can be the costs that can be saved if a certain solution is chosen. This means that even if a rush order is possible, the benefits from this solution might not weigh up to the costs of the solution. Therefore it is important to have an idea of what risk is taken when no solution is used, ergo, an order line is cancelled. This is where the lifetime value (LTV) of a customer comes in.

3.6.1. Costs of the problem solving approaches

To filter out the important disturbances it is important to couple costs to the disturbances and the consequences they have. When there is a problem (the stock is lower than expected), there are five possibilities: there is no solution needed today, a rush order, a store pick, a substitutes or cancelling the order line.

No solution needed

Although there was a disturbance in the supply chain it is possible that there is no solution needed. An example can be that a certain product was ordered but not delivered. The company can have enough stock in store which means there are not consequences to the disturbance. Therefore there are no costs involved in this disturbance.

Rush order

There are several reasons why a rush order is less efficient then a normal order. The main problem is that the order amount are a lot smaller which influences the entire process. It is important to know that at Boni the pickers pick in many different product groups. For every product group from every order the picker has to carry out the steps as shown in Figure 34.

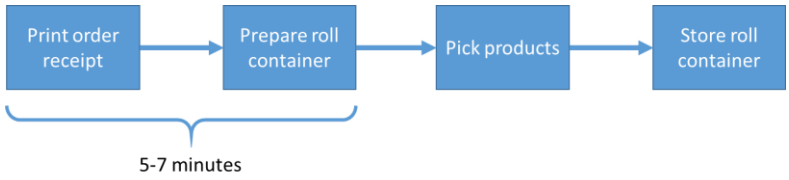


Figure 34: Processes of a picker at Boni

What can be seen is that no matter the amount of products to be picked, the picker loses 5-7 minutes just preparing the pick round. Especially with rush orders this means that the picker loses relatively much time preparing his or hers pick round. On top of this Picnic orders arrive at Boni in several receipts so the orders can be easily split at Picnic along the isles. This results is the fact that pickers often have to undergo the entire picking process several times for a few items. After an interview with a logistics employee of Boni [28] the difference between normal order picking and rush order picking was made clear. Where normal order picking has a pick speed of around 1320 CE/hour, rush order picking as a speed of only 640 CE per/hour. This mainly because of the reasons mentioned above.

The second problem is that when low quantities are ordered the truck driving transporting the items is filled very poorly. This means that a relatively high price has to be paid for renting the truck, paying for gas and paying the driver.

Store pick

Store pick is the most expensive solution because it is very work intensive and the costs of the products are relatively high. The reason store pick is still done is just to keep the customer satisfied. The costs of the store pick is relatively easy to calculate with the following formula (Equation 1):

Equation 1:
$$C_e = \left(P_s + W_m - P_p\right) + \frac{t_{mh}}{N_p} \times C_s + \frac{C_f}{N_p}$$

C_e: Extra costs per product as a result of store pick

P_s: Price at the store

W_m: The margin on the original product

P_p: The purchase price

t_{mh}: The man hours it took to store pick

N_p: The number of products that is store picked that day

C_s: The salary of the store picker

C_f: Fuel costs

D: Discount price

Substitute

As mentioned before the company also has the choice to deliver a substitute instead of the ordered product. Depending on the policy of the company the accompanied costs can be calculated several ways. A common policy is to give the client a certain discount. This leads to the following formula (Equation 2):

Equation 2:
$$C_e = P_{p,substitute} + W_m - D$$

Cancelled order line

Even though there are no direct extra costs involved when a product is cancelled from the order line, the indirect costs can be very high. This is also the reason why the costly solutions rush order and store pick are done. The problem with a cancelled order line is that the customers satisfactions drops a lot when a product doesn't arrive. This can even lead to the client not ordering at the company anymore. This is in particular important for online grocers since the clients often need the products at the same day as the delivery at their house.

One variable to help decision making is the lifetime value (LTV) of a customer. When there is a disturbance in the process the LTV could help in the choice between fixing the disturbance (rush order, store pick or a substitute) or not doing anything about it. At this moment the costs for fixing the disturbance or the chance of losing a customer should be considered. Obviously the supervisor or flow operator can't do this for every case therefore a good work plan should be composed where these factors are taken into account.

Unfortunately it is very difficult to calculate the LTV. Therefore there are several manners to do this and on top of that some assumption have to made. Here two formulas for calculating the LTV are given but in the end the company obviously has to decide how much a customer is really worth. For both methods the following variables are necessary:

- s: Customer expenditure per visit [€]
- c: Number of visits per week
- t: Average customer life span [years]
- r: Customer retention rate [%]
- p: Profit margin per customer [%]
- i: Rate of discount [%]
- m: Average gross margin per customer lifespan [€] (= 52 $(t \times a \times p)$)

Equation 3: Custom LTV $t \times s \times c \times p$

Equation 4: Traditional LTV $m(\frac{r}{1+i-r})$

Since these equations are only an indication often companies use the average of both in order to get a decent inside in the LTV of customers. After an interview with the Trading Team within Picnic [29] the LTV of a customer was estimated to be around €206,-. Here the following assumptions were made:

Customer expenditure per visit:	€60,-
Number of visits per week:	1
Average customer life span:	5 years
Customer retention rate:	75%
Profit margin per customer:	0.7%
Rate of discount:	1%

Considering the LTV of a customer various solution for problems in the FC can be chosen depending on the costs of the solutions. A rush order for example might be way too expensive for an FC which is located far from the supplier but when it is located closer, is could be a viable solution.

The LTV of a customer multiplied by the chance that a client stops ordering at Picnic are the maximum costs that can be invested in a solution per item. This can be taken as a reference value to see when rush order, store picks and substitutes are effective and when not.

Another KPI are the amount of disturbances in the warehouse. The goal is a 'happy flow' which means that these disturbances should be kept to a minimum. Since different root causes have a different effect distribution, solving one root cause might have more influence on minimizing disturbances then the other. This KPI can be represented as the percentage of the total which leaves the warehouse on a certain day.

Furthermore the disturbance distribution could be so the costs are minimized but be very bad from a commercial point of view. When too much customers get a substitute instead of a product they actually ordered, Picnic might get a wrong reputation.

3.7. Results

In this section the results of the disturbance and consequence analysis are shown for the order groups: agfdc, agfxd, arla and freshdc combined (i.e. most of the fresh products). The complete results are also shown in the graphs which can be found in Appendix B: Cause and effect of disturbances and Appendix C: Root cause analysis graphs. In this section the results are discussed.

3.7.1. Disturbances

In Figure 35 the disturbance distribution of the items can be seen. The reason that the number of un-orderable items is not in Figure 35 is that this number is unknown, the only fact that is known is that the product is unavailable at the supplier. What can be seen with a quick look is that the major disturbances in number of items in the FC are delivery failures, receiving's mistakes and unexpected clearances. This is mainly because when there is such a disturbance it normally involves a lot of items per SKU. Therefore the distribution in SKUs is more evenly with the exception of 'shortage at supplier', 'non-fifo picking' and the 'quality buffer'. The fact that the disturbance 'shortage at supplier' doesn't occur so often is because it is very coincidental. When the is an actual shortage at the supplier it is very normal that there is nothing to order since other supermarkets already ordered the last items. Non-FiFo picking is on the other hand remarkably low. This means that pickers actually do a good job in checking for the shortage expiration date on the shelve while picking. The 'quality buffer' was expected to be this low since it doesn't happen because normally the quality of the products is at least sufficient.

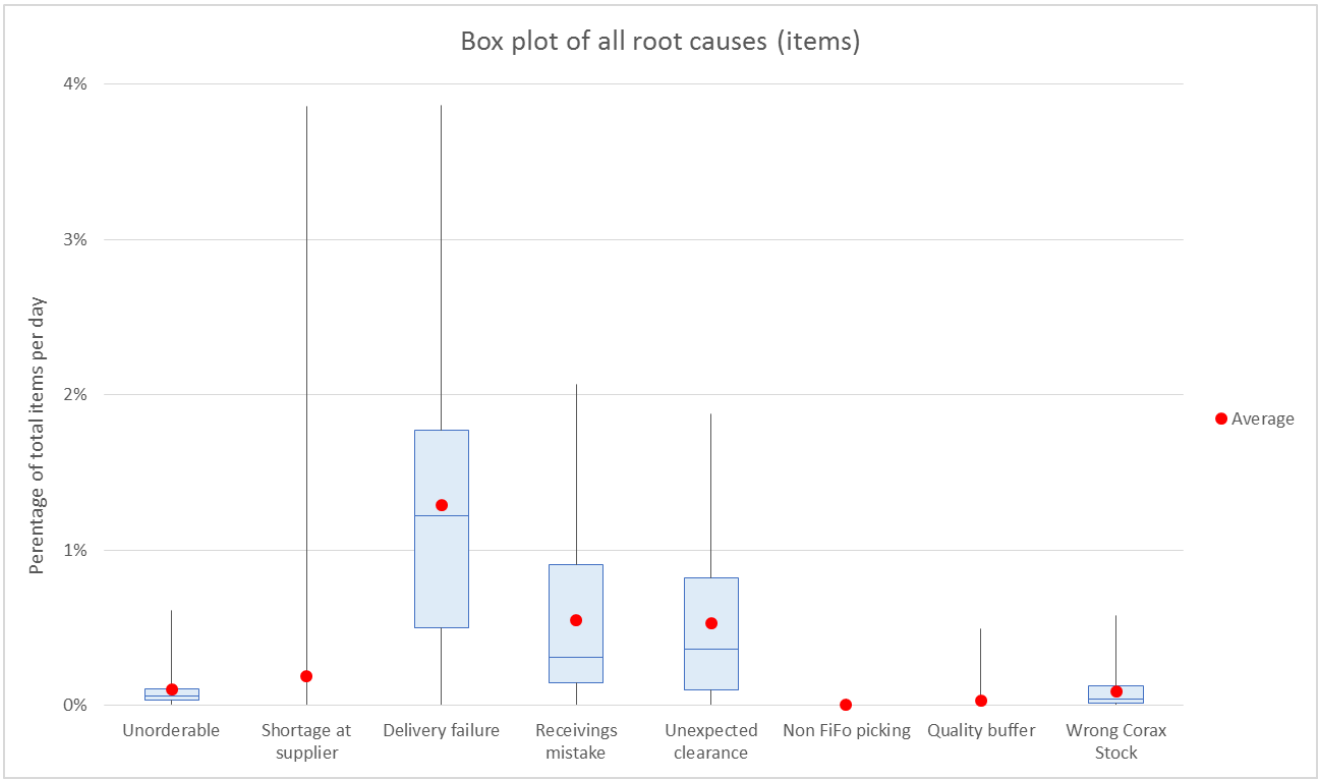


Figure 35: Disturbance distribution (items)

When looked at the consequences coming from these disturbances a few things can be noticed (Appendix). First of all, most of the time when a disturbance occurs there are no consequences. Only non-fifo picking, a quality buffer and a stock mismatch almost always result in a consequence which is to explain by the fact that they all have to lead to a consequence unless someone counts the products before a shortage occurs. Even more, the quality buffer has per definition a consequence since otherwise there wouldn't even be a quality buffer.

3.7.2. Consequences

In Figure 36 the distribution of the consequences of disturbances can be seen. What immediately can be noticed is that most of the consequences are either rush order or store pick. This means that in most cases a cancelled order line is avoided. This is the goal of Picnic since this way the customer doesn't notice little to nothing when a disturbance occurs in the FC. When a rush order or store pick is not possible the option of give away a substitute is possible for two third of the cases, the rest is an unavoidable cancelled order line.

When looked into more detail at the root cause of the rush orders, store picks, substitutes and cancelled order lines (Appendix C: Root cause analysis graphs) it can be seen that for rush order the root cause is by far in most cases a delivery failure, followed by receiving's mistakes and un-orderable at the supplier. Store picks have also mostly as root cause a delivery failure, but also often a stock mismatch. The reason for this is that a stock mismatch often is noticed during the day when a rush order is not possible anymore. Substitutes can be done as a last solution for delivery failure but there are some peak days when suddenly a huge amount of items need the substituted because of quality reasons. When there is no solution found and the items have to be cancelled the root cause divided into four main reasons: un-orderable at the supplier, delivery failure, non-fifo picking and a stock mismatch. This is explicable since a cancelled order line is highly unwanted and therefore only occurs when nothing else is possible. A stock mismatch and non-fifo picking are often revealed at the end of the day when no solution is possible anymore. Furthermore, when a delivery failure is made this is often solvable by a rush order or a store pick, which means it is less likely to be the root cause of a cancelled order line. The fact that a product was or is un-orderable at the supplier means that it is hard to get by and therefore a solution is more difficult to find. Therefore an un-orderable product is often the root cause of a cancelled order line.

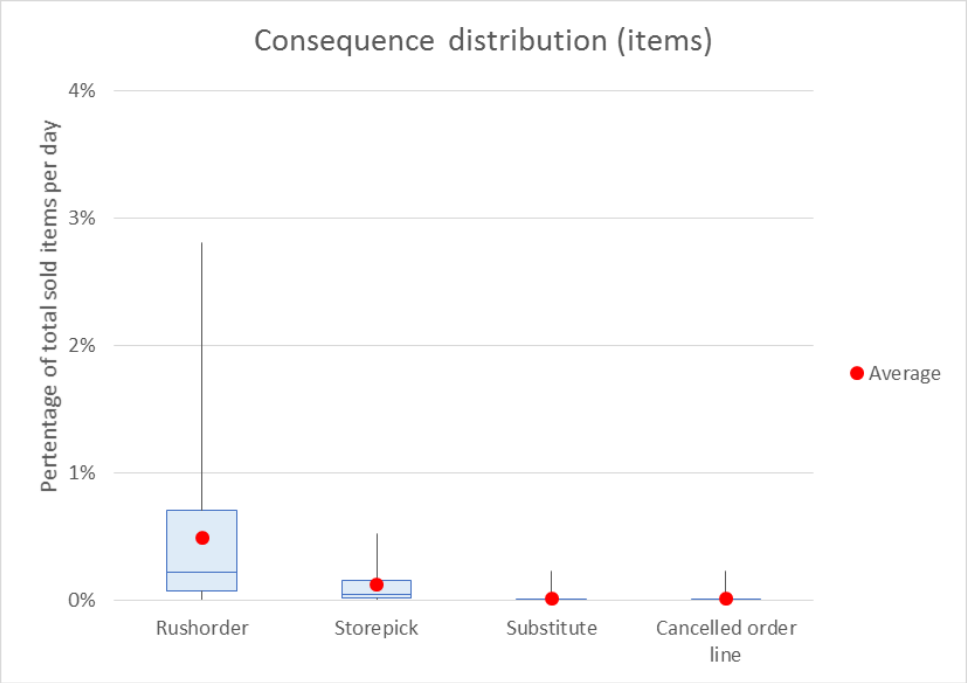


Figure 36: Distribution of consequences of disturbances (items)

3.7.3. Impact of a root cause

In order to measure the impact of a root cause there are a few variables of importance: how often the root cause occurs, the type of effect the root cause has and its peak to average (PTA). With these variables a ranking can be made between the different root causes using Equation 5 (average impact) and Equation 6 (peak impact). Here a clear similarity can be found with risk calculations where risk equals probability times loss [30].

Equation 5: Average impact $\sum_{i=1}^{n} A_i \times C_i$

Equation 6: Peak impact $\sum_{i=1}^{n} A_i \times C_i \times PTA = \sum_{i=1}^{n} C_i \times Peak$

Here i are the different effects of the root causes, A is the average percentage of occurrences, C is a constant which represents the severity of the effect and PTA is the peak to average of the root cause and effect. The values for C are chosen as follows:

No consequence:	0
Rush order:	0.5
Store pick:	2
Substitute:	4
Cancelled order line:	8

These values are chosen in agreement with an expert from Picnic [31]. The higher the value the more severe the consequence of the root cause is. Filling in Equation 5 and Equation 6 leads to the values shown in Table 5. This clearly shows that the delivery failures are the most important root cause off them all. Secondly the root cause ‘un-orderable’ and ‘stock mismatch’ have a big influence on the processes in the FC. This means logically that these root causes need to be taken care of to improve the overall process in the FC. Unfortunately during an interview [32] it became clear that due to complicated negotiations with suppliers it is almost impossible to decrease the amount of un-orderable products. Therefore improving the delivery rate and the inside of the warehouse are the logical choses. Furthermore improving inside of the warehouse can tackle some of the non-fifo picks in an earlier stage so that won’t cause an unwanted effect either.

Table 5: Impact of the root causes

	Average impact [impact factor]	Peak impact [impact factor]
Un-orderable	0.1082	1.000
Shortage at supplier	0.0000	0.000
Delivery failure	0.3869	4.200
Receiving's mistake	0.0260	0.400
Unexpected clearance	0.0212	0.400
Non FiFo picking	0.0955	0.400
Quality buffer	0.0921	0.300
Stock mismatch	0.1399	1.000

3.8. Conclusions of analysis

In order to get an overview of the processes within the FC of Picnic an analysis is done using both the DSA (PROPER-model) and the IDEF-0 approach. First only the inputs and outputs of the entire process where taken into account where after these processes were discussed in increasing detail. Here the PROPER model has given a good inside in what purpose every process has where the IDEF-0 approach gave a better inside in the interaction between the processes.

The processes at the FC start at the inbound with as input the orders and articles. This process is controlled by order management. The next processes are receiving, replenishing, picking, storing, consolidating and shipping. These processes are executed by employees on the work floor and controlled by the supervisor and flow operator. Every process has their own necessary input and an output ready for the next process. In the end product is an order line which is ready to ship.

In a 'happy flow' every there is a balanced input (order, articles and equipment) to enable all the necessary output (shipped order lines), and there are no disturbances along the way which result in a problem. Here a problem is the shortage of a certain article during the day. Unfortunately this is rarely the case. Therefore a several root causes of problems are differentiated namely: un-orderable or shortage at supplier, delivery failure, receiving's mistake, unexpected clearance, non-fifo picking, quality buffer and a stock mismatch. These root causes can have four different effects: rush orders, store picks, substitutes and cancelled order lines.

After an analysis of the root causes and effects in the FC (Appendix B: Cause and effect and section 3.7.3) a few things can be concluded. First of all in number of items and SKUs the root causes un-orderable, delivery failure, receiving's mistake and unexpected clearances seem to be the most important disturbances. However these disturbances do not always have a consequence. Furthermore, there is a huge difference between the gravity of an effect. Rush orders are more desirable then store picks, which are on their turn more desirable then substitutes. Cancelled order lines are averted as much as possible. For this reason the root cause of the effects is also analysed (Appendix C: Root cause analysis graphs). From this it can be concluded that the main root causes of rush orders are un-orderable items, delivery failures and receiving's mistakes. The same goes for store picks with the exception of receiving's mistakes. Substitutes are also often used after a delivery failure but also as a quality buffer. The main reason for a cancelled order line are delivery failure and a stock mismatch, followed by non-fifo picking and unexpected clearance. After quantifying the severity of the root causes (3.7.3) it can be concluded that delivery failures and stock mismatches are the most important root causes to be taken care of.

4. Design

After the literature research and the analysis of the current situation at Picnic, new design alternatives can be described which is done in this chapter. The design alternatives are discussed and possible KPIs are suggested. After this is done a way to assess the design alternatives with a Monte Carlo simulation is explained.

4.1. Design alternatives

From the analysis some conclusions have been drawn, see paragraph 3.8. From these conclusions some design alternatives can be made which are discussed in this section. In chapter 3 it became clear that delivery failures have a huge impact on the processes at the FC. This means that changes in the performance of the delivery can result in significant performance changes in the entire upstream supply chain. Furthermore it was seen that rush orders and store picks are relatively labour intensive, therefore the influence of these processes needs to be investigated more. Obviously the location of the FC and the future growth of Picnic play a major part in the costs of the operation of the upstream supply chain. Therefore these variables need to be taken into account while the design alternatives are investigated.

When looked at design alternatives a separation can be made between tackling the root causes of the problems or changing the way problems are handled.

4.1.1. Root causes

Alternative 1: Reduce delivery failures (RDF)

The most important (root) cause of the problems at the FC are the delivery failures. Not only the processes at Picnic are disturbed because of this, but also the processes at Boni since a significant part of the delivery failures result in a rush order. Since the rush orders are highly inefficient the investments in reducing delivery failures might be easily earned back because of the decrease of rush orders.

Unfortunately it is (almost) impossible to reduce the delivery failures to 0 since Boni it also depending on its own suppliers, but there is already a team set up which focusses on the improvement opportunities and implementation in the delivery process. This can mean improving the order amounts in comparison to the (predicted) demand but also better warehouse management in order to know better which products can be delivered and which not.

Alternative 2: Improve warehouse insights (IWI)

Although in total the amount of stock mismatches is not very high in comparison to for example the delivery failures, it is still a very significant root cause for store picks, substitutes and cancelled order lines. Improving the insight of the warehouse could result in less undesirable effects in the warehouse. Although people are involved and therefore the human errors (in for example counting) will always be a factor an improvement step can be made in this area. There will be extra costs involved since an extra employee has to be paid to count the stock.

Alternative 3: Direct delivery (DD)

As mentioned before, while Picnic grows, more and more products will be delivered directly to Picnic. Although this results in a more efficient process since the intermediate step at Boni will be taken away, this can have some negative effects as well. The advantage of having a DC of Boni as a supplier is that there always is some buffer when there is for example a production failure. This means that with direct delivery the amount of delivery failures might rise and be more unpredictable. For this alternative there will not be extra costs involved since the fact that Picnic will have to change to direct delivery is a given.

4.1.2. Changing the problem solving procedure

Alternative 4: Different store pick procedure (DSPP)

When Picnic started store picking was a necessary part of the process because otherwise a unacceptable part of the order lines would have to be cancelled. At that time (August 2015) it was already mentioned that store picking would have to be stopped after a few months because of its high costs per item. Unfortunately it seemed to be a crucial part in keeping up client satisfaction in terms of order completeness. Now the amount of items which are shipped per day is rising to such high numbers that (more) store picking will soon not be possible anymore. Therefore a prediction of what can happen is store picking stops is an important design alternative to be analysed.

Another possibility is that the store pick procedure changes in such a way that some products are allowed to be store picked when they are of great importance to the customer, and other don't. An example would the potatoes that could be used for dinner that same night would be store picked, but a role of peppermint would be a cancelled order line. In order to implement this DSPP some extra costs have to be taken into account to make this possible.

Alternative 5: Improve rush order process (IRP)

As explained in section 3.6.1 the costs of the rush orders are partially high because of the inefficient way of working at Boni. The picking speeds for rush orders appears to be three times as low as that of a normal order. This means that there is a huge improvement opportunity here. Although it will definitely cost something to implement these improvements it is very interesting to what the savings could be.

An example of how the process could be improved is by putting the entire rush order on one receipt. This would mean that only one picker is needed for the rush order, only one receipt has to be printed out and only one container has to be prepared. This way some unnecessary actions are eliminated resulting in a more efficient picking process. For this, every day an employee has to make sure the right products end up on the same receipts, or this process has to be automated.

4.1.3. Variables

Future growth

One of the most important things that changes constantly are the amount of orders and items that are handled per day at Picnic. Therefore growth most be accounted for when looked for design alternatives in the future. Another reason why growth ought to be taken into account is because some of the alternatives won't be realistic unless there is a growth stroke, for example direct delivery. This also works the other way around where some design aren't feasible anymore in the not too distant future, for example store picking.

Location of the FC

The location of the FC is obviously important for various reasons. First of all it should be easily accessible for suppliers and distribution. When looked at the disturbances at the FC in the upstream supply chain the location has mainly an influence on the costs of the rush orders. These orders have to be transported from the supplier to Picnic which simply means that the further the FC from the supplier, the more it costs. When these costs per item surpass a certain boundary is might simply not be desirable to place a rush order.

Transportation costs

The costs to transport items from the DC of Boni (for rush orders) and from the supermarkets (for store picks) to the FC of Picnic are taken into account. For this the costs of fuel and the rent of the vehicles are the most important factors that influence the total transport costs. Furthermore the time it takes to load and unload the vehicles are included in this variable.

Costs of employees

For every process where employees have to be put to work, extra costs are involved. Therefore the hourly wage of the employees and the amount of hours they have to work is an important input which influences the output of the model.

4.2. Assumptions

In the model a few assumption are made.

- It is assumed that the distribution of the root causes remains the same unless the design alternative influences the distribution.
- In the model there can only be one root cause per product. In reality this is not always the case but the amount of times it happens (0.15%) is negligible.
- There is no relation in root cause distribution between the consecutive days.
- The salary of every employee is the same.
- The average speed of the truck is independent from the distance.
- The extra costs for SUBs and COLs remains the same throughout the simulation.
- The distance from supplier to the FC is chosen to be 5 kilometres in order to compare the alternatives. A sensitivity analysis in done in Appendix E: Sensitivity analysis distance supplier.

4.3. Simulation model

Since there is a large variation in the results from the analysis, a simulation has to be made in order to be able to see the influence of the different design alternatives. For this the data from the analysis will be used as input and for the different alternatives this input can be changed. In order to calculate the KPIs of the design alternatives more input is needed which is discussed in section 4.3.2. With these data the model calculates the output (KPIs) which is schematically showed using the black box approach in Figure 37.

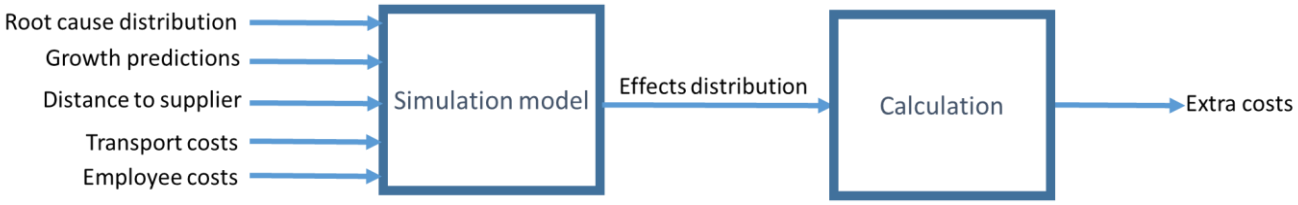


Figure 37: Schematic representation of the simulation model

4.3.1. Monte Carlo simulation

The stochastic nature of the processes should be reflected in the simulation. For this the Monte Carlo simulation is used [33] [34]. A Monte Carlo simulation is a widely used technique in probabilistic analysis's. It is a numerical experimentation technique to obtain the statistics of the output variables, given certain input variables. In each experiment, the values of the input variables are sampled based on their distribution. Using a computational model the output variables are then calculated. This way a number of experiments is carried out and the results are used to compute the statistics of the output variables. Besides the fact that the Monte Carlo simulation is used so often for statistical analysis, other researches have successfully used the Monte Carlo simulation in order the further analyse the effects of root causes (*Boiarkina et al* [35] and *Bailey et al* [36]). In *Boiarkina et al* a fault diagnosis of an industrial plant was done using a Monte Carlo analysis. Here different root causes where simulated in order to make an estimation of the effect distribution. In *Bailey et al* possible root causes of power electronic modules have been identified after which the possible effect distribution is simulated using the Monte Carlo method. These papers have shown that the Monte Carlo method is a useful tool to simulate the effects of root causes given a certain distribution.

4.3.2. Input data for the model

The inputs can be divided into four main input groups: the root cause distribution, growth of Picnic, location of the FC, transport costs and employee costs. From these input groups the root cause distribution is the most complicated, followed by growth. The rest of the data is relatively easy to look up. A more detailed explanation of the inputs is already given in section 4.1.1 until 4.1.3.

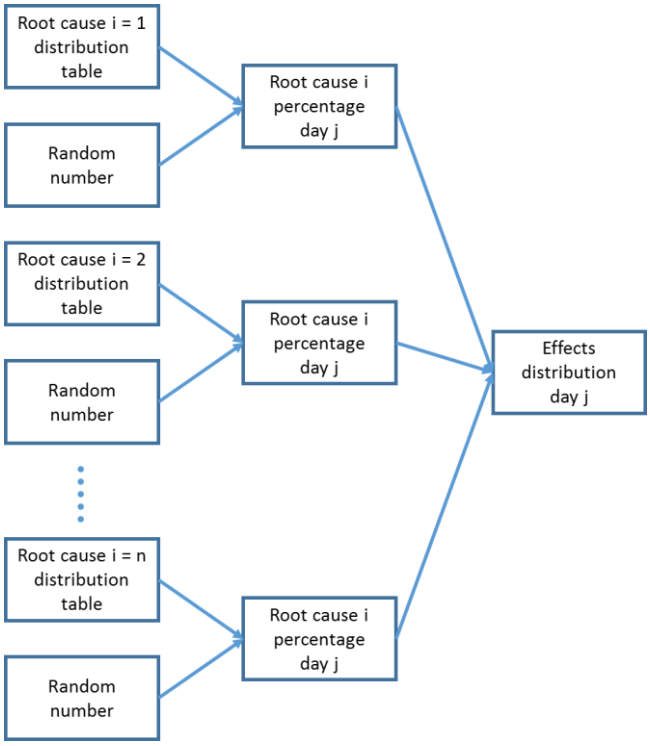


Figure 38: Creation of the distribution of the effects of a random day

4.3.3. The model

Directly from the root cause distribution the effects of the disturbances are distracted. These effects then have their own frequency distribution per day and with these data and the other input groups, the extra costs in the process can be calculated and compared. The root cause distribution is given with five numbers: a minimum, first quartile, median, third quartile and a maximum. So a percentage for a certain day can be created in a few steps. First a random number between 0 and 1 has to be created, when this number is between 0 and 0.25, a percentage has to be created between the minimum and the first quartile. If the number is between 0.25 and 0.5 a percentage has to be created between the first quartile and the median and so on. This percentage can be created with the following formula:

Equation 7: $$lower\ bound + (lower\ bound - higher\ bound) \times random\ number$$

Here the random number is again a number between 0 and 1. Now a percentage for a root cause is created for a random day given a certain distribution. This is shown schematically in Figure 38. For every day a percentage is created for every root cause. From these root cause the effect distribution is known from the analysis. Therefore it is also possible to calculate the effects distribution for this particular day. This can be done for n days.

4.3.4. The output of the model

If the effects distribution is known for n days an average can be calculated. This results in an average percentage of effects per day which means, using the inputs of the model, the average extra costs per day can be calculated due to the effects of the root causes, see Figure 37.

4.4. Model verification and validation

The applicability of the model depends on the output. This output needs to be an accurate representation of the reality. Although a model, per definition, is an simplification of reality, it should give sufficient insight in what happens in the real world. To test this the model has to be verified and validated.

According to *Sargent* [37] verification is 'assuring that the computer programming and implementation of the conceptual model is correct'. In this case the verification is done in collaboration with experts from Picnic. By building up de model step-by-step and continuously check whether the input and formulas where used correctly the model was verified. When irregularities where found, the error was traced and then double-checked by the experts.

Before the simulation can be used it has to be validated. This is done by comparing a set of experiments with the current situation at FC0. For this extra data was collected of twenty days. Using the same root cause distribution as described in section 3.7 as input, similar effect distribution should be found as in the extra data set.

First of all when the model creates root cause distributions per day and its effects, the distribution of the created root causes should be the same as its input. This means that the created figures should result in the same quartiles. This is, with small negligible deviations, the case.

Secondly the averages of the root causes ought to be close to the measured values. This means that the average of the created values divided by the measured average is close to 1 (see Equation 8). The number N for 600 simulation round is on average for all root causes 1.21. The reason there are big deviations compared to the extra data set is that for some root causes the outcome of Equation 8 is very high. Root causes that occur little, can quickly result in high outcomes of Equation 8.

Equation 8: $$\frac{A_s}{A_m} = N \approx 1$$

The next check is to see whether the quartiles of the effects of the simulations match the measured values from the analysis. After a thorough investigation of the way the effects are distributed along the root causes the quartiles of the effect match satisfactory. Then the averages of the effects should match as well. For this equation 5 can be used once more. In this case the average of N is 0.93. Here the average is a little bit lower than the measured values. This is because the distribution of the root causes is apparently slightly different.

4.5. Conclusions of the design

In this chapter a simulation model is described which makes it possible to compare different design alternatives in relation to the root causes of problems and their effects. The different design alternatives can be divided into two groups: changing the root cause distribution and changing the problem solving processes. The alternatives are chosen on the basis of what appeared to be the most important root causes from chapter 3. Furthermore following this same analysis two different problem solving processes are proposed.

For the model the root cause distribution data from chapter 3 is used as a basis. Using these data the effect distribution is determined and with that the extra costs of the effects is calculated. Computing the extra costs of the design alternatives means that the input of the root cause distribution has to be changed. The results from these simulation can then be compared with the current situation (the baseline) and alternative that all orders lines are cancelled instead of solved. The last will result in the loss of clients which can be seen as extra costs.

5. Assessment

In the design phase multiple design alternatives for the future have been discussed which could improve, or have a negative influence on, the performance of the FC. These alternatives are described in the previous chapter along with the KPIs and the simulation model. In this chapter the different alternatives are assessed and subsequently their performance will be discussed.

5.1. Experimental plan

As stated before the five different alternatives from section 4.1 need to be tested in a Monte Carlo simulation in order to get insight in their influence on the performance of the FC. In this section the goal, classification and scope of the simulation are discussed. Furthermore a detailed explanation about the input is given along with the chosen KPIs.

5.1.1. Goal

The goal of the simulation is to gain insight in the effects of different plausible alternatives and their influence on the performance of the FC. These alternatives are as follows (see section 4.1):

Alternative 1: Reduction of delivery failures (RDF)
Alternative 2: Improve insight in the FC (IWI)
Alternative 3: Transition to direct delivery (DD)
Alternative 4: Change the store pick procedure (DSPP)
Alternative 5: Improvement of the rush order process (IRP)

The experiment has as a purpose to assess these alternatives and compare them to the reference case or in other words, the current situation. The performance is measured in the change in extra costs due to problems in the FC. Since the inputs of the alternatives are based on assumptions a sensitivity analysis is also needed.

5.1.2. Classification

The model is a discrete dynamic model. The extra costs are calculated per period and therefore include the effects of rapid growth. Following the goal of the research the extra costs are calculated on the basis of averages, and are therefore discussed from a strategic point of view.

5.1.3. Scope

In order to be able to make good conclusions about the simulation a clear scope is needed. Therefore the following system boundaries are chosen:

- The model assumes every FC stands on its own. Therefore improvements in efficiency by working together with other FC are not possible.
- The model only calculates the effects within the order groups afgdc, agfxd, arla and freshdc. This means it is not possible to extrapolate the results to the entire FC
- The simulated FC is able to grow to a maximum of 10000 orders per day. This means that there is a limit to the growth of the FC. The reason for this is that the current biggest FC (FC1) has a maximum capacity of around 5000 orders per day but future FCs are meant to be significantly bigger.

5.1.4. Input

The input of the model are the different alternatives as described in section 4.1. These alternatives are described very broad and there a more precise description of the effects is needed. It needs to be mentioned that every alternative is an adaption to the current

situation. It needs to be stated that these alternatives are based on assumptions and therefore the sensitivity analysis is important in order to make conclusions.

Alternative 1: Reduction of delivery failures

As concluded in the results of the analysis the delivery failures have a huge influence on the performance of the FC. Therefore a reduction is wanted for both Picnic and Boni. In the current situation almost 2% of the items which are ordered result in a delivery failure on average. Although this seems like a reasonably amount, the items that Picnic wanted to order but couldn't are not taken into account, which would make the delivery performance of Boni significantly worse. Therefore improving this to a delivery failure to 1% looks like a good goal for the long-term and is therefore chosen to simulate. This means that every effect of delivery failures will divided by two compared to the current situation.

The be able to accomplish this reduction in delivery failures, investments have to be made. In consultation with experts from Boni and Picnic the assumption is made that a team of specialists could accomplish this goal by working on this project for 2 weeks using the current resources so no extra investments are needed. Since this would be an overall improvement for Boni not all costs are on the account of Picnic the extra costs involved are within reasonable limits. These costs are divided over the 60 weeks of setting up an FC which resulted in an educated guess of €15,- extra costs per day to implement this alternative.

Alternative 2: Improve insight in the FC

Improving the insight in the FC is simply possible by assigning employees to counting the products in the FC. This is already done but in this alternative this would be done more regularly. Since there is still a human error involved the insight can never be a 100% therefore a reduction of stock mismatches of 33% is chosen. This influences not only the inexplicable stock mismatches but also the mistakes in non-fifo picking, since during these checks these mistakes will also be found.

The extra costs involved with this alternative are simply the costs of paying the extra employee whom checks the inventory. In this case one extra person will perform a check round one day in the week which results in extra investment costs of €20,- per day.

Alternative 3: Transition to direct delivery

Although direct delivery seems to have a lot of advantages, there are, especially when the negotiation position is not yet very strong, some down sides. Since the DC of Boni works as a sort of buffer the delivery performance can decrease with direct delivery. Furthermore rush orders will highly likely not be possible anymore. This means that instead of rush order the problems need to be fixed with store picks or substitutes or cancelling the order line. Since Picnic is growing fast and direct delivery seems unavoidable, this alternative is taken into account. In Appendix A: Direct delivery, some insight is given in how the percentage of direct delivery grows. Since vegetables are within the order groups that are analysed and these are all collected by one company at different suppliers for the simulation it is assumed that after a while 15% of the deliveries will be direct delivery.

Since direct delivery is unavoidable given the current growth, no extra costs are involved in this alternative. This alternative simply gives insight in what would happen in the scenario that the performance of direct delivery is bad. Or in other words, it shows the importance of clear (performance) deals with potential deliverers.

Alternative 4: Change the store pick procedure

Since store picking is relatively very expensive it would be good to do this as little as possible. Therefore it is suggested to limit the amount of store picks and only store pick important items for the client. Items that are easily substituted or are regarded as less important for the client are therefore not store picked. In the simulation the effect of reducing the amount of store picks with 50% are calculated.

Since determining whether a product is important enough to store pick is a judgement call of the supervisor, there are no extra costs involved in this alternative.

Alternative 5: Improvement of the rush order process

Since the rush order process at Boni is currently highly inefficient [28] a big improvement step can be made here. Currently the normal pick speed at Boni is around 1920 CE per hour. For a rush order this drops to around 640 CE per hour and therefore results in a lot of extra costs. Improving this process seems relatively easy (one employee can do one rush order pick round instead of

several employees, several round for one rush order). For this reason the assumption is made that it is possible to improve the rush order picking to 1280 CE per hour.

To implement this the pickers at Boni need to be given one receipt instead of several ones. This means an employee has to merge the correct receipts takes some time every day. Therefore the extra costs per day are chosen to be €10,-.

Growth

The growth of Picnic is a major issue which has a huge influence on the extra costs in the FC. In the simulation it is assumed that the growth in the FC will be 5% per week, which is the goal of Picnic. This growth will continue until the maximum of 10000 order per day is reached as mentioned in the assumptions. A new FC takes over an area of older FCs which means it won't start at 0 order per day but at 500 order per day.

# of weeks	0 week	10 weeks	20 weeks	30 weeks	40 weeks	50 weeks	60 weeks
Orders per day	500	814	1326	2160	3520	5734	9340

5.1.5.KPIs

As mentioned earlier the most important KPI of the simulation is the extra costs that are related to the alternatives. These extra costs are calculated using the averages of the effects of the unexpected shortages in the FC. Therefore the distribution of the different effects can also be seen as a KPI. Knowing the influence on the effect distribution also gives a lot of information about the different alternatives. Furthermore having insight in this distribution can be very important from a strategic point of view when plan for the future are made. The extra costs can be evaluated in several ways:

- Total extra costs per day
- Average extra costs per day per item with an unexpected shortage
- Average extra costs per order per day
- Average extra costs per order per day relative to the current situation

5.1.6.Method

First of all the model described in chapter 4 will be used for every alternative. This means that the input of the model changes for every alternative. The Monte Carlo simulation is done 2300 times in order to gain reliable averages. The reason for this amount is that the results of the simulation are then reliable enough. Repeating the same experiment 14 times resulted in a maximum coefficient of variation of 0.09. After the effect distribution is calculated by the simulation model the calculations described in section 3.6.1 are used to calculate the extra costs for every alternative.

5.2. Results

The results are given in two parts: first the effect distribution is analysed for the different alternatives and subsequently the corresponding extra costs.

5.2.1.Effect distribution of the alternatives

In Figure 39 the effect distribution of the different alternatives as described in section 5.1.4 is shown. For more detailed figures reference is made to Table 6 and Table 7. The first thing that might stand out is that alternative 5 is not shown. The reason for this is that alternative 5 has the same distribution as the current situation, the only difference is that the extra costs calculation is done differently. For the effects distribution it is important to keep in mind that the Monte Carlo simulation is based on stochastics which means that not all differences are significantly big enough to make conclusions of.

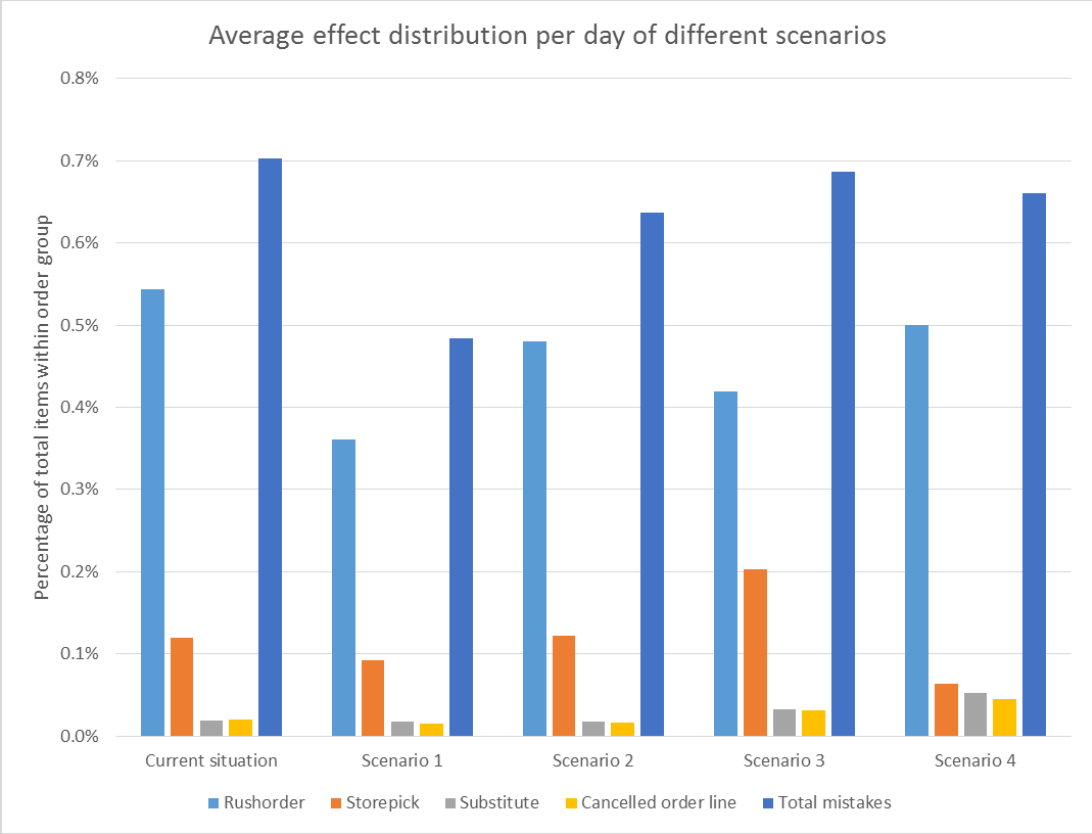


Figure 39: Effect distribution of the different alternatives

Alternative 1: Reduce delivery failures (RDF)

When comparing alternative 1 to the current situation there are a few clear differences. First of all the total unexpected shortages at the FC is dropped significantly with almost a third. This confirms the presumption that the delivery failures have a huge influence on the amount of problems at the FC. This drop of problems is mainly thanks to the drop in rush orders. There is also a significant drop in the amount of store picks (-28%) but the influence on substitutes and cancelled order lines is, though definitely present, slightly less clear.

Alternative 2: Improve insight in the FC (IWI)

This alternative has clearly less influence on the performance of the FC then alternative 1, but is still very positive. The drop in problems at the FC is not as clear as in alternative 1 but is definitely still present. Although the overall drop of problems is less, there is a relatively higher effect on the number of substitutes and especially cancelled order lines. This can be explained by the fact that when there is a stock mismatch this is normally discovered very late in the process and their often results in a substitute of a cancelled order line.

Table 6: Detailed figures of the effect distribution of different alternatives

Effect	Current situation	RDF	IWI	DD	DSPP
Rush order	0.538%	0.369%	0.504%	0.447%	0.509%
Store pick	0.128%	0.092%	0.116%	0.208%	0.063%
Substitute	0.018%	0.015%	0.017%	0.032%	0.054%
Cancelled order line	0.019%	0.014%	0.016%	0.031%	0.044%
Total mistakes	0.704%	0.490%	0.653%	0.718%	0.670%

Table 7: Increase or decrease effect occurrences compared to current situation

Effect	RDF	IWI	DD	DSPP
Rush order	-31%	-6%	-17%	-5%
Store pick	-28%	-9%	62%	-51%
Substitute	-19%	-7%	75%	191%
Cancelled order line	-23%	-15%	67%	139%
Total mistake	-30%	-7%	2%	-5%

Alternative 3: Direct delivery (DD)

In this alternative it is assumed that a part of the items is delivered directly. These direct deliveries are assumed to have a lower performance and rush orders are not possible. The last results in a significant drop of the amount of rush orders. Unfortunately this does not mean that it is a good thing. Namely, the drop in rush orders has direct effect on the rise of store picks, substitutes and cancelled order lines. This also explains why there is only a minimum rise in total problems in the FC since direct delivery mainly provides a different distribution of the effects.

Alternative 4: Different store pick procedure (DSPP)

As expected there is a very clear drop in number of store picks, since not every item that is unavailable, is store picked in this alternative. This then results in a huge rise of number of substitutes and cancelled order lines. Though there also a drop in rush order this is not due to the different store pick procedure but simply to the stochastic nature of the simulation.

5.2.2. Extra costs of the alternatives

The average extra costs can be analyzed in a lot of different ways. First of all it is important to keep in mind that these calculations are done one the effects distribution described in the previous section, and are there affected by the stochastic nature of the Monte Carlo simulation. In this section there will be looked into the total extra costs per day, the extra costs per item and the average extra costs per order line.

First of all, in order to gain a good overview, there will be looked into the average extra costs per day, see Figure 40. As can be seen is that at first all the alternatives result in more extra costs compared to the current situation. This can be explained by the fact that most alternatives have investment costs or have other extra costs per day. Although the extra costs are higher at the beginning one alternative clearly results in a big improvement, namely the reduction of delivery failures (RDF). Other alternatives that eventually lead to an improvement are improvement in warehouse insight (IWI) and improvement of the rush order process (IRP). Direct delivery (DD) leads to more extra costs which was expected since in this case it was assumed that the performance of DD was worse than that of Boni. Furthermore the different store pick procedure leads to a lot of extra costs since the extra costs of no store pick (substitutes or cancelled order lines) are very relatively high. This clearly shows the importance of customer satisfaction.

In Figure 41 and Figure 42 respectively the average extra costs per order and the relative extra costs per order (compared to the current situation) are shown. First of all what can be seen in Figure 41 is how the average extra costs per order decrease during growth for all design alternatives. The main reason for this is because a lot of costs are fixed. For example when a rush order is placed the truck has to drive, whether it is for one or a thousand articles. These fixed costs have less influence after growth of the FC. This means that as long as the amount of orders grows the costs per order will approach a certain minimal value.

The differences between the alternatives are more clearly shown in Figure 42. Here, again it can be seen that all alternatives have higher extra costs in the start-up face of the FC. But after 30 weeks the reduction of delivery failures is already cheaper than the current situation and improvement of insight of the FC and improvement of the rush order procedure follow after 60 weeks. The negative effects of direct delivery and the different store pick procedure can results in an increase of 40% extra costs per order compared to the current situation.

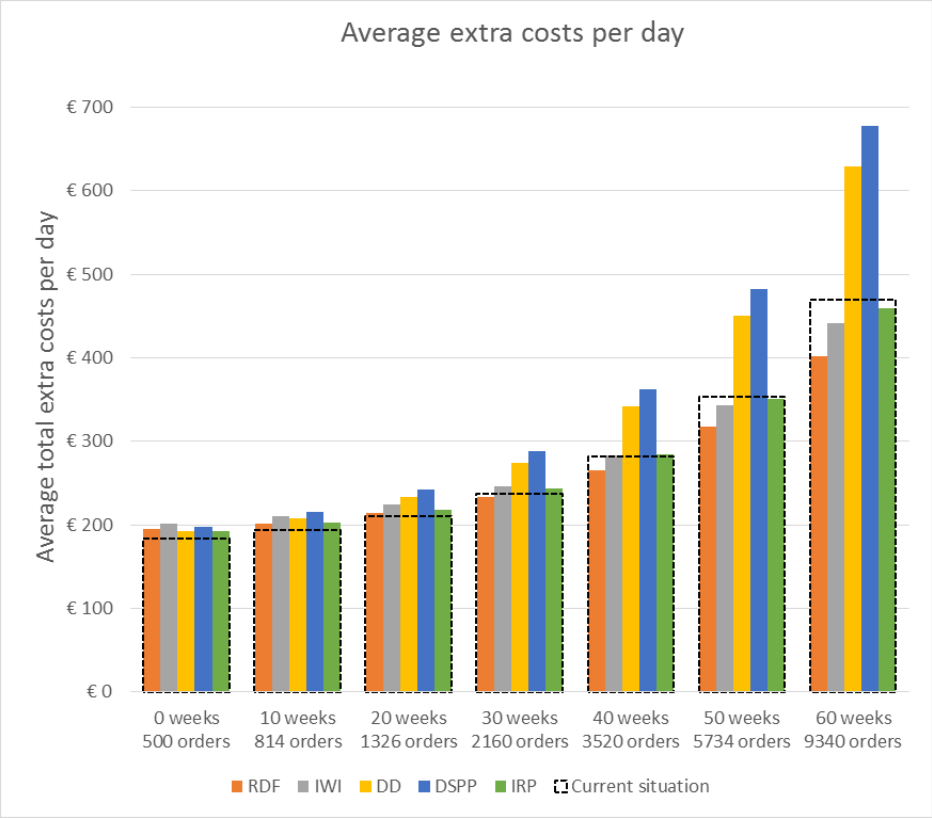


Figure 40: Average extra costs per day of different alternatives

Figure 41: Average extra costs per day per order of different alternatives

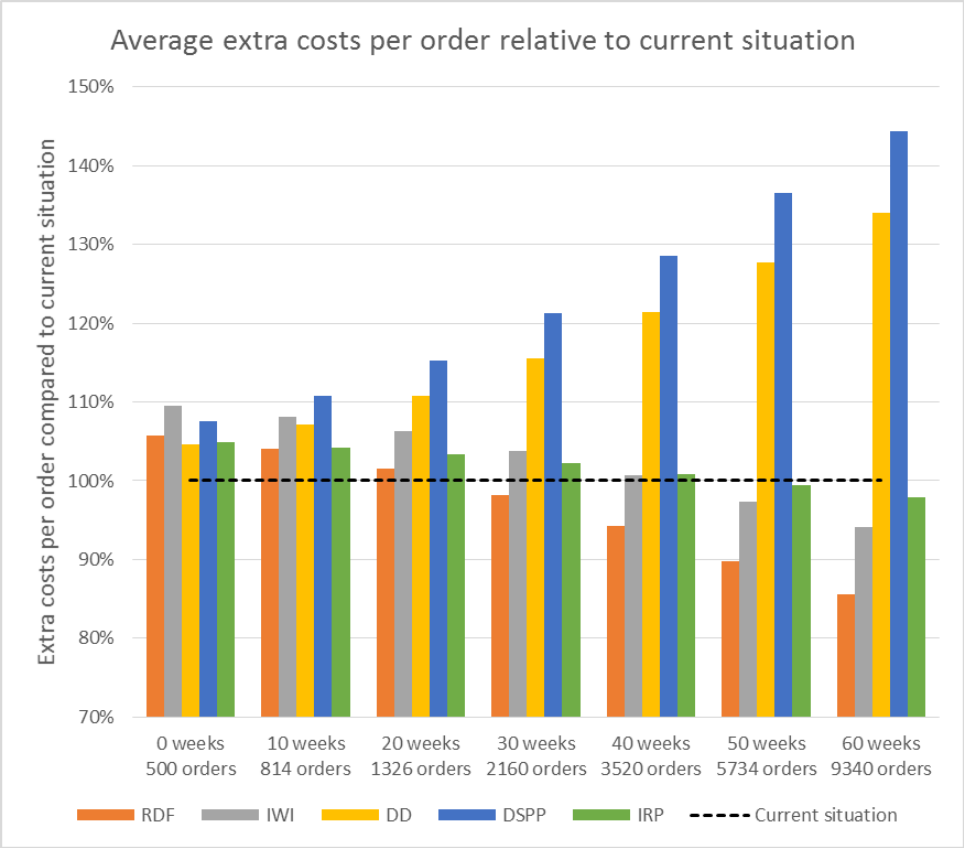


Figure 42: Average extra costs per day per order compared to current situation

5.3. Sensitivity analysis

In this section a sensitivity analysis is given. For every alternative the simulated results from the previous section are compared to what would happen if there would be a change of +20%, +10%, -10% and -20% in the input of the simulation. The results from these analysis are the shown in a graph of the average extra costs per order relative to the current situation.

5.3.1. Analysis RDF: Reduction of delivery failures

In the simulation from section 5.2.1 a reduction factor of 2 was chosen. In this sensitivity analysis this would mean that this reduction factor is changed between 2.4 (+20%) and 1.6 (-20%). The results are shown in Figure 43. It can be seen that in every case the extra costs are higher than the current situation at the start-up phase, but after 30 weeks the costs per order are already lower than the current situation. In every case the extra costs reduction is around 10% in the end-phase. This can also be seen clearly in Figure 43.

5.3.2. Analysis IWI: Improve insight in FC

For alternative 1 every reduction would result in a reduction of the extra costs per order. This is not the case for improving the insight in the FC, as seen in the results of the simulation. More insight means also more extra costs per day in order to gain this insight. Therefore for this sensitivity analysis the insight improvements are changed between 40% (+20%) and 27% (-20%), see Figure 44. In the analysis it can be seen that a small improvement does not have the desired effect in reducing the costs per order. Only bigger improvement appear the have influence. Here must be kept in mind that this only works for large amount of orders. Furthermore the extra costs for the improvement are difficult to estimate so further research needs to be done before major changes are applied.

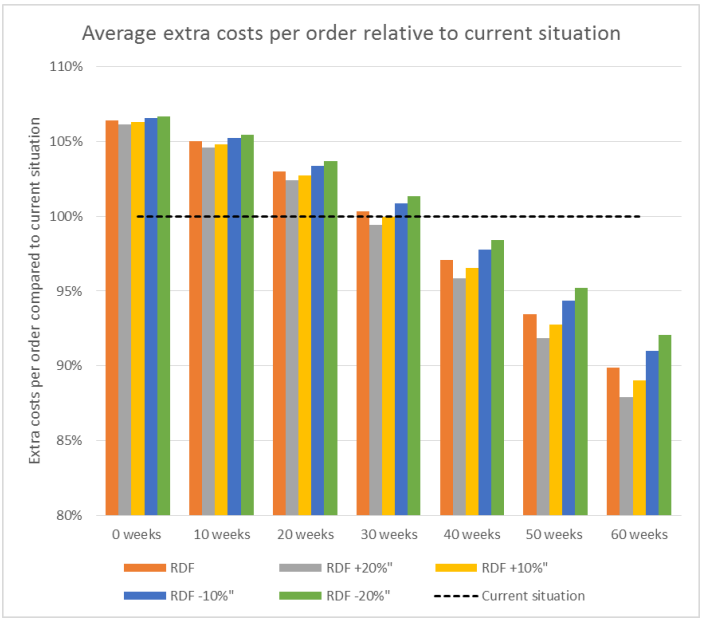


Figure 43: Sensitivity analysis of RDF

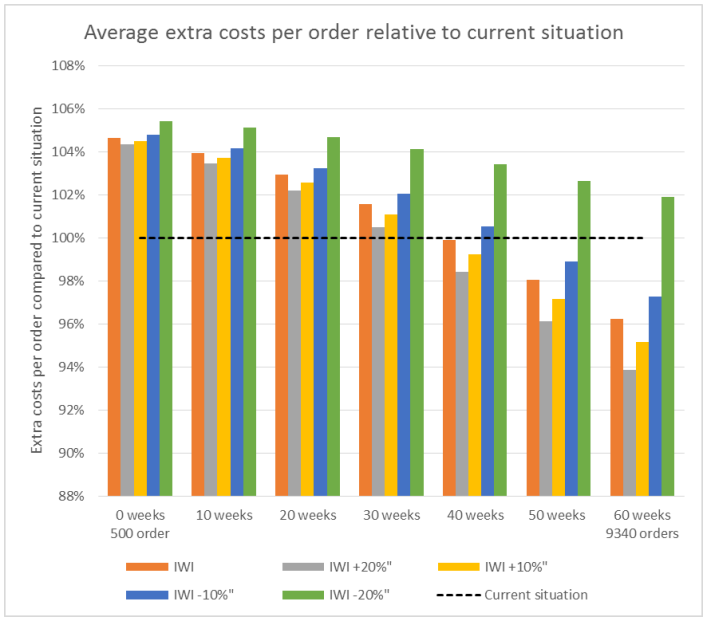


Figure 44: Sensitivity analysis of IWI

5.3.3. Analysis DD: Transition to direct delivery

In the transition to direct delivery there is been chosen to simulate that 20% of the items are delivered directly. Therefore in this analysis the change between 24% (+20%) and 16% (-20%) is looked into. The results of this can be seen in Figure 45. Since direct delivery would means lesser performance, more direct delivery would mean even worse overall performance. This can also been seen in Figure 45. The overall performance can increase from 25% extra costs (16% direct delivery) to more than 40% extra costs (24% direct delivery) compared to the current situation for 10000 orders. This confirms how important it is to first gain a good negotiation position before switching to direct delivery.

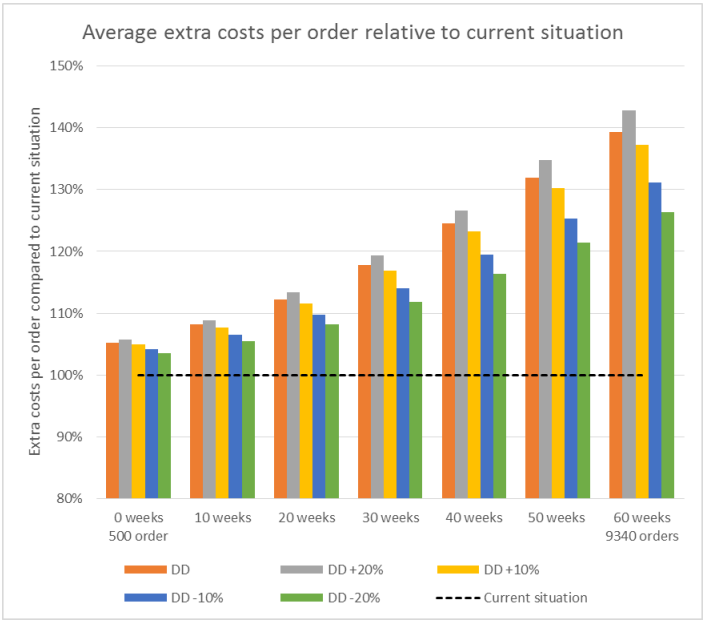


Figure 45: Sensitivity analysis of DD

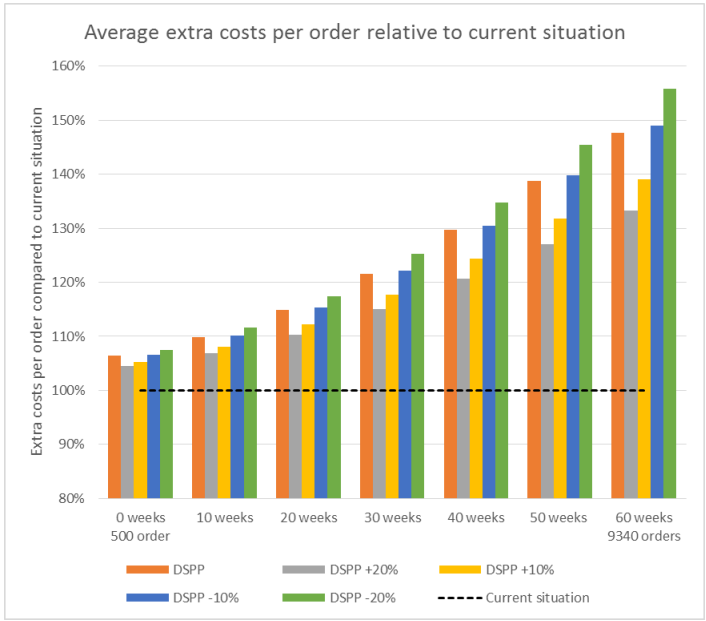


Figure 46: Sensitivity analysis of DSPP

5.3.4. Analysis DSPP: Different store pick procedure

In Figure 46 the differences between 60% reduction of store pick items (+20% compared to the simulation) and a 40% reduction of store pick items (-20% compared to the simulation) is shown. Since the simulation has already shown that this reduction would mean more extra costs compared to the current situation, more reduction in store pick items would also result in more extra costs. This can

be seen in Figure 46. An extra reduction of store pick could of 5% could mean an increase in costs of around 5% as well for 10000 orders. This is not always exactly the case because of the stochastic nature of the Monte Carlo simulation but it is a close approximation.

5.3.5. Analysis IRP: Improvement of the rush order process

In Figure 47 the differences between an extra improvement of the rush order process (+20%) and a slightly lesser improvement (-20%) compared to the simulation is shown. Again it is clear that this improvement would definitely only have a purpose for large order quantities. Furthermore, before implementing a new method, the improvements should be very well calculated, since a slightly smaller improvement would only mean extra costs. Another thing that can be concluded from the simulation and this analysis, is that the extra fixed costs, have the biggest influence on the costs of this process. This means that coming up with a plan to reduce these costs would be the most beneficial.

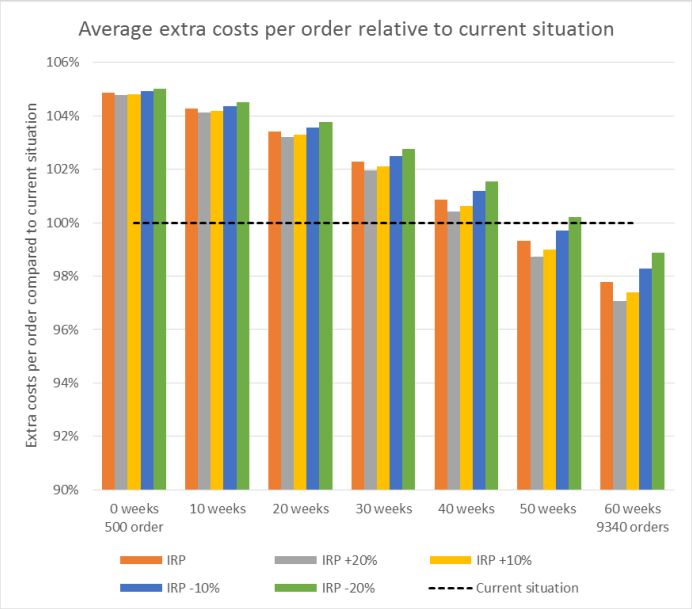


Figure 47: Sensitivity analysis of IRP

5.4. Conclusions of the assessment

In the assessment 5 alternatives have been compared to each other and the current situation. First of all the investments needed for the alternatives resulted in the fact that in the start-up phase the extra costs compared to the current situation are higher. The alternative with the most clear improvements in the end-phase would be the reduction of delivery failures. Since this reduction has a positive effect on all processes within the FC, the unexpected shortages are clearly decreased and thus the extra costs. Reduction of delivery failures with 50% can result in a reduction of extra costs of more than 10% (at 9000 orders). Improving the insight in the FC (alternative 2) has a definite effect on the customer satisfaction because of higher order completeness, but is not evidently cost effective. The reason for this is that gaining this extra insight means also extra costs per day in order to achieve this insight. Therefore improving insight in the FC is only cost effective from around 5000 orders per day. Although it is difficult to predict how the performance of direct delivery will change (alternative 3), the possible negative effects as shown in this chapter, can have a huge effect on the extra costs of the operations in the FC. When 15% of the deliveries will be direct the extra costs could be increasing with more than 30% at 9000 orders compared to the current situation.

Alternative 4 and 5 were focussed on what would happen if the solution procedures would change. Alternative 4 was a reduction of the expensive store pick procedure. Although this seems like a good costs saving idea, the negative effects of more substitutes and cancelled order lines result in more total extra costs. This is mainly because of the fact that every item that isn't store picked has to be substituted or cancelled. In alternative 5 the seemingly inefficient rush order process was improved. Unfortunately because of the extra fixed costs needed for this improvement, this would only have a positive effect for high order amount (>8000) per day.

Conclusions & Recommendations

Conclusions of the research

The goal of the research was to answer the main research question: "How can the additional costs due to disturbances of an upstream supply chain of an e-grocer be reduced while accommodating expected rapid future growth?". Here additional costs are a combination of easy-to-calculate extra costs to solve disturbances in the FC, and extra costs linked to consequences such as cancelled order lines. Although there are many disturbances in the supply chain that influence the extra costs of the supply chain, the most important root cause of unexpected shortage is delivery failure of the supplier (chapter 3). Therefore reducing the delivery failures can help decrease the extra costs of the supply chain significantly. A reduction of 50% of delivery failures would mean around than 10% reduction in the extra costs per order compared to the current situation in the end-phase of an FC. Furthermore, fast growth leads to transition to direct delivery from bigger suppliers. A weak negotiation position (chapter 2) would mean worse performance of the deliveries, resulting in a decrease in reliability and efficiency of the supply chain.

In the literature research (chapter 2) it was found that though much is known about supply chain improvement strategies but little is known about the root cause and effects of unexpected shortages in an FC, let alone their influence on the processes during fast growth. Although the online retailing business has been growing in the past years, e-grocers have not yet profited from the willingness of customers to order online. Figures from the UK, were online grocers have started earlier than in the Netherlands, show that there is a huge market gap to step in. Even though this opportunity is present, success will only be possible with an efficient supply chain. Here the expensive last mile of home delivery can cause major problems along with historic pitfalls of other online grocers:

- Over automation
- Weak negotiation power
- Customer acquisition
- Low order frequency

To save costs several supply chain improvement techniques are known like making the supply chain more lean or agile. These techniques have as a goal to make sure that the supply chain runs as smoothly as possible while keeping customer satisfaction in mind. Less is known about what can cause a disturbance (unexpected shortage) and its consequences in supply chain of an e-grocer, not to mention how these root causes and consequences evolve during fast growth.

In the analysis of the current processes at Picnic and Boni (chapter 3) several root causes were found and their relationship to their consequences (see section 3.7, Appendix B: Cause and effect of disturbances and Appendix C: Root cause analysis graphs). A comparison is made of the impact of the different root causes which is shown in Table 8.

Table 8: Impact of the different root causes

	Average impact [impact factor]	Peak impact [impact factor]
Un-orderable	0.1082	1.000
Shortage at supplier	0.0000	0.000
Delivery failure	0.3869	4.200
Receiving's mistake	0.0260	0.400
Unexpected clearance	0.0212	0.400
Non FiFo picking	0.0955	0.400
Quality buffer	0.0921	0.300
Stock mismatch	0.1399	1.000

It can be seen that the delivery failures have the most negative effect on the processes in the FC, followed by stock mismatches, un-orderable products and non-FiFo picking. This resulted in the construction of five plausible design alternatives which could influence the processes in the FC and preferably positively and possibly negatively (detailed explanation can be found in section 5.1.4):

Alternative 1: Reduce delivery failures (RDF)
Alternative 2: Improve insight in the FC (IWI)
Alternative 3: Direct delivery (DD)
Alternative 4: Change the store pick procedure (DSPP)
Alternative 5: Improve the rush order process (IRP)

The comparison between the alternatives and the current situation is done in chapter 5 where the different alternatives are assessed using the Monte Carlo simulation described in chapter 4. In Figure 48 the development of the extra costs per order relative to the current situation are shown. Due to investments to make the design alternatives possible every alternative has more extra costs in the start-up phase of the FC. It can be seen that the reduction of delivery failures (RDF) has a positive effect up to a reduction of more than 10% at 9000 orders. Improvement of insight in the FC (IWI) has only a positive effect for higher number of order because of the extra costs involved in more stock checks. The same goes for improvement of the rush order process (IRP).

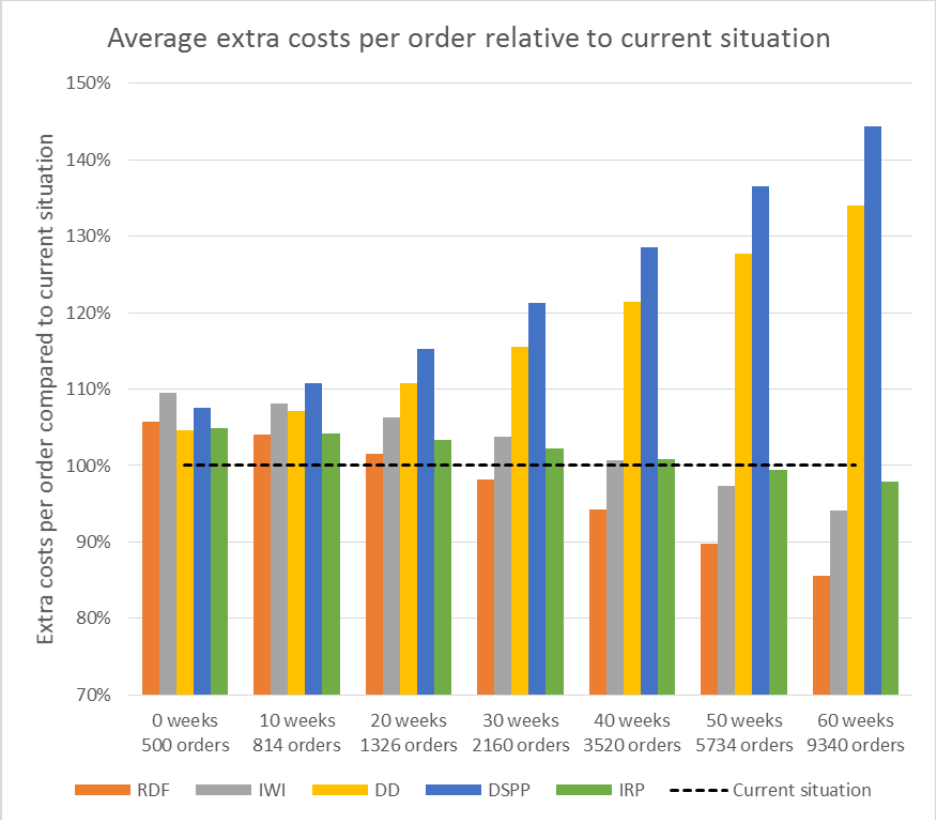


Figure 48: Average extra costs per order per day relative to current situation

Direct delivery (DD) and a different store pick procedure (DSPP) have a clear negative effect on the extra costs per order. The main reason for the negative effect of DD is that direct delivery can result is a less reliable supplier where rush order would not be possible. This means many items have to be store picked, substituted or even cancelled which comes along with lots of extra costs. The extra costs because of the DSPP are explainable by the rise of substitutes and cancelled order lines compared to the current situation.

Recommendations for Picnic and Boni

This research is commissioned by Picnic and done in collaboration with Boni. In this section the recommendations that are drawn from this research are given.

Decreasing delivery failures

As mentioned in the conclusion of the research, the delivery failures have a huge impact on the performance of the processes in the FC. Even more, because delivery failures result in most cases in a rush order, the efficiency of the processes at Boni also decreases. Therefore it is in favour of both parties to keep working together in decreasing the delivery failures. As can be seen in Figure 48 reducing the delivery failures result in a significant drop in extra costs per order compared to the current situation. This drop is partly explainable by the fact that the amount of rush orders drops significantly as well which means both Boni and Picnic take advantage of this alternative. In order to keep track of the improvements, it is important to keep track on the delivery failures, in a way were both parties agree upon, on a daily basis. This is done in this report (section 3.5) for several weeks but was very labour intensive because of foggy communication.

Transition to direct delivery

Although the transition to direct delivery from supplier seems impossible to avoid because of the growth of Picnic, it should not be rushed into. The negative effects because of possible bad performance of the supplier have a direct influence on the performance on the FC (section 5.2). Therefore, at the negotiation table clear agreements have to be made about the minimum delivery performance of the supplier. During this negotiation the current performance of the Boni can be used as a point of reference. Furthermore, as stated in the previous paragraph, the performance should be measured on a daily basis, preferably (semi-)automated.

Insight in the FC

Gaining more insight in the FC is important to reduce the amount of unexpected shortages due to mistakes in the FC. Currently employees get the assignment to count the items in the shelves and adjust the amount when a mistake is made. Unfortunately there is still a human factor involved which means 100% insight will not be possible. At the moment the only way to improve the insight in the FC is by assigning more employees to check the shelves. At the moment there are a lot of development ongoing which might make it possible to automate this process. One of these developments is using RFID in e-supply chain in grocery retailing [38]. Although this might be a bit futuristic, keeping track of these developments can help the improvement of insight in the FC.

Customer perception

As explained in this report the extra costs involved in the different alternatives (section 3.6.1) are based on some assumptions. An important assumption is that the extra costs for a substitute and a cancelled order line are higher than that of store picks and rush orders and equal for all products. This feels like a logical choice since the customer satisfaction highly depends on receiving the products he or she ordered. Nevertheless some clients also comment on the fact that one of the perks of ordering at Picnic is the customer service and how Picnic handles cancelled order lines and substitutes. Therefore it is recommended that more research is done in how customer satisfaction can be influenced. Using this information items can be put into categories in how important these are for the client. A cancelled beef for the evening meal of the customer can have a very negative effect whereas cancelling a pack of gum can be handled properly by customer service.

Recommendations for future research

The following recommendations are made for the scientific community:

Root cause analysis entire e-supply chain

In this report a root cause analysis is done of the problems (unexpected shortages) in an FC and its effects within this FC. This analysis can be done more broadly involving the entire supply in the analysis. This means that the secondary root causes from for example a delivery failure are also taken into account. This could lead to very interesting results as for example what the influence is of a failed harvest of grapes on the customer in the Netherlands.

With this information a prediction model can be made were the consequences of a failed harvest can be predicted which enables the rest of the supply chain to react much quicker to such an unexpected event.

Life time value of a customer

The life time value (LTV) of a customer is calculated in this report in order to gain some insight in how much a cancelled order line would cost. This LTV is not depending on the design alternative or the amount of orders. This was fine for this research since only an indication was needed but for future research the dependence of the LTV of a customer on design alternatives and order amount can be looked into. The fact that this value depends on a lot of different variables within a company makes it that much more interesting.

Relation between different days

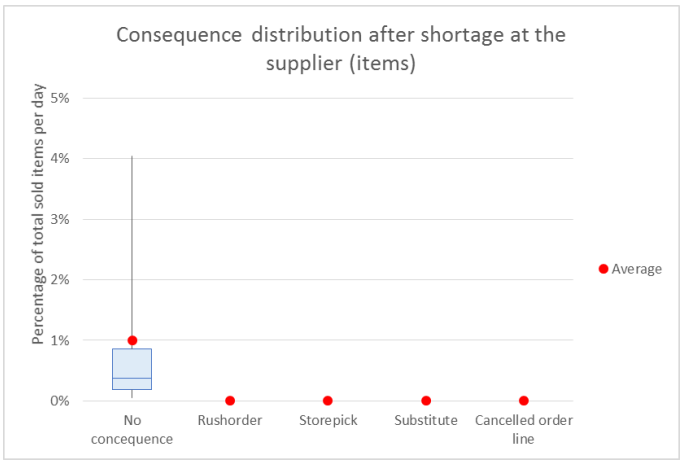
In this report a Monte Carlo simulation is used to execute the experiments with the different design alternatives. These experiments did not take into account that there could be a relation between the disturbance distribution of the consecutive days. Since there is a possibility that this relation exist it would be interesting to take a look at this. Furthermore, implementing this relation in the simulation would make the results of the experiments more reliable.

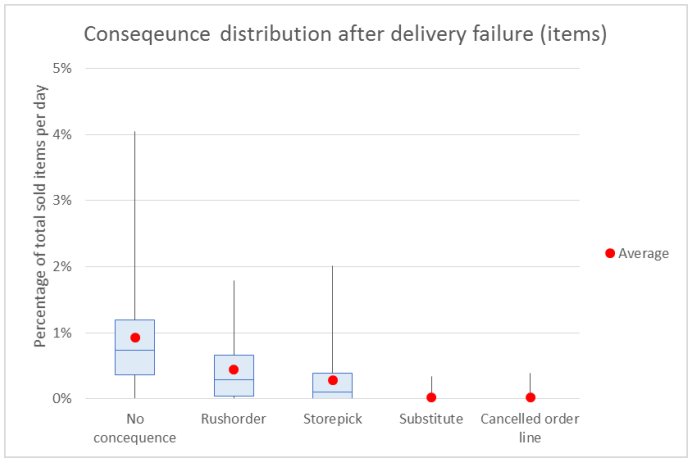
Appendix A: Direct delivery

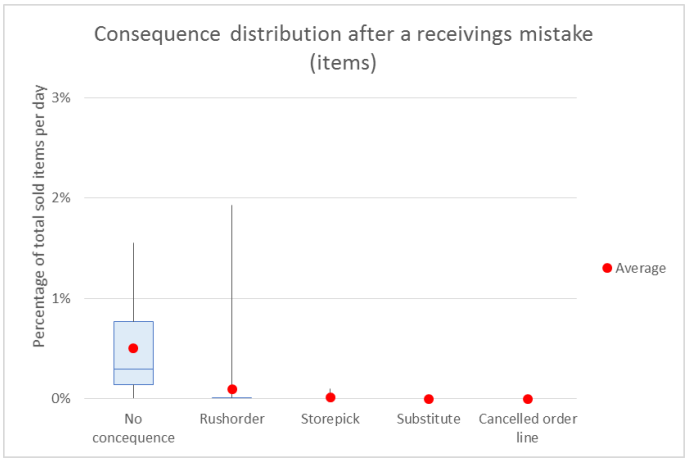
0.175439	1500	4500	7500	10500	13500	16500	19500	22500	25500	28500	31500	34500	Number of
40	0.04	0.08	0.10	0.12	0.14	0.18	0.23	0.26	0.27	0.27	0.29	0.29	
45	0.04	0.08	0.09	0.11	0.13	0.15	0.18	0.23	0.25	0.27	0.27	0.29	
50	0.04	0.08	0.09	0.11	0.13	0.13	0.17	0.19	0.23	0.25	0.27	0.27	
55	0.04	0.07	0.08	0.10	0.11	0.13	0.15	0.18	0.19	0.23	0.25	0.27	
60	0.04	0.07	0.08	0.10	0.11	0.13	0.13	0.15	0.18	0.21	0.24	0.25	
65	0.04	0.07	0.08	0.09	0.10	0.12	0.13	0.14	0.17	0.18	0.22	0.24	
70	0.04	0.07	0.08	0.09	0.10	0.11	0.13	0.13	0.14	0.18	0.18	0.23	
75	0.04	0.06	0.08	0.08	0.10	0.11	0.12	0.13	0.13	0.15	0.18	0.19	
80	0.04	0.05	0.08	0.08	0.09	0.10	0.11	0.13	0.13	0.14	0.16	0.18	
85	0.04	0.04	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.13	0.14	0.17	
90	0.04	0.04	0.07	0.08	0.09	0.10	0.10	0.11	0.13	0.13	0.14	0.15	
95	0.04	0.04	0.07	0.08	0.08	0.10	0.10	0.11	0.13	0.13	0.13	0.14	
100	0.04	0.04	0.07	0.08	0.08	0.09	0.10	0.11	0.11	0.13	0.13	0.14	
Minimal filling rat of truck													

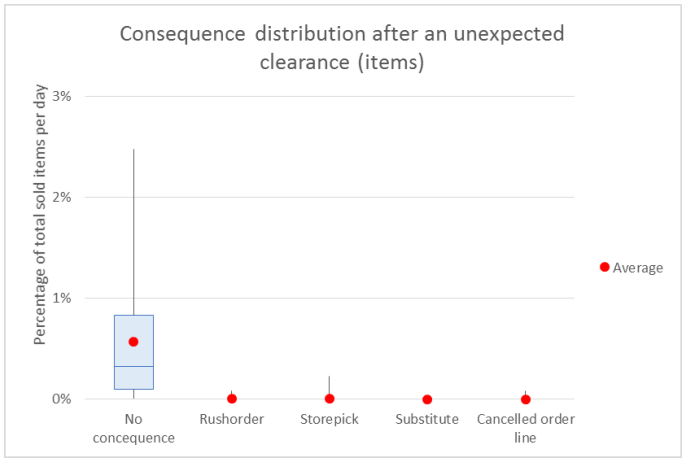
Appendix B: Cause and effect of disturbances

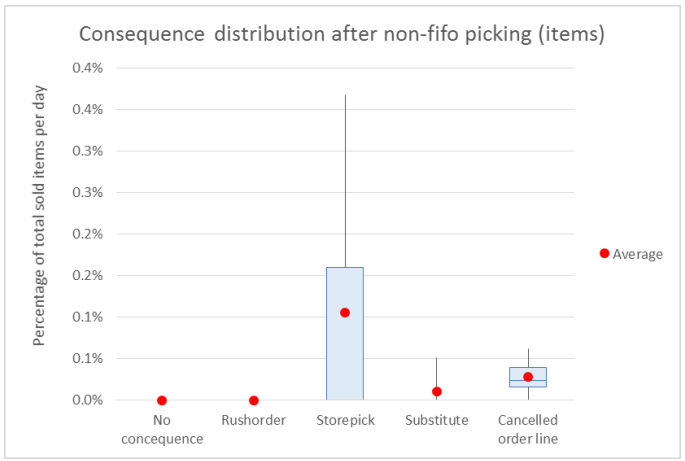
Items

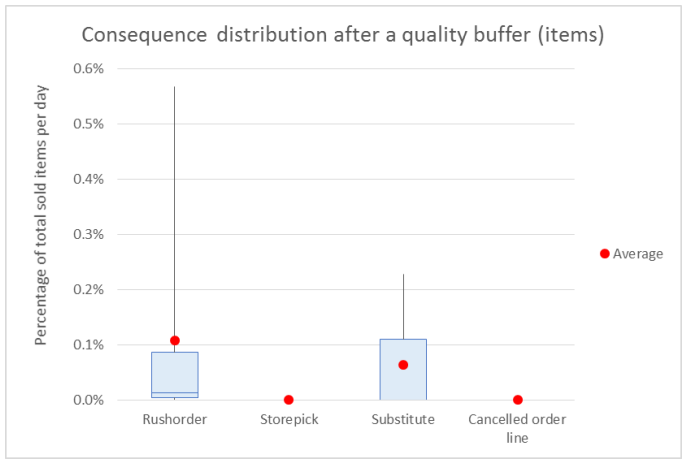


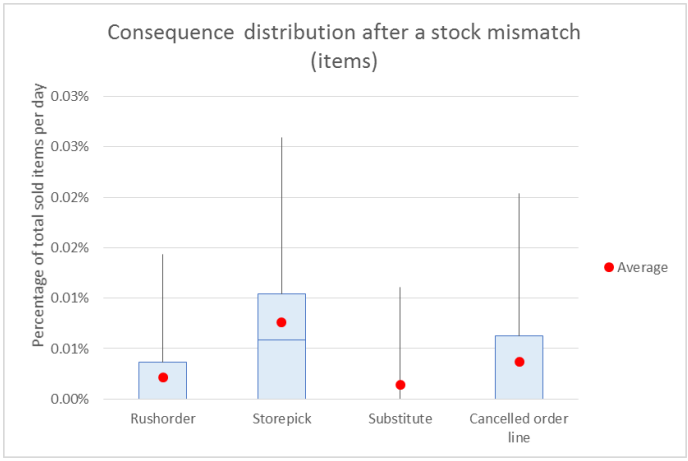




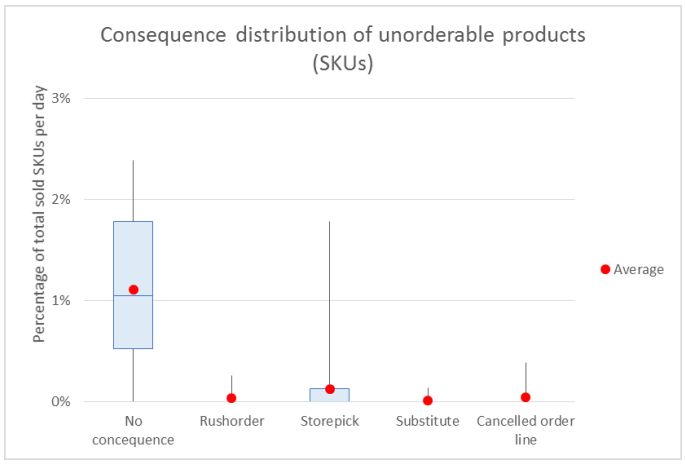


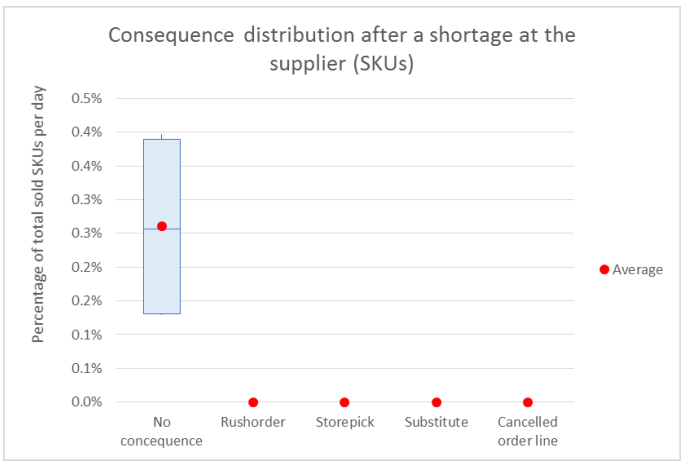


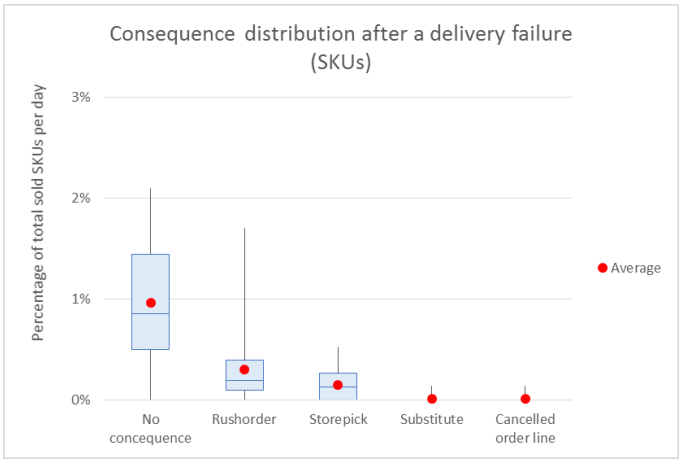


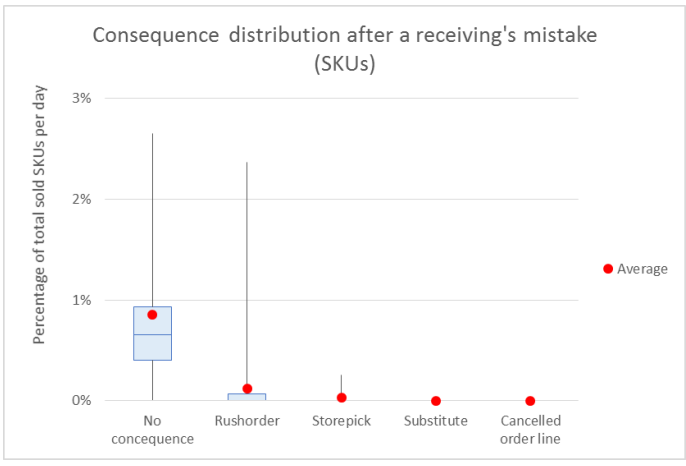

Consequence distribution after a stock mismatch (items)
Percentage of total sold items per day
0.03%
0.03%
0.02%
0.02%
0.01%
0.01%
0.00%
Rushorder
Storepick
Substitute
Cancelled order line
Average

SKUs

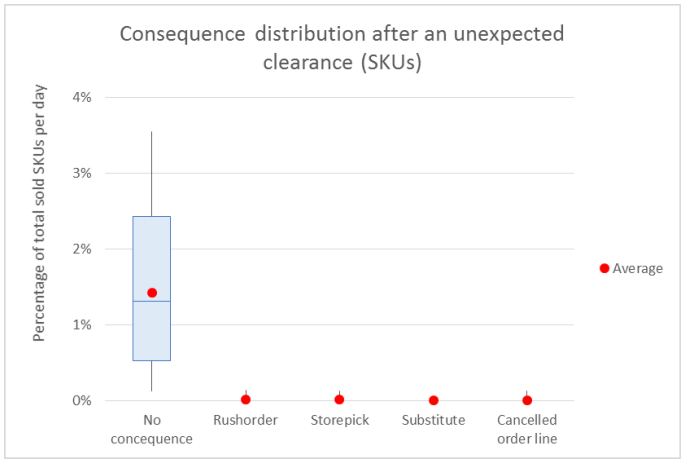

Consequence distribution of unorderable products (SKUs)
Percentage of total sold SKUs per day
3%
2%
1%
0%
No concequence
Rushorder
Storepick
Substitute
Cancelled order line
Average

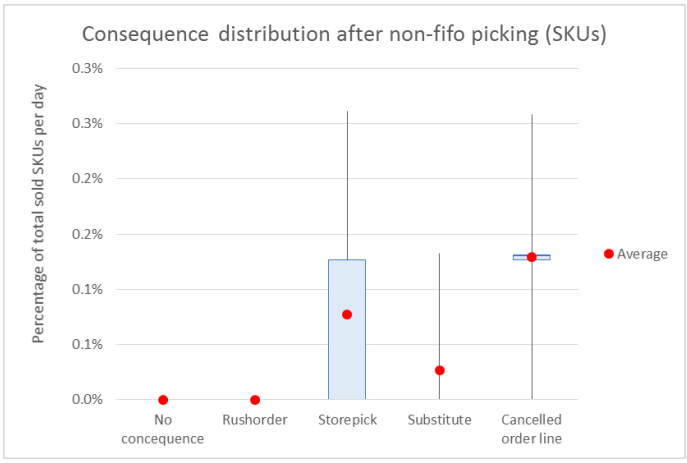

Consequence distribution after a shortage at the supplier (SKUs)
Percentage of total sold SKUs per day
0.5%
0.4%
0.4%
0.3%
0.3%
0.2%
0.2%
0.1%
0.1%
0.0%
No concequence
Rushorder
Storepick
Substitute
Cancelled order line
Average

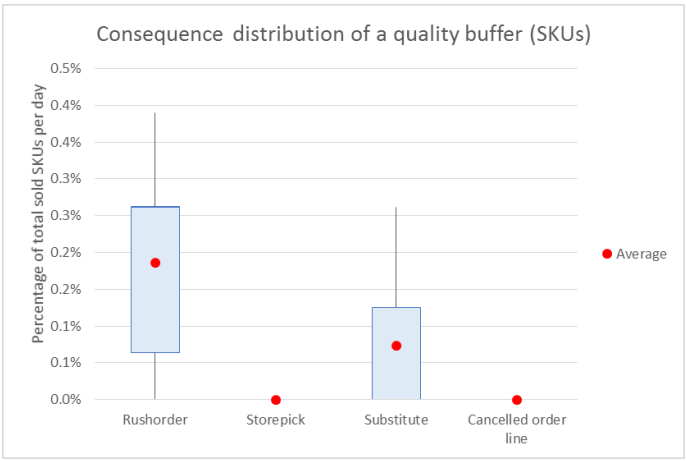

Consequence distribution after a delivery failure (SKUs)
Percentage of total sold SKUs per day
3%
2%
1%
0%
No concequence
Rushorder
Storepick
Substitute
Cancelled order line
Average

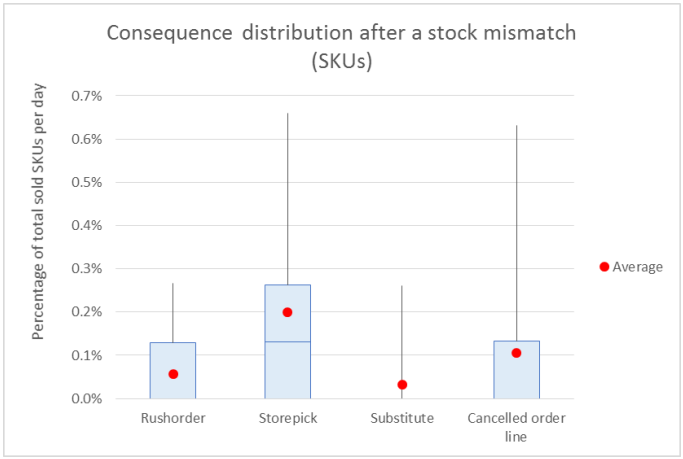

Consequence distribution after a receiving's mistake (SKUs)
Percentage of total sold SKUs per day
3%
2%
1%
0%
No concequence
Rushorder
Storepick
Substitute
Cancelled order line
Average

Appendix B: Cause and effect of disturbances



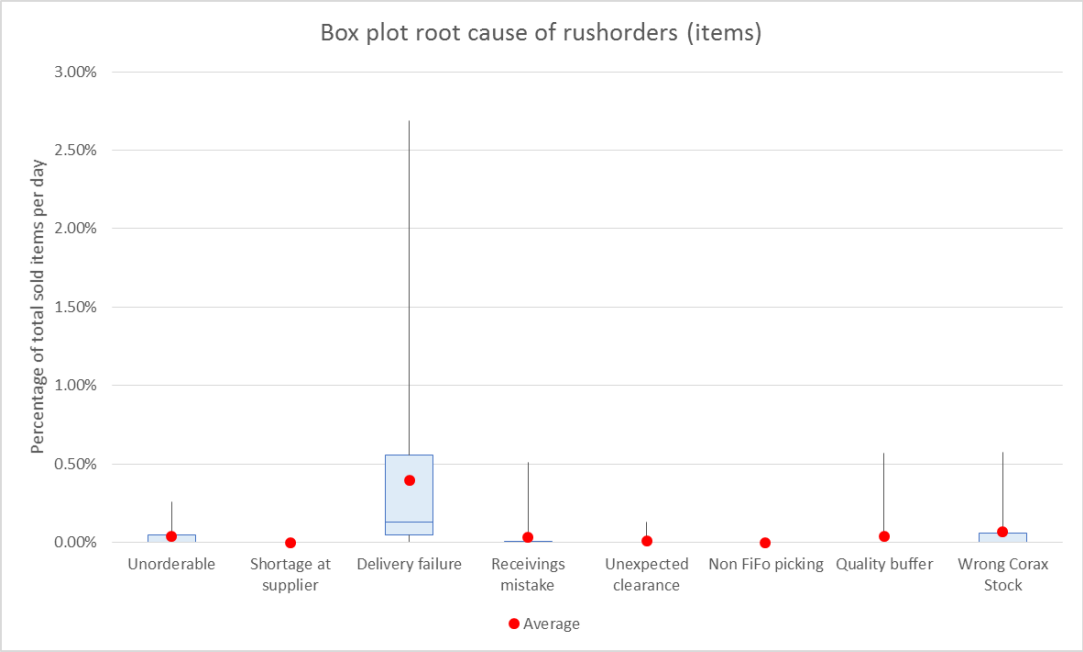


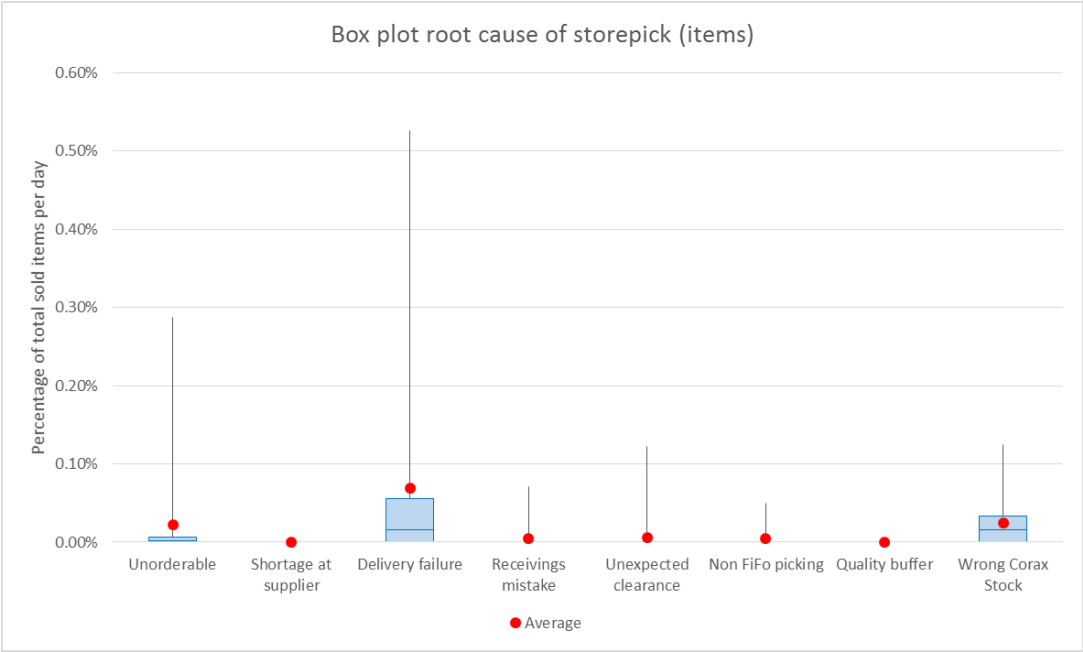




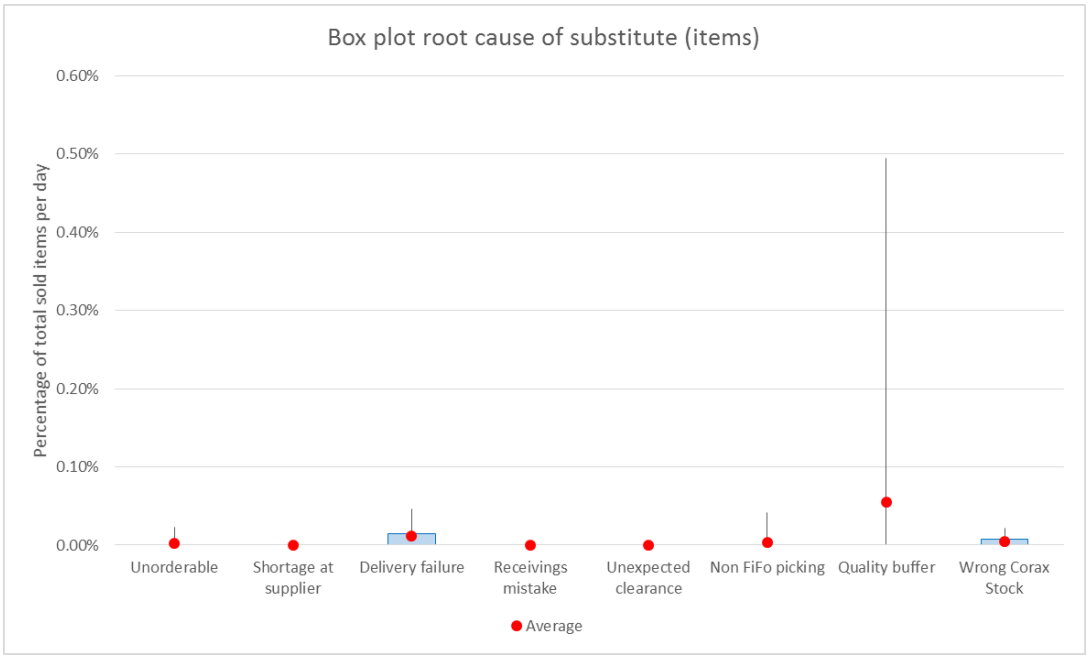
Appendix C: Root cause analysis graphs

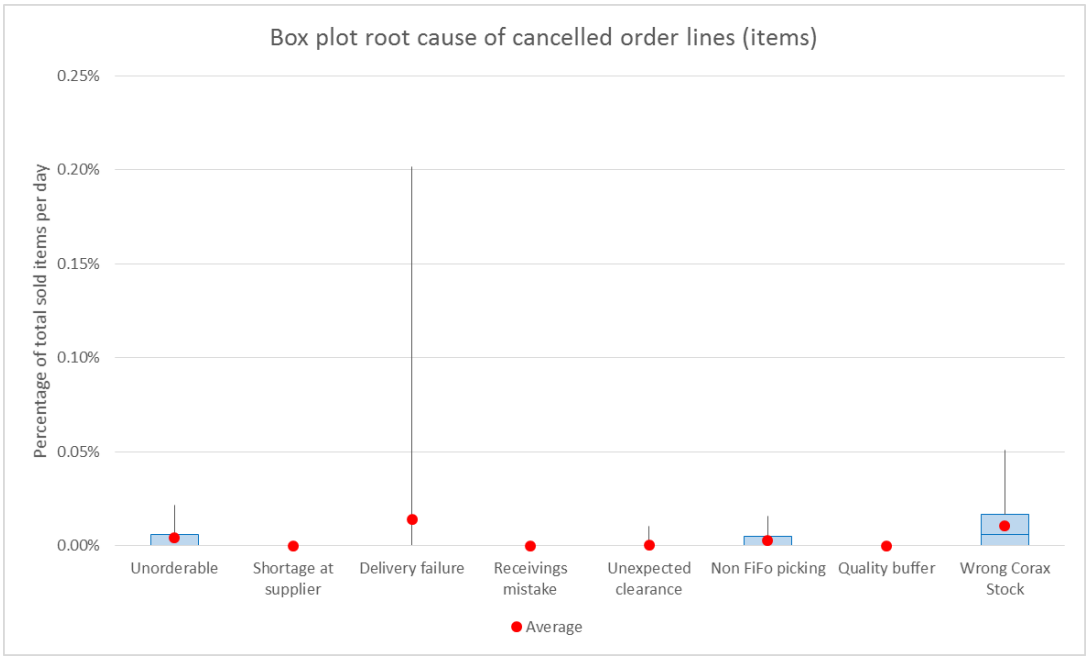
Items



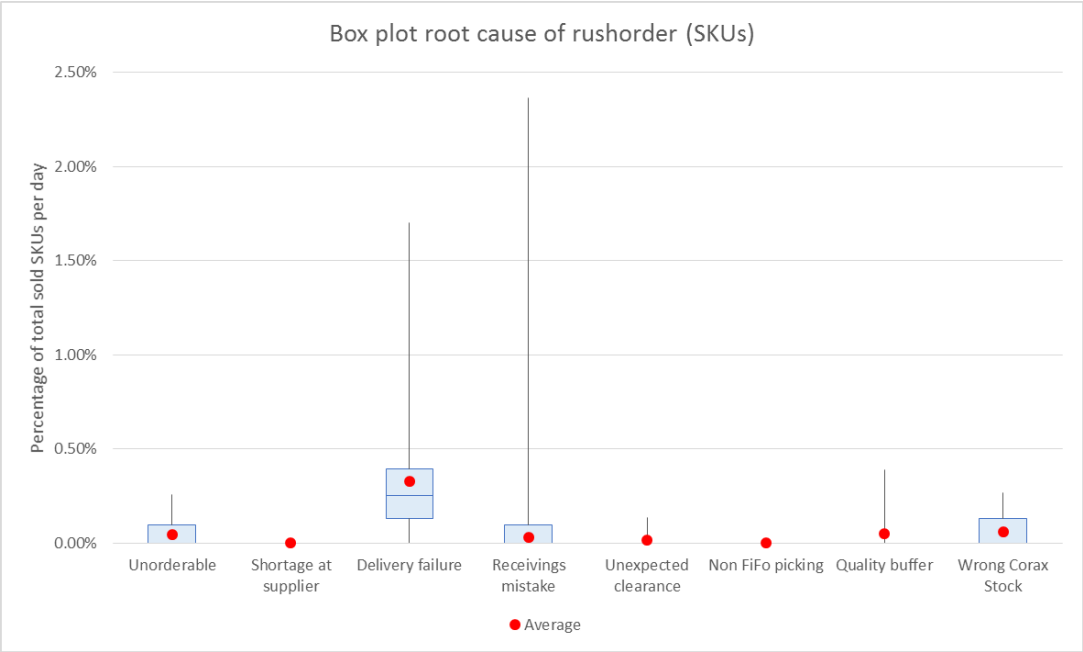


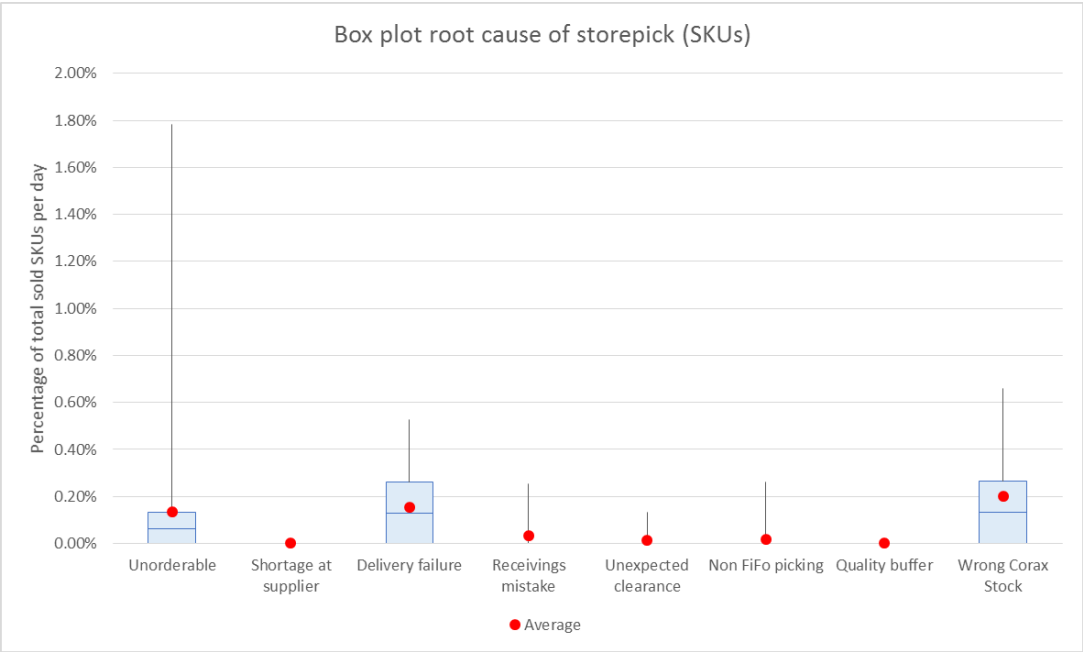
Appendix C: Root cause analysis graphs



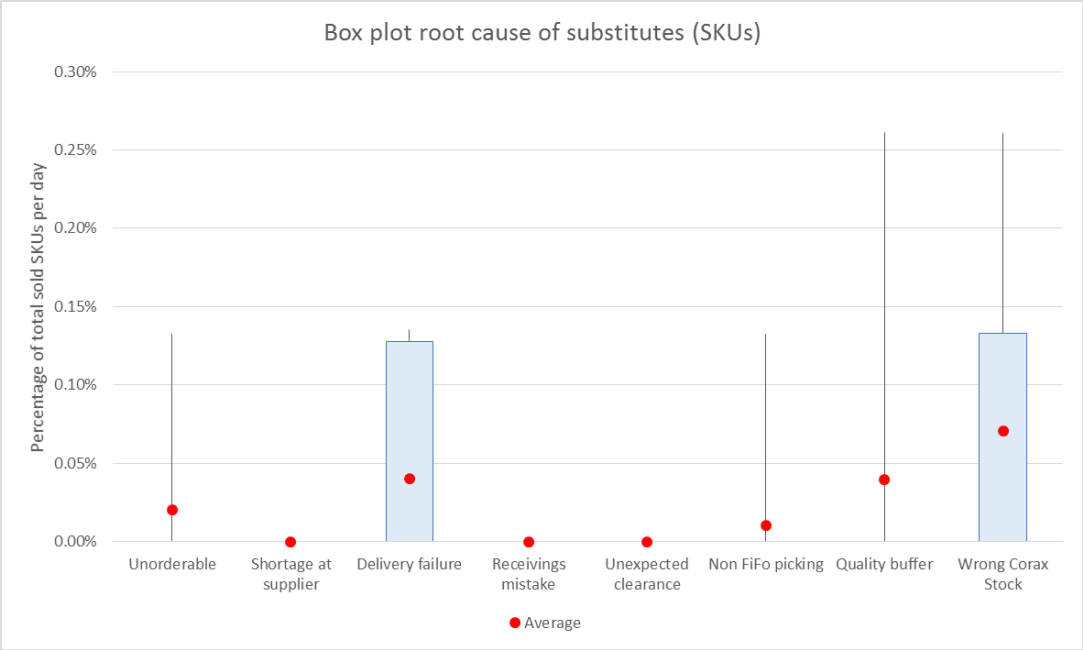


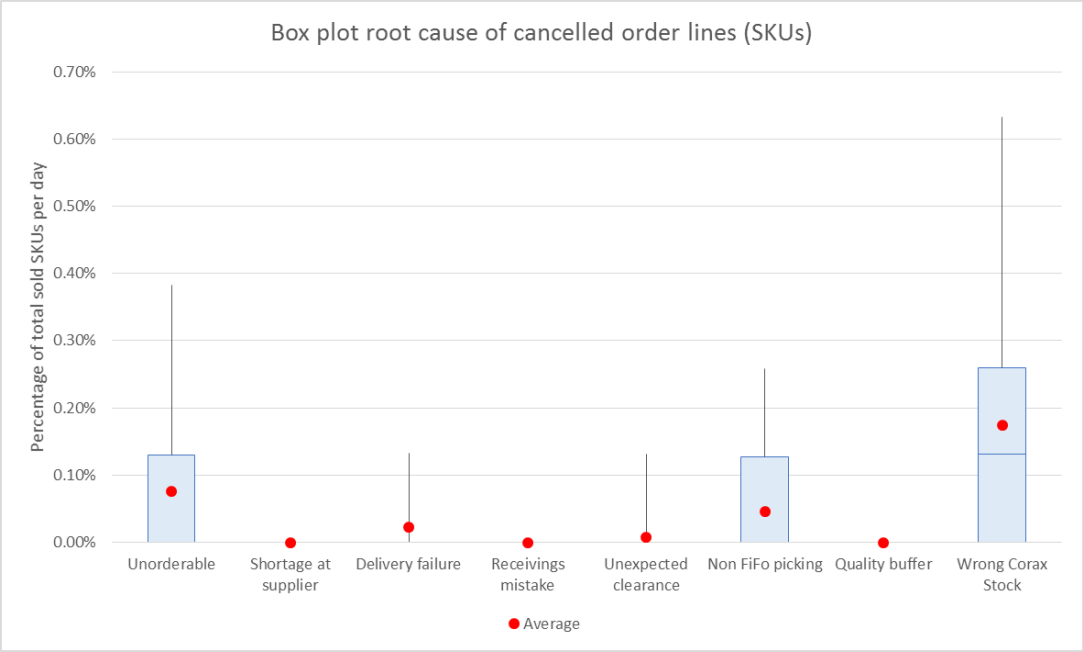
SKUs


Box plot root cause of rushorder (SKUs)
Percentage of total sold SKUs per day
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
Unorderable
Shortage at supplier
Delivery failure
Receivings mistake
Unexpected clearance
Non FiFo picking
Quality buffer
Wrong Corax Stock
Average


Box plot root cause of storepick (SKUs)
Percentage of total sold SKUs per day
2.00%
1.80%
1.60%
1.40%
1.20%
1.00%
0.80%
0.60%
0.40%
0.20%
0.00%
Unorderable
Shortage at supplier
Delivery failure
Receivings mistake
Unexpected clearance
Non FiFo picking
Quality buffer
Wrong Corax Stock
Average

Appendix C: Root cause analysis graphs





Appendix D: Sampling of the root causes

As mentioned in chapter 4 an important part of the inputs are the root causes and how these are distributed. The figures from the analysis are known and represented using box plots. This means for every cause and accessory effect a minimum, first quartile, median, third quartile and maximum is known. Furthermore an average is known. Although this is a good way to clearly show how data is distributed, it is not known how the data is distributed within the quartiles. Therefore an assumption has to be made: the data within these quartiles is evenly distributed. When shown in a graph this looks like shown in Figure 49.

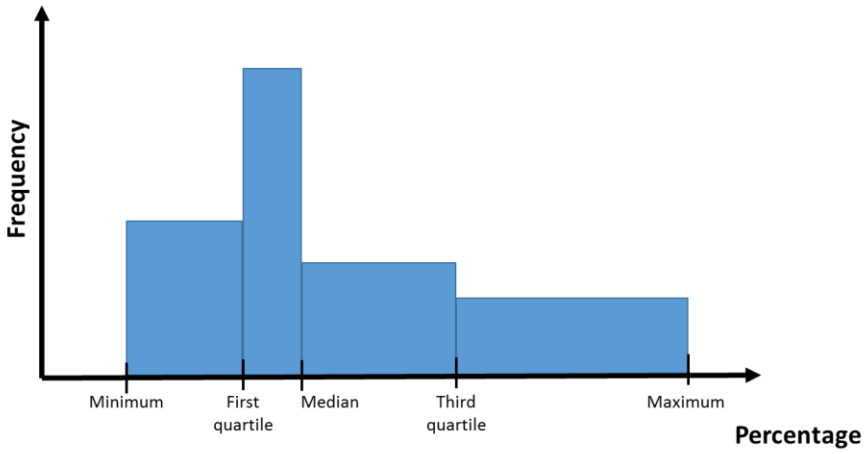


Figure 49: Even distribution within quartiles

When a random figure has to be created according to the distribution shown in Figure 49, the following steps can be followed:

1. Create a random number between 0 and 1

   0 – 0.25 → First quartile
   0.25 – 0.5 → Second quartile
   0.5 – 0.75 → Third quartile
   0.75 – 1 → Fourth quartile

2. Calculate difference between maximum and minimum within the quartile
3. Multiply the difference from step 2 by a randomly created number between 0 and 1
4. Add the outcome of step 3 to the minimum of the quartile from step 1
5. A random number according to the distribution from Figure 49 is created

Although this can be a good approximation of the truth this is not always the case. For example when an unexpected clearance occurs, at least 75% percent of the time nothing happens. This means that the fourth quartile has a minimum of 0% and in this case a maximum of 0.13%. After closer inspection the frequency distribution within this fourth quartile is not even but the lower values are more common. This means another distribution has to made. This can be done by quadrate the randomly chosen number from step 3 (x) if the number is in the fourth quartile (outcome step 1). So this number will be x^2. If the distribution needs to be shifted more extreme this number could be changed to x^3 or even x^4. An example of how this distribution looks like can be seen in Figure 50.

A third possibility is that the higher values within a quartile (often the fourth) are more common. A similar solution as discussed in the paragraph above can be used. Now instead of quadrate the randomly chosen value of step 3 (x), this number will be $1 - x^2$. Again if the shift needs to be more extreme this can be changed to for example $1 - x^4$. In Figure 51 an example of this is shown schematically.

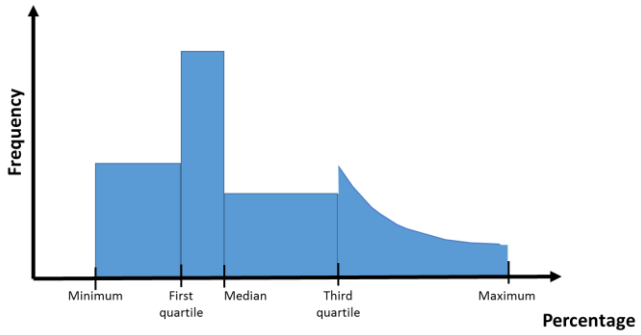


Figure 50: Example of a not even distribution in fourth quartile (1)

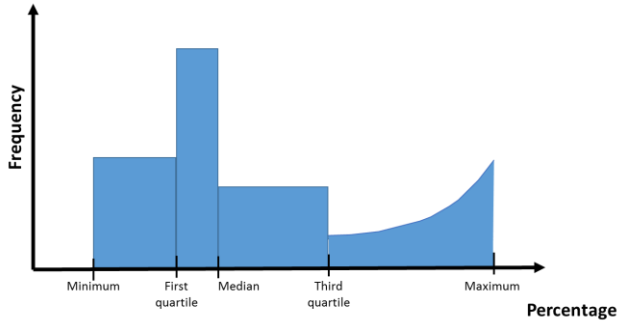


Figure 51: Example of a not even distribution in fourth quartile (2)

Which needs to be noted is that the distribution of the root causes is measured only when a root cause occurs. This means that if a certain root cause only occur one in four days, this has to be taken into account into the simulation model.

Other inputs are the growth predictions made from Picnic which are already described in 3.1.4 and 4.1.3. Furthermore the location of the FC is an important variable which might lead to different process strategy depending on its distance to the supplier. This is also already discussed in section 4.1.3.

Appendix E: Sensitivity analysis distance supplier

Although in the research it is assumed that the distance to the supplier remained the same throughout the simulations, this variable has a significant influence on the extra costs. Here the extra costs of the different alternatives are compared for the following distances: 5km, 25km, 65km and 100km. The extra costs increase because of the higher transport and employee costs for the rush orders. As expected, the total extra costs increase along with the higher distance from the supplier (an increase of more than €100,- per day in the current situation for 5 and 100 km). This influences all the alternatives. The higher the distance the less of a difference is between the alternatives in comparison to the current situation.

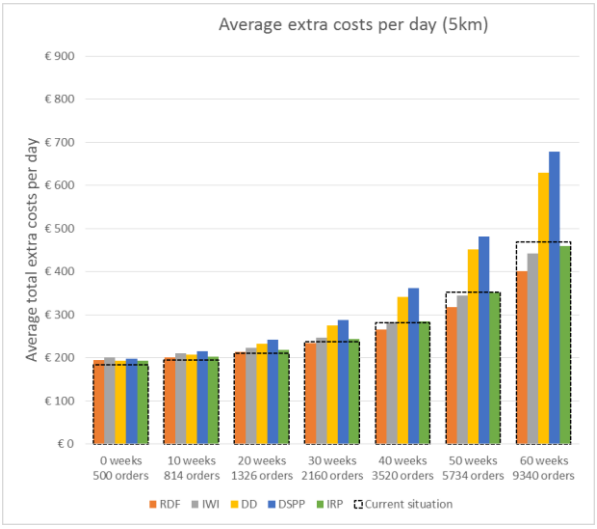


Figure 53: Average extra costs per day (5km)

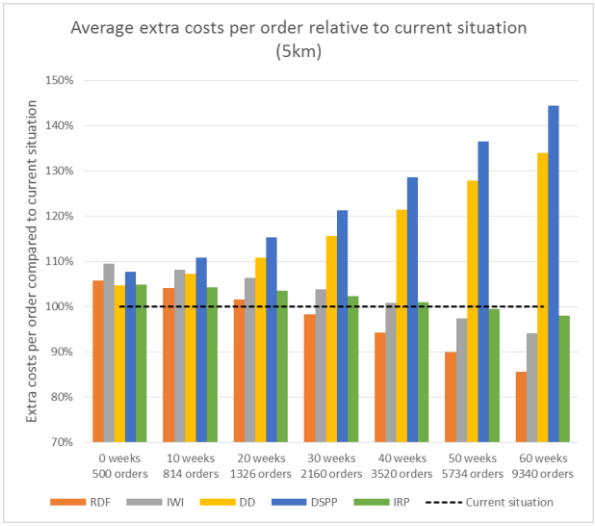


Figure 52: Average extra costs per order relative to current situation (5km)

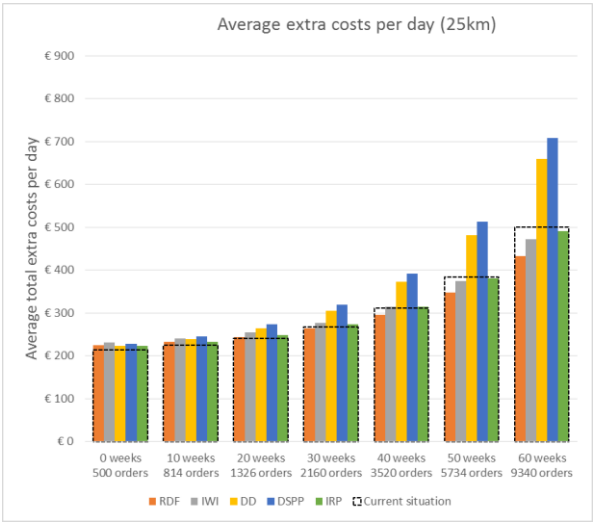


Figure 55: Average extra costs per day (25km)

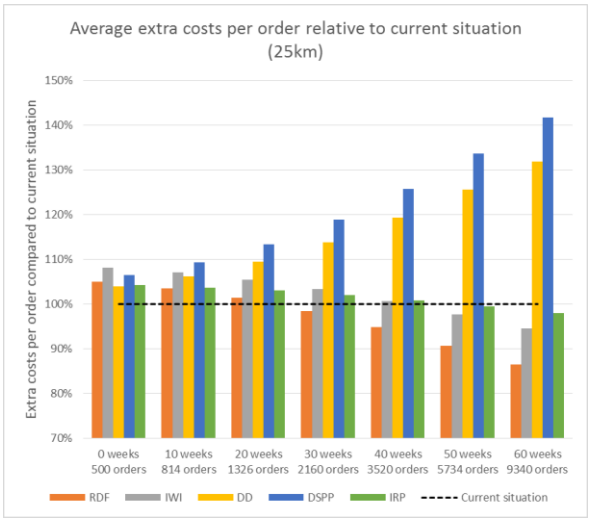


Figure 54: Average extra costs per order relative to current situation (25km)

Appendix E: Sensitivity analysis distance supplier

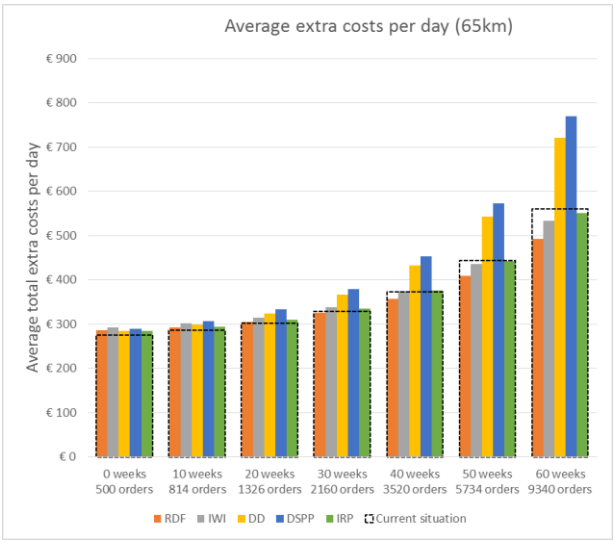


Figure 59: Average extra costs per day (65km)

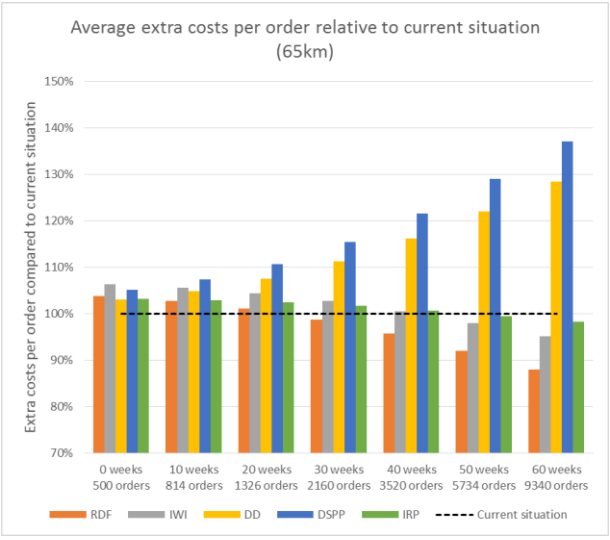


Figure 58: Average extra costs per order relative to current situation (65km)

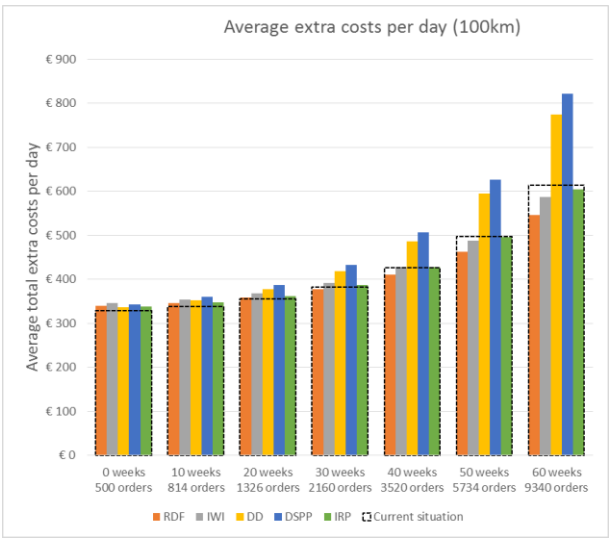


Figure 57: Average extra costs per day (100km)

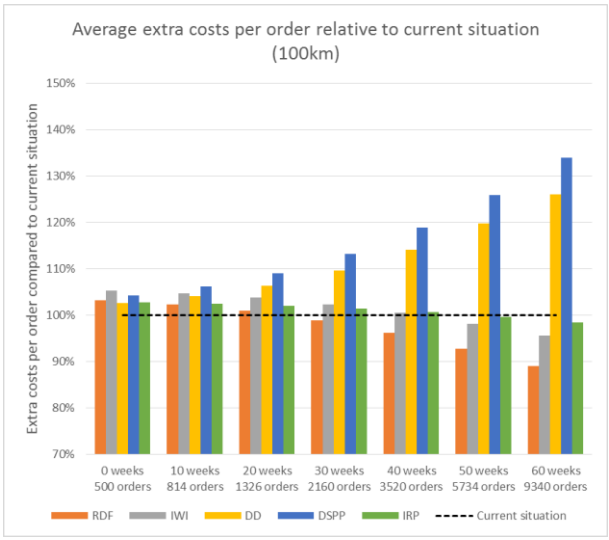


Figure 56: Average extra costs per order relative to current situation (100km)

Bibliography

[1] E. Tkacz and A. Kapczynski, Internet - Technical development and appilcations, Springer Berlin Heidelberg, 2009.

[2] "Ecommercenews," 2016. [Online]. Available: http://ecommercenews.eu/ecommerce-per-country/ecommerce-the-netherlands/.

[3] R. Smit, "Financieel Dagblad," 7 jan 2016. [Online]. Available: https://fd.nl/ondernemen/1134162/online-boodschappen-doen-blijft-voorlopig-een-nichemarkt.

[4] V. Kämäräinen, "Developing cost-effective operations for the e-grocery supply chain," 2002.

[5] L. J. Krajewski, L. P. Ritzman and M. K. Malhortra, Operations management: processes and supply chains Ninth edition, New Jersey: Pearson Education, 2010.

[6] D. J. Thomas, "Coordinated supply chain management," 1996.

[7] K. Garret, "Accaglobal," 2014. [Online]. Available: http://www.accaglobal.com/hk/en/student/acca-qual-student-journey/qual-resource/acca-qualification/p3/technical-articles/value-chains.html. [Accessed 22 11 2016].

[8] M. Hesse, "Shipping news: The implications of electronic commerce for logistics and freight transport," *Resources, Conservation and Recycling*, 2002.

[9] T. Vanelslander, "Commonly used e-commerce supply chains for fast moving consumer goods: comparison and suggestion for improvement," 2013.

[10] J. Gustavsson, C. Cederberg, U. Sonesson, R. van Otterdijk and A. Meybeck, "Global food losses and food waste: extent, causes and prevention," *FAO*, 2011.

[11] J. P. Womack, D. T. Jones and D. Roos, The machine that changed the world, Harper Perennial, 1990.

[12] R. Basu and J. Wright, "Lean and agile supply chain," *Total supply chan management*, no. ISBN 9780750684262, pp. 199-228, 2008.

[13] B. J. Naylor, Naim, Mohamed, Berry and Danny, "Leagility: integrating the lean and agile manufacturing in the total supply chain," *International Journal of Production Economics*, vol. 62, pp. 107-118, 1999.

[14] M. Christopher, "The Agile Supply Chain," *Industrial Marketing Management*, vol. 29, pp. 37-44, 2000.

[15] R. Mason-Jones, B. J. Naulor and D. R. Towill, "Engineering the leagile supply chain," *International Journal of Agile Managemeent Systems*, 2000.

[16] M. Christopher and D. Towill, "Supply chain migration from lean and functinonal to agile and customised," vol. 5, no. 4, 2000.

[17] A. Gunasekaran, C. Patel and E. Tirtiroglu, "Performance measures and metrics in a supply chain environment," *International Journal of Operations & Production Management* , vol. 21, no. 1/2, pp. 71-87, 2001.

[18] L. Harrington, "Untapped savings abound," *Industry Week*, pp. 53-8, 1996.

[19] S. Warschun, "Future of retail grocery in a digital world," *McKinsey & Company*, 2014.

[20] Annual report, "Delivering the best platform for online grocery," Ocado, 2015.

[21] P. Dorsett, "An insight report by Kantar Worldpanel THE ONLINE FMCG," 2014.

[22] A. Desceras, "The State of Online Grocery Retail in Europe," Syndy, 2015.

[23] D. T. Ross, "Applications and Extensions of SADT," *SofTech*, 1985.

[24] H. P. M. Veeke, J. A. Ottjes and G. Lodewijks, The Delft Systems Approach, Delft: Springer, 2008.

[25] X. Lin, R. R. Negenborn and G. Lodewijks, "Survey on operational perishales quality control and logistics," *Computational Logistics, 6th ICCL '15,* vol. 9335, pp. 398-421, 2015.

[26] F. Gorte, L. Rietveld and E. Adelmund, Interviewees, *Distrubances at the FC.* [Interview]. December 2016.

[27] J. M. Juran and A. B. Godfrey, Quality Handbook, McGraw-Hill, 1998.

[28] S. van Goor, Interviewee, *Efficiency comparison between normal orders and rush orders.* [Interview]. 31 January 2017.

[29] H. Snepvangers, L. Veen and F. Gorte, Interviewees, *Lifetime value of a customer.* [Interview]. 4 April 2017.

[30] P. A. McNamara and R. Beers, DHS Risk Lexicon: 2010 Edition, Department of Homeland Security, 2010.

[31] F. B. Gorte, Interviewee, *Severity of different root causes.* [Interview]. 2017.

[32] B. Janssen, Interviewee, *Supplier relations.* [Interview]. December 2016.

[33] D. P. Kroese and R. Y. Rubinstein, Simulation and the Monte Carlo Method, John Wiley & Sons, Incorporated, 2016.

[34] T. A. Cruse, Reliability-Based Mechanical Design, CRC Press, 1997, pp. 123 - 127.

[35] I. Boiarkina, N. Depree, W. Yu, D. Wilson and B. Y. Young, "Fault diagnosis of an industrial plant using a Monte Carlo analysis coupled with systematic troubleshooting," *Food Control*, vol. 78, pp. 247-255, 2017.

[36] C. Bailey, T. Tilford and H. Lu, "Reliability analysis for power electronics modules," in *Emerging Technologies for Electronics Packaging*, Greenwich, 2007.

[37] R. G. Sargent, "Verification and validation of simulation models," *Proceedings of the 2015 Winter Simulation Conference*, pp. 130-143, 2015.

[38] E. Prater, G. V. Frazier and P. M. Reyes, "Future impacts of RFID on e-supply chains in grocery retailing," *Supply Chain Management: An International Journal*, vol. 10, no. 2, pp. 134-142, 2005.

[39] H. Min and G. Zhou, "Supply chain modeling: Past, present and future," *Computers and Industrial Engineering*, vol. 43, no. 1-2, pp. 231-249, 2002.

Appendix F: Research paper

Improving and adapting the upstream supply chain of an e-grocer during fast growth

A case study at Boni and Picnic

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***Abstract*—This research paper investigates the root causes of unexpected shortages and their effects in a fulfillment center of an e-grocer. Several feasible future design alternatives are created and tested using a Monte Carlo simulation model. It is found that the reliability of the supplier is essential for an e-grocer to achieve their desired performance level.**

Keywords—E-grocer; Supply Chain; Root Cause Analysis; Monte Carlo simulation

I. INTRODUCTION

Since online shopping is invented in 1979 by Micheal Aldrich [1] there has been a shift in the way customers shop. Nowadays, more and more people can access the world wide web (currently 92% of the Dutch population [2]) and online shopping seems to be the future. Especially in the last few years there has been a dramatic increase in the online sales where companies have mainly focussed on slow moving, non-perishable goods, see fig. 1 [4]. Traditional supermarkets like Albert Hein (since 2012) and Jumbo (since 2014) try to profit of this market gap by offering online shopping as well, also called the click-and-mortar concept.

Although click-and-mortar is a major change in the way people do their grocery shopping the main focus of the traditional players is still their classic supermarkets. This is one of the reasons why the total market share of online grocery shopping is still only 1.1% in the Netherlands [3] of which 55% is in the hands of AH. The market share of online grocery shopping will grow up to 5% in 2025 if the growth continues at the current rate. However, this growth could go faster if more competitors, like Picnic or AmazoneFresh, enter the market, according to 'Het Financieele Dagblad' [3]. Furthermore, neighboring and similar countries like the UK, have showed stable growth of e-grocers in the past decade, which implies that the same could be achievable in the Netherlands [6]. This new way of

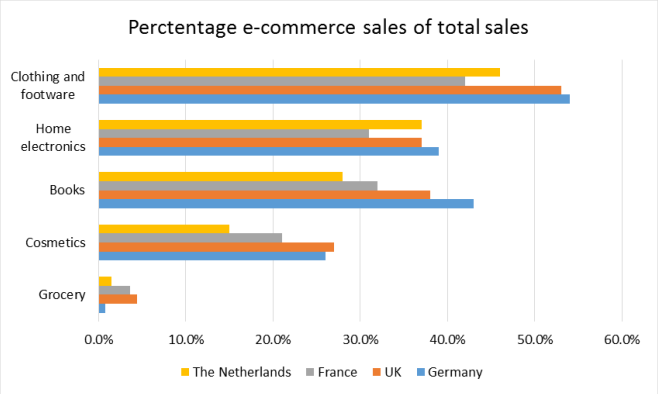

Fig. 1. Percentage e-commerce sales of total sales in the Netherlands, France, the UK and Germany

grocery retailing comes with other logistics, requirements and challenges. In this report the challenges in the supply chain with the expected rapid growth of Picnic are discussed and a proposition is done on how this challenge could be best handled.

A. *Research goal and scope*

The aim of this assignment is to research how an upstream supply chain of an online supermarket can control its additional costs due to disturbances during fast growth. The research is executed by performing a case study at Picnic, a pure player e-grocer. This resulted in giving Boni (the main supplier) and Picnic an advise in how they could best adjust the upstream supply chain from Boni to Picnic in the future. In the end, more generic conclusions, about maintaining and improving the upstream supply chain during fast growth are drawn.

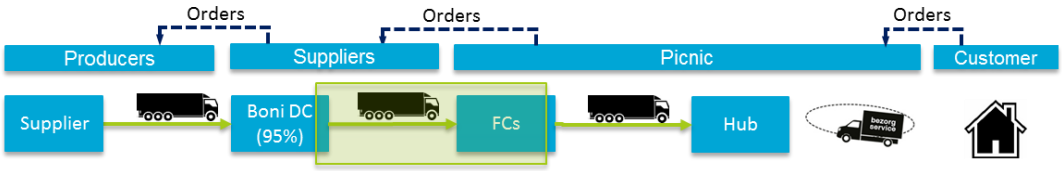

Fig. 2. Schematic overview of the research scope

The scope of the research starts at the outbound of the supplier, Boni, and ends at the outbound of the fulfillment center (FC) of Picnic, see fig. 2. These system boundaries are chosen because within these boundaries a wide range of data is available and there two clear decoupling points: 1: shipment towards Picnic and 2: shipment ready to ship from the FC. This makes it possible to find the root causes of unexpected shortages in the FC. Furthermore the scope is narrowed down to fresh products since these are the most sensitive to disturbances in the supply chain. The cause of these disturbances is easier to find which makes the data more reliable.

II. Research Method

The approach of this research consists out of the five steps: first, in the exploration phase, the available literature about supply chain management, improvements strategies and e-grocers is looked into. Secondly, an elaborate analysis of the current processes and disturbances in the FC is done. This leads to a synthesis were different feasible design alternatives are created along with a model to test them. In the assessment the different design alternatives are tested which results in conclusions and recommendations.

III. Analysis

The analysis of the current situation in the FC contains four parts: the processes in the FC, the effects of unexpected shortages at the FC, growth of Picnic, and the root cause analysis of unexpected shortages and their effects.

A. *Processes in at the FC*

There are several processes in the FC which transform the incoming articles into order lines for the client. The processes are as follows: inbound, receiving, replenishment, picking, consolidating, storing and shipping.

- *The inbound* are the articles that are delivered at the FC from Boni. The amount depends on the order amount of the previous day. The articles are normally delivered in trading units (TUs) and packed on roll containers (RCs)
- *Receiving* is the process of dividing all the RCs along the correct aisles in the FC of Picnic and checking their content.
- *Replenishment* is done when the articles are at the right aisle but still need to be put on the right shelves. This is ideally done without interfering the picking process.
- *Picking* is carried out by the shoppers on the floor. The shopper walks with a picking cart (PC) with totes a fixed route through the FC while picking articles from the shelves and putting them into the totes.
- *Storing* of the totes in dispatch frames (DPFs) is done when the picking round is over. The totes are stored before shipping them to one of the hubs.
- *Consolidating* may be needed when an article was not present at the shelves during the picking round. A late received article is then added to the tote to complete the order.
- *Shipping* the DPFs in trucks is the last step of the process in the FC. The order lines are then transported towards the hubs.

B. *Effects of unexpected shortages in the FC*

An unexpected shortage can be detected in several processes: the inbound, receiving, replenishing and picking. The earlier in the process such an unexpected shortage is detected, the more options there are to resolve the problem. The first choice is to place a rush order (RO). Although the pick process for rush orders at the supplier is highly inefficient, it ensures most processes run smoothly at Picnic. Pickers get several receipts instead of one which means they have to walk several rounds. If a RO isn't possible a store pick (SP) can be done. An employee then buys the missing items at the local supermarket. This is a relatively expensive solution. If a RO or SP aren't possible, a substitute (SUB) can be added to the order line. If one of these solution is found, the late received articles can be

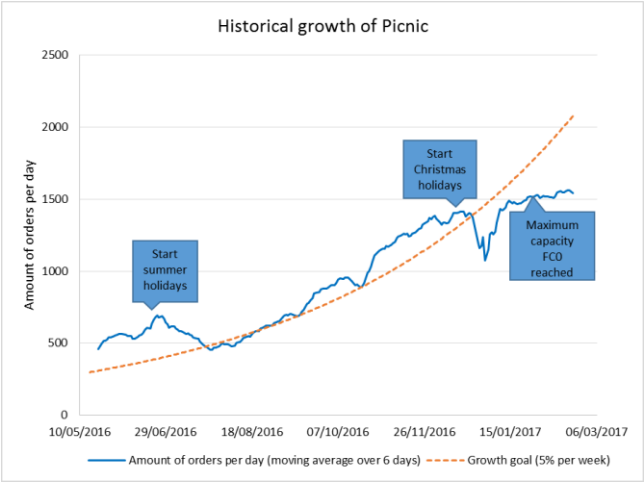

Fig. 3. Historical growth of Picnic

added to the order lines at the consolidation process. If neither of the previous solutions is possible, it becomes an cancelled order line (COL), which is highly unwanted for the customer and thus for Picnic.

C. *Growth of Picnic*

Since the goal of Picnic is to grow fast and the influence of this growth is part of the research, growth speed of the past is analysed. The amount of orders per day is collected for more than 9 months, see fig. 3. Here it can be seen that, with exception to the holidays, the goal of Picnic to grow 5% per week is reached.

D. *Root cause analysis and effects of unexpected shortages*

In the root cause analysis of the unexpected shortages in the FC eight different root causes were found: un-orderable at supplier, shortage at supplier, delivery failure, receiving's mistake, unexpected clearance, non-fifo picking, quality buffer and stock mismatch. Every cause could have either no consequence (other than a stock adjustment) or one of the following effects: RO, SP, SUB or COL.

In table 1 the average results of the root cause analysis can be found. Notable is that a great deal of the un-orderable products can be solved by placing a rush order or a store pick. Furthermore it can be seen that delivery failures have the biggest influences on the processes within the FC. Although this gives good insight in the distribution of root causes and their effects, there is no clear overview in the impact of the root causes. To rank the impact of the different root causes every data is filled in in equation 1 and equation 2. Here 'A' is the average occurrence per day, 'C' is a constant depending on the effect, and 'P' is the peak value. 'i' stands for the different effects of the root causes.

$$\text{Average impact} = \Sigma\, A_i \times C \qquad (1)$$

$$\text{Peak impact} = \Sigma\, C_i \times P_i \qquad (2)$$

The results of equation 1 and 2 (the average impact and the peak impact of different root causes) are shown in table 2. Green means that there is little to no impact and red

	RO[%]	SP[%]	SUB[%]	COL[%]
Un-orderable	0.0381	0.0222	0.0022	0.0046
Shortage supplier	0.0000	0.0000	0.0000	0.0000
Delivery failure	0.3445	0.0650	0.0050	0.0081
Receiving's mistake	0.0324	0.0049	0.0000	0.0000
Unexpected clearance	0.0077	0.0073	0.0076	0.0003
Non-FiFo picking	0.0000	0.0100	0.0059	0.0065
Quality buffer	0.1841	0.0000	0.0000	0.0000
Stock mismatch	0.0606	0.0248	0.0022	0.0064

Table 1. Average percentages of sold items per day, root causes and their effects

	Average impact [impact factor]	Peak impact [impact factor]
Un-orderable	0.1082	1.000
Shortage at supplier	0.0000	0.000
Delivery failure	0.3869	4.200
Receiving's mistake	0.0260	0.400
Unexpected clearance	0.0212	0.400
Non-FiFo picking	0.0955	0.400
Quality buffer	0.0921	0.300
Stock mismatch	0.1399	1.000

Table 2. Impact of root causes

stands for the highest impact. It can be seen that the delivery failures have the most negative effect on the processes in the FC, followed by stock mismatches, un-orderable products and non-FiFo picking. Quality buffers, unexpected clearances and receiving's mistakes have less impact, especially because they are less common and mainly result in ROs. A shortage at a supplier has never lead to any effect during the analysis phase of this research.

IV. Alternative Designs

From the analysis different alternative designs arise, these are emerged from the impact of the root causes in table 1 and detected inefficient processes. Although the un-orderable products have significant influence on the processes in the FC, no alternative is created which decreases this amount, because there are too much politics involved in this area which makes is highly unlikely that the amount un-orderable products can be influenced.

Alternative 1: Reduce delivery failures (RDF): Since the delivery failures are the most important root cause it is wanted for both supplier as e-grocer to reduce the delivery failures. Less delivery failures means less rush orders which disturb the process of the supplier, and less negative effects on the performance of the FC of the e-grocer. To achieve this an investment has to be made in a team of experts that can make this improvement possible.

Alternative 2: Improve insight in the FC (IWI): Since stock mismatches and non-FiFo picking are mostly noticed late, the effect is relatively often a substitute or a cancelled order line. Therefore improving insight can prevent some of these effects. For this an extra employee is needed to count the stock.

Alternative 3: Direct delivery (DD): Because of the growth of the items ought to be delivered directly in the near future to decrease the pressure on the distribution center (DC) of Boni. Since the DC works as a buffer, it is plausible that the delivery performance may drop. Furthermore, no rush order is possible at these suppliers. In this alternative the effects of this performance drop are assessed.

Alternative 4: Change the store pick procedure (DSPP): Because of its inefficiency, store picking is relatively expensive. Therefore reducing the amount of store picks to only important items for the customer is a design alternative.

Alternative 5: Improving the rush order process (IRP): The current rush order process is highly inefficient since it is designed for much larger order amounts. Therefore a different RO design which increases the average pick speed of the ROs can be a huge improvement to save extra costs. For this improvement receipts have to be merged every day which is done by an employee.

V. Model

Following the analysis and the design alternatives a model needs to be made in order to assess the different alternatives. The model should be able to, given a certain input, to calculate a root cause and effect distribution. This distribution can then be used to calculate the extra costs (the KPI) involved in the design alternative in order to compare them with each other. The extra costs are defined as the costs involved in solving an unexpected shortage and costs are assigned to unwanted effects like SUBs and COLs. A schematic overview of the conceptual model can be seen in fig. 3.

A. Model input

There are several inputs needed to simulate an effects distribution and to calculate the extra costs. First of all the root cause distribution. This distribution highly depends of the design alternative chosen to assess.

- *RDF:* There is chosen for a reduction of 50% of delivery failures along with an investment of €15,- per day to make this possible.
- *IWI:* A reduction of 33% is made possible by increasing the stock checks (which is accompanied €20,- per day).
- *DD:* 15% of all the items are delivered directly. It is assumed that these suppliers do not work with rush orders which influences the effect distribution. Furthermore the delivery performance is assumed to be worse. No investment costs are involved since this DD is unavoidable given the current growth rate.
- *DSPP:* Instead of store picking when possible a reduction of 50% (the less important items) of store picks is chosen. This means that for these items another solution must be found.
- *IRP:* The rush order speed is an average of the normal pick speed and the current rush order pick speed. This is made possible by merging receipts daily (€10,- per day).

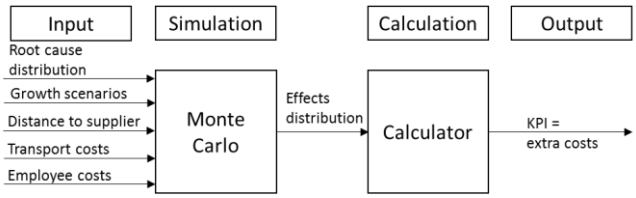

Fig. 4. Schematic overview of the conceptual model used for the assessment

Another input is the expected growth of Picnic. Because the goal of Picnic is to grow 5% per week and Picnic has proven to be able to do so in the past, this growth scenario is chosen. This growth start at the opening of the FC (500 orders per day) until the maximum capacity is reached of around 10 000 order per day.

The distance to the supplier has significant influence on the extra costs involved with a rush order. Although this is an important variable to recon with, in this research the distance is chosen to be fixed at 5 kilometer. Furthermore there are transport costs and employee costs needed in order to calculate the total extra costs.

B. Monte Carlo simulation

The stochastic nature of the disturbances in the processes should be reflected in the simulation. For this a Monte Carlo simulation is used [5]. The Monte Carlo is a widely used technique in probabilistic analysis's. It is a numerical experimentation technique to obtain the statistics of the output variables, given certain input variables. In each experiment the values of the input variables are sampled based on their distribution. Using a computational model the output variables are then calculated. This way a number of experiments is carried out and the results are used to compute the statistics of the output variables. The more experiments are done, the more precise the results are.

C. Key performance indicator

To be able to compare the different design alternatives, a KPI is needed. Since the design alternatives do not interfere with the 'happy flow' (a flow of articles without any disturbances in the processes) the alternatives are compared by calculating the extra costs in comparison with the happy flow. The extra costs are then calculated in total per day (C_t) and per order line (C_p) using the average order amount per day (O_a). The costs are calculated by summing the fixed extra costs (C_f) and the variable extra costs (C_v) of each effect, see equation 3 and equation 4. 'i' stands for the different effects that can occur: ROs, SPs, SUBs and COLs.

$$C_t = \Sigma \left(C_f(i) + C_v(i)\right) \quad (3)$$

$$C_p = \Sigma \left(C_f(i) + C_v(i)\right) / O_a \quad (4)$$

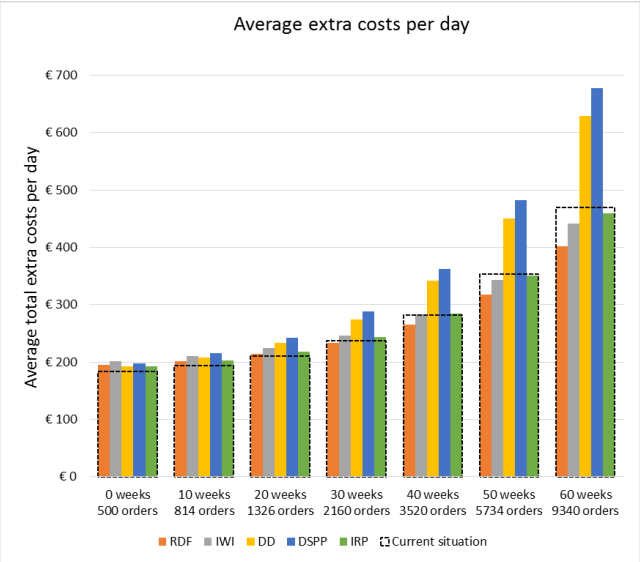

Fig. 5. Average extra costs per day of the different design alternatives

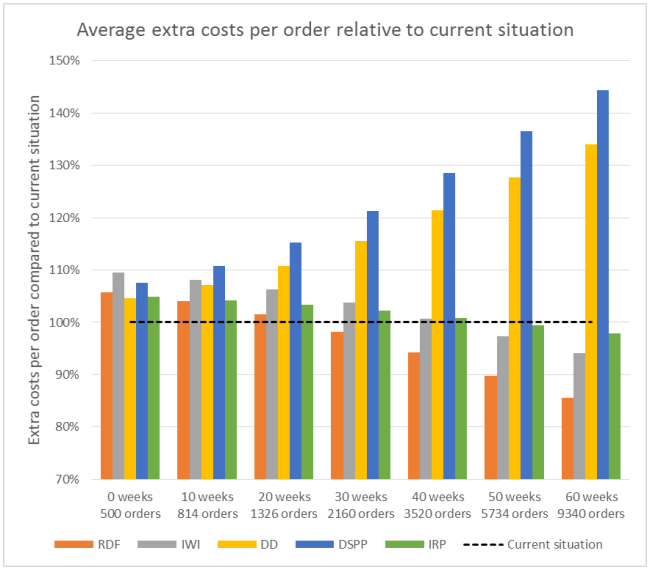

Fig. 6. Average extra costs per order compared to current situation of different design alternatives

VI. RESULTS

The goal of the research was to find possible root causes of disturbances at the FC and find out how these causes could influence the performance of the FC in the future. Therefore different design alternatives are compared by looking at the total extra costs per day and the extra cost per order in a predicted growth scenario of 5% per week.

In fig. 5 the average extra costs per day of the different alternatives are shown. It is shown that the overall extra costs increase along with the amount of orders, although the costs per order drop. Due to investments, every alternative has more extra costs, compared to the current situation in the start-up phase of the FC. It can be seen that RDF has the most positive effect in the end-phase. Changing the store pick procedure leads to a lot of extra costs since more items have to be substituted or cancelled. The poor delivery performance of direct delivery results in a lot of disturbances in the overall process of the FC, which results in high extra costs per day.

In order to compare all the alternatives fig. 6 is more usable. Here the extra costs per order are shown relative to the current situation. This shows that the delivery performance has a huge influence on the performance of the FC. RDF clearly shows improvement in comparison to the retrogression of DD. The extra costs per day to make IWI and IRP possible mean that they would only show improvement after respectively 25 weeks and 40 weeks. Although the store pick procedure is relatively expensive, the alternative, that there is inconvenience for the customer, results in a lot of extra costs per order, see DSPP in fig. 6.

VII. DISCUSSION

Although there are several areas open for improvement, the most important factor in improving or sustaining the performance of the FC, is the reliability of the deliveries. Therefore there should first be looked into working together, to improve the delivery performance of Boni. Looking further in the future clear delivery performance deals have to be made with new direct suppliers which have to be checked on a regular basis. Here the delivery performance of Boni can be used as a reference.

The extra costs involved with the SUBs and COLs are highly dependent from the goal of the company. A company with the goal of growing attach more value to keeping the customer satisfied and therefore the extra costs of a COL are relatively high. A company which is already established has as a main focus to make profit which means is not the highest priority. Also, the extra costs per SUB or COL are assumed to be constant. In practice this is not the case. Therefore the influence of making these parameters variable should be looked into.

An important assumption is the Monte Carlo simulation of this research, is that the root cause distribution of every day is independent from the other days, even though it is highly likely that the chaos of one day can significantly affect the root cause distribution of the next day. For this reason the influence of days on each other should be examined.

ACKNOWLEDGMENT

This research is done commissioned by Picnic and supervised by Frank B. Gorte whom I would like to thank for his inexhaustible knowledge about the company and his willingness to help. Furthermore the supervisor from the TU, Mark Duinkerken, has had a tremendous influence on the smooth running of the project by giving critical remarks on content and work methodology.

REFERENCES

[1] E. Tkacz en A. Kapczynski, Internet - Technical development and appilcations, Springer Berlin Heidelberg, 2009.

[2] „Ecommercenews," 6 10 2016. [Online]. Available: http://ecommercenews.eu/ecommerce-per-country/ecommerce-the-netherlands/.

[3] R. Smit, „Financieel Dagblad," 7 jan 2016. [Online]. Available: https://fd.nl/ondernemen/1134162/online-boodschappen-doen-blijft-voorlopig-een-nichemarkt.

[4] H. Ericsson, „E-Commerce in Europe 2015," PostNord, Kopenhagen, 2015.

[5] D. P. Kroese en R. Y. Rubinstein, Simulation and the Monte Carlo Method, John Wiley & Sons, Incorporated, 2016.

[6] P. Dorsett, „An insight report by Kantar Worldpanel THE ONLINE FMCG," 2014.