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Dynamic fill-up and picking process for small and middle sized companies in the food market industry

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Dynamic fill-up and picking process for small and middle sized food market companies

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Ing. Matthias Bauer, BSc

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Kurzfassung

Durch die fallenden Preise für Artikel und der immer kürzer werdenden Lieferzeiten werden optimale Lagerverwaltungssysteme immer wichtiger. Bei der Erstellung und Optimierung von Lagerverwaltungssystemen muss dies auch von Unternehmen in der Lebensmittelbranche berücksichtigt werden, um weiterhin konkurrenzfähig zu bleiben. Dadurch ist es notwendig, den Artikeldurchsatz zu erhöhen, die Artikel dort zu lagern, wo es am passendsten ist und die Wege für die Angestellten so kurz wie möglich zu halten. Diese Arbeit zielt darauf ab, den Nachschlicht und Kommissionierprozess zu optimieren. Zuerst werden durch eine Literaturrecherche die wichtigsten Parameter eines Lagerverwaltungssystems und des Nachschlicht- bzw. des Kommissionierprozesses erarbeitet. Durch Interviews mit den verantwortlichen Lagerleiter/innen von drei verschiedenen Unternehmen der Branche werden die wichtigen und zeitkritischen Parameter und Prozesse identifiziert. Basierend auf der Literaturrecherche und den Interviews werden verschiedene Ansätze zur Optimierung des Nachschlichtprozesses umgesetzt und in einem ERP System einer Firma implementiert. Für den Kommissionierprozess werden ebenfalls verschiedene Ansätze zur Erstellung einer Sammel-Kommissionierung und der optimalen Wegeberechnung für die Angestellten erarbeitet und implementiert.
Das Resultat der vorliegenden Arbeit zeigt, dass die Optimierungen des Nachschlichtprozesses keine erheblichen Vorteile bringen, jedoch einen großen Einfluss auf den Kommissionierprozess haben. Mit dem derzeitigen Personal und räumlichen Umständen kann das Optimierungspotential erheblich gesteigert werden. Ohne den davor eingeführten Nachschlichtprozess wäre dies nicht in dieser Größendimension möglich.

Abstract

Inventory management techniques gain more and more importance due to decreasing prices of goods and faster delivery times. In the food market industry, this must be included when creating or optimizing a stock management system. Therefore, it is necessary to optimize the throughput of articles, store the articles in the most proper stock location and minimize the employees' ways. Thus, this master thesis aims to create an approach to fill-up articles and pick articles in an optimal manner.
First, essential parameters of stock management systems and the fill-up and picking processes are identified by a literature review. After that, the responsible stock managers from three different companies in this sector were interviewed to identify the most time-consuming and critical processes within a stock management system. Different approaches for filling up goods in a warehouse in an optimal manner regarding short distances to the packing tables were applied and implemented into the ERP system of a company investigated. The second part of this thesis handles the optimization of the picking process. Therefore, different approaches to creating a batch order and the optimal way through the stock for the picking personnel were implemented into the ERP system. The results of this thesis show that the optimization of the fill-up process does not create a big difference to the current approach but has an impact on the picking process. At the current personal and spatial circumstances, the throughput of the picking process can be increased.

Contents

CHAPTER 1

Introduction

1.1 Problem definition

There are about 8,400 trading companies in Austria with approximately 140,000 employees (full and part-time) in the food market industry[1]. There are about 500 new companies founded every year in this industry. Most of them have a big stock but no possibility or enough experience to optimize their stock management. Stock management means finding the optimal stock location for every product. An optimal stock location has the following characteristics.

- **Time-saving:** Product pickers should have precise ways to the most common products.
- **Cost-saving:** There are many factors to save costs with an optimized stock management system. One of them is that it is unnecessary to have an enormous amount of goods in the main inventory. The optimized way is to store just the amount of one or two days in that stock. Therefore, the demand for the following days and the demand of previous periods are needed. The main stock is that part of the inventory where the pickers collect their goods for B2C (Business-to-Customers) customers that usually order lower amounts of goods. The other part is for fill-up purposes of the main stock and for B2B (Business-to-Business) customers. Another cost-saving possibility is to save labor by an optimal picking and fill-up process. This can be achieved by saving time at these processes.
- **Consider existing conditions:** Some products have specific product specifications like strong smell, whether they absorb the aroma of other goods, expiration dates or whether the product must be cooled. The products should be placed in such a way that nothing happens regarding these specifications.

[1] http://wko.at/statistik/BranchenFV/B_301.pdf

- **Optimal picking processing:** Short ways from processing to the stock location saves time and money.
- **Optimal picking spatial distribution:** The best products (products with the highest inventory turnover ratio) should not be placed next to each other to avoid accidents caused by picking personnel and stackers.
- **Optimal picking product quality:** The stock management should also think about different product quality levels. Different quality levels are needed in different product families.
- **Optimal picking batches:** With B2B customers, it is not allowed to send them elder batches of a good compared to deliveries before.
- **Optimal seasonal goods' stock location:** It is possible to have seasonal goods like an advent calendar in winter or potatoes in summer.

These specifications of stocks can lead companies to create a dynamic inventory. A dynamic stock means that an article does not have one standard place in the stock. The stock management system must learn from the data where the best place for this article can be. If one article is a product with a high turnover ratio, it is sometimes better to have it near the packing tables to minimize the pickers' ways. If a processing step is finished, a picker has to fill it up at the stock. The system has to calculate out of constraints which stock place is ideal for this article. Therefore, one stock place may be filled with two or more different products because it fits better to the constraints.

Another dynamic step is the picking process. If a person starts a picking process, he/she should get the right stock place for an article. If the stock management can work with more than one good per stock location, the article of the current picking process must be available for the picker.

It is very complex to ensure all specifications of an optimal stock. Therefore, many the companies do not want to change anything on their product distribution in their stocks. Because this is a complex topic, the company cannot test it before. Some books are available, but they include just examples, how it can work and which factors are important. Usually, these books do not contain constraints that have to be ensured to create a dynamic inventory.

1.2 Expected outcome

The expected result of this master thesis is in the first step a list with all identified parameters for a dynamic fill-up and picking process. Important parameters for the fill-up process can be for instance the expiration date, request of an article in a specific period of time, inventory ratio turnover of an article, whether an article is in an external warehouse and whether product specifications like a strong smell or absorbing aroma from other goods. Parameters for the picking process are for example the minimal way of the pickers, grouping the most similar orders, identifying the best number of pickers or finding the next best inventory place with regard to the expiration date or batch of a specific good. Interviews with the stock managers and his/her substitutes from Sonnentor, Kastner and Kiennast will identify these parameters.

The second step handles the fill-up process. After a good is delivered by a supplier or is produced in the production hall, the system has to calculate the best place for this article to fill it up in the inventory. Therefore, one stock place may be filled up with more than one product. This best stock place will lead to a reduction of time when picking the goods for the orders. After the fill-up process, the picking process will be handled. If a picker wants a new picking task, the system calculates one collection order. A collection order is an order with a specific number of similar batched orders to minimize the picker's way.

This part of the master thesis ends up in separate algorithms for the fill-up and picking process, which are also integrated into the test environment of the stock management system of Sonnentor[2].

The last step of the master thesis is to show the differences between a standard stock management system with a non-dynamic fill-up and picking process and the dynamic one. Differences will be the reduction of time at both of these processes. The results will be provided by different plots to create awareness of the potential improvement of the system.

1.3 Methodology

1.3.1 Literature review

At the beginning of this master thesis, a literature review will be done to gain insights into the stock management workflows. This will be done by following the guideline to create a meaningful and qualitative literature review stated in [DKW17]. Thus, the research question's fundamental work to define constraints for the fill-up and picking process and which parameter influences the calculation to find the optimal stock place were examined. The literature review also gives an overview of the different approaches to find the optimal stock place and how a person should be walking through the stock when picking goods.

1.3.2 Qualitative analysis

The second step will be to create a qualitative analysis by having an interview with the responsible stock managers in the food market industry. These interviews will start by carrying out a study to determine which data is needed for this thesis (amount of stocks, amount of racks, number of pickers per shift, list of goods and specifications). This will

[2]For more information on Sonnentor see the Appendix 5

be achieved by reading and comparing different papers, interviewing the responsible people from Sonnentor, Kiennast and Kastner and showing the most important stock management parameters. Questions to answer after the interviews will be:

1. Do articles have any specifications?
2. What kind of racks are the most important ones in the food market industry?
3. What are the most important packaging units in the food market industry?
4. Should every picker and stacker use all corridors? (To avoid accidents and conflicts)
5. Should each picker take one order or more than one simultaneously?
6. How to calculate the request for an article for a specific period?
7. What are the most time-consuming workflows within the stock management?

1.3.3 Implementation of a prototype for a fill-up and picking activity

Based on the literature review and the qualitative analysis, a prototype will be implemented into the test environment of Sonnentor. The prototype will handle the most time-consuming process, which is the fill-up and picking process. In this prototype, the different approaches of each process will be implemented to get a meaningful outcome. The prototype will be implemented so that the parameters are easy to change to create a semi-autonomous process.

1.3.4 Statistical evaluation of ratio of optimization

In the last step, the awareness of the optimization potential will be shown for the fill-up and picking process. Therefore, a statistical evaluation will be carried out to show the time improvements from a non-dynamic to a dynamic system for the picking and the fill-up part. This will be shown by different plots.

1.3.5 Research questions

This master thesis will handle the two most time-consuming parts of a stock management system: the picking and fill-up process. Therefore, this master thesis will aim to find an optimization potential in that process. After this, this thesis will split up into two different parts: the picking part and the fill-up part. The fill-up part will calculate the correct stock location for an article based on the literature review parameters and qualitative analysis. The picking part ensures getting the right stock-place from the system and handles an optimal collection of different orders. Therefore, the system has to analyse the collected data from the previous periods and the following days or weeks' orders. The research questions of this master thesis are:

1. Can a dynamic fill-up process be provided by a semi-autonomous algorithm?
    - Which constraints are important for a fill-up process?
    - What is the demand on an article with respect of the current orders and previous periods?
    - What are the parameters needed to define an optimal place of a product with respect of their specifications?
2. Can a picking process be provided by a semi-autonomous algorithm?
    - What is the best algorithm to group orders together?
    - Which parameters are needed to define an optimal picking process?
    - What is the shortest way for a picker through the stock?

1.4 Structure of the work

This master thesis is structured as follows. In Chapter 2, the theoretical background of a stock management system and the specific processes are described. Chapter 3 shows the result of the interviews with Sonnentor, Kastner and Kiennast, gives an overview of the important parameters of an article and describes the implementation of the fill-up and picking-process. The master thesis ends with an evaluation in Chapter 4 and the conclusion and future work in Chapter 5.

CHAPTER 2

Related Work

2.1 State of the art

The current state of the art has no comparatively scientific work available, describing different parameters and aiming for an optimal fill-up and picking process. There are some comparable papers and books available that describe approaches on how to guide a person through the stock or give away some classification methods for the fill-up process. Commercial products were investigated in this thesis too.

2.1.1 Scientific work

The paper [DSAS18] aims to find an optimal order picking system to minimize the time in a multidimensional stock. The authors use the genetic algorithm to determine a minimum route through the Single Picker Routing Problem (SPRP) which is a Traveling Salesman Problem (TSP). In this paper, the authors considered a three-dimensional stock environment, where the z-axis is the height of the racking system. The height of the racking system is needed to include the vertical lifting speed of the stacker to the overall time which is needed for picking.

The paper [vGRCdK18] shows an overview of the state of the art, a classification of the planning problems and a review of efficient picking systems by combining different approaches. The authors give a general overview of the different planning problems from different points of view:

1. **Strategic:** The strategic planning problems deal with the design of a warehouse. This includes the decision of the design or the level of automation.
2. **Tactical:** Tactical planning problems mean the resource dimension like the storage capacity and size of the racks at a specific place in the warehouse.

3. **Operational:** The operational planning problems are for example batching and routing through the racks.

[Ign17] gives an overview of a complete logistic system. A complete logistic system means starting with an efficient order system to have enough on stock every time and ending with an optimized distribution and retail system. This paper shows how to optimize the stock system to minimize the costs for storing the goods.

The paper [DCR07] handles the reordering process of an inventory at mid-season. Mid-season means the point of time when one type of product is obsolete and new products arrive. Therefore, the authors of this paper calculated the demand for the new products without substitutes to have the optimal amount of these products on stock.

2.1.2 Commercial products

There are also some commercial products for inventory systems. The system with the most dynamic approach is *Dynamic Inventory*[1]. Dynamic Inventory has two main tasks. First to track all products at every point in time in the store. This will be ensured by scanning the codes of the article and the stock location at every goods movement. The second task is to handle purchase and sales orders.
Systems with a similar approach are *Oracle Netsuite*[2], the inventory management system from ASAP Systems[3], *Manage Inventory And Monitor Assets* from freshworks[4] or the ERP system from fab4minds[5].
Most of the commercial products are not published and there is not too much information available. The best example is Amazon. There are just a few interviews with regional managers of Amazon where they did not tell much about their stock management system[6]. Amazon works with the *chaos approach*. This means that every product will be stored at the next available stock location. Two same products can be far away from each other. The *chaos approach* can also be applied at bigger warehouses where it is not so important to have ways as short as possible.

2.2 Fill-up approaches

Fill-up approaches are necessary to create an optimal article distribution on stock. Nowadays the supply chain becomes more and more important to reduce costs. An article with a high forecasting accuracy can be ordered just in time and can be stored at a more prominent position than a high variable article. This is why the supply chain

[1]https://www.dynamicinventory.net/inventory-management-software/
[2]https://bit.ly/2RTUKy5
[3]https://bit.ly/2pXVF3Z
[4]https://bit.ly/2QXTokO
[5]https://bit.ly/2QSXD0P
[6]https://bit.ly/3tj5ck9

gets more attention than ever, as described in [ABA+19]. The goal of fill-up approaches related to this master thesis is to find the best stock location at the fill-up stage to ensure an efficient picking strategy. Filling-up strategies are the basis of an efficient picking system. The stock management system has to calculate the customer demands or access frequencies in real-time from the last periods and the upcoming orders to optimize the pickers' ways. Therefore it is necessary to have predefined methods to find the best stock location. The most common stock management types are the clustering of goods with ABC-cluster, XYZ-analysis, the combination of these two approaches or to have a chaos approach.

2.2.1 ABC-cluster

The ABC-cluster analysis ensures to separate the significant from the insignificant goods in the stock. Therefore, it is necessary to calculate the demands of the previous periods to identify the importance of an article. One approach to ensure this is described in [Nev14], which classifies an article based on the access frequency into A, B and C articles. For the calculation, it is necessary to get the picks by an article in a predefined period and sort it in descending order. The sorted list ensures to assign the goods to the suitable stock locations. The most significant good gets the nearest location of cluster A to the picking tables, shown in Figure 2.2. Another approach of clustering is the classification based on the part of the total sales. This approach follows the 80/20 principle described in [DJ20] or [CLL08] and implied that 80% of the total turnover will be generated by 20% of the articles. 30% of the articles will generate 15% of the total revenue and the other 50% of the articles generate the other 5% of the revenue. This is also known as the "Pareto principle" and will be shown in Figure 2.1.

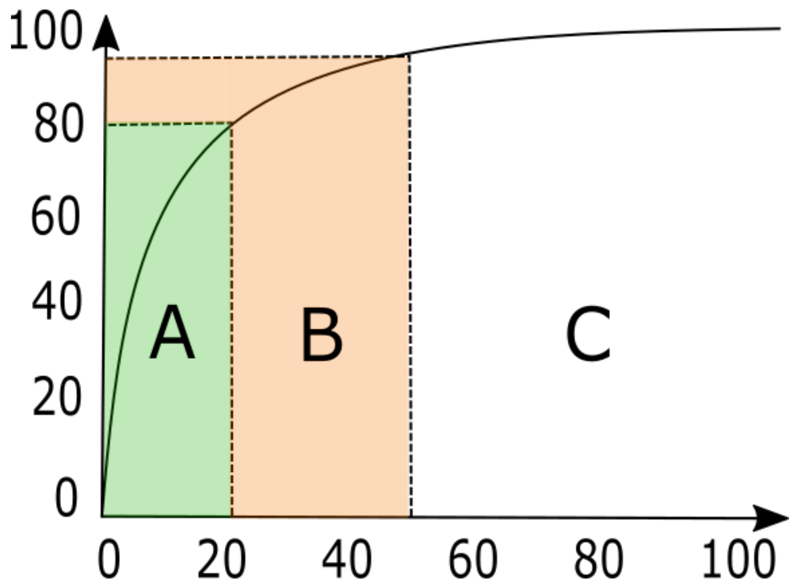


Figure 2.1: ABC-Pareto principle based on [CLL08]

No matter which clustering approach will be used, the specification of a class will be the same. Cluster A has a high, B has a moderate and C has a low access frequency in the stock. Articles within class A should be next to the packing table, B in the next sector and C can be far away from the packing table. This methodology is shown in Figure 2.2. For the calculation of the thresholds, different approaches are available. It is possible to set fixed thresholds to fill the classes, but then there may be a non-uniformed distribution through the classifications. The better approach is to cut the calculated values into three pieces to ensure uniform distribution.
Inside of one cluster, it is possible to calculate an ABC-cluster again. Defining more classifications ensures a more precise definition of the stock location for one article. Groups like AA, AB, BA, ... are possible in that case.

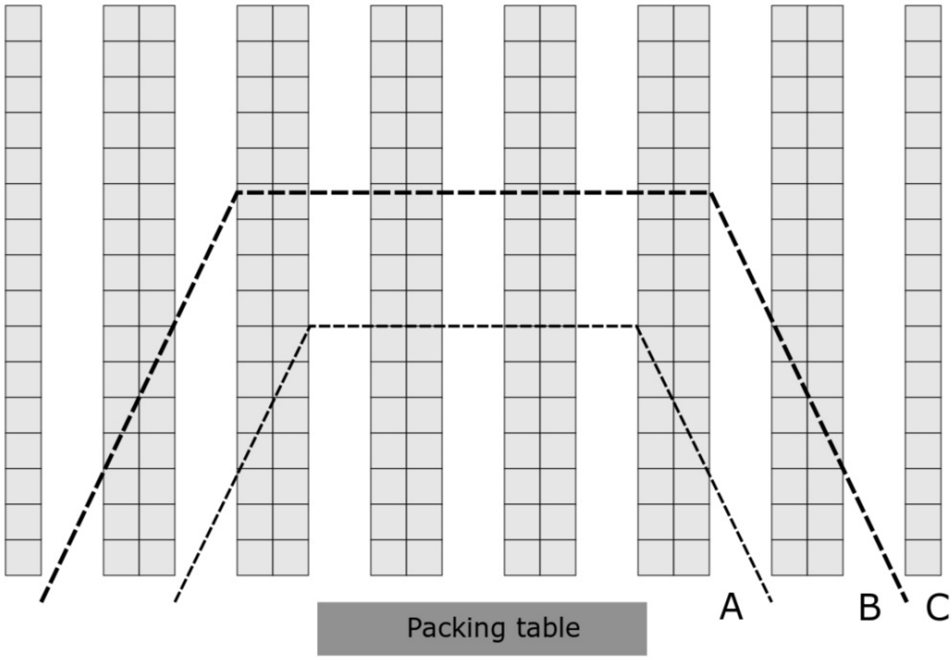


Figure 2.2: ABC-clustering at a stock described in [Nev14]

2.2.2 XYZ-analysis

Another clustering method is the XYZ-analysis [Nev14]. The difference to the ABC-clustering is that the XYZ-analysis defines the prediction accuracy. In the case of a company in the food market industry, the standard deviation of the sales contracts of the last period will be taken into account. Based on the deviation, the article can be classified into X, Y or Z. This variability of the different goods, as described in [ABA+19], should handle the stock location of a good. Different circumstances define whether an article has high, moderate or low variability. There are "seasonal fluctuation, trends, economic factors" [ABA+19], which influence the prediction accuracy. For the calculation, predefined properties can be taken into account, which will influence the prediction accuracy. Parameters for the food market industry can be:

- demand in previous periods (e.g., the demand of this good in the same month as one year before)
- demand for the next days/weeks (calculated out of the open orders)
- product turnover ratio
- worth of orders from previous periods (higher earnings of one good has higher priority for the company)

Based on this data, an article can be classified in one of the three classes X, Y or Z. The cluster X has a high, Y has a moderate and Z has a low prediction accuracy. An article will start in class Z when launching the article. Based on the number of sales or stock turnover ratio, the article can raise its classification to Y or X.
There are different ways to create the classification with the calculated goods. It is possible to create fixed thresholds that define the classes. As default, the thresholds are a standard deviation under 25% for a X article, between 25 and 50 percent for an Y article and over 50 percent for a Z article. The disadvantage of this strategy is that a fixed threshold can lead to a inhomogeneous distribution across the different classes.

2.2.3 Combination ABC-XYZ-analysis

It is also possible to combine the ABC-clustering and the XYZ-analysis [Nev14]. This combination ensures that the goods have the best stock location regarding access frequency and prediction accuracy. The results of this strategy bring a two-dimensional classification like AZ, BY and so on. With that classification, it is possible to sort it regarding significance. Because the result is two-dimensional, a stock manager has to decide which sort mechanism he/she applies for the stock. In some stocks, it is better to rate a moderate access frequency higher than a moderate prediction. Table 2.1 shows the different results of the combination of ABC-clustering and XYZ-analysis.

Another critical factor is at which point in time the calculation of the classification will be done. [SRHMB12] shows a big difference if performing the calculation once a year and for an extended period or calculating it more often. When calculating the classifications once a year with a long period, only 60% of the articles will be in the right classes compared to a more periodic calculation. The results of this study show that it is more efficient to calculate the classification more often and for a predefined period like 12 months. As already mentioned, the number of calculations is also important. In [SRHMB12], the authors reviewed 2 cases and compared whether the calculation should be done once a year or more often. This results in the deviation of "class changes" over time. Case 1 calculates the deviation by adding and subtracting one month to the base month of

	A	B	C
X	high access frequency high prediction accuracy	moderate access frequency high prediction accuracy	low access frequency high prediction accuracy
Y	high access frequency moderate prediction accuracy	moderate access frequency moderate prediction accuracy	low access frequency moderate prediction accuracy
Z	high access frequency low prediction accuracy	moderate access frequency low prediction accuracy	low access frequency low prediction accuracy

Table 2.1: Results of combination of ABC-clustering and XYZ-analysis [Nev14]

one year. The result is a deviation of 4.24 percent. This means that a calculation by adding or subtracting one month to the base period of one year will change the classes by about 4.24 percent. On the other hand, shifting the base period every month will change the classes by 6.5 percent. The higher deviation will be preferable to have a dynamic classification method. A low change rate of classification leads to a static inventory. Figure 2.3 from [SRHMB12] shows the two cases in detail.

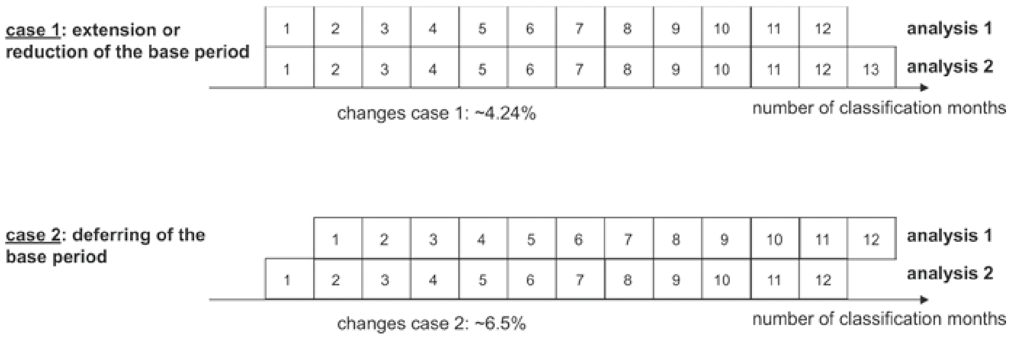


Figure 2.3: Compare of classification frequencies [SRHMB12]

Also, the forecasting amounts of an article can be taken into account for the ABC-XYZ analysis. To create a meaningful forecast, the data of planned orders and growth rate should be taken into account. It is necessary to update the calculation periodically to get a usable result. The quality of the forecast will decrease over time, as shown in Figure 2.4. This is because the planned customer orders, which are part of the forecasting, will decrease, as shown in Figure 2.5.

2.2.4 Chaos approach

Another strategy to find the optimal racking position is to create a chaos inventory [See05]. There are two different meanings of chaos inventory. First, an article can be stored at every stock location and the stock management system will choose one of

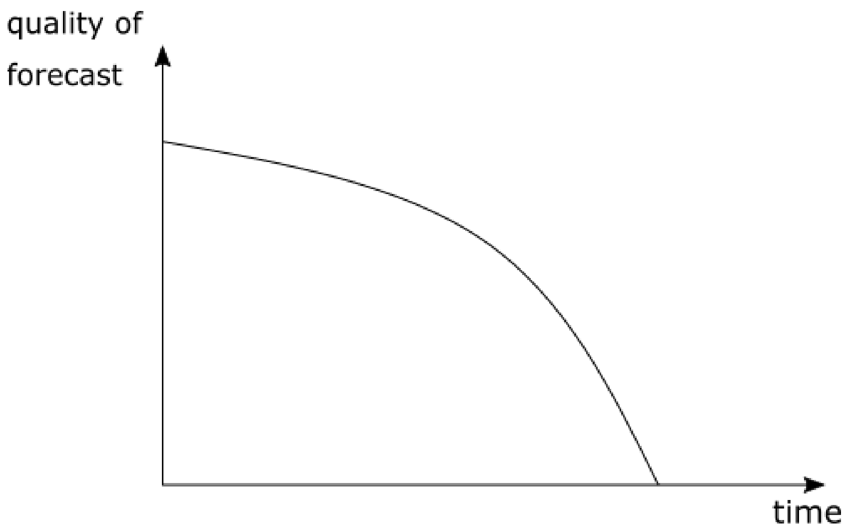


Figure 2.4: Quality of forecasting [SRHMB12]

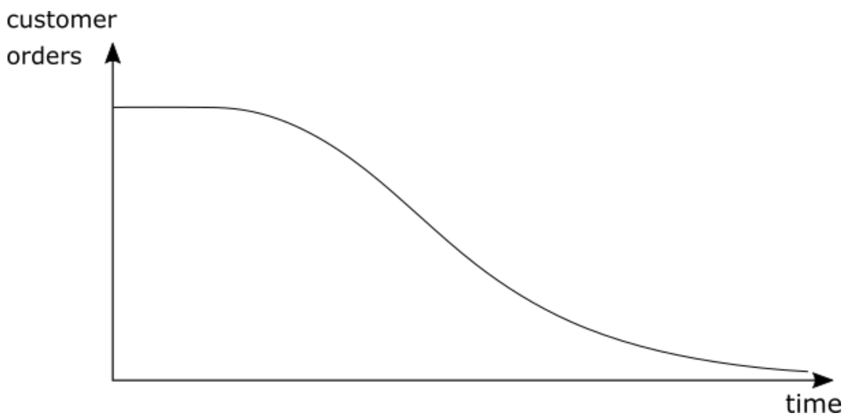


Figure 2.5: Planned customer orders over time [SRHMB12]

the empty places randomly. The other approach is that every article has a fixed stock location. At every fill-up and picking process, the article can be picked or filled up from these specific stock location. When having the random version, every inventory place must be equal to the others to ensure no convergence or something similar at the stock. At a chaos inventory, the picking and fill-up strategies must be a travelling salesman problem to find the optimal way through the inventory.
This approach is not applicable for a company in the food market industry. A chaos inventory makes sense when there are no restrictions of regulatory or certifications available. Also, the different sizes of the stock locations or pallet sizes makes the chaos approach irrelevant for the food market industry.

2.3 Picking process approaches

In the VDI-Guideline 3590, a picking system is defined as "... the compilation of specific subsets (articles) from a provided total quantity (assortment) on the basis of demand informations (orders)" [Ber97]. This thesis will analyse the picking process within a company in the food market industry and provide tools to manage it efficiently.
Different picking process approaches exist, which depend mainly on the type of goods and the article packaging sizes. The main difference is whether the pickers have a stacker to collect the goods, walk through the inventory, collect the goods by hand (picker-to-parts) or whether there are picking robots available in the stock (parts-to-picker). There are three other types of picking systems available, the "picker-to-box", "picker-and-sort" and "completely automated picking" approaches [DMM09]. This thesis will concentrate on the "picker-to-parts" approaches because this is the most common one in a small or middle sized company. The picker needs a stacker if he/she has a larger amount of goods which is impossible to carry or if the stock location is too high to reach. The third approach is that the racks come to the pickers. Robots will achieve this. The advantage of this system is that robots are cheap and can work at all times. One big company which uses robots for picking goods is Amazon[7]. Another differentiation of the picking process is paperless or paper picking. At the paper picking process, the picker has to print all picking lists with all positions of the defined orders. For paperless mode no paper is needed and the positions will be shown on a device or will be applied by a voice from the stock management system. The following sections will describe the different picking approaches.

2.3.1 Pick-by-document

Pick-by-document is a picking approach, where the picker needs a picking list [SZ16]. At installed terminals, the pickers can print one (or more) picking lists with all positions for the specific orders. On those documents with all positions and racking positions the picker can collect all of these orders.

2.3.2 Pick-by-voice

With this approach, every picker has a headset to ensure the communication between the picker and the picking system [SZ16]. The stock management system leads the picker from stock place to stock place. An advantage of this is that the pickers do not have any scanners or other things in their hands. They can work with both hands to pick the goods. The picker confirms the withdrawal by talking to the system. For this approach, the stock management system must be extended by speech recognition software and a pick-by-voice software component. Another advantage of this approach is that the number of pickers per corridor is unimportant because every picker gets the order from the stock management system directly to the headset. A disadvantage of this approach is to train every picker to the pick-by-voice system.

[7] https://www.amazon.de/

2.3.3 Pick-by-light

The stock management system leads the pickers with the pick-by-light [SZ16] approach to the next stock location by showing lights. Each stock location has a light at the front, followed by a small display for the amount which should be picked. There are usually buttons to confirm the picking process from this stock location so that the system knows when the next stock location light should be turned on. A disadvantage of this approach is that the number of pickers per corridor is essential so that the pickers do not get confused by the lights of other pickers. This can be solved by different luminous colors to increase efficiency. An advantage is that there is nearly no training needed.

2.3.4 Dynamic picking system

In a dynamic picking system [GK08], the stock management system ensures that the goods are brought to the picker automatically. Robots will achieve this. They bring parts of a rack directly to the picker. The picker takes the goods out of the boxes/racks and brings the racks/goods with the robots or the flat conveyor back to the stock location.

2.3.5 Pick-by-terminal

A fixed installed terminal at the stacker, tables or other picking vehicles will achieve Terminal-Picking[8]. A scanner helps the pickers to get the article numbers, serial numbers or batch numbers of the picked goods and ensures a fast and low error rate picking approach [SZ16].

2.3.6 Pick-by-scan (pick by MDE)

Pick-by-scan is a paperless approach that will be handled by a mobile device (MDE)[RA18]. This MDE replaces the picking list, so that the picker receives all relevant information on the display of the device. MDE's are, most of the time, hand-held computer or something similar like a watch with a more prominent display (hence sometimes called pick-by-watch) and an integrated bar code scanner. The stock management system and the device are connected and show the picker step by step all positions from the given order(s). Confirmed by the scan of the goods bar-code, the stock management system has an overview whether the picker is at the right stock and picks the right good.

2.3.7 Pick-by-point

The pick-by-point approach[9] is a new way to collect goods from the warehouse. This approach was developed by LUCA GmbH[10] and is a paperless picking system. At the Pick-by-Point approach, the communication between the stock management system and the picker is handled by a laser. At every corridor, a laser is installed and it shows the

[8] https://logistikknowhow.com/bestandsverwaltung/pick-by-terminal/
[9] https://logistikknowhow.com/bestandsverwaltung/pick-by-point/
[10] http://www.luca.eu/

	Advantage	Disadvantage
Pick-by-document	+ also available if system crashes + cheap	- high failure rate - slow if it isn't optimized - paper and printing costs
Pick-by-voice	+ fast + nearly no failures + many pickers at the same time possible	- training of pickers - high initial costs - training of system
Pick-by-light	+ no training needed	- every picker needs own corridor
Dynamic picking system	+ fast + no failures + distance between corridors can be minimized + high picking rate + ergonomic workplace	- dependend on internet connection and system availability - high initial costs - low flexibility
Pick-by-terminal	+ low failure rate + dynamic stock taking possible	- low picking rate - training of pickers - language barrier can lead to failures - initial costs
Pick-by-scan (MDE)	+ real time communication with system + no idle times + low failure rate + optimization possible	- not "hands-free" - unreadable or soiled bar-codes can be time consuming - training of pickers
Pick-by-point	+ low failure rate + high picking rate + dynamic stock taking possible	- high initial costs - high maintenance costs

Table 2.2: Overview of Advantage and Disadvantage of different picking approaches [tHSB11]

next stock location by tracing a laser pointer at the next stock location. To reduce the failure rate, there can be sensors at the front of each stock location. If the picker takes goods from the wrong stock place, he/she will get an acoustical signal or something similar.

2.3.8 Comparison between this approaches

Table 2.2 gives an overview of all picking approaches, which are described above and describes the advantages and disadvantages. In some stock management systems, it is reasonable to combine different strategies. One combination can be Pick-by-scan and

Pick-by-Document. At this combination, the picker prints a picking list and collects all positions of this list. When he/she arrives at the racking position, he/she can scan the goods from the stock. The system can check if he/she has the right article and reduce the failure rate. Another advantage of this combination is that the system knows the approximately amount of the goods. It is important that the data on the stock management system is as good as possible to start the right processes at the right point in time.
Nevertheless, miscounts of pickers cannot be excluded by this approach. The combination of Pick-by-Scan and Pick-by-Document is also a cheap possibility. Only the acquisition of scanners, training of the employees and integration in the software lead to costs.

2.4 Order batching

At the picking process, a fundamental question is how to pick the goods from the stock in an optimal manner. This can be done in several different ways. At some point in time, this step must be optimized to handle all orders in a controlled way. The picking process is another big part that can be optimized in the stock. These changes can have a big impact on the order processing rate.
Most of the small and middle sized companies pick their goods order by order. This can be optimized by batching several orders together. "Some researchers resort to order batching to minimize the order-picking travel distance. With order batching, orders are batched together, and their items are picked in the same picking trip. Order batching can reduce the order-picking travel distance if orders with similar picking locations can be picked together." [HT06] This means that the overall travelling time for every picker will be reduced by defining which orders should be picked in one picking process.
Every order batching approach, which will be described in the following sections, in the first step defines a seed order. Based on this seed order, other similar orders will be grouped together to one picking order. This can be done by different approaches, which will be described in the following sections.

2.4.1 Seed order

The seed order is the basis to group orders together. When selecting this specific order, it is important to think about how the company works and whether there is a promise to the customer that must be fulfilled. The authors of the paper [HT06] described different approaches to select a seed order. Only the approaches which apply to a company in the food market industry will be described in this thesis. Approaches to select the seed orders are:

- Random Rule: The seed order will be selected randomly out of all open orders in the system.
- Smallest/greatest number of picking locations (SNPL/GNPL): These two approaches calculate the smallest or greatest number of order picking locations.

The idea for the smallest number of picking locations is that there are many similar orders which can be grouped to this order. In the next step, the approach selects the accompanying orders, which should be picked together. With the approach to select the greatest number of picking locations, a wide variety of stock locations over the hall will be preferred. It is difficult to find similar orders for such orders. Therefore, this type of order will be selected as a basis for other orders. A possible approach to find additional orders can be to minimize the way between the articles of the seed order and the other orders.

- Smallest/greatest number of picking aisles (SNPA/GNPA): This is a similar approach to the smallest or greatest number of picking locations. The number of aisles where the goods are stored must be low or high for the same reasons as in the approach before.

All other selection approaches can not be applied in the food market industry because one good will be stored most of the time at one stock location. The other approaches are relevant if the investigated good can be stored at different stock locations simultaneously.

2.4.2 Order batching approaches

Based on the seed order, the system must calculate specific accompanying orders. This must be done by specific rules. In the literature, some different approaches to select these orders are available. The authors of [HT06] described the different approaches.

- Random selection: Out of all open sales contracts in the system, random contracts will be picked and grouped together with the seed order.
- Smallest number of additional picking locations (SNAPL): This approach selects, based on the seed order, just these orders, which minimize the additional picking locations. This means that every additional picking location, based on the seed order, has a negative impact on the calculation. In the best case, the seed order and the accompanying order have the same picking locations.
- Greatest number of identical picking locations (GNIPL): Only these orders where the amount of identical stock loactions is high will be taken. With this approach, a different number of articles per order does not depend.
- Greatest picking-location similarity ratio (GPLSR): With this approach the ratio of identical stock locations on the total number of picking locations will be calculated. The number of identical stock locations will be divided by the total number of picking locations which the picker must visit when he adds this investigated order to the picking process.
- Greatest picking-location covering ratio (GPLCR): The covering ratio defines the ratio of the identical stock locations of the seed and additional order to the number of picking locations of the seed order.

2.5 Structure of the stock

When having a batch order, it is necessary to look at the different structures of a stock. Based on physical and the company's restrictions, there are different types of stocks available. In Figure 2.6, all different stock types are shown. The construction type of the stock is a company decision. Important questions of the structure of a warehouse are:

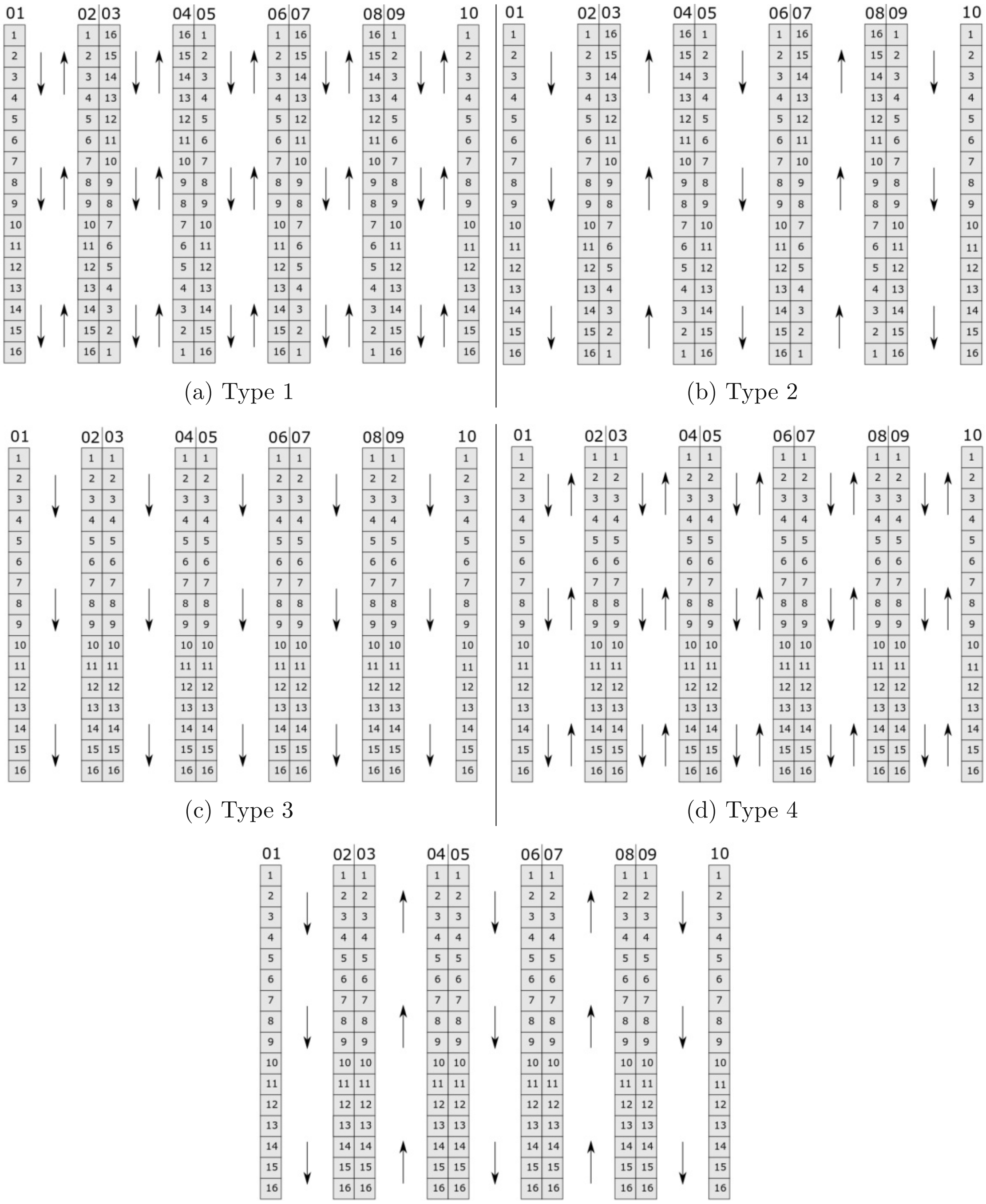
- Is the aile accessible on both sides?
- Is there any direction given by the stock management?
- Is an aisle available for pickers and machines?
- Will the numbering start with the same numbers at the different aisles?
- Is it allowed and possible that more than one person is in an aisle at a time?

The characteristic of the different types which are shown in Figure 2.6 are:

- **Type 1:** Within one aisle, the direction can be changed. The numbering is simultaneously on both sides of the aisle.
- **Type 2:** In this type, every aisle has a direction. Every person or machine must walk in this predefined direction. The direction in the aisles and the numbering of the stock locations in the different aisles alternate.
- **Type 3:** The direction within one aisle is predefined and does not alternate between the different aisles. Also, the numbering does not alternate between the different aisles.
- **Type 4:** In this type, the aisles do not have any predefined direction. The numbering of the stock locations stays the same between the different aisles.
- **Type 5:** This type is similar to type 2, but the numbering stays the same between the different aisles.

Type 1 and 4 are also possible to have just one entrance and exit per aisle. This leads to more storage areas. At types 2, 3 and 5, it is possible to create alleyways just available for one person or machine at once. In addition, the impact on the probability of having an accident should be taken into account. A small aisle available for stackers and picker with no direction has a higher probability of an accident than a wider aisle with a predefined direction.

The type of stock has an impact on the approach to find the best path through the stock. Different approaches will be shown in the following section.



(a) Type 1 (b) Type 2

(c) Type 3 (d) Type 4

(e) Type 5

Figure 2.6: Different types stock structures defined by the author of this thesis

2.6 Strategies to find a path

For the picking process, it is necessary to guide the picking person through the inventory in an optimal manner. Therefore, different approaches to handle this can be applied. To find the optimal way through the inventory can be seen as travelling-salesman problem (TSP). The goal of a travelling-salesman problem is to find a way to visit all cities [IJ14]. In the food market industry, every stock location can be seen as a city defined in the travelling-salesman problem definition. The picker person gets a set of articles at a specific stock location and has to find an optimal way to pick all goods. All algorithms to find the optimal way with the travelling-salesman problem are too complex and can not be adapted for the stock management system. The picker would need several minutes to find the optimal way. Therefore, the way through the stock will be calculated by different heuristics. A heuristic will find a way through the stock but may not be optimal [ADO09]. The goal of a heuristic is to minimize the average distance a picker will go in the stock. An advantage of a heuristic is that the strategy is predefined and will be done at every process. Calculating a heuristic is also not that complex as a travelling-salesman problem. This is important so that no time will be wasted when waiting for a route through the stock.
A heuristic for a stock management system will be classified as a one or two-dimensional heuristic. One-dimensional heuristics are given when the picker moves vertical or horizontal. In a two-dimensional heuristic, the picker can move vertical and horizontal. For a two-dimensional approach, a picking device will be needed. For a middle sized food market company, just the one-dimensional person-to-goods approach will be suitable when having a big amount of picking actions.
There are five heuristics to find an optimal way through the stock in a good execution time.

- S-shape strategy without skipping
- S-shape strategy with skipping
- Return method without repetition
- Return method with repetition
- Mid-point heuristic

All of these heuristics can be the optimal one. The best heuristic can be chosen for every stock management system based on the fill-up strategy and inventory structure. These six heuristics will be described in detail in the following sections.

2.6.1 S-shape strategy without skipping

The "S-shape without skipping" is the easiest way to find a way through the stock and reaching all goods on the route. At this approach, the picker will walk through all

corridors even if there is no article to pick in the specific hallway. At every front side of a corridor, the picker has to change the hallway. After finishing the picking process, the picker has to return to the packing tables to start the next action. The best use of this approach is when every picking process has a high amount of different goods. When having a long picking list, there is a high probability of having to walk through all corridors in a picking process. Another advantage is to avoid accidents. In a big inventory, there are stackers and pickers on the way. When having a predefined direction, the probability of having accidents where pickers and stackers are involved can be decreased. It is also a big advantage to simplify the routing strategy when training new employees. The training effort for new employees will be minimal for this strategy.
A big disadvantage of this method is that employees have to walk unnecessary ways when there is no article in a specific corridor. The S-shape strategy without skipping will be shown in Figure 2.7. All stock locations which store an article that must be picked in the current picking process are highlighted in red.

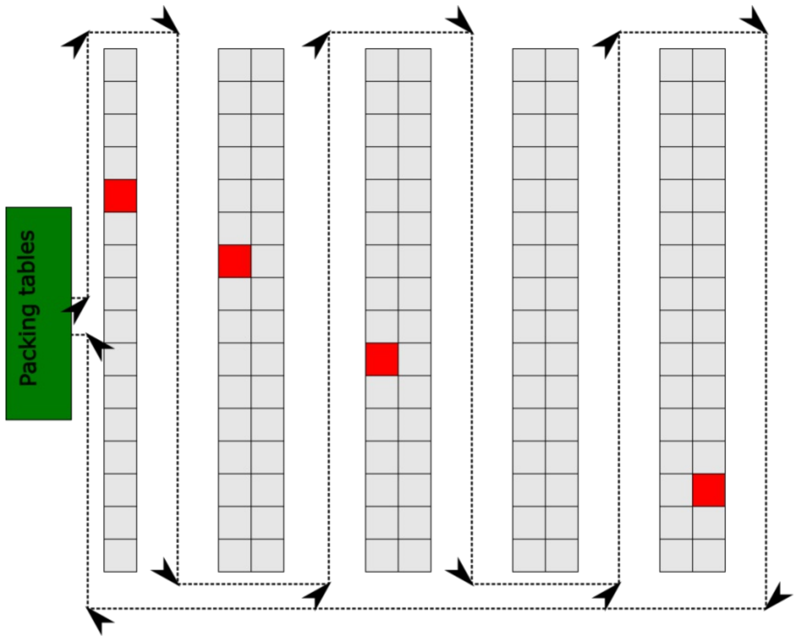


Figure 2.7: S-shape strategy without skipping [Nev14]

2.6.2 S-shape strategy with skipping

The “S-shape strategy with skipping” optimizes the “S-shape strategy without skipping” by allowing to skip corridors where no article needs to be picked. In this heuristic, every picker has to walk through the corridors in an S-shape. This increases the picking performance because unnecessary distances will be avoided in this heuristic. The avoidance of accidents between stacker and picker will not be given in this approach because the direction of how people are allowed to enter the corridor can change. Therefore, the width of the corridor must be sufficient for more than one picker or stacker. Figure 2.8 shows how to walk through the stock in the S-shape with a skipping strategy.

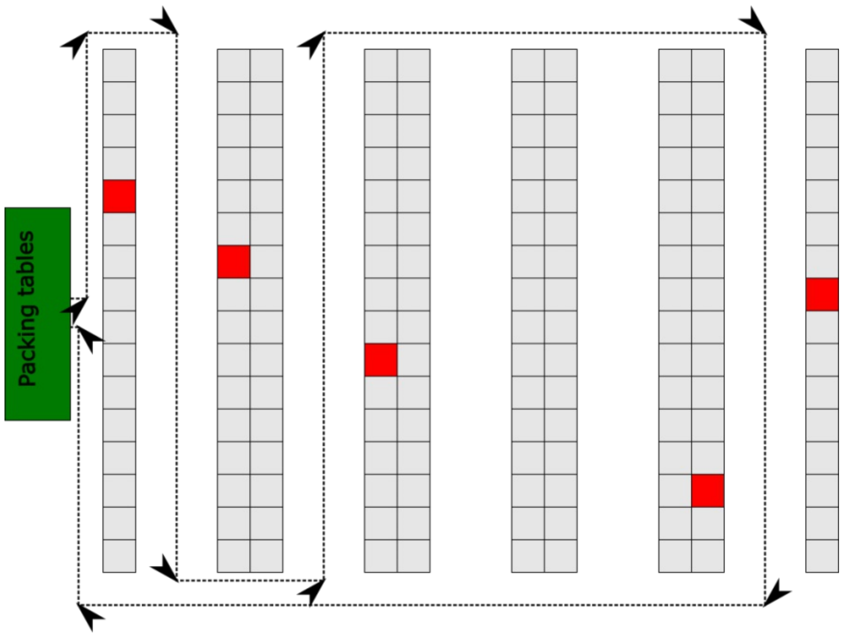


Figure 2.8: S-shape strategy with skipping [Nev14]

2.6.3 Return method without repetition

Another common heuristic is the "return method without repetition". At this method, the picker can only walk on one side of the corridor. If an article is in a corridor, the picker walks to the stock location, picks the good and returns to the face side. The picker has to walk into each corridor that holds an article and leaves the corridor where he/she walked into it. An advantage of the return method is that it is unnecessary to plan a space for changing the corridors at both sides. However, there must be enough space for several picker doing their jobs simultaneously. Otherwise, the pickers, which use the corridor simultaneously, will block each other. The space-saving advantage will be faced with the longer distance of the picker. The picker has to walk to the very last stock location for just one article in the worst case scenario. This can be prevented by taking the access frequencies of the articles into account when filling up the stock locations. Figure 2.10 shows, how this method works.

2.6.4 Return method with repetition

The second specification of the return method is the "return method with repetition". This means that a picker is allowed to enter the corridor once per article. If there is a second good in this corridor, the picker has to return to the hallway's face side and enter

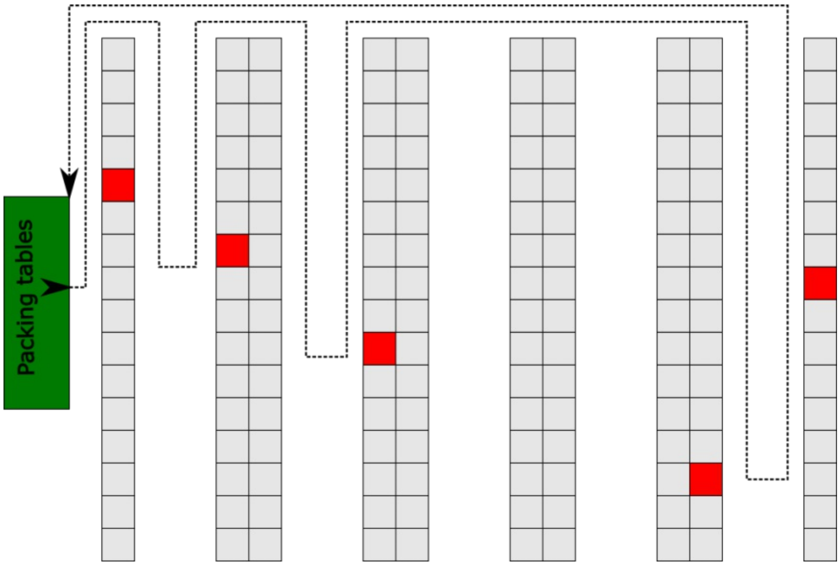


Figure 2.9: The return method without repetition [Nev14]

the corridor again. The repetition approach can be applied when there is not enough space to enter a corridor with a picking device. The advantage of this approach is to save more space than in the approach without repetition. There is no need to have a space to change the corridor and it is unnecessary to increase the width of a corridor for entering with a picking device. This method faces the disadvantage of the longer distance that a picker has to walk through the stock. This disadvantage can be reduced by decreasing the picking frequency per corridor and adding a suitable allocation of stock locations. In Figure 2.10 a use case will be shown when applying the "return with repetition" approach.

2.6.5 Mid-point heuristic

A special "return method" is the "mid-point heuristic". This means that every corridor will be cut into halves. The picker is now allowed to pick just these goods from the first half of the corridor where he/she entered the hallway. When the person picked all goods from the first half of the corridor, he/she changes to the backside of the corridor and starts to pick again only the article from the first half of the corridor. The picker has to enter just these corridors where articles for picking are available. When applying this method, the access frequency of each article has to be taken into account when filling up the stock locations. This means that articles with a high access frequency should be stocked next to the face sides of the corridors to avoid unnecessary walking distances. It makes sense if the saved distance per corridor is bigger than the distance to change from the front to the backside of a corridor. The "mid-point heuristic" will be shown in Figure 2.11.

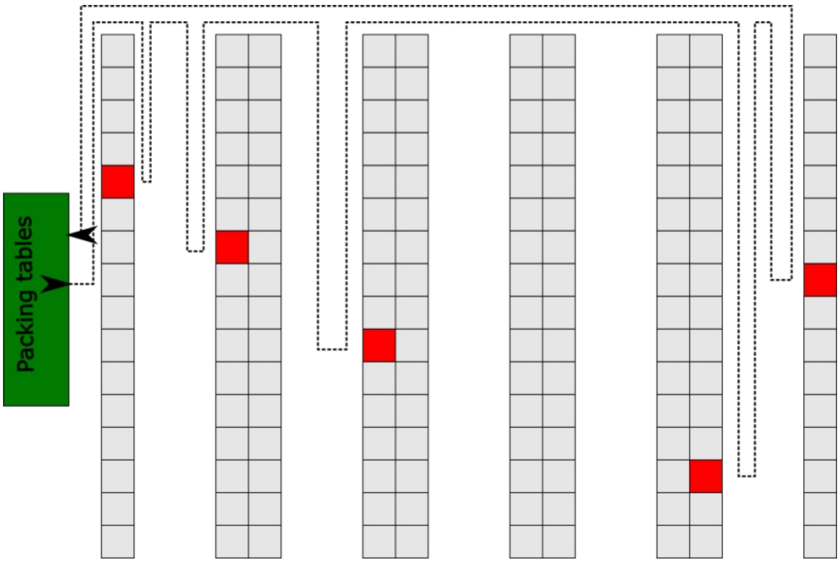


Figure 2.10: The return method with repetition [Nev14]

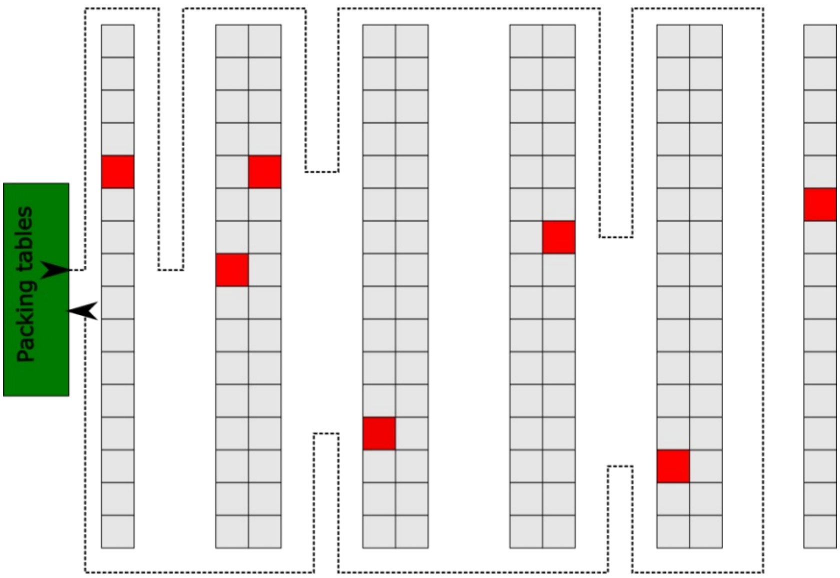


Figure 2.11: The mid-point heuristic [Nev14]

CHAPTER 3

Implementation

3.1 Interview summary

The interviews were held with the responsible stock managers from Sonnentor Kräuterhandels GmbH 5, Kastner GroßhandelsgesmbH 5 and Kiennast Lebensmittelgroßhandels GmbH 5. These companies were chosen because they are all in the food market industry, have about 200 to 300 employees and are situated in Lower Austria. Companies from the food market industry were taken into account because food has more and strict requirements regarding stock management. The summary is split into three parts: properties of the articles, the structure of the stock and the workflow inside the stock management. In Section 5 the whole interviews of all companies can be read.

3.1.1 Properties of the articles

This question deals with the articles and how they have to be stocked. Some restrictions come from food regulations, whereas others come from different certifications. The three companies trade mainly food so the products can be cooled, have a strong smell, accept the aroma from other goods, easily perishable and some articles should not be stacked or are touch-sensitive. A small part of their goods are poisonous or acidly. These articles are for example cleaning powder or laundry detergent. They will be stored in a separate part of the stock.
The different types of goods need different conditions. A temperature-dependent product must be stored in a hall with an appropriate temperature level. The products in these temperature levels can be classified as follows:

- 20° C: The dry assortment will be stored at this temperature level. Dry assortment means all products that are packed or in another way preserved like spicery, cans or drinks.

- 15° C: At this temperature level, exotic fruits and bananas will be stored.
- 11° C: In stocks with about 11° Celsius, there are fruits and vegetables.
- 4° C: Dairy products like milk, cheese or yogurt will be stored at about 4° Celsius.
- 2° C: Leafy vegetables are stored at this temperature level. This type of goods needs a humidity of about 99% in addition.
- 0° C: Meat, bacon, sausages and other raw products will be stored.
- -21° C: This is the lowest temperature level. All frozen products will be stored at this temperature level.

Not only the temperature is essential. The packages can also influence the articles. Two of the three companies interviewed have international customers, so another attribute of an article is the language of the label. One company separates the goods with different languages as independent articles with an individual stock location. The other company stores these articles without a label. When a customer buys this article in a different language, the package will be labeled on demand. This approach creates another challenge to know the expiration date and the batch number of these goods precisely since they do not have a label.
The packaging size of an article is another critical characteristic. Most of the stock management systems did not know this type of information. The size and weight of a packaging unit are essential whenever an article should not be stacked. All companies stated that it is crucial to pick the products based on the weight of the goods descending to deliver entire articles.
Another specialty is individual goods. An individual good is a product that is not in stock but can be ordered by the customer. Individual goods are for example vouchers, goods with a personal text or "providers". A "provider" is a good that can be ordered by a customer, but it is not in stock. These goods will be ordered from individual suppliers and delivered to the customers after a few days. These goods will not be ordered that often, so it is not profitable to have it in stock. "Providers" are for example rare cheese, a unique whiskey or an exquisite bottle of wine.

3.1.2 Structure of the stock

This section gives an overview of the structure and the organization of the stocks at the companies interviewed.
The interviewed companies Sonnentor, Kastner and Kiennast have comparable stock environments. Kiennast has one logistic center in Gars am Kamp, where they handle all orders. Sonnentor has its center in Sprögnitz and an external warehouse in Waldhausen, about five kilometres away. This external warehouse has no independent stock management system. The system from Sprögnitz has to involve the goods from this external warehouse in the calculations. Every day, there are just a few transportations from

Waldhausen to Sprögnitz. The stock management system has to take this circumstance into consideration. Kastner has its logistic centre in Zwettl and six other warehouses in Vienna (North and South), Eisenstadt, Jennersdorf, Krems and Amstetten. All warehouses work independently with their own stock management systems. The next warehouse or the warehouse with a specific truck route handles the orders from the customers. At Kastner, the external warehouses do not have any effect on the stock management system because of their independence.
Every warehouse from the three companies interviewed has nearly the same structure and differentiate only about the dimension. All warehouses have shelves, a separate place for packing and labelling and a place for outgoing goods. The most important types of shelves are flow storage, pallet shelves, high-level racks and small part warehouses. All different goods can be stored on one of these shelves.
The fresh meat and things that are easily perishable are stored in flow storage. The flow rack at the picking warehouse at Sonnentor can be seen in Figure 3.1. Articles will be put in at the backside of the flow rack and taken out at the front. This method of operation guarantees the FIFO (first-in-first-out) principle. Small part warehouses store all articles

Figure 3.1: Flow rack at the picking warehouse at Sonnentor

sold bit by bit and that are too small to store them on a pallet shelf. Perishable goods with a high turnover ratio like fruits and vegetables are stored on a pallet shelf. Every interviewed company has high-level pallet racks with up to 6 levels which can be seen in

Figure 3.2. All articles that have a high turnover but are not perishable will be stored

Figure 3.2: High level pallet racks at Sonnentor

on this type of shelf. The dry assortment like spicery and packed goods are stored in high-level racks. Figure 3.3 shows the part at the main warehouse of Sonnentor. There are some more warehouses, but these are for raw materials and production only. The warehouse shown is more interesting for fill-up and picking actions. There are different colours in this figure, which the different parts of these warehouses. The green part is the packaging area where all goods come together and will be packed for every customer. Yellow is for small parts which can be sold additionally to the food, which can be shaker or teapots. The red part is the picking-warehouse for B2C customers. This part of the warehouse should hold the amount for the next few days in the stock. The way for the pickers will be short, and there will be flow racks for an optimized picking process. The blue part is the main part where the articles will be stored on pallet racks. The articles picked from this part will be picked for B2B customers only or will be filled up to the picking warehouse (red).
The organization of corridors and stock numbers are also comparable at the interviewed companies. An overview of the different types will be given in Chapter 3.2.1. These types of organizations are important to handle the different ways for the picker and fill-up

persons. Therefore, the type of the stock organization will be a parameter for calculating of the shortest way for the involved people. The parameter will be a global setting for each company because the organization of the stock will not change that fast.
In the different researched companies, stock numbers are just a way to help the picking or fill-up persons to orientate. These numbers are important for the organization of the stock management system, but are useless for the software. In the system, every racking position should get a predefined order number. This internal order number helps the system to calculate an optimal way through the stock.

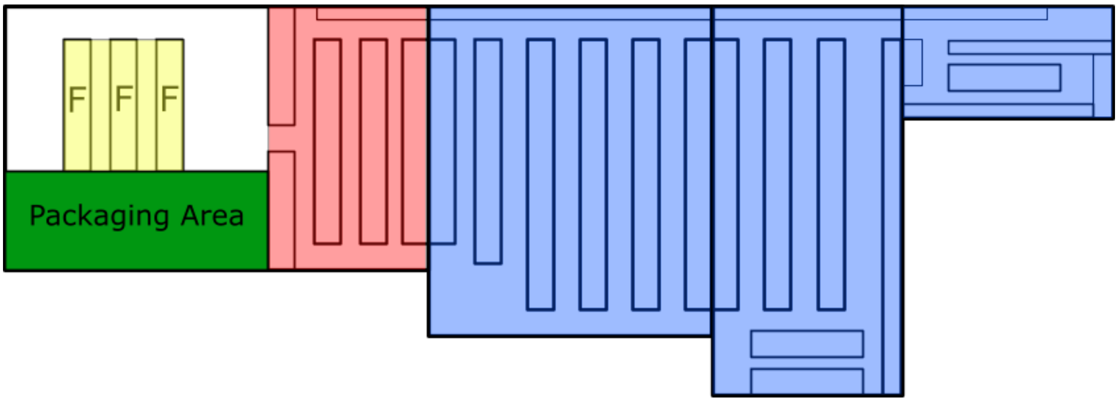


Figure 3.3: Overview of the main Warehouse of Sonnentor

3.1.3 Stock management workflow

The following section gives an overview of the workflow within the stock management. A workflow within stock management will be influenced by the customers, how they can order the goods, the properties of the goods and which articles they have, the working time, how they pick the goods and when and how they get the goods from their suppliers. All these specialties can influence the companies, how they work and the optimization potential of the stock management system. How they get the goods and how they transport the articles to the customers will not be handled within this thesis. To differentiate how they get the orders from the customers will be simplified to group customers into Business to Customer (B2C) and Business to Business (B2B).

Customers

Sonnentor works different in comparison to Kastner and Kiennast regarding their customers. Sonnentor has its franchise shops and other companies (Business to Business - B2B) and a significant amount of individual customers (Business to Customer - B2C). This leads to a different workflow within the stock processes. Kastner and Kiennast only have B2B customers who are gastronomy, gas stations, shops and other types of institutions. The B2B orders contain, most of the time, a more significant amount of goods than at Sonnentor, so there is no need to group orders at Kastner and Kiennast

most of the time. If there are orders with a high amount of goods, picking order by order may be a better approach.
The companies have similar ways to get customer orders. All three have their webshop for their clients. At Kastner and Kiennast, the regular customers also have electrical devices like “Bestfriend” or other MDA (mobile data acquisition) devices directly linked to the company. How to handle the different amounts of goods that have to be on stock is different through the companies. At Sonnentor, they have to stock the raw material from the farmers. This raw material will be taken in the production hall to produce end products. Most of the goods are seasonal, so they have to plan how much they need and how much they can process. Their plan is based on the last periods added with a specific amount to handle all open orders throughout the year. At Kastner, they collect all their customer orders throughout the day, and at midday they order the goods from their suppliers. When the good is on stock or its suppliers have the good on stock, the customer will receive the products the next day. If the product is a “provider”, the article will arrive after a few days. Kiennast also wants to order the goods from their suppliers based on open orders. They also add events to their calculations. A special event can be an exhibition where the orders will increase for a short period of time. All companies interviewed stated that the calculation of the demand for the products is not optimal. They have their open orders for the next days, weeks or months, but they do not know the amount from the last years. At Kiennast they would have to collect all e-mails from the last years to know the amount of goods ordered from the last exhibitions. The responsible employees in these companies indicate that this task takes much time and is based on personal experience.

Articles

The different articles’ characteristics mentioned above lead the companies to differentiate the workflow of their stock management. Different languages lead to two different approaches. The first possibility is to store them in a separate stock location. When the customer orders the product, the stock management system must know where the picker can find the article in the correct language. The second approach is to store the goods without a label at one stock location. This approach leads to new challenges in accessing batch numbers and other essential information like an expiration date. The information and the additional time for labelling will depend on the workflow.
Not only common goods will be sold by the companies. When an order with an individual good arrives, the product has to be ordered from their suppliers, be printed if it is a voucher or labelled with the unique text. The customer gets information that his order has an individual good, which takes a few days longer than usual. At the fill-up process, the special good gets its stock location and will be stored in the system. When the picker gets the picking task, the good will be shown up at this stock location. The stock management system has to release the picking process after the individual good is on the stock.
At every company, the articles have a standard stock location. This means that every article will be stored at the same location in the stock every time. The system knows,

based on the article master data, the stock location. Every picking and fill-up process will take the good from this location. If a new good comes on stock, the location will be taken based on the “chaos approach”. The next free stock location will be used for the new article. There is no intelligent calculation behind the allocation of the stock locations. At Kiennast, one pallet shelf can contain more than one article with the same stock location number. The picking person has to choose the right article for this order. This can only be on a pallet shelf because every product is available for the picker. At Sonnentor and Kastner, every article is at one specific stock location with a unique number. So at these companies, one pallet shelf can be more than one stock location.

Picking

All three companies merge two different picking types, which are the “pick-by-terminal” and “pick-by-document” approaches. They need the document approach because their stock management systems do not have the intelligence to sort the open positions from the order in the right way. The picker prints this document and acts with his/her experience to pick the heavy goods first and the light ones last and find the fastest way through the stock. At the companies, the corridors are available for all people and machines. Pickers and stackers use the same corridors. Sonnentor and Kastner experiment with defined driving directions to avoid accidents. This has to be done because pickers use picking vehicles, and fill-up persons use a stacker. An accident can cause problems for people and companies.
One important thing at the three companies interviewed is that a new picking process can be needed if the picker detects that not enough products are available. This can happen if a picker miscounts at a picking process, but the stock management system thinks that he/she takes the right amount.

Working time

The three companies Sonnentor, Kastner and Kiennast, have different approaches regarding working hours. Kastner has shift work with weekends. Sonnentor and Kiennast have a regular working time from 9 am until 5 pm. The work ends when all orders have been picked, packed and are ready for delivery.
Kiennast and Kastner deliver the roll containers with trucks, whereas Sonnentor sends its parcels with a delivery operator. The delivery from the suppliers is different between these three companies too. Kastner and Kiennast try to get the goods in the morning. At Sonnentor, this is a bit difficult because they also work with regional farmers with no possibility to store the goods in the right way. Therefore, the farmer delivers the goods a whole day after harvesting. This information is essential to identify the peaks of the fill-up and picking process. All three companies indicate that mondays and tuesdays are weak regarding customer orders.
The companies also try to increase the performance of their employees with a bonus system. These bonus systems also differentiate through these companies, but all systems are based on the time they need to pick one good.

Certificates

Different certificates also have an impact on stock management systems. The most important certificates for the food market industry and the three interviewed companies are:

- "IFS Logistics is a Standard for auditing companies whose activities are logistics oriented for food and non-food products, such as transport, storage, loading/unloading. It applies to all types of transport: delivery by road, rail, ship or plane; frozen/refrigerated products or stable ambient products (different states of matter: liquid, solid or gas). This standard also applies to (un-)freezing service providers as well as for logistics companies using service providers for their transport and storage activities[1]".
- The MSC (Marine Stewardship Council) is a certificate for seafood. This board of control ensures and audits along the supply chain, from "ocean to plate". The MSC label of a product guarantee, "that companies just purchase certified products from certified suppliers", "certified products are clearly identifiable", "certified products are separated from non-certified", "certified products must be traceable and recorded" and "the company must have a management system"[2].
- ABG (Austria Bio Garantie) is a board of control to audit companies and enforce the Austrian bio standard[3].
- Another important board of control in Austria is Demeter. This certificate ensures that "all goods, raw materials and ingredients of different quality levels (Demeter, Conversion to Demeter, organic and conventional) must be separated at all steps of the supply chain (storage, transport and processing)[4]".

Summary

Although the companies have similarities regarding goods, customers and stock management, these similarities will influence the workflow within the stock management. The lawgiver or certificates sometimes predefine the conditions of articles so they can be seen as global parameters. These settings will not be changed that often and are fixed for the specific articles. A big problem is the intelligence of their IT-systems. On the one hand, they are satisfied because the managers can see the turnover and the stock amounts of every good in real-time, whereas on the other hand, the employees see room for improvement of the daily workflow. Managers see their IT-systems in the way to

[1] https://www.ifs-certification.com/index.php/en/standards/265-ifs-logistics-en

[2] https://www.msc.org/standards-and-certification/chain-of-custody-standard

[3] http://www.abg.at/bestimmungen-zu-bio/gesetzliche-bestimmungen-zu-bio/

[4] https://www.demeter.de/sites/default/files/richtlinien/richtlinien_gesamt.pdf

"never change a running system". Employees want more support from the system. Parts of the picking and fill-up process are based on the long experience of every employee to guarantee the intactness of the goods. This leads to mistakes whenever a new employee starts his/her job. So it is a challenge to give the managers the correct amounts and stock locations of their goods. For the employees, it is important to simplify and improve the stock management system to reduce the period of vocational adjustment.

3.2 Defining important parameters

Based on the interviews in Chapter 3.1, it is possible to define parameters and constraints which should be fulfilled at the picking and fill-up task. These constraints can be split into global parameters and mandatory constraints for the picking and fill-up process. Global parameters are facts of a company that will not change very often. An example of a global parameter can be the structure of stock, working time per shift or the number of persons per shift. Mandatory constraints are identified in all three interviewed companies. These types of constraints have to be fulfilled for the company given. An example for such a constraint can be the temperature of a cooled good or what types of articles can be stored next to each other. These constraints are given by regulations or certificates most of the time. In the following sections, the identified parameters and constraints will be defined for the picking and fill-up process.

3.2.1 Global parameters

As already mentioned, there are parameters that will be valid for the whole company. These parameters are predefined and will not change too often. A change of one of these parameters means a significant change in the structure of the stock management and workflow. Every parameter in this list has a significant impact on the different processes of the stock management system. Global parameters that will be handled in this thesis are:

- Way through stock: The way through the stock is essential for calculating the fastest way through the corridors. Some companies started experiments with predefined ways through the stock to avoid accidents between persons and stackers. Most of the time, the companies give up the experiments because of inefficiency. Picking and fill-up persons were not supported by the system to find the fastest way based on these predefined ways. The way through the stock is described in Section 3.2.1 and shown with arrows in Figures 3.4 and 3.5.
- Numbering of stock locations: This parameter is connected to the way through the stock. The parameter means if every corridor starts with the number one or if the corridors alternate with the starting numbers through the aisles. The different approaches are described in Section 3.2.1 and the constant and alternating numbers are shown in Figures 3.4 and 3.5. This parameter is important for calculations in the background of the system to find the fastest way.

- External warehouse available: This information is important to know if the system has to involve an external warehouse. The external warehouse influences the calculation if the good is not available in the main warehouse. A picking process will not be started until the goods are in the main warehouse. This leads to delays in picking and fill-up processes. This feature is a true or false information and is available in the attributes of an article. To have similar information on two different places is in that case just for upcoming performance reasons.

- Numbers of persons per shift: The number of persons per shift is important for upcoming steps. Calculations of stock locations, ways through corridors or collection orders pollute the server. The upcoming step will be to increase the performance of the calculation. Preliminary calculations can achieve this. If the number of persons per shift is high, the system must save a higher number of calculated collection orders and ways in advance. When a person asks for the next process, the system can take one of those already calculated steps.

- Working time: This parameter is also for saving resources. At night, there are several tasks for the servers. Server tasks in the night can be to create backups, restart or import/export data. For this reason, the servers should not be interrupted by calculations of ways or stock locations when nobody is working.

- Period of previous orders: This parameter identifies the time period for selecting the previous orders. All orders with a specific article within the last year will be analyzed. The current date minus one year will be used and a range of days given in this parameter will be added.

Structure of stock

Based on the surveys, there are two models of stocks at the companies examined. The structure can be as shown in Figure 3.4, where the way through the stock is a wiggly line. Stock locations are numbered and alternate throughout the corridors. Figure 3.5 shows the other approach. The whole stock has the same structure and every corridor has the same numbered stock locations. This information has a big impact on the calculation of collection orders, the way through the stock and where to fill up the articles on the stock based on a cluster.
Not only the numbers of stock locations can alternate. Some companies define directions of traffic. This approach is, on the one hand, safer for picking persons and stackers but, on the other hand, more time-consuming. The structure of the stock has a big effort of calculating ways through the stock to find the best way for the pickers. The two different approaches are shown with arrows in Figures 3.4 and 3.5.

Properties of a stock location

There is also some important information about every stock location needed. Based on this information, the system can decide where the entry point of the stock location is

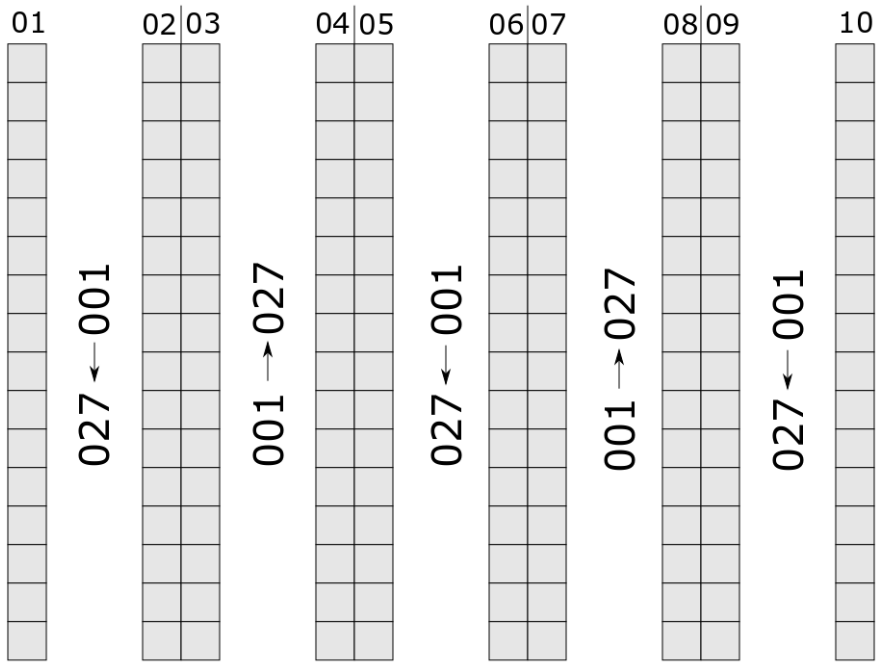


Figure 3.4: Structure of stock with alternating numbers and ways through the stock

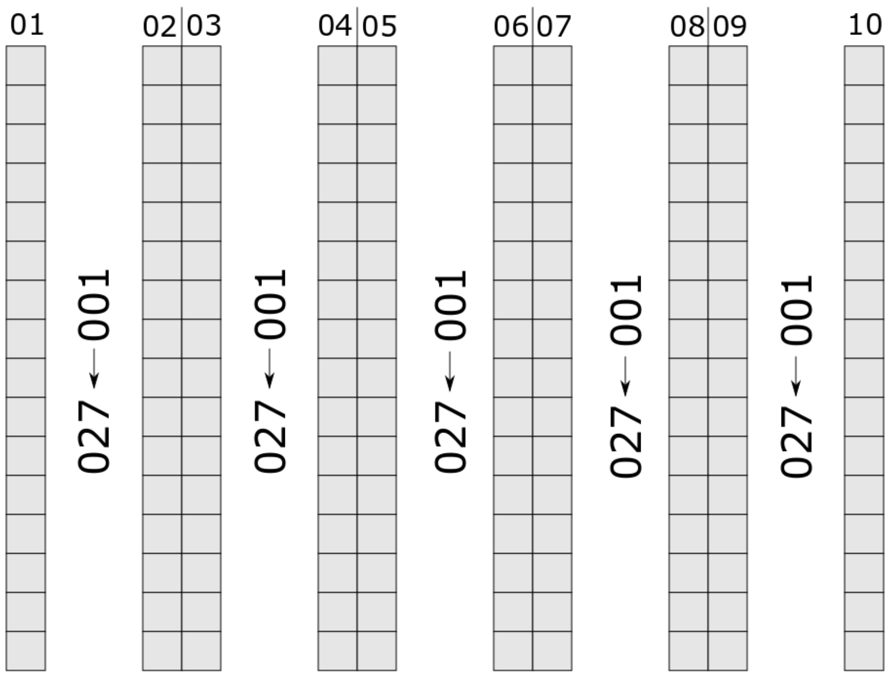


Figure 3.5: Structure of stock with constant numbers and ways through the stock

and which articles and can be stored in this specific store. The following information is essential:

- More articles allowed at one stock location: Within the interviewed companies, there are two types of stock locations allowed. Type 1 is to store one article at a specific stock location. Type 2 allows storage of more than one article at a specific stock location. This makes sense whenever an article needs to be available in more than one language.
- Type of stock (regarding customers): This is important to know because, at some companies, it makes a different for the picking process to pick for a B2B or B2C customer. A B2B customer usually orders a bigger amount and wants the newest batches of the stock. For a B2C customer, the batch is not that important, and the amount will be less. At Sonnentor, they differentiate between two types of stock areas. One for B2C and one for B2B customers. The B2C stock locations are next to the packing tables. B2B orders will be handled from the main stock.
- Type of racking system: One of the most important information is the type of racking system. The system has to know the best way to withdraw from and fill up a stock location. At a pallet rack, the fill-up and picking point is the same. At a flow rack, the fill-up person fills the article from the back side of the aisle and a picking person takes the good from the front side.
- Amounts: The maximum and minimum amounts of goods are important as well. The minimum amount defines at which amount a fill-up person has to restock this specific article. The maximum amount defines the highest amount of articles that can be stored at this stock location. This characteristic can also be a volume parameter for defining the capacity in a cubic meter. This is important whenever the stock location is filled with goods in bulk. Also, the actual stock amount is important to calculate the importance of the article to fill up or decides which stock location will be taken at the picking process.
- Locked stock: It can also happen that a batch needs to be locked. Therefore, it can also be useful to lock a specific stock location. The system is not allowed to take articles from this stock location. At the picking process, this type of store must not be shown until the lock is released from the quality management department.

Preparation of a stock location

Another important preliminary step is to define an order number of every single stock location which is needed for filling up or picking goods. This order number will be needed to calculate the shortest way through the stock. When defining the order numbers, it is necessary for every stock manager to decide which stock location is reachable by persons or stackers. This is only needed if there are different types of fill-up or picking persons. In a middle sized company, there will be a stacker and a person working together in a stock. The type of worker is important because the change from one type to another will cost time. A person cannot reach the fourth level in a pallet rack. With the order number, the stock management system can steer the worker in their specific level of heights. Figures 3.6 and 3.7 show the assignment of sort order numbers. In Figure 3.6, the order numbers separate between the different types of workers. In the figures, every stock location has a unique name. This name is structured as followed (for example, 10-04-01A):

- 10: Number of the warehouse if there are more than one available
- 04: Number of a corridor in the warehouse
- 01: Number of the racking position in the corridor
- A: Shows the level of height in the pallet rack

10-04-01A is the lowest stock location of the first pallet rack in corridor 4, located in warehouse 10. Every corridor can have two different numbers if it is possible to access both sides of a pallet rack.
Levels A and B are reachable for persons without technical support. Levels C to E are only reachable by a stacker. The change of the number define the costs to reach a specific stock location. When a specific type of worker reaches more than one level, the order numbers will increase the costs by 10. If there is a change of worker type, the order number will increase by 100,000. This ensures that a position of an order from Level A or B finds another position of an order in Level A or B. For the picking or fill-up process, the minimal difference of the stock locations defines the way through the stock. Figure 3.7 shows the assignment of the sort order numbers when no change of worker type is needed. This can happen if in a specific part of the stock are just worker allowed. For a middle sized company in this segment, Figure 3.6 will be the normal case of working structure. Another differentiation of the order numbers is if there is more than one warehouse available. The way between the warehouses can also be separated in different steps. The costs will be higher for an external warehouse instead of a warehouse at the same location. Figure 3.8 shows the costs between the different warehouses. In this case, the costs between the warehouses 1 to 4 are 1,000,000, which are at the same location. The cost for the external warehouse 5 is 10,000,000. If there is more than one external warehouse, it is also possible to differentiate between these. An external warehouse can cost more than another external warehouse if the way to this location is longer than the other.

Properties of articles

Most of the articles have characteristics based on the acquisition. This means that a cooled article must be stored at a stock location with a lower temperature level than an article from the dry assortment, which can be stored at room temperature. Other parameters of articles are defined by authorities or certifications. These parameters

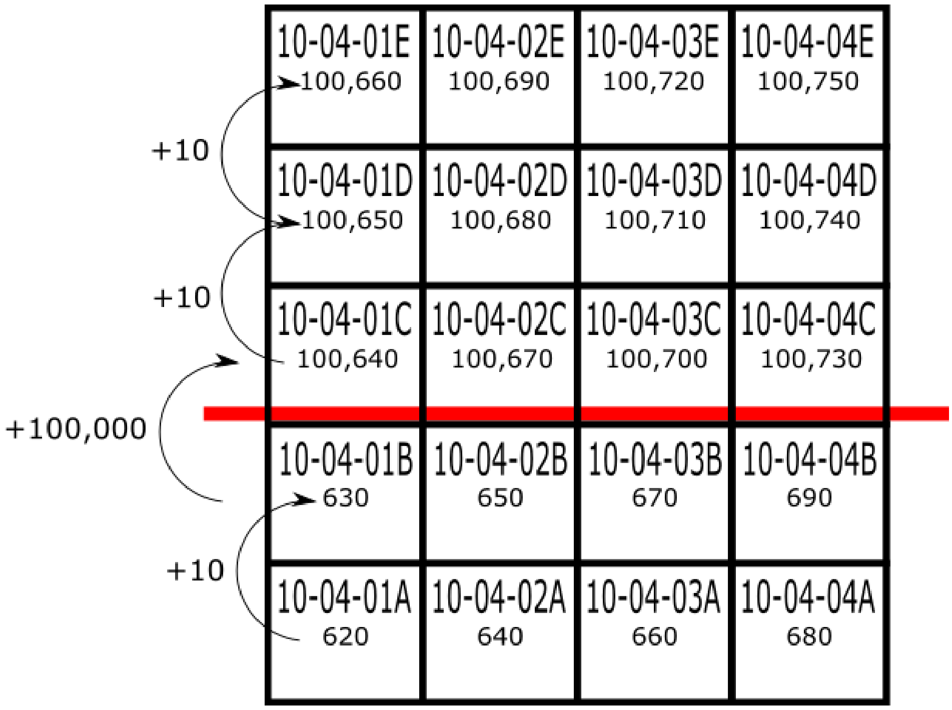


Figure 3.6: Order numbers for different type of workers

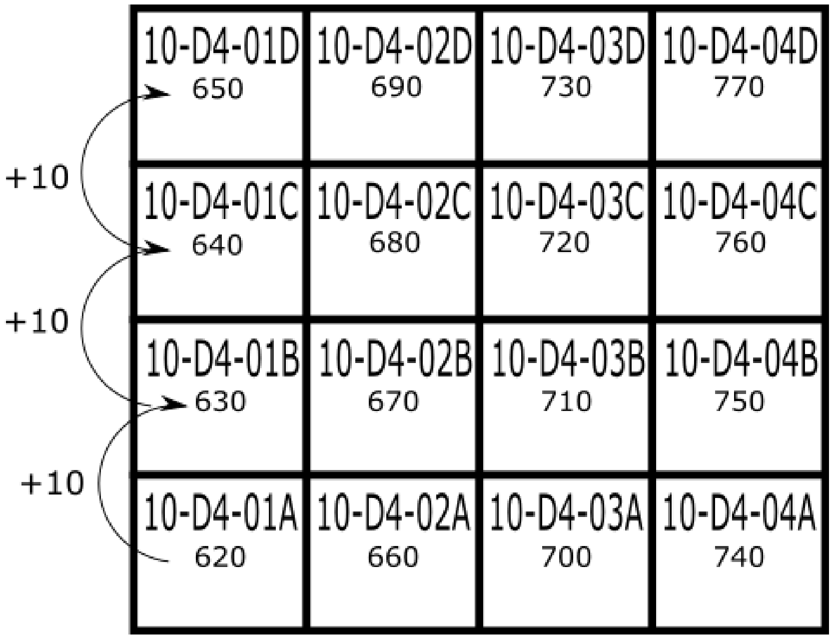


Figure 3.7: Order numbers for a single type of worker

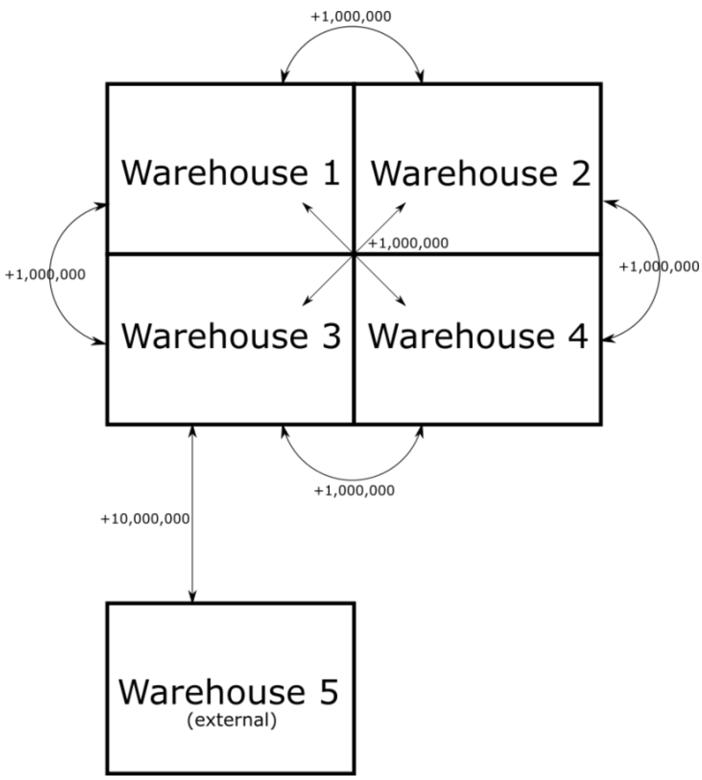


Figure 3.8: Costs between different warehouses

have to be ensured to get the selling concession and sell articles labeled with a specific certification logo. The requirements of certifications and regulations are strict and will be monitored in a specific period. Some important information of articles are:

- Temperature level: Based on constraints by authorities and certification, every article has its temperature level. This must be observed because, for some articles, it is not allowed to interrupt the cold chain. If that happens, the article can not be sold and needs to be thrown out. Persons who work in the not cooled warehouse are not allowed to work in the cooled part of the warehouse and vice versa. Therefore, the processes are equal but must be split into different processes for different users.
- Expiration date and batch number: The batch number, which is linked to the expiration date, is significant. B2B customers only take goods with an elder expiration date as the orders before. For some business customers, this is strict because they also store it for a longer time. If the expiration date is lower than an order before, they have to rearrange their stock management with extra work. The expiration date is also crucial for B2C orders. No customer wants a good which can be uneatable after a few days. The expiration date is important when filling up the stock locations. When the good is in the picking warehouse, the expiration date

can be unattended because this part of the warehouse has flow racks and holds just the goods for the next few days.

- Weight: The weight of the article is essential to sorting the picked articles. The most cumbersome articles should be picked at first to avoid broken boxes. At the time of the interviews, this will be managed by the picking persons. The system needs to support these persons.

- Packaging unit: The packaging unit will declare the size of the article. There are different volumes of single unit amounts per packaging unit available. This can differ from article to article.

- Language: This attribute means that it is essential to include the language into the calculation at some companies. Some companies have articles in another language in a separate stock location, and others store their articles without a label. This leads to a delay in the picking process because they need to be labelled before they are picked. This attribute can change within the articles of a company. An article with a higher turnover ratio in different languages will be stored already labelled in those different languages in separate stock locations. If an article is available in another language but not that frequently ordered, it will be stored unlabelled and labelled on demand.

- Batch in quarantine: This indicates whether the article is not allowed to fill up and pick. This is necessary if the quality standard can not be reached or there are chemical residues found in the article.

- Special article: A special article can also lead to a delay in the picking process. Individual articles are, for example, personalized gifts with a personal text on them. At Sonnentor, this can be a tea with a special dedication on it. The printing department will get these articles and prints the personal text on the labels. Currently, there is a delay in the picking process of about three hours of orders with individual articles.

- Customer demand in previous periods: The system will calculate the demand of the article in a specific period (for instance the last year). Every article has a specific demand, which can change over time. The demand for articles will change over time because of seasonal variation. At every interviewed company, the time around Christmas leads to a peak of customer orders. This is also shown in Figure 3.9, which shows the number of orders per day at Sonnentor.

- Current orders: This parameter shows the amount of the orders currently open of this article. The parameter is essential to know for how much must be on stock for the next day(s). If the amount in stock is too small, a fill-up process must be started.

- Rate of growth: The growth rate is important for the fill-up functionality and the calculation of the significance of an article to fill up at the stock. This rate should be stored per article per year.

Figure 3.9: Orders per day from October 2018 to January 2020 selected from Sonnentor

3.2.2 Properties for fill-up process

For the fill-up process, the system must calculate, on the one hand, the most urgent articles and, on the other hand, the best stock location for a specific good. The most urgent article is a list of goods, where the amount on stock is under a specific threshold or there is not enough on stock to handle all open orders for this day. Finding the best stock location for an article also has a significant impact on the picking process. The stock location is calculated and assigned to a specific cluster. This ensures that an article with a high turnover ratio is stored near the packing tables. The clustering approach guarantees that the ways for picking persons are as short as possible. For these calculations, the system has to know the following information:

- Clustering-method: As already mentioned in Section 2.2, the system needs to know which type of clustering must be used for the calculation. ABC, XYZ and the mixed clustering ABC-XYZ can be chosen. This approach ensures that the most frequent article with the highest prediction will be store next to the packing tables.
- External warehouse: This information is essential if the source article is stored in an external warehouse. If the good is in the main warehouse, there is no delay in filling up. If the good is in an external warehouse, the system should involve the way from the external to the central warehouse in the calculations.
- Next transportation date from external warehouse: If the article is in an external warehouse, it is important to know the next time of transportation between external

and main warehouse. There can be a fixed point of time (like every day at 2 pm) or a fixed period of time (like 2 hours after the order the article will be in the main stock). This should be added to the calculation.

3.2.3 Properties for picking process

The system calculates every single picking process. This involves the batch order and the shortest way for the picking persons. Therefore, it is important to have individual parameters at every single picking task. A picking task should have the following information:

- Finished picking process: This information is essential if the picker finishes the picking process. A picker may miscount the goods during the picking process. The system thinks there is an amount on stock, but the pallet is empty. Therefore, the picker must have the chance to save this information at every picking process. The picking person will finish these tasks later when the good is available again. This task is given by the functionality of the ERP system and will not be taken into account in this thesis.

- Order already batched: Due to the complexity of batch orders, this type of order must be pre-calculated by the system. Therefore, the system must know if the order is already in an active batch order or not. When an order is batched, it is not possible to delete it from this type of order. Even if it would fit better into the other order.

- Shortest way approach: This information is necessary for calculating the shortest way through the stock for the picking persons. Based on that information, the numbering of the stock location will be changed to guarantee the shortest way with the specific approach.

- Selection of seed order: There are different ways to select a seed order. The seed order is the starting point of a batch order. When interviewing the stock managers of Sonnentor, Kastner and Kiennast, they all mentioned that the most important rule is that all customers should get their goods as fast as possible. This decision also has an impact on the way to select the seed order.

- Selection of accompanying orders: Based on the seed order, the accompanying orders will be selected. There are also different ways to do that, so the system must know which approach needs to be taken. Other parameters like the number of different articles, the size of the stock, the number of picking persons or the stock structure influence this approach.

3.3 Fill-up process

The fill-up process is the first part for implementing a prototype on the test environment of Sonnentor. At this process, it is important to differentiate between B2C and B2B customers whenever this is needed. The investigated companies Kiennast and Kastner did not differentiate between B2B and B2C, whereas Sonnentor differs between these customer groups. This is important because B2C handles a smaller amount per order than a B2B order. The B2C part of stock also differentiates regarding packaging units and type of stock. At Sonnentor, the B2C part is a flow stock. All other stock locations are pallet racks. Therefore, there is some preliminary work to do which is already handled in Section 3.2.
To get an overview of the significance of the optimization of this action, Figure 3.10 shows the number of fill-up processes per day in the last three years at Sonnentor. All data in this figure are visualised by a dot in the timeline. The blue line is the linear regression model "loess" with a span of 0.05. "Loess" is a way to show data smoothly. The span shows the granularity of the regression line. The lower the value of span, the more the granularity will be more precise and show a wigglier line. Every point in the scale will be rated. The rating includes all neighbours in decreasing order regarding the distance of the investigated point. This leads to a smoothed visualisation where the outliers will not be taken too much into account. This regression line shows a seasonal variation in the data of Sonnentor. At Christmas, there are the most fill-up processes in the system. Therefore, it is significant to optimize the overall fill-up action.

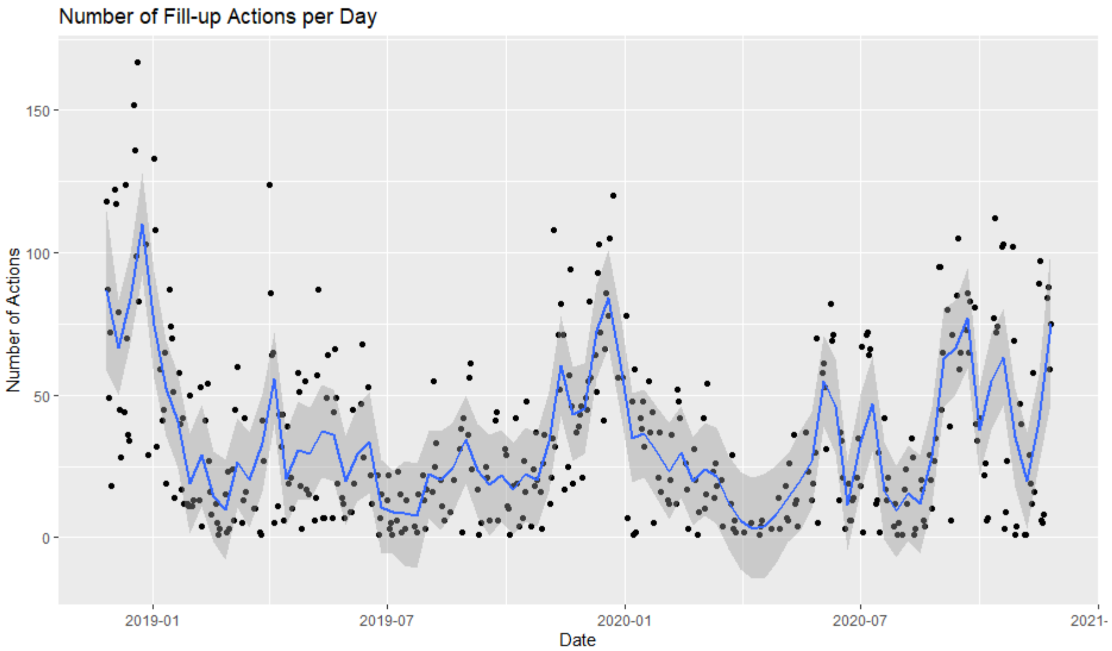


Figure 3.10: Fill up activities per day from November 2018 to November 2020

To find optimization potential at the fill-up action, it is necessary to get an overview of the whole process. The process also should have a look at the upcoming tasks after these actions. An optimal fill-up strategy is needed to reduce ways in the upcoming picking tasks. In the companies examined, there are different ways to fill up stock. At Kiennast and Kastner, picking and fill-up persons are different. This leads to a division of work. At Sonnentor, those persons are the same. Whenever they have time during their picking processes, they requests the most important fill-up article. The different ways to fill up stock amounts have no impact on the optimization strategy.
Some base functions will be created to implement an optimal working approach, which will be used for the overall process.

3.3.1 Base functionality

At all investigated companies, the main stock will be used by different persons who will be using the articles differently. One person can use an article on stock to fill it up at the picking stock, another person uses it for a B2B sales order and another person reserves the goods for a special customer. Therefore, it is necessary to create all workflows to select just these articles, which are free to use. This leads to some limitations and functionalities which are used for the B2C and B2B workflow, which will be described in the following parts of this thesis.

Articles to fill up

To create a useful fill-up action, it is necessary to select all articles, which are open to fill-up. This selection does not give away any ranking of the importance of an article. Therefore, the selection is used to identify just these articles which are needed the next time. A user's motivation will drop when he/she fills up one package at a time. For this reason, some constraints are created which must be fulfilled to get into the point ranking, which will be described later on. At Sonnentor, an article should be filled up when the following four criteria are fulfilled.

1. At first, there must be articles on stock to fill up for the investigated article.
2. The minimum fill-up amount for the investigated article must be over one transportation box. Otherwise, the article is unnecessary.
3. Fill up just these articles, where enough articles are on stock. If there are not enough in stock, the article should not be filled up at the picking warehouse.
4. The articles from the stock should be free. These articles should not be reserved for another customer.

The following Listing 3.1 shows the criteria from above as a SQL statement.

```
/* Criteria 1 */
and avl.amount>0
/* Criteria 2 */
and cast((s.AlertAmountMax1-isnull(stock.amount,0))/
 isnull(apbp.UnitAmount,isnull(apstd.UnitAmount,1)) as int) >= 2
/* Criteria 3 */
and (s.AlertAmountMax1-isnull(stock.amount,0))/
 isnull(apbp.UnitAmount,isnull(apstd.UnitAmount, 1))
*isnull(apbp.UnitAmount,isnull(apstd.UnitAmount,1))
<= isnull(avl.amount,0)-isnull(stock.amount,0)
/* Criteria 4 */
and sourceStore2.Source_Store_SID is not null
and sourceStore2.Source_StockGrpAttr_SID is not null
```

Listing 3.1: Criteria which article should be filled-up

These constraints ensure that just a high amount of an article needs to be filled up and the articles have to be free at the stock. Otherwise some people will be confused if a reserved article is not in stock when they need it.

Lock articles

Another important part is to guarantee that more fill-up persons do not fill up the same article simultaneously. Therefore, it is necessary to find a mechanism to flag a specific transaction that other fill-up persons can select. This will be done by locking the destination stock location of a fill-up action. When a user starts a fill-up action at a specific time, the system locks the destination stock location by inserting a lock in a temporary table. Other fill-up actions can use this temporary table to check if another person wants to fill up in the same destination stock location. Every fill-up action checks at selecting the next article if this stock location is currently locked. Nevertheless, the lock can lead to several problems. If the scanner of the user loses the connection to the internet or loses the session of the system, he cannot finish the task, and the stock location will be locked all the time. The same thing happens if the user cancels the fill-up action without saving the progress. This circumstance leads to a timed lock of a stock location. The time period for a lock should be, on the one hand, long enough that a fill-up person can finish the progress and, on the other hand, not too long that a problem with the scanner locks the most important article for a too long time period. After a few tries, the lock is configured for five minutes. Within five minutes, the user has to select and bring the article to the picking stock. When the articles are in the picking stock, it is unnecessary for other fill-up actions until the reorder point will be reached for this good.

3.3.2 B2C

At Sonnentor most of the articles will be sold to private customers. Therefore, the fill-up process at this company is one of the most important steps to create an optimal stock process. This is needed to save time and money when they reach their main season, when they have up to 400 orders per day (December 2018 - 3.9).

Most important fill-up article

Every fill-up transaction can consist of one or more positions. The selection of the first position is different from the following positions to ensure optimality.
The first step to get an overall optimized fill-up process is to get the most urgent article to fill up. This will be achieved by calculating a point rating system for every article, which can be used to get the most urgent article. Listing 3.2 shows the part, which calculates a stock rating out of the base aspects of the article, stock location and the stock amount. These aspects are:

1. Alert Amount Max: Every stock location needs different specifications as already defined in Section 3.2.1. For the calculation of the most urgent article, the maximum alert amount will be needed. This specification stores the highest amount of articles that can be stored at this stock location. In the calculation, this is needed to get the fill-up amount per stock location. The higher the difference between the actual stock amount and the maximum alert amount is, the higher the necessity is to fill up the article.

2. Alert Amount Min: This parameter defines the opposite way of the first parameter. The minimum amount per stock defines the level at which the stock should be refilled latest. This amount is defined regarding the packaging units and the average selling amount of the next days. Every article has its own minimum amount for the picking warehouse.

3. Actual stock amount: The actual stock amount is important for showing the importance of the article for the fill-up process. This amount will be taken into account when calculating the point rating of the article.

4. Article and article packaging unit: In the first stage of extension, it is necessary to know the article and the specific packaging unit. The packaging unit is important to get a minimum amount to fill up. For Sonnentor, a minimum of two packaging units per article is defined.

5. Required amount: This amount is the sum of all open orders for the next two days. Forecasting as described in Listing 3.7 is only meaningful for months and coarser granularity because the orders have no impact on other orders. It is only meant to look at a specific month, especially for seasonal products like advent calendars. Listing 3.3 shows the calculation of the open demand per article in the upcoming days.

6. Department of selling call-off: Every selling contract gets a specific department that has to do the next step. When a contract comes into the system, a department

called "Auftragspruefung" has to check every order, if the customer can pay or if the amount of the articles can be handled. Also, the processing of the different customer groups will be handled within different departments. These departments are called like the customer groups "B2B" and "B2C". For the required amount to calculate the most important fill-up articles, only the orders which are not at the department "Auftragspruefung" will be taken into account.

7. Status of orders: Also, the status of every order is important for the required amount of the upcoming days. There should be only orders which are currently not invoiced and not finished.

The first step of the listing is to calculate the difference between the current stock amount and the maximum amount the stock location can hold. This is done within line 4. Lines 5 and 7 calculate out of the amount of the right packaging units. In the system, every article can have different packaging units. The standard packaging unit and the bulk pack, which define the transportation unit, are also relevant for the fill-up process. Line 9 adds the required amount of an article to the difference between the maximum and the current amount. The required amount is shown in the listing in lines 15 to 19. At this function call, all selling contracts for the next two days for B2B and B2C are taken into account.

```
1  (
2  (
3  cast(
4          (s.AlertAmountMax1-isnull(stock.amount,0))
5          /isnull(apbp.UnitAmount, isnull(apstd.UnitAmount,1))
6          as int)
7          *isnull(apbp.UnitAmount, isnull(apstd.UnitAmount,1))
8          )
9          +isnull(req.AmountBooking,0)
10 )
11 /  s.AlertAmountMax1
12
13 ...
14
15 outer apply (
16     select sum(oo.demand) as amountbooking
17     from fn_custMB_open_Orders(2, null) oo
18     where oo.Article_SID = a.sid
19 ) req
```

Listing 3.2: Calculation of the point rating for the first position

The point calculation per article summarized into a mathematical formula looks as follows:

$$P(A) = \frac{Max - Act}{Max - Min - Req}$$

$$P(A) = \text{point calculation for article A}$$
$$Max = \text{Alert amount Max as described at Section 3.3.2 point 1}$$
$$Min = \text{Alert amount Min as described at Section 3.3.2 point 2}$$
$$Act = \text{Actual stock amount as described at Section 3.3.2 point 3}$$
$$Req = \text{Required amount as described at Section 3.3.2 point 5}$$
$$\text{At which } Max - Act \in N \text{ to have just whole numbers to fill-up.}$$

As already described, the functionality to calculate the demand of the upcoming days is outsourced to a separate function. Listing 3.3 shows the query to get the open orders for the next days per customer. The output of this function is the article's information like unique identifier, name and status, then the demand per customer and at last the type of the contract (B2B, B2C or both). With this query, the user can restrict the open orders for a predefined number of days. This is needed to make the whole fill-up process steered by parameters. Parameters of this SQL-function are:

1. @days: All open orders which are available in the system in the upcoming days. If null will be set as a parameter, all open orders from the system will be shown as a result.

2. @type: To use it for as many processes as possible, there will be differentiation regarding the type (B2B and B2C). This query will take 0, 1 or null as a parameter. 0 means all B2C, one all B2B selling orders and null will calculate B2B and B2C orders. The type of order will be selected by the department which is selected in the selling order. There are different departments of the stock location which handle the different customer types.

```
Create function [dbo].[fn_custMB_open_Orders]
(
  @days int,
  @type int
)
RETURNS TABLE
AS
RETURN

select
    a.sid as Article_SID,
    a.aname as Article_aName,
    case
        when a.FK_RecordState_SID not in (0, 10)
             or a.aname like '%AUFGELASSEN'
             then 'invalid Article'
        else 'valid article'
    end as Article_Status,
    cp.amountbooking as Demand,
    c.FK_CRMPartnerDest_SID as CRMPartnerDest_SID,
```

```
    case
        when @type = 0 then 'B2C'
        when @type = 1 then 'B2B'
        else 'B2C+B2B'
    end    as Contracttype
from  CoPos cp
    inner join Contract c on    c.SID = cp.FK_Contract_SID
        and cp.FK_RecordState_SID = 0
    inner join Article a on a.SID = cp.FK_Article_SID
    inner join ProductGroup wg on wg.SID = a.FK_ProductGroup_SID
    inner join ProductGroup owg on owg.SID = wg.FK_ProductGroup_SID
where c.assFrom <= DATEADD(day, isnull(@days, 9999), getdate())
      and c.FK_ContractType_SID = 2
      and isnull(c.FK_Department_SID, 0) <> 5006
      and ((@type = 1 and c.fk_department_sid in (5007))
      or (@type = 0 and c.fk_department_sid in (5001))
      or (@type not in (0, 1)
      and c.FK_Department_SID in (5001, 5007)))
      and c.FK_EnqState_SID not in (7,35)
      and cp.finished = 0
```

Listing 3.3: Calculation of the open orders grouped by B2B, B2C or both types

At the same time, when the most important article is selected, all source locations of this article is calculated too, which can be seen in Listing 3.4. The article's source stock location selects all batches that are not reserved and ready to deliver to a customer. Lines 18 and 19 of the statement also checks if the stock location is locked. This can be the case if one of the ingredients has harmful residues after the quality check. The quality check can last several days, so it is possible to produce an article, and when the article is finished, the batch must be locked.

Another important check is from lines 20 to 31. These lines select just these batches on the stock with the minimal expiration date. Especially for B2B customers, this check is really important. B2B customers check the expiration dates of the incoming batches, and they should not be older than the batch before. However, the expiration date is important for B2C customers and stock management too. B2C customers should also have the chance to consume the product for several months. If this check of the expiration date will not be done, the eldest batches stay at the stock forever.

Lines 32 to 36 are limitations to specific stock locations which are reserved for a specific customer. This query selects, as already described, all batches which are available to fill up in the picking stock. Therefore, a destination article can have several source stock locations, which are probably not the optimized ones. The selection of the optimized stock location is made in a second step. When the user asks for the article, the source stock location is selected in real-time by Listing 3.5. From line 3 to 8, the query selects the optimized article ordered by the expiration date. Lines 9 to 15 select all stock locations for the investigated article. The most important line in this selection is line 17. This line restricts all source stock locations by the distance to the optimal stock location. The

distance to this one must be within 100 points. These points are coming from the order number from the stock location, which is described in Figure 3.6. One hundred points are the distance within five pallet racks left and right of the optimal one.
This is done because there are sometimes different batches stored at one stock location. When the fill-up person comes to that stock location, there is no difference in which batch will be taken. If the amount to fill up can not be taken from this stock location, the user can decide if he/she takes it from another stock location that is near to the optimal one. These stock locations can differ regarding expiration date and amount. At the scanner, this can be done by duplicate the source positions and selecting the new batch. Figure 3.11 shows the scanner surface. When there is a source position with more than one available batch, the user can duplicating the position with one button and select the other batch. The user can also overwrite the amount which is suggested by the system.

```
outer apply(
    SELECT distinct
        st.Store_SID as Source_Store_SID,
        st.FlexStockCode1 as Source_FlexStockCode1,
        st.FlexStockCode2 as Source_FlexStockCode2,
        st.FlexStockCode3 as Source_FlexStockCode3,
        st.DateExpire as Source_MHD,
        a.sid as Source_Article_SID,
        st.amountFree as Source_Amount_Free,
        ss.orderNumber as Source_OrderNumber,
        st.StockGrpAttr_SID      as Source_StockGrpAttr_SID
    FROM F4MBS.dbo.fn_Stock_Search(getdate()) st
        inner join f4mbs.dbo.Store ss
            on ss.SID = st.store_sid and ss.FK_RecordState_SID = 0
    WHERE (st.Article_SID = a.sid
        AND st.StockGrouper not like N'PK:%'
        AND st.StockGrouper not like N'EX:%'
        AND (st.Store_locked <> 1 OR st.Store_locked IS NULL)
        AND (st.StoreGrp_locked <> 1 OR st.StoreGrp_locked IS NULL))
        AND (st.DateExpire in
                (
                select MIN(dateexpire)
                from f4mbs.dbo.vw_stock minexp
                    inner join f4mbs.dbo.article a
                        on a.SID = minexp.FK_Article_SID
                where minexp.fk_Article_SID=a.sid
                    and minexp.Amount>0
                    and minexp.FlexStockCode1 <> '09'
                    and st.Store_SID <> s.sid
                    and minexp.FK_Store_SID <> a.FK_Store_SID
                group by minexp.FK_Article_SID
                )
                and st.stockgrouper not like '%-PACK:%'
                and st.FlexStockCode1+'-'+st.FlexStockCode2
                    +'-'+st.FlexStockCode3 <> 'DE-NN-REE'
```

```
                    and st.FlexStockCode1+'-'+st.FlexStockCode2
                        +'-'+st.FlexStockCode3 <> 'V-P-P'
                )
            AND (st.STOCKGROUPER is not null)
            AND st.AmountFree > 0
) sourceStore
```

Listing 3.4: Selection of all source stock locations of an specific article

```
select nex.Source_StockGrpAttr_SID
from (
        select top 1 fu.Source_Article_SID,
                fu.Source_OrderNumber
        from f4mbs.dbo.vw_cust_fillup_optimized fu
        where Article_SID = ##article_sid##
        order by DateAdd(Day, DateDiff(Day, 0, fu.Source_MHD), 0) asc
    ) opt
    inner join (
        select fu.Source_StockGrpAttr_SID,
                fu.Source_Article_SID,
                fu.Source_OrderNumber
        from f4mbs.dbo.vw_cust_fillup_optimized fu
        where Article_SID = ##article_sid##
    ) nex on nex.Source_Article_SID = opt.Source_Article_SID
      and
      (abs(opt.Source_OrderNumber - nex.Source_OrderNumber) < 100)
```

Listing 3.5: Selection of the optimized and nearby stock locations

Optimized way to fill-up

After the most urgent article and the source location is selected, the next position within a transaction will be selected by the minimum distance to the previous article, which must be filled up. Which articles are needed to be filled up is already defined by Listing 3.1.

The order number will calculate the minimum distance to another stock location. Every stock location has a unique order number from a specific schema regarding the level and the warehouse. The structure of the order numbers is shown in Section 3.2.1 and has to be done to get an optimal way through the stock. If a stock location does not have an order number, it will be replaced by the high standard value 9999999. This ensures that a stock location with an order number is ranked higher than one without an order number because of the absolute distance between the two points. A pre-calculation of the optimal way is not possible because the stock locations from every article are not fixed. Since relocation or production can always occur, this would destroy the optimal route through the stock in real-time. Listing 3.6 shows the part which decides if the position is the first article in the fill-up transaction or not. The place holder “prev” gets the previous position from the fill-up transaction. If this place holder is null, it is the first

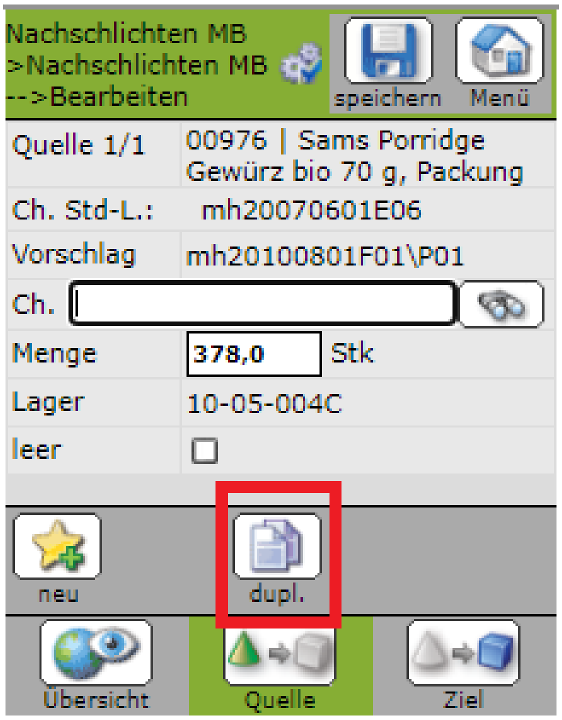


Figure 3.11: Duplicate functionality on the scanner surface

position, and the optimal product is selected with the point rating. If the place holder is unequal to null, the positions will be ordered by the absolute distance to the previous stock location. The minimum distance wins and will be selected as the optimal way. In this selection, the way to the first and from the last stock location is not considered. This is a conscious decision because the stock locations in the back part of the warehouse should have an equal chance to fill up as the articles in the front part. The size of such a warehouse can be seen in Figure 3.3.

```
order by
      case
        when prev.ordernumber is null
           then (points * -1)
        else
           abs(isnull(fu.Source_OrderNumber, 9999999) - prev.ordernumber)
      end,
fu.Article_SID
```

Listing 3.6: Selection of the next position with minimum distance

3.3.3 B2B

The B2B approach differs to the B2C by the scale of the amount per order and the size of the warehouse. This part will take place at the blue part of the warehouse, as seen in

Figure 3.3. At Sonnentor, the term B2B has a broader range because usually B2B means just business customers. The B2B approach at Sonnentor also declares selling contracts over a specific amount as B2B. This will be done to avoid the emptying of the picking warehouse within a single order. The B2B fill-up at Sonnentor is different to Kastner and Kiennast because they are their own producer. Sonnentor gets the ingredients from the farmers and produce the selling product. Filling-up for B2B is, in that case, to bring the complete pallets of the selling product from the production hall to the stock. At Kastner and Kiennast, there are only B2B customers available, but they do not have a separate picking warehouse for smaller orders. At both these companies, they do not produce any products on their own. They get their products from another supplier. The B2B fill-up means, for their understanding, to bring the goods from the truck to the stock location. This section describes how the needed stock amount will be calculated as a forecast and where the articles should be stocked. The stock location of every article based on the forecasting is important for the picking process to avoid long ways through the warehouse. At this part, there is no optimization of the way required because every fill-up process will be done pallet per pallet.

Forecasting

The warehouse capacity at the blue sector, as seen in Figure 3.3, is usually high because to store the next months in it. Therefore, it is useful to forecast every article and stock location. This should be done to optimize ways for the upcoming fill-up to the picking warehouse process or picking process for B2B customers.

Forecasting means calculating the number of goods that are needed for the upcoming time. This will be the first step at the fill-up action for B2B orders. This is needed to rate the articles with a higher turnover ratio at a specific previous period in time higher than others. A higher rating leads to a more prominent place at the stock to reduce ways for the picking persons. The selling contracts from previous periods will be reviewed and adjusted with the growth rate for a specific article and a specific customer group to get this data. The forecasting functionality should be parametrized to simplify changes at the starting point or the time periods of the calculation. Also, the differentiation of B2B and B2C will be important. B2B orders affects the calculation more than B2C orders because of the amount of every order.

The responsible persons from the companies examined want to consider the data per year, per half-year, quarter and month. The rate of growth should be handled at every article per year, as already mentioned in Section 3.2.1. Also, the differentiation between customer groups should be handled. The expected rate of growth of the wholesaler can be higher than gastronomy or the other way round. It is also possible to have a specific rate per partner when it can be expected to have an extraordinary growth of one customer. This functionality can be used to plan the production if there are too few products on stock, to plan the optimal stock locations of every article or to order the right amount of goods from the suppliers.

The following equation shows the calculation of the forecasting amount with respect to the growing rates per article and customer.

$$FA(A) = (\sum_{n=1} C_nAm_A * GRC_n) + (Am_A - \sum_{n=1} C_nAm_A) * GRA_A$$

$$FA(A) = \text{forecasting amount of article A}$$
$$n = \text{number of customers which bought article A}$$
$$C_nAm_A = \text{amount of article A which was sold to customer n during the previous period}$$
$$GRC_n = \text{expected growing rate of customer n for the upcoming period}$$
$$Am_A = \text{quantity of sales of article A during the previous period}$$
$$GRA_A = \text{expected growing rate of article A for the upcoming period}$$

```
CREATE FUNCTION [dbo].[fn_custMB_forecast]
(
   @investigationDate datetime,
   @period int,
   @days int,
   @type int
)
RETURNS TABLE
AS
RETURN

select
   f.Article_SID as Article_SID
   , f.Article_aName as Article_aName
   , round(sum(f.Customer_AmountGrowingRate), 2) as ForecastingDemand
from (
         select a.sid as Article_SID
                  , a.aname as Article_aName
                  , sum(prev.Demand) as Prev_DemandCustomer
                  , ( select sum(demand)
                      from [fn_custMB_prev_Demand]
                           (@investigationDate, @period, @days, @type)
                      where article_sid = a.sid
                  ) as CoPos_AmountAdminOveral
                  , convert(float, cpDest.altid3) as Customer_GrowingRate
                  , sum(prev.Demand) * convert(float, cpDest.altid3)
                        as Customer_AmountGrowingRate
                  , prev.CRMPartnerDest_SID as CRMPartner_SID
                  from f4mbs.dbo.article a
               inner join [fn_custMB_prev_Demand]
                        (@investigationDate, @period, @days, @type) prev
               on prev.Article_SID = a.sid
               inner join crmpartner cpDest
               on cpDest.sid = prev.CRMPartnerDest_SID
               and cpDest.fk_recordstate_sid = 0
            where a.FK_RecordState_SID = 0
            group by prev.CRMPartnerDest_SID
```

```
                        , a.sid
                        , a.aname
                        , cpDest.ALTID3
) f
group by f.Article_SID
               , f.Article_aName
               , f.CoPos_AmountAdminOveral
```

Listing 3.7: Forecasting per article

Limitation of forecasting: The limitation of this functionality is the investigated time period. At all companies interviewed the customers do not order cyclic the same amount of goods periodically. Therefore, the forecasting method can only be used within a coarser granularity of time. This means that a forecast for just a few days is not useful and should always be for several weeks or months. Figure 3.12 shows the orders of the best-selling articles per week through 2020 at Sonnentor. The figure shows that there is no real continuity recognizable within different weeks in one year. Also, if we take a look at just one article and compare it through different years, as seen in Figure 3.13, there is no meaningful continuity recognizable.

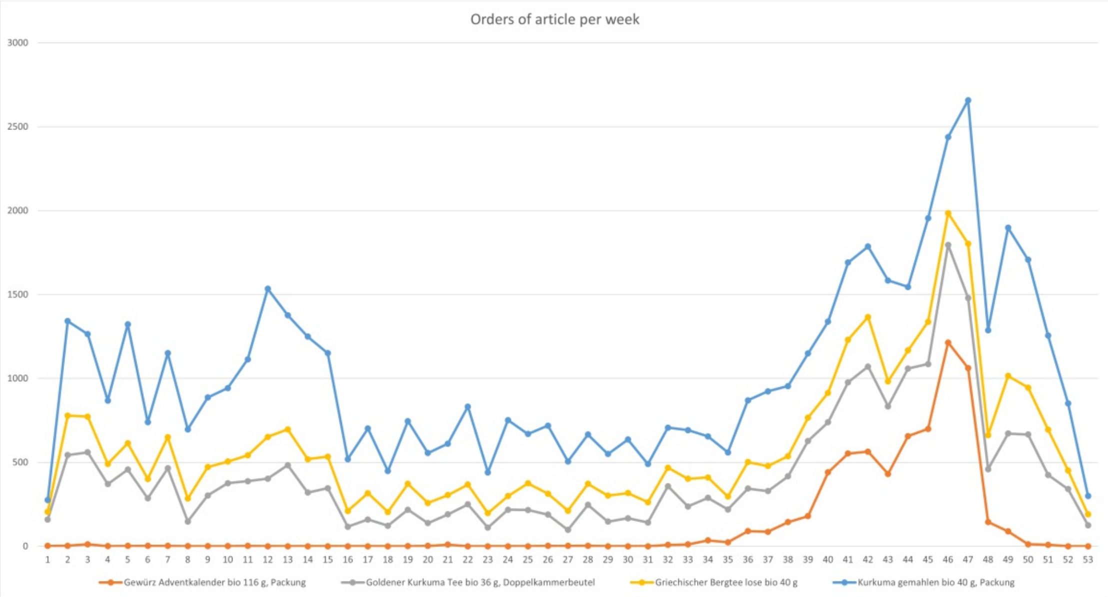


Figure 3.12: Orders of selected articles per week

Demand of previous periods

To calculate the demand of previous periods means that all orders of an article will be shown within a specific time gap of a previous period. The previous demand is important to get an overview for which amount of an article can be needed in the next weeks or

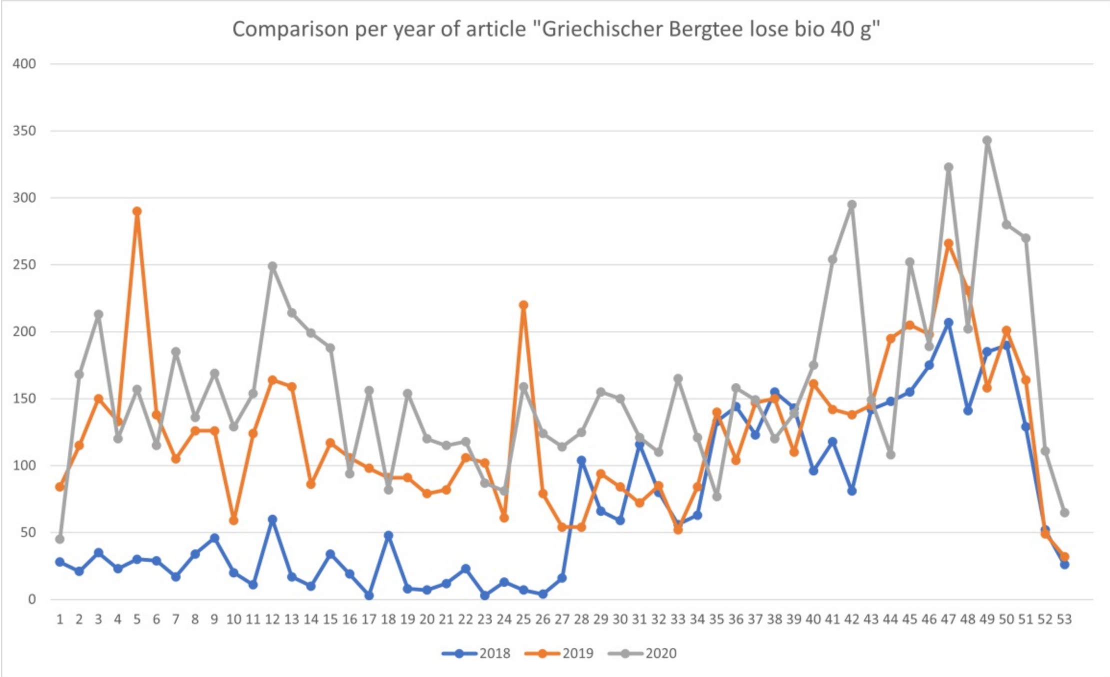


Figure 3.13: Orders of selected articles per week

months and is a base functionality of the forecasting. At Kiennast and Kastner, this is important because until now, this is based on the experience of the stock manager. This forecasting should also be included when calculating the amount of the articles during the fill-up process. Now, the fill-up action gives the amount of free space at the destination stock location. This should be replaced by the amount which is really needed for the upcoming days. Parameters for the calculation of the previous demand are:

1. @startdate: The date, which will be the starting point of investigation. In practice, this will be the current date most of the time. With this parameter, it is possible to get an overview of different points in time during the year.

2. @period: The period is an integer and is defined as the number of months subtracted from the start date. This number will be negated in the function.

3. @days: This parameter describes the number of days which will be investigated from the start date minus the number of months given in the parameter period. If the user wants the orders within two weeks, this parameter will be seven. The number of days will create a gap around the date investigated. In this example the period investigated will start seven days before and end seven days after the requested date.

```sql
CREATE FUNCTION [dbo].[fn_custMB_prev_Demand]
(
  @startDate datetime,   /* Date of investigation
                          (most of the time current date) */
  @period        int,    /* period in months */
  @days          int,    /* +/- Days of startDate - period */
  @type          int     /* type: 0=B2C); 1=B2B;
                          in any other case = both */
)
RETURNS TABLE
AS
RETURN

select
     a.sid          as Article_SID,
     a.aname        as Article_aName,
     case
         when a.FK_RecordState_SID not in (0, 10)
              or a.aname like '%AUFGELASSEN' then 'invalid Article'
         else 'valid article'
     end     as Article_Status,
     cp.AmountAdmin as Demand,
     c.FK_CRMPartnerDest_SID as CRMPartnerDest_SID,
     case
         when @type = 0 then 'B2C'
         when @type = 1 then 'B2B'
         else 'B2C+B2B'
     end     as Contracttype
from CoPos cp
     inner join Contract c on c.SID = cp.FK_Contract_SID
         and cp.FK_RecordState_SID = 0
     inner join Article a on a.SID = cp.FK_Article_SID
     inner join ProductGroup wg on wg.SID = a.FK_ProductGroup_SID
     inner join ProductGroup owg on owg.SID = wg.FK_ProductGroup_SID
where ((@days is not null
     and c.assFrom >
     DATEADD(MONTH,(@period*(-1)),dateadd(day,(@days*(-1)),@startDate))
     and c.assFrom <
     DATEADD(MONTH,(@period*(-1)),dateadd(day @days,@startDate)))
     or
     (@days is null
     and c.assFrom > DATEADD(MONTH,(@period*(-1)),@startdate)
     ))

     and c.FK_ContractType_SID = 2 /* selling call off */
     and ((isnull(@type, 999) = 1
               and c.fk_department_sid in (5007)) /* B2B */
     or (isnull(@type, 999) = 0
              and c.fk_department_sid in (5001)) /* B2C */
```

```
50        or (isnull(@type, 999) not in (0, 1)
51            and c.FK_Department_SID in (5001, 5007))) /* B2C; B2B */
```

Listing 3.8: Calculates the demand of previous periods

The output of Listing 3.8 is, on the one hand, a list of information about the article like unique identifier, name and status. An article status indicates if an article is deleted or not relevant in the future. After that, a list of the article demands per customer will be provided to have an overview, which customer orders which amount of articles in the investigated time period. This is needed at the forecasting calculation because every customer can get a different rate of growth. The last column is the type of contracts that is given as a parameter to the function. This can be B2B, B2C or both.
The filter of this statement is, on the one hand, the selection of just the contracts within the period that the user handles as parameters to the function. At first, the user's "startdate" is reduced by the parameter "days". The outcome of this function will be reduced by the period, which is given by the number of months to the function. This is done from lines 35 to 43. On the other hand, the statement filters all selling contracts belonging to the user from the given type. This is done in lines 45 to 51. The contracts can be 0, which means all B2C orders, 1 for all B2B orders or any other number for B2C and B2B orders.

Cluster analysis of an article

When an article is filled up at the blue part of the stock, as seen in Figure 3.3, it is necessary to have a strategy at which stock location the article should be. The different strategies are already described in Section 2.2. All fill-up approaches will be tried out, and the best fitting strategy will be taken. At first, there will be a proceeding for the chaos approach, followed by the ABC and XYZ cluster analysis and the combination of these two calculations.
For the ABC and the XYZ analysis, it is important to split the stock into three parts. The first part (A/X) is near to the picking warehouse and the packaging area and has to contain the most important and scalable articles. The second part (B/Y) stores the articles that have a moderate importance/scalability and the last one (C/Z) stores the articles that will not be sold that often. Figure 3.14 shows all three parts highlighted at the stock at Sonnentor. The grey part of the stock is the picking warehouse and should not be available for B2B customers and B2B fill-up actions. The light green part of the stock is reserved for A or X articles. Light orange shows the part which must be filled with B or Y articles. The light red part is for all articles, which have a low stock turnover rate and clustered as C or Z.
For the ABC-YXZ analysis, each of these three parts from above has to be split into another three parts. This ensures that each part of those nine parts can store the ABC and XYZ clustering analysis. An AX article must be stored more prominent to the packaging tables as an AZ article. Figure 3.15 shows the stock split into three parts A, B and C. Each part is again split into three parts X, Y and Z.

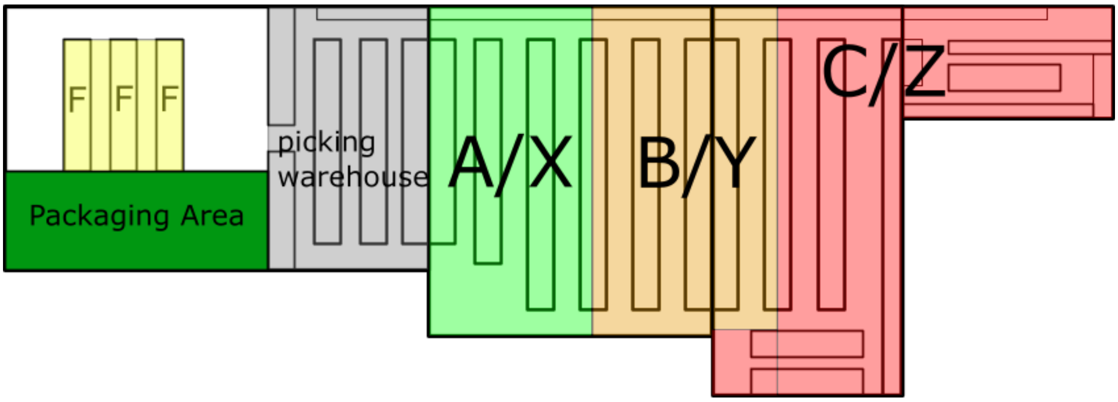


Figure 3.14: Split stock into three parts for ABC or XYZ clustering

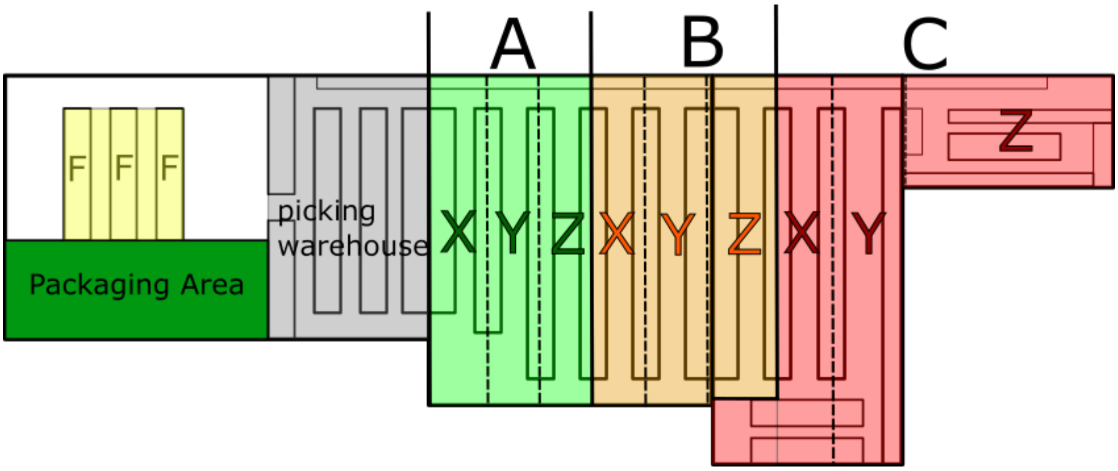


Figure 3.15: Split stock into three parts for ABC-XYZ clustering

Chaos approach: The chaos approach is the easiest way to fill up the stock location. All empty stock locations or stock locations with the investigated article and enough free amount can be selected. This selection can be seen in Listing 3.9. The lines 19 to 24 select all necessary tables together. The lines 25 to 28 select just these stores, which are empty or have enough space for the new goods. The remaining lines restrict the list by specific stock locations, which should not be taken for a B2B fill-up action. This listing only selects all available stock locations where the article can be stored. In a second step, the system selects out of this list one randomly. This will be done by Listing 3.10.

```
1 CREATE FUNCTION [dbo].[fn_custMB_ChaosAnalysis]
2 (
3     @article_SID as int
4     , @bookingamount as float
5 )
6 RETURNS TABLE
```

```
AS
RETURN

select   sgm.sid as StoreGrpMain_SID
         , sg.SID as StoreGrp_SID
         , s.SID as Store_SID
         , sgm.aShortName as StoreGrpMain_aShortname
         , sg.aShortName as StoreGrp_aShortname
         , s.aShortName as Store_aShortName
         , s.AlertAmountMax1 as Store_AlertAmountMax1
         , st.FK_Article_SID as Article_SID
         , st.Amount as Stock_Amount
from     store s
         inner join storegrp sg on sg.sid = s.FK_StoreGrp_SID
             and s.FK_RecordState_SID in (0, 10)
         inner join StoreGrpMain sgm on sgm.sid = sg.FK_StoreGrpMain_SID
             and sgm.FK_RecordState_SID in (0, 10)
         left outer join vw_Stock st on st.FK_Store_SID = s.sid
where    ((st.FK_Article_SID = @article_SID
         and (isnull(st.Amount, 0) + isnull(@bookingamount, 0)
         <= isnull(AlertAmountMax1, 9999)))
         or st.StockGrouper is null)
         and s.FK_RecordState_SID in (0, 10)
         and sgm.aShortName in ('10')
         and sg.aShortName not like 'F%'
         and sg.ashortname not like 'K%'
         and sg.ashortname not like 'D%'
         and s.aShortName not like '%A'
         and s.aShortName not like '%B'
         and s.ashortname not like '?'
GO
```

Listing 3.9: Selecting a stock location for an article by the chaos approach

```
select top 1
         , StoreGrpMain_aShortname
         , StoreGrp_aShortname
         , Store_aShortName
from (
         select   StoreGrpMain_SID
                  , StoreGrp_SID
                  , Store_SID
                  , StoreGrpMain_aShortname
                  , StoreGrp_aShortname
                  , Store_aShortName
                  , Store_AlertAmountMax1
                  , Article_SID
                  , Stock_Amount
                  , newid() as id
         from     [fn_custMB_ChaosAnalysis](##article_sid##,
```

```
                                  ##article_bookingamount##)
    ) x
order by x.id
```

Listing 3.10: Output of the stock location for an article by the chaos approach

ABC cluster analysis: The ABC cluster analysis calculates for every article an A/B/C ranking as described in Section 2.2.1. This ranking shows the importance of an article to the company. In the case of a company in the food market, the articles must be ranked regarding the sales from the previous year. The ABC analysis in this thesis will follow the single criterion of annual sales of the investigated article. When selecting a whole year, the seasonal effect will be minimized. A disadvantage of selecting a whole year is that new articles that are not available for one year cannot be taken into account with this calculation. Listing 3.11 analyse the selling contracts of the last period starting with a predefined date of investigation. Based on these parameters, the selling amounts will classify the goods as A, B or C. Therefore, line 29 selects the previous demand of the last period back from the parameter "investigation date" for B2B and B2C customers. The function "prevDemand" is already described in Listing 3.8. Lines 32 to 34 return the number of all articles, which are sold in the last period. This is needed to calculate the three classifications based on the sales orders. The most important part of this query are lines 16 to 21. In these lines, every article will be defined as A, B or C article. It is an A article when the ranking of the article is in the first third of the total ranking. A B article must be in the second and a C article in the last third of the total ranking. This classification method is chosen because the number of picks of an article is relevant to storing the article in a prominent position.
After the classification of each article, the system selects a random stock location within the calculated class of the article. This selection will be made by Listing 3.12. The classification of the article will be compared to the classification of the stock location. If it matches, a list of stock location which is empty or filled with the investigated article will be provided. One stock location of this list will be taken randomly by the system and provided to the user.

```
1  CREATE FUNCTION [dbo].[fn_custMB_ABCAnalysis]
2  (
3    @investigationDate datetime,
4    @period int
5  )
6  RETURNS TABLE
7  AS
8  RETURN
9
10 select h.Article_SID
11        , h.Article_aName
12        , h.Demand
13        , h.ranking
14        , h.NumberOfOrders
```

```
            , maxcount.cnt
            , case
                when h.ranking <= (maxcount.cnt/3) then 'A'
                when h.ranking >
                    maxcount.cnt/3
                    and h.ranking <= (2*(maxcount.cnt/3)) then 'B'
                when h.ranking > (2*(maxcount.cnt/3)) then 'C'
            end as Class
from (
    select Article_SID
                , Article_aName
                , sum(Demand) as Demand
                , RANK() over
                (order by sum(demand) desc, article_sid asc) as ranking
                , count(Article_SID) as NumberOfOrders
    from fn_custMB_prev_Demand
        (@investigationDate, @period, null, null)
    group by Article_SID, Article_aName
    ) as h
    , (select count(distinct article_sid) cnt
        from fn_custmb_prev_demand
            (@investigationDate, @period, null, null)
    ) as maxCount
group by h.Article_SID, h.Article_aName, h.Demand, h.ranking
            , h.NumberOfOrders, maxcount.cnt
```

Listing 3.11: Selecting a stock location for an article by the ABC cluster analysis

```
select  top 1 sgm.ashortname, sg.aShortName, s.aShortName
from f4mbs.dbo.fn_custMB_ABCAnalysis(GETDATE(), 12) cluster
        inner join f4mbs.dbo.store s
            on left(s.extid, 1) = cluster.class
        inner join f4mbs.dbo.storegrp sg
            on sg.sid = s.FK_StoreGrp_SID
        inner join f4mbs.dbo.storegrpmain sgm
            on sgm.sid = sg.FK_StoreGrpMain_SID
        left outer join f4mbs.dbo.vw_Stock st
            on st.FK_Store_SID = s.sid
where cluster.article_sid = ##article_sid##
        and (st.StockGrouper is null
        or st.FK_Article_SID = cluster.article_sid)
order by newid()
```

Listing 3.12: Output of the stock location for an article by the ABC cluster analysis

XYZ cluster analysis: Another clustering method is the XYZ approach. This approach, described in Section 2.2.2, calculates a classification for every article as already done in the ABC cluster analysis. The difference to the ABC analysis is that an XYZ ranking shows the prediction accuracy of the article. This will be done in this thesis by

the single criterion of a standard deviation per month of an article of the last predefined period. All average sales per month of the last period and the forecasting amount of the next month of the investigated date influence the standard deviation of an article. The predicted sales are based on the sales of previous periods and the rate of growth per article per customer. To create a meaningful classification, it is necessary to know which time period in the future can be taken into account. For the picking warehouse, just a few days are necessary. For the B2B warehouse, a few months should be taken into account. This is because of the different sizes of each warehouse. Only the demand of open orders, which is described in Listing 3.3, can not be used because the open orders reach several days in the future for the majority of the customers. Therefore, for a B2B fill-up action, the forecasting method which is described in Section 3.3.3 will be used for creating a useful calculation.
Listing 3.13 shows the classification of the articles. Lines 21 to 32 select all articles and their sales per month over the last period. Lines 36 to 41 calculate the forecasting amount of the investigated article. Based on the standard deviation, which is calculated in line 19, the article will be classified into X, Y and Z articles in lines 12 to 14. If an article had no sales in the last period, it gets the deviation of 999 and is automatically a Z article. An X article has a low deviation over time and can be predicted very well for the future. Therefore, the article can be planned for the upcoming periods. A Y article has a moderate deviation and the prediction of a Z article is very hard. The stock managers of Sonnentor decided, that they want to give an X article a more prominent stock location than a Y or a Z article. Based on the fact that the calculation can be done at every fill-up action, the classification can change very fast but has to be as detailed as possible. The calculation at every fill-up action will be done in advance if the performance gets worse. This can happen if the number of selling contracts increases over time.

```
1  CREATE FUNCTION [dbo].[fn_custMB_XYZAnalysis]
2  (
3     @investigationDate datetime
4  )
5  RETURNS TABLE
6  AS
7  RETURN
8
9  select Article_SID
10          , Article_aName
11          , case
12              when Deviation >= 0 and Deviation < 25 then 'X'
13              when Deviation >= 25 and Deviation < 50 then 'Y'
14              when Deviation >= 50 then 'Z'
15          end as Class
16 from (
17          select Article_SID
18                  , Article_aName
19                  , isnull(STDEV(Selling_Amount), 999) as Deviation
20          from (
```

```
                select a.SID as Article_SID
                       , a.aname as Article_aName
                       , month(c.schedfinishdate) Month_Number
                       , sum(cp.amountadmin) Selling_Amount
                       , 'Contract' as Typ
                from contract c
                     inner join copos cp on cp.fk_contract_sid = c.sid
                         and cp.fk_recordstate_sid = 0
                     inner join article a on a.sid = cp.fk_article_sid
                where c.fk_contractversion_sid in (5005, 3)
                      and c.SchedFinishDate
                          >= dateadd(year, -1, @investigationDate)
                group by a.sid, a.aname, month(c.schedfinishdate)

                union all

                select
                  Article_SID
                  , Article_aName
                  , month(dateadd(month, 1, @investigationDate))
                       as Month_Number
                  , ForecastingDemand as Selling_Amount
                  , 'Forecasting' as Typ
                from fn_custMB_forecast
                    (@investigationDate, 12, 30, null) forecast
        ) x
        group by Article_SID, Article_aName
) h
```

Listing 3.13: Selecting a stock location for an article by the XYZ cluster analysis

Listing 3.14 selects a specific stock location based on the XYZ analysis function. Each stock location has the classification X, Y or Z, which is shown in Figure 3.14. Based on the analysis function above, a random stock location with the same classification will be used. Line 3 and 4 create the connection between the analysis and the stock location classification.

```
1  select top 1 sgm.ashortname, sg.aShortName, s.aShortName
2  from f4mbs.dbo.fn_custMB_XYZAnalysis(GETDATE()) cluster
3       left outer join f4mbs.dbo.store s
4           on substring(s.extid, 3, 1) = cluster.class
5       left outer join f4mbs.dbo.storegrp sg
6           on sg.sid = s.FK_StoreGrp_SID
7       left outer join f4mbs.dbo.storegrpmain sgm
8           on sgm.sid = sg.FK_StoreGrpMain_SID
9       left outer join f4mbs.dbo.vw_Stock st
10          on st.FK_Store_SID = s.sid
11 where cluster.article_sid = ##article_sid##
12      and (st.StockGrouper is null
13      or st.FK_Article_SID = cluster.article_sid)
```

```
order by newid()
```

Listing 3.14: Output of the stock location for an article by the XYZ cluster analysis

ABC-XYZ cluster analysis The clustering methods above can be combined to the ABC-XYZ analysis. As already described in Section 2.2.3, each article gets a classification about ABC and XYZ criteria. The classification per article means that, on the one hand, if the article has a high turnover ratio at the stock and, on the other hand, if the demand for an article will be high in the next weeks. An A-Y classification will identify an article with a higher priority than an article with B-X classification. At Sonnentor, the stock is split as described in Figure 3.15. Therefore, each ABC classification will be split into the three XYZ parts. Listing 3.15 gets the value of the article from the ABC analysis in line 17. Line 18 gets the value of the article from the XYZ analysis. The output combines both methods in line 16.

```
1  CREATE FUNCTION [dbo].[fn_custMB_ABCXYZAnalysis]
2  (
3    @investigationDate datetime,
4    @period int
5  )
6  RETURNS TABLE
7  AS
8  RETURN
9
10 select abc.Article_SID,
11        abc.Article_aName,
12        abc.Demand as PrevDemand,
13        abc.class as ABCClass,
14        xyz.ForecastingDemand as Prediction,
15        xyz.class as XYZClass,
16        abc.Class + xyz.Class as ABCXYZClass
17 from   fn_custMB_ABCAnalysis(@investigationDate, @period) abc
18        inner join fn_custMB_XYZAnalysis(@investigationDate) xyz
19            on xyz.Article_SID = abc.Article_SID
```

Listing 3.15: Selecting a stock location for an article by the ABC-XYZ cluster analysis

When the classification is done for each article, the system needs a specific stock location for the investigated article. This will be done with Listing 3.16. Lines 3 and 4 select all stock locations with the specific classification value from the database. When an article with B-Z classification arrives all stock locations that are defined as B-Z articles will be selected. Lines 12 and 13 restrict the list to the empty stock locations or the stock locations which is currently filled with the same article.

```
1 select top 1 sgm.ashortname, sg.aShortName, s.aShortName
2 from f4mbs.dbo.fn_custMB_abcxyzanalysis(GETDATE(), 12) cluster
3      inner join f4mbs.dbo.store s
4          on substring(s.extid, 5, 2) = cluster.ABCXYZClass
```

```
      inner join f4mbs.dbo.storegrp sg
          on sg.sid = s.FK_StoreGrp_SID
      inner join f4mbs.dbo.storegrpmain sgm
          on sgm.sid = sg.FK_StoreGrpMain_SID
      left outer join f4mbs.dbo.vw_Stock st
          on st.FK_Store_SID = s.sid
where   cluster.article_sid = ##article_sid##
                and (st.StockGrouper is null
                or st.FK_Article_SID = cluster.article_sid)
order by newid()
```

Listing 3.16: Output of the stock location for an article by the ABC-XYZ cluster analysis

3.4 Picking process

The second part of this thesis deals with another important and time-consuming process. In a stock management system, the picking process has an enormous impact on the overall processing time and can be done in several ways. The different ways are stated in Section 2.3. All investigated companies in the food market industry stated that just the pick-by-document or pick by MDE, which is a picker to goods approach, is applicable. This means that a picker gets the information about the articles that have to be picked on a printed list or a mobile device. The picker has to walk or drive with his picking device to the stock location and pick the goods. All investigated companies pick order by order. At all companies, they have scanners for the pickers. At Sonnentor, these are available additionally to this printed lists if there is an issue with the internet connection, a software bundle or other unforeseen events.

At the picking process, there are several important specifications needed. The overall workflow of an order, which orders will be picked by which pickers and how the picker walks through the stock. This information is necessary to optimize the process. The biggest optimization potential can be found in batching orders together to pick several orders in one picking process. Therefore, it is needed to select a base order which is called "seed-order". Based on this seed order, the accompanying orders can be selected on the basis of specific rules. Another important optimization factor is the shortest way through the stock.

This section is split into the description of the workflow of an order which is stated in Section 3.4.1, followed by the implementation of the different approaches to find a seed order which is described in Section 3.4.2. After that, the different approaches to find orders, which should be picked together, will be shown in Section 3.4.3. At last, the optimized walking strategies will be shown in Section 3.4.4.

3.4.1 Workflow of an order

There are several steps an order passes through until the article will be sent to the customer, shop or another company. To optimize the way of an order, it is important to get an overview of all the steps at this workflow. Figure 3.16 gives an overview of all

tasks and departments starting with the order in the online shop until the staff sends the parcel to the customer. The BPMN model shows the way of a B2C and B2B order at once. The differentiation of the orders will be done after the order will be imported to the ERP system.
The customer order in the online shop is the first step of the whole process. At Sonnentor, there are two different online shops available. One is for B2C and one for B2B customers. The online shop and the ERP system are from different service providers and are interlinked with an interface that exchanges the data cyclically. When the ERP system receives the data, all online shop orders will create one selling order in the system with the customer information and the articles but without a department that will handle this order. The department, which is shown as swim lanes in Figure 3.16, will be set to the orders when the customers are checked by the department "Auftragspruefung". This department checks the customers' liquidity and if there is no reason to deny this order, they create the call-off. During the creation of the call-off, an algorithm sets the department of every call-off. The department depends on the customer group, the product group or the amount of the article. Currently, the B2B and B2C orders are handled the same way. The picking persons get all orders on their scanner and have to complete one after another. If an order contains a personalized article, the printing department prints the corresponding label. The printing department also prints the labels if the customer has a different language than German and English on demand. When the orders are picked from the warehouse, the parcel will be packed and sent to the customer. At every point in time, the fill-up process can be done. Therefore, the person sees the most urgent article to fill up in the warehouse on their scanner.
Figure 3.17 shows the optimized version of the picking process. The way from the online shop through the department "checking orders" and creating of the call-off will be the same. When every call-off has set the right department, the system should generate different ways to handle B2B and B2C orders. B2B orders will be handled order by order. This has to be done because the amount of the goods in these orders is too high to pick more than one order simultaneously. The system generates, based on all open B2C orders, a predefined number of batch orders. This step will be done automatically every 5 minutes by the system. The number of predefined batch orders in the system must be selected wisely. If the number of pre calculated batch orders is too high, it is possible that some orders are too long untouched in the system which may not be optimal regarding new incoming orders. On the other hand if the number of pre calculated batch orders is too short, it can be possible that picking persons have to wait until new batch orders are available. The turnover of batch orders needs to be high and should be calculated as often as possible to include also the newest orders which comes to the system.

3.4.2 Seed order

To create a batch order, it is necessary to have a base order, which forms the basis of such a batch order. As stated in Section 2.4.1, there are different approaches available to select a seed order. In the literature, there are many other approaches available. This thesis will consider just the approaches which are relevant for a small or middle sized company

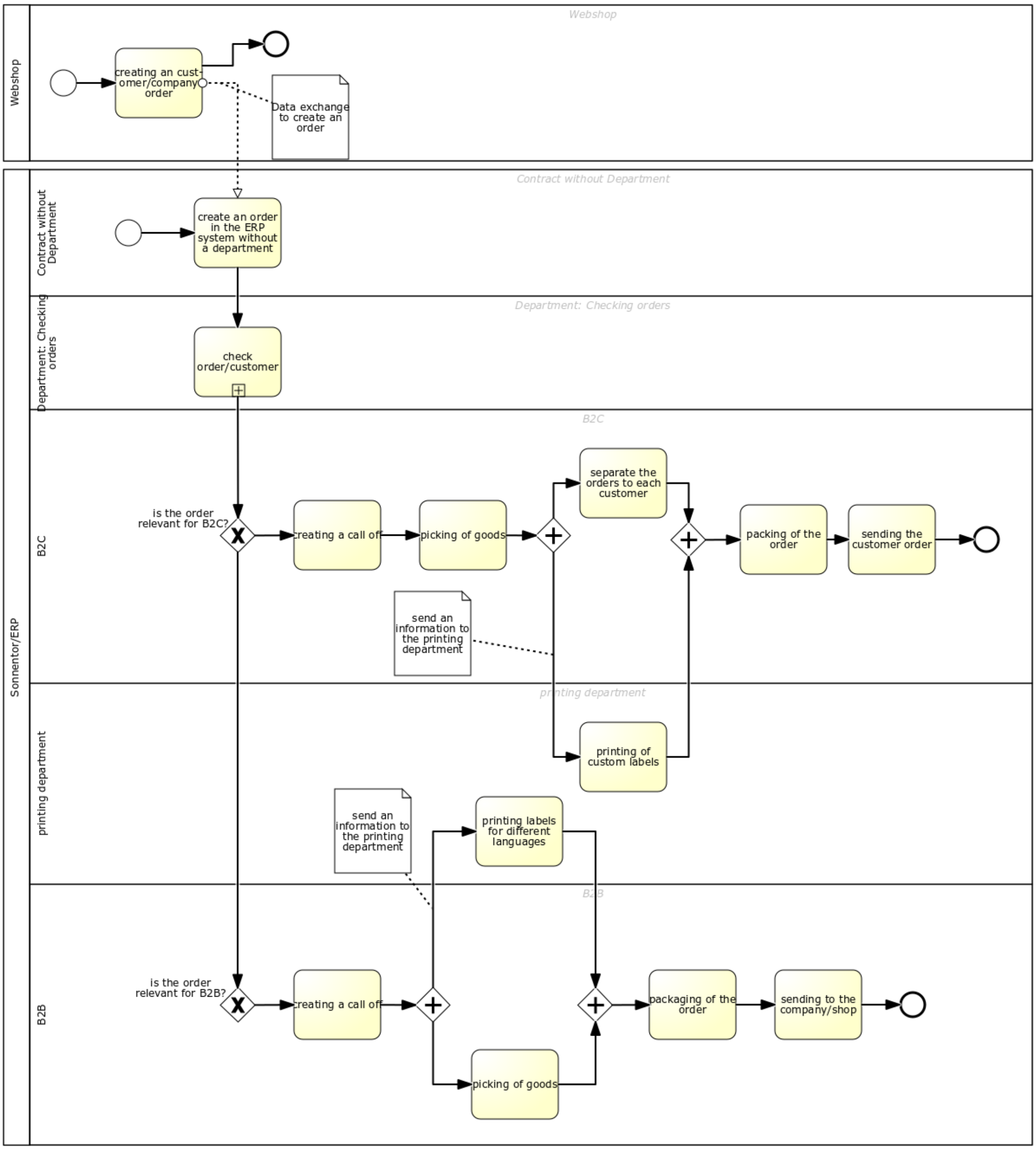


Figure 3.16: The old workflow of an order at Sonnentor

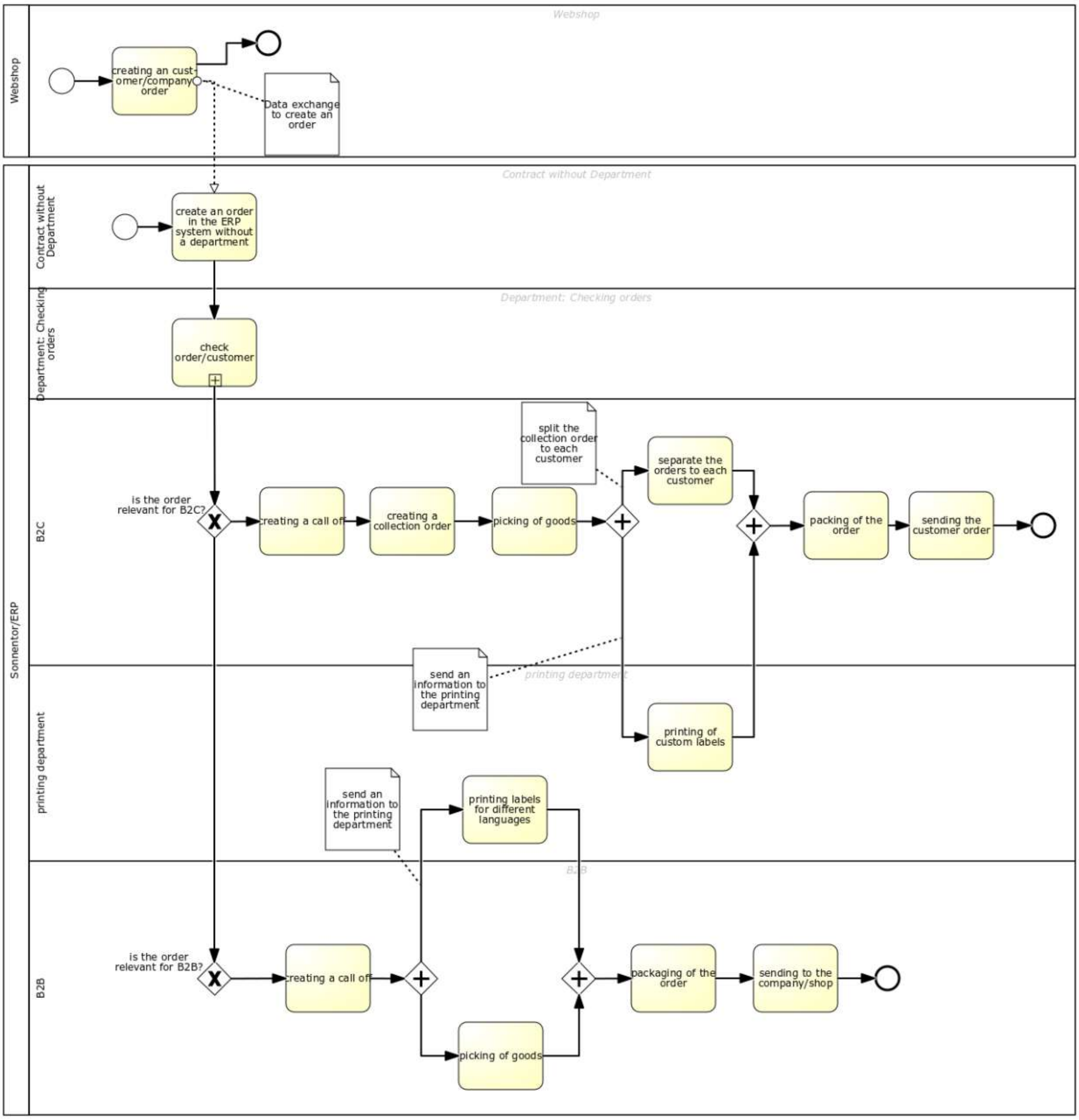


Figure 3.17: BPMN model of the new workflow of an order at Sonnentor

in the food market industry. Other approaches can handle different stock locations of one good. For all of the companies examined, this is not necessary because every good has just one stock location for picking at a time.
The approaches which will be implemented and described in detail are:

- Random Rule
- Smallest/greatest number of picking locations (SNPL/GNPL)
- Smallest/greatest number of picking aisles (SNPA/GNPA)

Random rule

The random rule represents the simplest way to find a suitable seed order. Based on all open selling contracts, one will be selected randomly as a seed order. This is the only approach where the creator of the algorithm can not lead the system to an optimal batch order. At some approaches to find accompanying orders, it can happen that orders with a special composition of goods can stay untouched in the system for a long time. With a suitable approach of the seed order, this can be steered to an optimal way. At the random approach, this can not be applied by the algorithm.
Listing 3.17 shows the random selection of the seed order. Lines 5, 6, 7 and 9 restrict the list of possible seed orders. These lines are responsible for checking whether the investigated order is already within a batch order. Lines 10 to 14 are a criterion of exclusion to select just the right orders based on contract types, departments and dates of validity. Out of this list, in lines 15 to 17, the random selection will be made. In SQL, it is not possible to have a random selection within a function. Therefore, a new view which returns a random number is provided.
This listing returns a seed order in a return table. The return table can be used as a basis for the calculation of the accompanying orders in a later step.

```
1  DECLARE @sid int
2  select top 1 @sid = c.sid
3  from f4mbs.dbo.CoPos cp
4        inner join f4mbs.dbo.Contract c on c.SID=cp.fk_contract_sid
5        left outer join f4mbs.dbo.CoPos cpColl ON
6              cpColl.SID = cp.fk_coposcollection_sid
7              AND cpColl.FK_RecordState_SID = 0
8  where cp.FK_RecordState_SID=0
9          and cpColl.SID IS NULL
10         and cp.FK_CoPosType_SID=2
11         and c.FK_ContractVersion_SID=5005
12         and isnull(c.FK_Department_SID,0)<>5006
13         and c.fk_enqstate_sid = 10
14         and c.validFrom > '2019-01-01'
15         and c.sid = (
16               select sid
17               from f4mbs.dbo.vw_custmb_PickingSeedContract_NewID
```

```
            )
```

Listing 3.17: Selection of a random seed order

Smallest/greatest number of picking locations

Another approach to finding a seed order is selecting the order with the smallest or greatest number of picking locations. Selecting the seed order based on the smallest number of picking locations should not be used for a company with small and light goods. When taking the greatest number approach, it is easier to find similar orders which can be batched. At the smallest number approach, it can happen that the orders with a high amount of different goods will stay untouched in the system because every time a usual order comes in the system, it will match better to the seed order than an unexpected order. Therefore, for a company in the food market industry it is better to select the greatest number of picking locations approach. This approach is shown in Listing 3.18. The structure is the same as in the random approach. Additionally to the random selection, the GNPL approach selects just the order with the greatest number of different stock locations. In the picking warehouse, every article has a separate stock location. Therefore, the SQL statement selects just the maximum number of different articles in the order. This will be done by lines 17 to 31. The sub-select orders the list of open orders descending on the basis of the count of different articles. Line 18 returns the top 1 order because more than one order may have the maximum number of different articles.

```
1  DECLARE @sid int
2
3  select top 1 @sid = c.sid
4  from f4mbs.dbo.CoPos cp
5        inner join f4mbs.dbo.Contract c on c.SID=cp.fk_contract_sid
6        left outer join f4mbs.dbo.CoPos cpColl
7            ON cpColl.SID = cp.fk_coposcollection_sid
8            AND cpColl.FK_RecordState_SID = 0
9  where cp.FK_RecordState_SID=0
10       and cpColl.SID IS NULL
11       and cp.FK_CoPosType_SID=2
12       and c.FK_ContractVersion_SID=5005
13       and isnull(c.FK_Department_SID,0)<>5006
14       and c.fk_enqstate_sid = 10
15       and c.validFrom > '2019-01-01'
16 group by c.sid
17 having count(cp.sid) = (
18       select top 1 count(distinct cp.sid) as MaxNumber
19       from f4mbs.dbo.CoPos cp
20             inner join f4mbs.dbo.Contract c on c.SID=cp.fk_contract_sid
21             left outer join f4mbs.dbo.CoPos cpColl
22                 ON cpColl.SID = cp.fk_coposcollection_sid
23                 AND cpColl.FK_RecordState_SID = 0
24       where cp.FK_RecordState_SID=0
```

```
                and cpColl.SID IS NULL
                and cp.FK_CoPosType_SID=2
                and c.FK_ContractVersion_SID=5005
                and isnull(c.FK_Department_SID,0)<>5006
                and c.fk_enqstate_sid = 10
                and c.validFrom > '2019-01-01'
        group by c.sid
        order by count(cp.sid) desc
)
```

Listing 3.18: Selecting a seed order by the GNPL approach

Smallest/greatest number of picking aisles

Similar to the GNPL approach is the smallest/greatest number of picking aisles functionality. The difference to the GNPL approach is that the number of different aisles is relevant for the calculation. In the literature, the smallest and greatest number of picking aisles are suitable approaches. Listing 3.19 shows the selection of a seed order by the smallest number of picking aisles. The structure of the first 17 lines is similar to the GNPL approach. In lines 18 to 38, the statement selects just these orders with the minimal number of different aisles a picker has to walk through when he has to pick that order. The ranking of the orders based on the different aisles is done in lines 21 and 22. These lines ranks the orders based on the column “flexstockcode2” which is the identifier for the aisles in the database. It is possible to have more than one order with a minimum amount of different aisles. In that case, the system will pick the first one as a seed order.

```
1  DECLARE @sid int
2
3  select top 1 @sid = c.sid
4  from f4mbs.dbo.CoPos cp
5        inner join f4mbs.dbo.Contract c on c.SID=cp.fk_contract_sid
6        inner join f4mbs.dbo.article a on a.sid = cp.FK_Article_SID
7        left outer join f4mbs.dbo.CoPos cpColl
8            ON cpColl.SID = cp.fk_coposcollection_sid
9            AND cpColl.FK_RecordState_SID = 0
10 where cp.FK_RecordState_SID=0
11        and cpColl.SID IS NULL
12        and cp.FK_CoPosType_SID=2
13        and c.FK_ContractVersion_SID=5005
14        and isnull(c.FK_Department_SID,0)<>5006
15        and c.fk_enqstate_sid = 10
16        and c.validFrom > '2019-01-01'
17        and c.sid = (
18            select top 1 x.sid
19            from (
20                select c.sid,
21                        dense_rank() over
22                        (order by count(distinct a.flexstockcode2))
```

```
                        as ranking
                from f4mbs.dbo.CoPos cp
                     inner join f4mbs.dbo.Contract c
                         on c.SID=cp.fk_contract_sid
                     inner join f4mbs.dbo.article a
                         on a.sid = cp.fk_article_sid
                     left outer join f4mbs.dbo.CoPos cpColl
                         ON cpColl.SID = cp.fk_coposcollection_sid
                         AND cpColl.FK_RecordState_SID = 0
                where cp.FK_RecordState_SID=0
                      and cpColl.SID IS NULL
                      and cp.FK_CoPosType_SID=2
                      and c.FK_ContractVersion_SID=5005
                      and isnull(c.FK_Department_SID,0)<>5006
                      and c.fk_enqstate_sid = 10
                      and c.validFrom > '2019-01-01'
                group by c.sid
              ) x
              where  x.ranking = 1
)
```

Listing 3.19: Selecting a seed order by the SNPA approach

The greatest number of picking aisles will be the same statement. Only the “order by” statement would change from ascending to descending. This will rank the maximum number of different aisles to the top.

Oldest order approach

After the first tests with the random, GNPL and SNPA approach, the results were not satisfying enough. The companies examined promised the customers that the goods arrive within three days. With the approaches above, it turned out that it is possible that an older order can stay untouched in the system. Therefore, an order may arrive later than that promised three days at the customer’s address.

The responsible stock managers from Sonnentor and the author of this thesis worked out the oldest order approach. At this approach, the oldest order of the open selling contracts will be chosen as a seed order. This leads on the one hand to a good processing time of the orders and on the other hand, special orders with an unusual amount of goods or unusual goods will also be handled at a point in time and can not be lost.

Listing 3.20 shows the SQL-script, which returns the oldest open order in the system, which is currently not picked. Line 10 checks if there is already an open collection order created for this selling contract. Lines 11 and 12 ensure that just relevant positions will be taken into account for the collection order, which must have a specific status. The last line orders the contracts in an ascending order based on the creation date. This ensures the first-in-first-out principle and returns just the oldest contract. When selecting the first order of this ordered list, which is done in line 3, just one of the oldest orders will be returned as a seed order. It is possible that more than one order is the oldest one. In that case, just the first one will be taken as a seed order.

```
DECLARE @sid int

select top 1 @sid = c.sid
from f4mbs.dbo.CoPos cp
     inner join f4mbs.dbo.Contract c on c.SID=cp.fk_contract_sid
     left outer join f4mbs.dbo.CoPos cpColl
          ON cpColl.SID = cp.fk_coposcollection_sid
          AND cpColl.FK_RecordState_SID = 0
where cp.FK_RecordState_SID=0
      and cpColl.SID IS NULL
      and cp.FK_CoPosType_SID=2
      and c.FK_ContractVersion_SID=5005
      and isnull(c.FK_Department_SID,0)<>5006
      and c.fk_enqstate_sid = 10
      and c.validFrom > '2019-01-01'
      order by c.validfrom;
```

Listing 3.20: Selecting the oldest order as seed order

The disadvantage of this approach is that the selection of the seed order may not be optimal regarding the accompanying orders. However the big advantage is that no order will be sent too late to the customer and no order can be lost.
To create a good batch order, it is necessary to find other orders based on the seed order, which are nearby or similar to each other. The number of orders that should be batched together is a decision by the responsible employees from Sonnentor and the author of this thesis. Five orders will be batched together because an average B2C order has eight articles and has a weight of about 1-kilogram. The limit for the picking persons is not the weight, but the number of goods which must be handled at the picking process and afterwards when splitting the goods to the specific orders. Forty products with an average weight of 5 kilograms are easy to handle and it is possible to keep the overview of all products at the splitting process.
In the following sections, different approaches to find accompanying orders to the seed order will be presented.

3.4.3 Accompanying orders

After selecting a seed order which is the basis of a batch order, other orders have to be selected, which must be picked within a picking process. As stated in Section 2.4.2, there are different approaches to handle this. In [HT06], the authors show that the “SNAPL” or “GNIPL” approaches would be the best approaches to batch orders together. However, for orders with a high variety of different articles, these approaches will not be suitable. These approaches would rank orders better when much of the articles are at the same stock location. This means a seed order with just two different stock locations has a high ranking to order with 20 stock locations where these two are included. The advantage of

the "GPLSR" approach is that the ratio of identical locations to the overall number of articles will be calculated. By calculating the ratio the number of different stock locations in the seed and accompanying order will be taken into account too.
The author of this thesis decided to implement and show the "Greatest picking-locations similarity ratio (GPLSR)" approach, which will be described in detail.

Greatest picking-location similarity ratio (GPLSR)

This approach calculates based on the seed order, which is selected by the oldest order approach, four accompanying orders. The workflow of an article gives the same stock locations. For picking purposes, every article has exactly one stock location in the picking warehouse. Therefore, the different picking locations can be seen as different articles in every order. This approach aims to find the most similar orders together based on the number of different articles of the seed order and the number of same articles of the accompanying order.
This will be done by comparing all articles of the seed order to all articles of the open selling orders in the system. The higher the number of same goods and the higher the equality of the number of articles per order is, the higher the rating will be.

$$pts = \frac{\sum_{A_i=0}^{n} \sum_{B_i=0}^{m} f(A_i, B_i)}{tnpl}$$

$$f(A_i, B_i) = \begin{cases} 1 & A_i = B_i \\ 0 & A_i \neq B_i \end{cases}$$

$$Ai = \text{articles from the seed order}$$
$$Bi = \text{articles from the currently analysed order}$$
$$n = \text{number of articles in order A}$$
$$m = \text{number of articles in order B}$$
$$tnpl = \text{total number of picking locations when order B is added the seed order}$$

Listing 3.21 returns four orders with the highest number of the same articles based on the base order. The statement is structured as a recursive function. In SQL, this is done with the "with" table expression. This expression is split into two parts. The first part selects the whole list of possible orders, which can be batched to the seed order. This part is implemented in lines 1 to 17 of the Listing 3.21. The second part calculates, based on the seed order and the list from the first part, the four best fitting orders. This is done from lines 19 to 40. Line 33 and 35 take the seed order, which is stored at the parameter "@sid". In line 35, the list of possible orders is joined to the seed order. The calculation, which order fits best to the seed order, is done in lines 28 to 31. These lines calculate the ratio of the number of same stock locations to the number of articles in the seed order. The result is a value that defines the percentage of identical articles, which is

returned in column “pts”. All point ratings in column “pts” are ordered from highest to lowest. Line 22 returns the top four orders of this list.
When the article identifier is the same in the seed order and the investigated order, the article and stock locations are identical.

```
1  with myCTE AS (
2  select c.SID as SID,
3          cp.FK_Article_SID as FK_article_SID,
4          Count(cp.SID) over (partition by cp.FK_Contract_SID) as cnt
5  from f4mbs.dbo.CoPos cp
6          inner join f4mbs.dbo.Contract c on c.SID=cp.fk_contract_sid
7          left outer join f4mbs.dbo.CoPos cpColl
8              ON cpColl.SID = cp.fk_coposcollection_sid
9                  AND cpColl.FK_RecordState_SID = 0
10 where cp.FK_RecordState_SID=0
11         and cpColl.SID IS NULL
12         and cp.FK_CoPosType_SID=2
13         and c.FK_ContractVersion_SID=5005
14         and isnull(c.FK_Department_SID,0)<>5006
15         and c.fk_enqstate_sid = 10
16         and c.validFrom > '2019-01-01'
17 )
18
19 INSERT INTO @rtnTable (sid, equals, pts)
20 select B_SID, max(equals) as equals, MAX(pts) as pts
21 from (
22     select top 4
23             b.sid AS B_SID,
24             sum(case
25                     when A.FK_Article_SID = B.FK_Article_SID
26                     then 1 else 0
27                 end) as equals,
28             100*sum(case
29                         when A.FK_Article_SID = B.FK_Article_SID
30                         then 1 else 0
31                     end)/A.cnt  as pts
32             , cast(b.SchedFinishDate as date) as SchedFinishDate
33     from myCTE A
34         full outer join myCTE B ON B.SID <> A.sid
35     where A.SID in (@sid)
36             and b.SchedFinishDate<GETDATE()
37     group by A.sid, B.sid, A.cnt, b.SchedFinishDate
38     order by pts desc
39 ) x
40 group by B_SID
```

Listing 3.21: Selecting accompanying orders by the GPLSR approach

The limitation of this approach is that the grouped orders may always be one of the newest ones. This leads to many orders in the system which will get older and older.

Thus the customers may get the goods too late. Therefore, the approach will be extended, which is described in the following section.

Priority of older orders

To improve the "GPLSR" approach, it is necessary to change the disadvantages. The biggest disadvantage of the first approach is that older orders need to be more important than newer orders, since it is necessary to have a short processing time for every order. This can be done by extending the "GPLSR" approach by a rating. The system calculates a rating out of the open orders and sorts it in descending order. Every day an order is not picked and sent to the customer, the rating will be increased by a factor of 100. The system takes the oldest order as the seed order and takes the other four orders based on the rating. The base functionality of sum up the number of same articles stays the same. The height of the factor which has an impact on the rating is important. On the one hand, a factor too high leads to the fact that only old orders will be batched together when they do not fit the seed order, and on the other hand, a factor too low can lead to batching only the newest orders together.
The formula to calculate the pts value is extended by the difference to the current date.

$$pts = \frac{\sum_{A_i=0}^{n} \sum_{B_i=0}^{m} f(A_i, B_i) + \frac{DIFD \cdot 100}{n}}{tnpl}$$

$$f(A_i, B_i) = \begin{cases} 1 & A_i = B_i \\ 0 & A_i \neq B_i \end{cases}$$

$$DIFD = \text{difference of days from the current date to the date of the order}$$
$$Ai = \text{articles from the seed order}$$
$$Bi = \text{articles from the currently analysed order}$$
$$n = \text{number of articles in order A}$$
$$n = \text{number of articles in order B}$$
$$tnpl = \text{total number of picking locations when order B is added the seed order}$$

To adapt the difference of days, line 37 of Listing 3.22 is added. This line calculates the difference between the current date to the date of the order. The difference in days will be multiplied by the factor 100. Also, lines 3 to 11 were added, which return the order date to the second part. This date is used to calculate the difference of days. All other lines stay the same. This ensures that an older order is ranked higher automatically. At this approach, a better fitting order can be ranked lower than an older order. The big advantage of this approach is that the orders arrives faster at the customer than in the usual approach.

```
1 with myCTE AS (
2 select c.SID as SID,
```

```
        case
          when ISNUMERIC(left(SchedFinishTime,2))=1
                and ISNUMERIC(right(left(SchedFinishTime,5),2))=1
                and c.SchedFinishDate is not null
          then dateadd(MINUTE, cast(right(
                left(SchedFinishTime,5),2) as int)
                ,DATEADD(HOUR, cast(left(SchedFinishTime,2) as int),
                cast(cast(SchedFinishDate as date) as datetime)))
          else isnull(SchedFinishDate, c.validFrom)
        end as SchedFinishDate,
        cp.FK_Article_SID as FK_article_SID,
        Count(cp.SID) over (partition by cp.FK_Contract_SID) as cnt
from f4mbs.dbo.CoPos cp
        inner join f4mbs.dbo.Contract c on c.SID=cp.fk_contract_sid
        left outer join f4mbs.dbo.CoPos cpColl
            ON cpColl.SID = cp.fk_coposcollection_sid
            AND cpColl.FK_RecordState_SID = 0
where cp.FK_RecordState_SID=0
        and cpColl.SID IS NULL
        and cp.FK_CoPosType_SID=2
        and c.FK_ContractVersion_SID=5005
        and isnull(c.FK_Department_SID,0)<>5006
        and c.fk_enqstate_sid = 10
        and c.validFrom > '2019-01-01'
)

INSERT INTO @rtnTable (sid, equals, pts)
select B_SID, max(equals) as equals, MAX(pts) as pts
from (
    select top 4
            b.sid AS B_SID,
            sum(case
                    when A.FK_Article_SID = B.FK_Article_SID
                    then 1 else 0
                end) as equals,
            (DATEDIFF(dd,b.SchedFinishDate,getdate())*100)+
            100*sum(case
                        when A.FK_Article_SID = B.FK_Article_SID
                        then 1 else 0
                    end)/A.cnt  as pts
            , cast(b.SchedFinishDate as date) as SchedFinishDate
    from myCTE A
          full outer join myCTE B ON B.SID <> A.sid
    where A.SID in (@sid)
          and b.SchedFinishDate<GETDATE()
    group by A.sid, B.sid, A.cnt, b.SchedFinishDate
    order by pts desc
) x
```

```
group by B_SID
```

Listing 3.22: Selecting accompanying orders by the GPLSR approach and prior older orders

After creating a batch order, it is necessary to think about the fastest way through the stock for the picking person. This leads to a more optimized picking workflow. The different approaches to walk through the stock will be described in the following section.

3.4.4 Shortest ways among articles

To find an optimized way through the stock means that every picking person walks just those distances that he/she needs to walk. The sequence of stock locations can be provided by the system and leads the picker through the stock in an optimal way.
There are many different ways to create an optimized way through the stock, which are stated in Section 2.6. Nevertheless, not only the approach how to walk through the stock is important. Also, the structure of the stock and company policies have an impact on the approach. This information will be handled in Section 2.5. If there are aisles that are reserved for walking personnel only or the different aisles have a specified direction the approach is another one than a stock, where every aisle has just one entrance and exit. All companies investigated stated that there is no restriction which persons or machines are allowed in a specific aisle. Also, there is no direction given and the aisles are open to both sides. The picking and fill-up persons are allowed to use every aisle in every direction.
To achieve the different ways through the stock, it is necessary to train the employees on the one hand where they have to walk and on the other hand to adapt the stock management system.

S-shape strategy

For the “S-shape” strategy, a new picking order number is implemented. This new numbering of the stock locations guides the employee through the stock. The employee himself/herself needs to know whether or not to skip aisles. A stock management system shows the employee the next stock location.
For this strategy, the stock location will be ordered in the way the picker needs to walk. The new number does not take the level of stock location into account. In the picking warehouse for B2C customers, all goods must be stored in levels a picking person can reach without any mechanical support. The fill-up approaches ensure this. The numbering is shown in Figure 3.18.

The allocation of the numbers was done by the responsible persons from Sonnentor together with the author of this thesis. This needs to be done once to create a useful way through the stock. After that, the numbers were allocated to the stock locations by creating a rank over the order number to fill up the positions. The difference to this order number is that it must be independent of the level of the stock location. In the

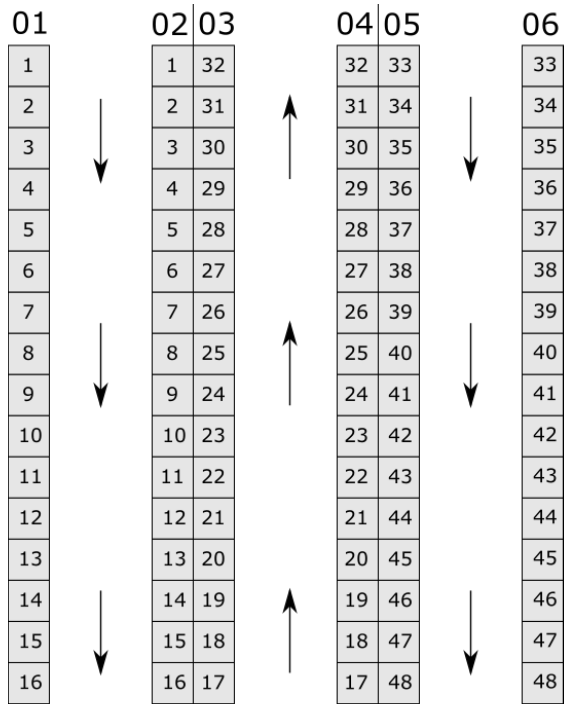


Figure 3.18: Allocation of order numbers for the S-Shape strategy

picking warehouse for B2C customers, only the first few levels are reachable for a person without any mechanical assistance. This is already differentiated by the fill-up action. Listing 3.23 shows the allocation of the new order number for the "S-Shape strategy". Lines 5 to 20 select just the necessary stock locations which are used by the B2C picking action. In line 6 a grouping information is created to delete the level of the stock location, which is given by the last letter. Line 2 and 3 return a number ordered by the order number of the fill-up process. This listing returns a list from 1 to the number of stock locations in the picking warehouse.

```
1  select s.sid
2          , dense_rank() over
3                  (order by x.minimumOrderNumberInventory) as myRanking
4  from (
5          select distinct
6                  left(s.aname, len(s.aname) - 1) as StoreLocation
7                  , min(s.orderNumberInventory)
8                    as minimumOrderNumberInventory
9          from transpos tp
10             inner join trans t
11                 on t.sid = tp.fk_trans_sid
12                 and tp.FK_RecordState_SID = 0
13                 and t.FK_Action_SID = 5025
14             inner join store s
```

```
                    on s.sid = tp.FK_Store_SID
                    and s.FK_RecordState_SID = 0
                inner join storegrp sg
                    on sg.sid = s.FK_StoreGrp_SID
                    and sg.FK_RecordState_SID = 0
        where tp.FK_RecordState_SID = 0
        group by s.aname
) x
inner join store s
    on left(s.aname, len(s.aname) - 1) = x.StoreLocation
```

Listing 3.23: Allocating the order numbers for the s-shape strategy

After the new order numbers are allocated, each picking process can guide the picking person through the stock based on this number. Listing 3.24 returns an ordered list based on the new order numbers. The system gets this list for the currently investigated contract and shows this ordering on the scanner of the picking persons.

```
select c.sid, tmp.myRanking
from contract c
     inner join copos cp
        on cp.fk_contract_sid = c.sid and cp.FK_RecordState_SID = 0
     inner join article a
        on a.sid = cp.FK_Article_SID
     inner join store s
        on s.aname = a.flexStockCode1 + '-'
        + a.flexStockCode2 + '-' + a.flexStockCode3
     inner join Store_OrderingPicking tmp
        on tmp.sid = s.sid
where c.fk_contractversion_sid = ##contract_sid##
       and c.FK_RecordState_SID = 0
order by tmp.myRanking
```

Listing 3.24: Ordered list of the orders based on the order numbers for the s-shape strategy

Return methods

The return methods will not be described in detail because this approach is just for companies with an aisle with one entrance/exit available. No company interviewed has a structure like this. Moreover, this warehouse design is very rare because of the high accident probability at high access frequencies to the stock locations. The aisles also have to be wide to drive easily and safely with a stacker.

Mid-point heuristic

For the "mid-point" heuristic, another order number approach is necessary. An invisible line in the middle of each aisle will be implemented. The picking persons are not allowed to cross this line. Figure 3.19 shows the approach to allocate the new order numbers to the stock locations. The picking person starts with the upper half of the stock, where the numbers are starting from 1 to 16. When all articles are picked in the upper half, he/she will change to the other side. In the last aisle where the picker changes the sides, he/she can pick the goods from all stock locations in this aisle. Therefore, the numbering is continuous in the last aisle. The order numbers in the lower half are from 33 to 48 in this example. At this implementation, the order numbers will be ordered from lowest to highest, so every picking person will start at the upper half and end in the lower half of the stock where he/she starts to pick the goods.

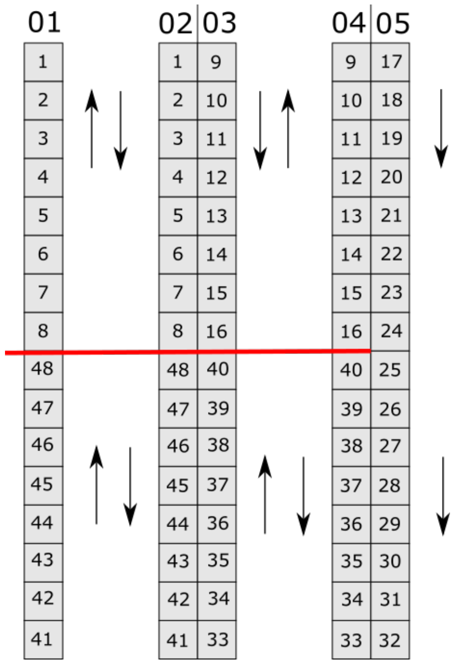


Figure 3.19: Allocation of order numbers for the “mid-point” heuristic

In Listing 3.25, the allocation of the order numbers for the “mid-point” heuristic will be shown. There are several steps to achieve this. The basis of this statement is the order number from the “S-shape” strategy. Only the stock locations from the picking warehouse will be selected. This is done in lines 48 to 65. Every aisle will be split into the first half and the second half. To achieve this, the mid-point of every aisle will be calculated by lines 22 to 31. In lines 11 to 14, every stock location gets the classification in the first or the second half of the aisle. Lines 2 to 6 allocate the numbers to the stock locations by ordering the first half ascending and the second half descending. The numbering starts with one and ends with the number of stock locations in the picking warehouse.

```
1 select y.StoreLocation
2        , y.numbering
3        , y.minordernumberinventory
```

```sql
        , y.half
        , dense_rank() over (partition by y.half
        order by case when y.half = 'first half'
                    then y.minordernumberinventory end asc ,
                  case when y.half = 'second half'
                    then y.minordernumberinventory end desc)
                  as ranking
from (
   select x.StoreLocation
            , x.numbering
            , x.minordernumberinventory
            , case
               when x.numbering <= x.AverageStoragePerAisle
               then 'first half'
               else 'second half'
             end as half
   from (
      select distinct left(s.aname, len(s.aname) - 1)
               as StoreLocation
             , cast(right(left(s.aname, len(s.aname) - 1), 3)
               as integer)
                 as numbering
             , min(s.ordernumberinventory)
                 as minordernumberinventory
             , (
                select avg(cast(left(st.ashortname, 3) as int))
                          as averageStores
                from store st
                     inner join storegrp stg
                         on stg.sid = st.FK_StoreGrp_SID
                         and stg.FK_RecordState_SID = 0
                where st.aname like concat(left(st.aname, 3), '%')
                        and st.FK_RecordState_SID = 0
                        and stg.aname = sg.aname
                        and isnumeric(left(st.ashortname, 3)) = 1
                group by stg.aname
                             ) as AverageStoragePerAisle
      from transpos tp
           inner join trans t
                on t.sid = tp.fk_trans_sid
                and tp.FK_RecordState_SID = 0
                and t.FK_Action_SID = 5025
           inner join store s
                on s.sid = tp.FK_Store_SID
                and s.FK_RecordState_SID = 0
           inner join storegrp sg
                on sg.sid = s.FK_StoreGrp_SID
                and sg.FK_RecordState_SID = 0
      where tp.FK_RecordState_SID = 0
```

```
    group by left(s.aname, len(s.aname) - 1), sg.aname
    ) x
    where x.StoreLocation in
        ( select distinct left(s.aname, len(s.aname) - 1)
          from (
            select distinct
                   left(s.aname, len(s.aname) - 1)
                   as StoreLocation
            from transpos tp
                 inner join trans t
                     on t.sid = tp.fk_trans_sid
                     and tp.FK_RecordState_SID = 0
                     and t.FK_Action_SID = 5025
                 inner join store s
                     on s.sid = tp.FK_Store_SID
                     and s.FK_RecordState_SID = 0
                 inner join storegrp sg
                     on sg.sid = s.FK_StoreGrp_SID
                     and sg.FK_RecordState_SID = 0
          where tp.FK_RecordState_SID = 0 and tp.source = 1
          group by s.aname
          ) x
        inner join store s
            on left(s.aname, len(s.aname) - 1) = x.StoreLocation
        where isnumeric(left(s.aShortName, 3)) = 1
        )
) y
```

Listing 3.25: Allocating the order numbers to the stock location for the “mid-point” heuristic

Same as in the “S-shape” strategy, the system gets an ordered list based on the order numbers, which are defined for the “mid-point” heuristic. The scanner of the picking person gets this list and guides the picking person through the stock. This is shown in Listing 3.24.

CHAPTER 4

Evaluation

This chapter, on the one hand, gives an overview of the important parameters which are evaluated at the qualitative analysis by interviewing the responsible stock managers from the companies Sonnentor, Kiennast and Kastner and, on the other hand, the optimization potential of the fill-up and picking process. These both parts are the most time-consuming processes of a stock management system. The result will be shown in detail. The optimization potential reflects all parts of the implementation. I will analyse all steps to create a stock management system in an optimal manner.

4.1 Important parameters for fill-up and picking processes

There are some important parameters of companies in the food market industry that are different to other industries. These parameters are necessary for a fill-up and picking processes. Some of these parameters are not only for the food market industry and can also be taken for other industries. Most of the parameters are fixed and will not change too often. Therefore, the stock management can expect that as fixed for the different processes. During the interviews and implementation, the following parameters are identified:

Numbering of the stock locations

One of the most important things is the numbering of the stock locations. Based on that order number, the stock management guide the picking persons through the stock. For every different way strategy, there is another order number approach implemented at the stock management system. This order of stock locations also defines the priority of a stock location. If the order number of the stock location is low, the stock location is closer to the packing tables than a stock location with a higher order number.

Cluster of the stock locations

Every stock location needs to also have a cluster. This is needed for the ABC, XYZ or the combined ABC-XYZ fill-up approach. At the ABC and XYZ approach, the cluster has just one letter. At the combined approach, the cluster of the stock location must have two letters. The classification of the stock location also defines the priority of a stock location to the company. Compared to the order number, this priority has fixed thresholds where one cluster ends and the next begins.

Availability of an external warehouse

This information is needed when implementing the order numbers of the stock locations. When there is an external warehouse available, the order numbers must manage these "costs" to bring goods from one warehouse to another. When implementing the prototype, the number between the different warehouses will differentiate by 10^6. Nevertheless, not only this order number is essential for the most needed article. Also, the expiration date has an impact on that. If the expiration date is lower than the batches in the main stock, this batch will appear for the fill-up process. The fill-up person does not drive to the other warehouse but will inform the stock manager to plan the truck. This good will be locked for the upcoming fill-up processes.

Working time

The working time is only needed to lower the burden of the servers. When nobody is working, the pre-calculation of some steps is not needed. On the other side, when all people are working, the system has to provide enough batch orders for all picking persons.

Investigated time period into past

This is a decision that needs to be made by the responsible stock managers. At the implementation of the prototype, it turned out that the orders of the past year should be taken into account. Based on that data, the seasonal fluctuations can be minimized. This data can be used for the fill-up approach to calculate the priority of and forecast for the different articles. If the main part of the customers is B2C clients, the variation of the orders will be by month and not by days or weeks. Therefore, a time horizon starting with one month for forecasting is needed to include all fluctuations into the calculations.

Way strategy

When optimizing the ways of picking persons, it is necessary to provide the wanted way strategy to the system. This is needed to take the right order numbers into account when having different strategies implemented.

Partition of the stock

The partition of the stock means that some companies in the food market industry differentiate between the main warehouse and the warehouse for picking purposes only. This part of the warehouse is just available for B2C customers' orders and holds just the stock for one or two days. At Sonnentor, this part of the warehouse has a separate description.

Type of the racking system

When filling up or picking goods from a stock location, there is a difference in the racking system. At a pallet rack, the fill-up and picking persons access the stock location from the same side. A flow rack will be filled on the backside and picked from the front. The order numbers must handle this circumstance for the different processes.

Amounts per stock location

Different amounts per stock location have an impact on the calculation of the most needed article to fill up. The maximum amount of a stock location defines the maximum amount of an article that can be held at this stock location. This number is fixed and can not be changed without any remodelling of the racks. The minimum amount is a threshold that defines when the good must be filled up. At the implementation, the difference between the actual amount and the minimum amount is also taken into account to create a ranking of the needed articles. The actual stock amount is also important. These parameters must be provided by the system and show the number of actually stored articles in that stock location.

Status of the stock location

The status of the stock location is for companies in the food market industry. It can happen that a batch does not reach the quality standards or have unhealthy ingredients. Therefore, the stock location must be quarantined or locked. No person can pick or fill up on this stock location until the quality department unlocks this batch or stock location. The status defines if this stock location is only for locked batches or not.

Article in quarantine

If a quarantined article is allowed on all stock locations, the information is essential for the processes if a batch is locked. If the quality department finds some abnormalities in the articles, it will lock the batch. No person is allowed to pick or send the goods to the customers.

Expiration date

One of the most important parameters is the expiration date of the batch. This differentiates from other industries because this parameter can cause problems when not taken into account. The expiration date is relevant for all processes in the company.

Packing units

The different articles can be packed in different packing units. At Sonnentor, the main packing units are 1, 6 and 41 pieces per unit, but special goods can also have other packing units. This information is needed when calculating the number of filled-up articles per stock location of which article packages must be picked for a specific customer order.

Language

Every article of the companies examined is available in different languages. The workflow how to handle this circumstance is different within the companies. One possibility to handle this is to have a separate stock location. The other one is to store unlabelled articles and label them when the order arrives. For both workflows, the stock management system must know where to get an article for the specific language.

Actual open orders

When calculating a forecasting demand or the priority of an article, the stock management system has to know the open orders which are already in the system. These are B2C orders which have a smaller amount of articles and must be sent as fast as possible, and B2B orders which can be planned a month or a year in advance.

Growing rates

For the forecasting functionality, it is needed to define growth rates. These growth rates will be taken into account when calculating the demand for the upcoming periods. Growing rates can be defined for articles, product groups, partners, partner groups or partners for a specific product. As fall back, every article should have a predefined standard growing rate, which will be considered when no specific growth rate is defined.

Clustering method

To fill-up the right articles into the right stock location, the stock management system must know, which clustering method will be used. This can be different from company to company. The clustering method is needed for creating the right clusters through the stock.

Status of the picking process

It may be possible that a picking process can not be finished. This can happen when the article is not available at the stock location, which it should be. When a picking person accidentally picks a higher amount than needed for one order, a difference between the amount of the stock management system and the real stock amount can occur.

These parameters are important factors for implementing a semi-autonomous stock management system. The optimization potential of such processes will be shown in the next steps of this thesis.

4.2 Fill-up process

To reach the goal of an optimized fill-up action, it is necessary to classify all stock locations into specific classes. Therefore, every stock location will get a specific classification presented in the specific clustering approach. Over 2,500 stock locations of the main stock of Sonnentor are classified in this step. There are more stock locations available at Sonnentor, but the classification should be done separately in every stock unit. A stock unit can be the part of the warehouse that holds the greige goods or where all commercial articles will be stored. At Sonnentor, this type of stock is different. At companies without differentiation between commercial articles and greige goods, the partitioning of the warehouse will be done by defining different zones with different temperature levels. This is also the workflow, how the goods will enter the company. Different articles will also be delivered by trucks with different temperature levels. No supplier or farmer will bring different types of goods to the company.
The frequency of the calculation is also important and influences the results. There are approaches to create the classification just once per predefined period. This time period may not be too long. A too long time period leads to non-useful data. The author of this thesis designed the calculation of the classification in a way that every fill-up action will calculate the classification new. This leads to data in real-time and will provide the best possible data for filling up. When the fill-up actions and the sales data increase, the data should be pre-calculated. This can be done once a day.

4.2.1 ABC-analysis

The ABC cluster analysis shows if an article is significant or insignificant to the company. This will be done by defining a classification A, B or C for every article. The significant articles get the A and an insignificant article has the rating of C. Based on the demand of previous periods, it is possible to create this classification. It is important which time period will be taken into account for the calculation of the classification. A time period too short leads to a less useful classification. The seasonal fluctuation will not be taken into account when evaluating the last month. A time period too long is also not useful because the article will be abandoned over time. If the time period of the last ten years will be taken into account to classify the articles, most of the articles will not have a rating because most of the articles have only been active for a few years. Therefore, the time period of one year will be taken into account. This ensures the correct handling of seasonal fluctuations of specific articles and that most of the articles will get a useful rating over time.

For the ABC analysis, the stock location will split into three parts. The classification was done by the responsible stock manager of Sonnentor and the author of this thesis. By having a plan of the whole stock, every stock location or whole corridor was specified into one of the three classes. This leads to the distribution of stock locations through the different classes, which are shown in Figure 4.1. The specific partitions of the whole stock will be shown graphically in Figure 3.14.

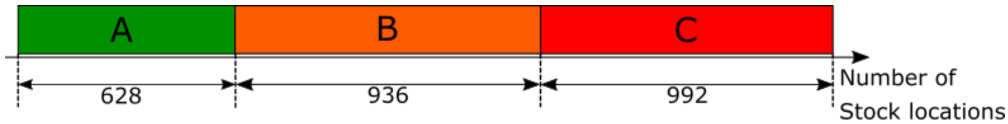


Figure 4.1: Distribution of Stock locations through the classification A, B and C

Based on the previous year's demand for every article, the author was able to classify the articles into A, B and C articles. Therefore, the demand for every article will be sorted in descending order and will split into three same-sized partitions. Thus, it is no surprise to get the distribution of the articles through the classifications that have the same size. Figure 4.2 shows, on the one hand, how many articles are available in every class and, on the other hand, the thresholds for reaching the next higher class. To get a A rating, the article must be sold over 1,117 times in one year. This figure is also interesting to compare the demands of the articles in the different classes. The article with the highest demand is sold over 116,000 times per year. On the other end of the A scale, it is also possible to get an A rating, just with 1,117 sales per year.

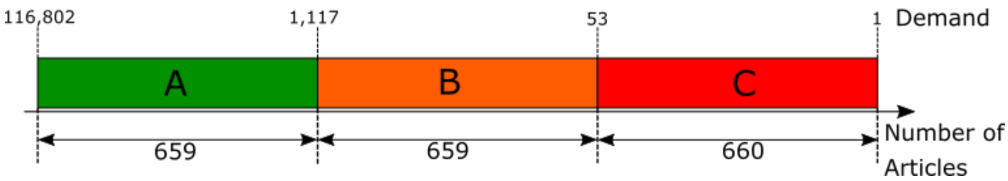


Figure 4.2: Distribution of Articles through the classification A, B and C

The figures above show that there are more articles in class A than stock locations available. This can happen all the time. A functionality must ensure that an A article that has no stock location within class A must be stored in the next class B and a B article must be stored in C if there is no suitable stock location available. The goal should be that there is enough free stock location available in every group at any point in time. This can be done by extending the stock.
Based on the data above it is possible to show the significance of an A article for Sonnentor. 94.4 percent of the articles which will be sold have the classification A, 5.4 percent have the classification B and only 0.2 percent of the articles have a C rating. This data will be shown in Table 4.1 and is based on the sales amount of commercial articles for the last year.

Another statistic can be done with the invoicing data of these articles. Based on the total turnover with this articles, it is possible to calculate the ratio of the classes based

Class	Percentage
A	94.4%
B	5.4%
C	0.2%

Table 4.1: Distribution of articles based on the classification based on overall sales of commercial articles

Class	Percentage
A	82.8%
B	9.2%
C	8.0%

Table 4.2: Distribution of articles based on the classification based on total turnover of commercial articles

on the total turnover. Table 4.2 shows that over 80 percent of the total turnover will be achieved with articles within class A, 9.2 percent with B articles and articles within class C will generate 8 percent of the total turnover.

4.2.2 XYZ-analysis

Another classification method is the XYZ analysis. The difference to the ABC approach is that the XYZ analysis shows the predictability of an article. An X article has high reliability, whereas a Y article has a moderate and a Z article has a low prediction accuracy for the upcoming time. This means that an article with a steady course based on the sales amount during a predefined time period will be ranked as X article and an article with a high seasonal fluctuation will be ranked as Z article. Articles without any sales or where the forecasting can not be calculated will be ranked as Z automatically. The XYZ analysis will be influenced, on the one hand, by the demand of previous periods and, on the other hand, the forecasting demand. The forecasting demand for every article includes the demand of previous periods, the open selling contracts in the system, the predicted growth rates for a specific customer and a predicted growth rate for a specific article.
Also, at the XYZ analysis, the time period has a big impact on the data. Same as in the ABC analysis, a time period too short can lead to seasonally unadjusted data. As an example the advent calendar can be provided, which is only sold in November and December. When having a look at the XYZ rating in January within a time period of one month, the advent calendar will appear as a X article. But in January, the advent calendars will not be sold any more. When taking a whole year into account, the calculation will be based on the selling data of one whole year and this will smooth the seasonal fluctuation. Therefore, one year will be taken into account when calculating an XYZ analysis for an article.
Same as in the ABC analysis, the stock location were classified as XYZ places by the

responsible persons from Sonnentor together with the author of this thesis. This leads to the distribution, which is shown in Figure 4.3.

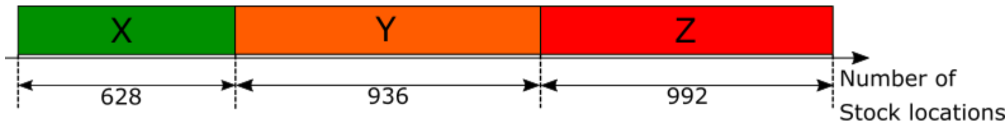


Figure 4.3: Distribution of Stock locations through the classification X, Y and Z

Different from the ABC approach, fixed thresholds will split the data into three parts. The calculation based on the previous demand and forecasting amount will be done for every month for every article of the last year. Based on this list, the standard deviation of every article will be calculated. If the standard deviation is between 0 and 25, the article is ranked as a X article, between 25 and 50 the article will be ranked as Y and over 50 the article will be classified as a Z article. Figure 4.4 shows how many article will be classified in which specific partition and which standard deviation an article needs to get in a specific class.

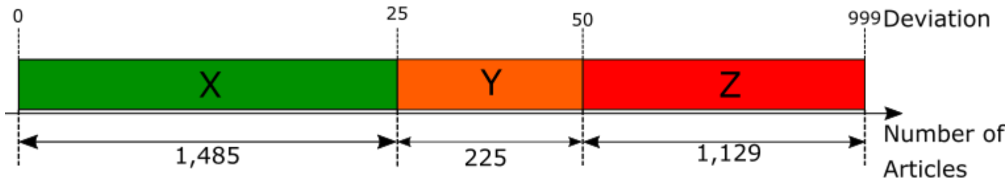


Figure 4.4: Distribution of Articles through the classification X, Y and Z

Same as in the ABC cluster analysis, there are more articles in the classes X and Z than there are stock locations. There are four ways to fix that:

1. Extending the stock and provide more stock locations for all classes.
2. Shift the fixed thresholds to other values to ensure that there are enough stock locations available. This does not ensure that this situation does not happen again.
3. Reduce the number of articles that will be sold over one year.
4. New articles should not be classified as Z articles and store them based on the chaos principle if there is no experience available.

Figure 4.5 shows the ratio of articles in a specific class. This leads to the questions, why the Y classification takes just a small part of the whole articles and how this can be changed. Removing all new articles will lead to the data given in Figure 4.6.

This shows that the ratio of Y and Z articles will be approximately the same, but the X articles will increase because the number of articles will decrease, and the number of X

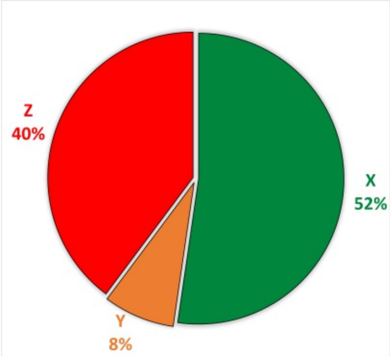


Figure 4.5: Distribution of Articles through the classification X, Y and Z

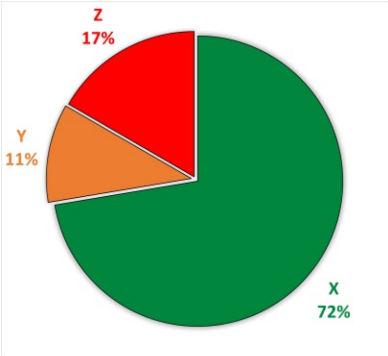


Figure 4.6: Distribution of Articles through the classification X, Y and Z without new articles

articles stays the same. As seen in the data, it is no reasonable approach to remove the new articles.

Another way is to shift the thresholds of the standard deviation. When all articles with a standard deviation between 0 and 3 will be classified as X, between 3 and 50 are ranked as Y and over 50 the article will be rated as an Z article, the distribution looks balanced. In this approach, the new articles will be classified as Z articles to lose no data. The data shows that there are many articles with nearly no deviation from the average. This means that most articles are not affected by seasonal fluctuations and are consequently more reliable for future calculations. Figure 4.7 shows the data with the shifted thresholds, followed by Figure 4.8, which shows the number of articles in the different classifications.

To get an overview how the selling amounts of an X, Y and Z article look like, Figures 4.9, 4.10 and 4.11 show the deviation of an article over a year in the different classes. The X-axis shows the months and the Y-axis the selling amount in the specific month. In each class are three articles shown for the specific classification as representatives.

The calculation of the different classes X, Y and Z is based upon the data of previous

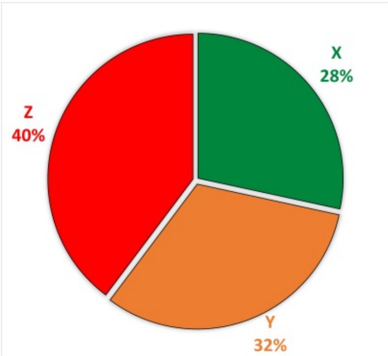


Figure 4.7: Distribution of Articles through the classification X, Y and Z with shifted thresholds

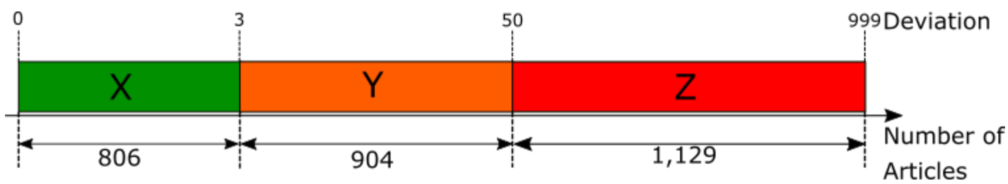


Figure 4.8: Ratio of Articles through the classification X, Y and Z with shifted thresholds

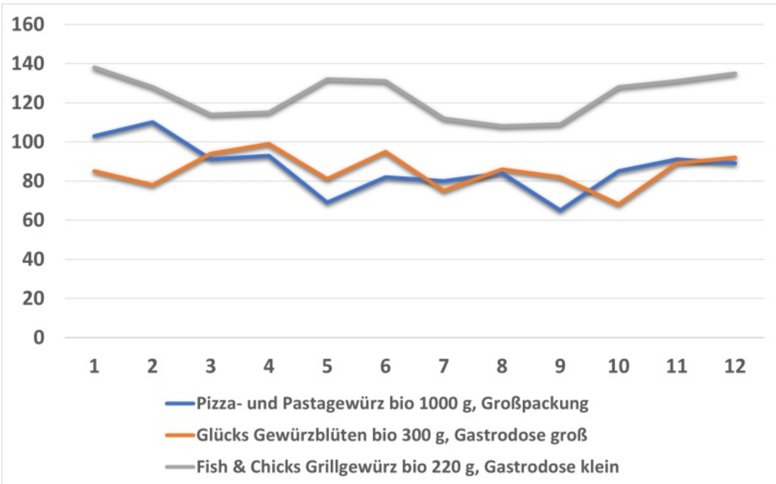


Figure 4.9: Deviation over the year in class X

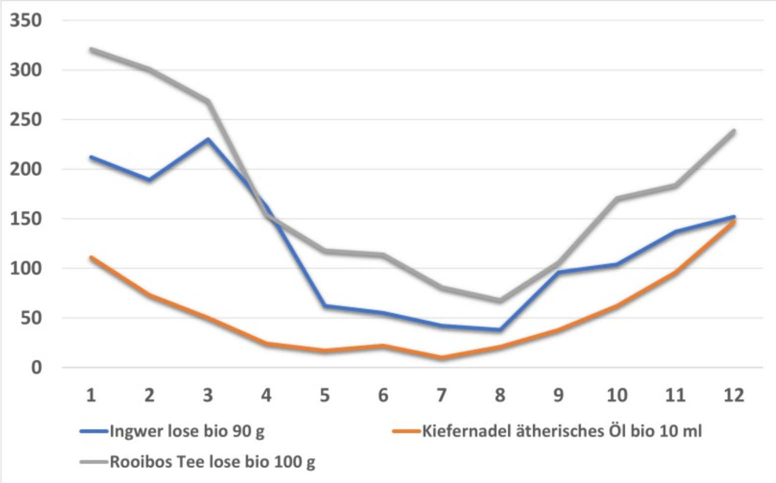


Figure 4.10: Deviation over the year in class Y

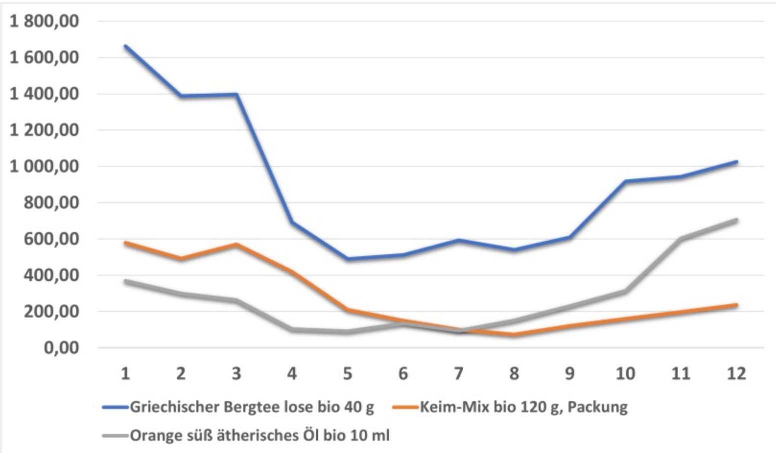


Figure 4.11: Deviation over the year in class Z

periods and the forecasting amount per article per partner. When comparing the forecasting amount and the real sales orders of the system over a time period of half a year (August 2020 until February 2021), the average difference is between -1.1 percent and +11.3 percent for the 20 most sold articles in this time. This time period is chosen because the winter months are the peak season at Sonnentor. The average difference is shown in Figure 4.12. This data can be used to improve the forecasting of every article and partner. Therefore, it is possible to go into detail about which partner is responsible for this imprecision and will reduce the growth rate in the future. Good forecasting is necessary to optimize stock management. The better this forecasting method is, the better the stock capacity can be planned.

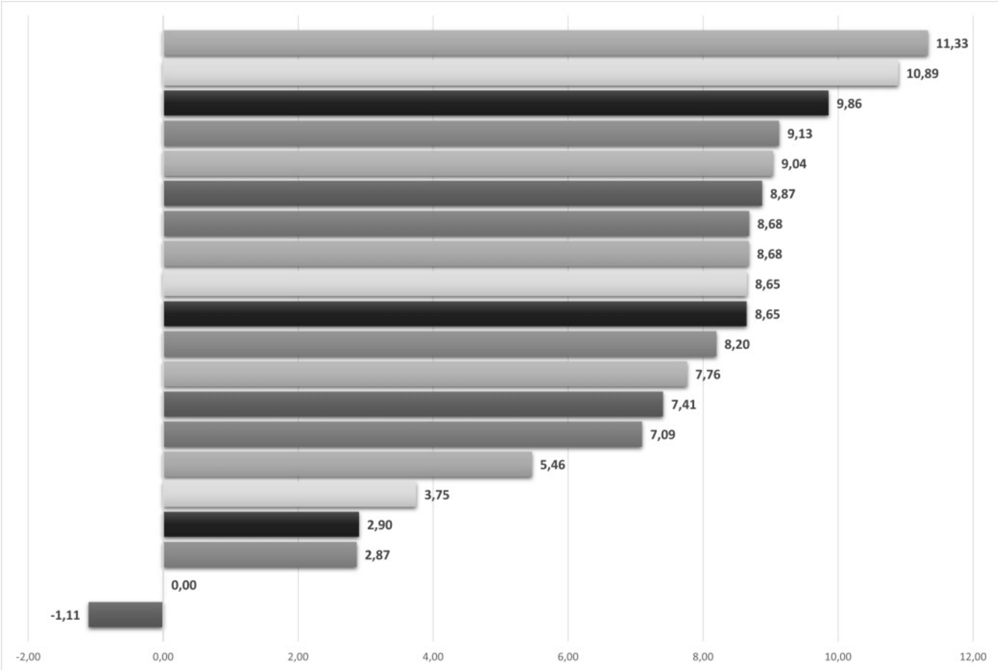


Figure 4.12: Comparison of Forecasting and Sales Contracts

4.2.3 ABC-XYZ-analysis

To create an optimal fill-up management, the ABC and XYZ analysis will be combined. Every article gets the rating A, B or C and additionally to that, the classification X, Y or Z. The double classification leads to nine parts from AX, which means that the article has a high demand and high prediction accuracy to CZ articles, which have low demand and low reliability. Also, the stock location gets the double classification for ABC and XYZ parts. Therefore, the stock is split into nine parts. Figure 4.13 shows the distribution of stock locations in the nine parts.

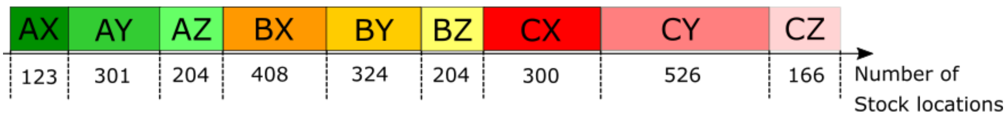


Figure 4.13: Distribution of stock locations through the classification for ABC-XYZ analysis

After the calculation, every article gets a specific classification. This leads to the distribution of articles through the classes. Figure 4.14 shows how many articles are classified in which part. The thresholds to reach a specific ABC or XYZ classification did not change for that approach. A demand between 116,802 and 1,117 pieces is necessary to get an A rating. A demand over 53 leads to a B rating and below 53, the article is ranked as a C article. These margins are also shown in Figure 4.14 on the top of each

ABC class. The thresholds for the deviation stay the same. An X article must have a deviation lower than 3. Between 3 and 50, the article gets the ranking Y and over 50 as Z.

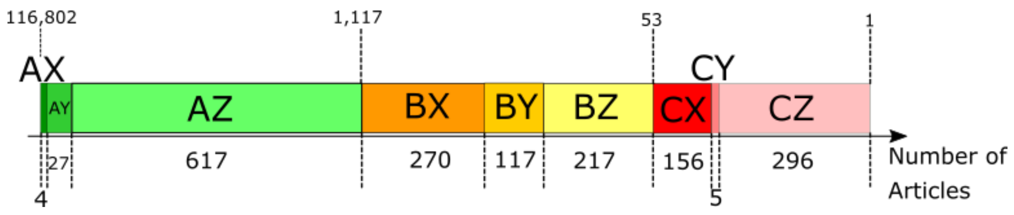


Figure 4.14: Distribution of articles through the classification for ABC-XYZ analysis

To see that within another scope, Figure 4.15 shows the ratio of each partition of every classification. Based on this figure, the massive class AZ can be identified. This means that most of the articles with high demand in previous periods also have a low prediction accuracy. There are only 18 new articles within the group AZ. The articles with the highest turnover in the stock have a high seasonal fluctuation.
When comparing this data with the stock locations in Figure 4.13, a functionality is needed to store the article in the next lower or higher class.

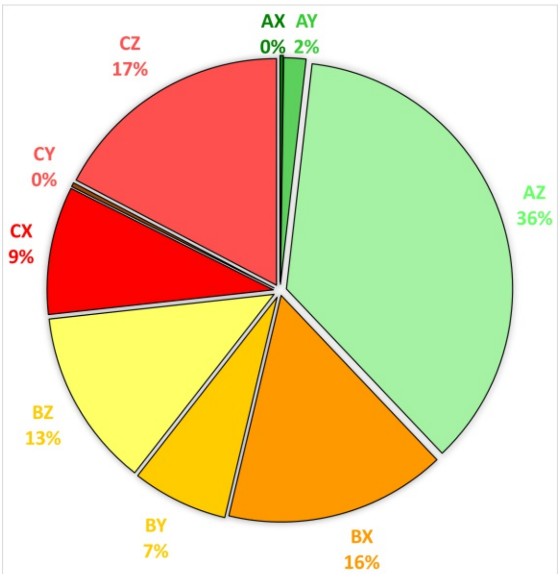


Figure 4.15: Ratio of articles in the specific classes for the XYZ analysis

This knowledge can lead to several actions in the future:

1. Expanding the stock and provide more stock locations.
2. Shift the classification of the stock locations to get a better distribution.

Just shifting the classification will probably only postpone the problem to a later point in time. Therefore, the enlargement of the stock should be the preferable approach. Figure 4.17 shows all empty stock locations in the specific classes. This must be seen as a snapshot and can change over time. This data can cause problems because too few stock locations can be provided in the different classes. The prototype can select no stock location at one point in time because there is no empty stock location available. Therefore, the classifications of the stock locations must be reallocated after the stock is expanded.

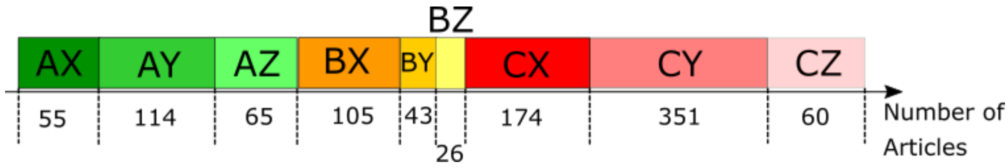


Figure 4.16: Empty stock location through the classifications for ABC-XYZ analysis

Figure 4.17 shows the ratio of the empty stock locations of the different parts graphically. Group CY excites attention. The reason for this is that, on the one hand, there are nearly no articles within this group that will fill up these stock locations and, on the other hand, these stock locations are used as a buffer if they need pallet places after production fast.

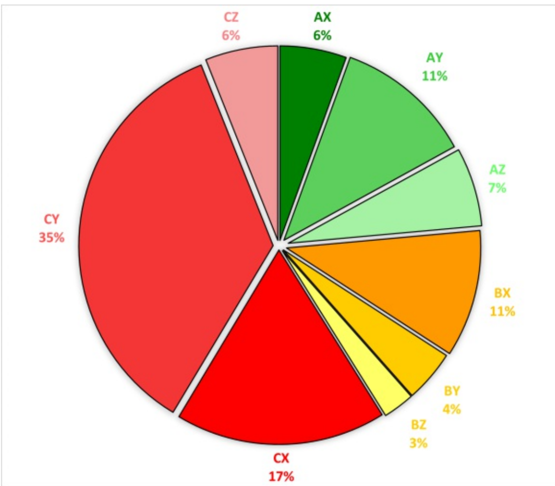


Figure 4.17: Empty stock locations through the classifications for ABC-XYZ analysis

The actual stock assignment of the articles in the stock, which the stock managers and fill-up persons did, can be compared to the ABC-XYZ analysis. Actually, there are 1,768 batches stored in the main part of the stock which will be examined in this master thesis. Out of these 1,768 batches, 557 articles are at the same classification as in the ABC analysis, 443 are the same as in the XYZ analysis and 185 are identical to the ABC-XYZ analysis. This data is shown in Table 4.3 in the column 0.
Not only the identical stock locations are interesting, but also the different ones should

be investigated. Therefore, Table 4.3 and Figure 4.18 show the differences of the actual stock to the specific approaches. The difference will be given as a comparison from the actual stock location classification and the article partitioning calculated by the specific approach. When the article is actually stored in an A location, but the ABC analysis calculates that this article must be in class B, there is a difference of 1. When the calculation results in class C, the difference is two. The same structure can be applied to the ABC-XYZ analysis. In this approach, the difference can vary up to 8 because there are nine different classes available.

Class	Difference by								
	0	1	2	3	4	5	6	7	8
ABC	557	878	333	-	-	-	-	-	-
XYZ	443	808	517	-	-	-	-	-	-
ABC-XYZ	185	527	397	200	220	162	31	36	10

Table 4.3: Differences of stock location classification to the different approaches

What can be seen in Figure 4.18 is that the identical classifications are indirectly proportional. This means that if there are more classes available, the number of identical classifications decrease.
What also gains attention in the figure is that over 80 percent of the articles which are calculated with the ABC approach are identically or have a difference by 1. For the XYZ approach, the number decreases to 70 percent and for the ABC-XYZ approach, there are 40 percent identical or differenced by 1. Based on that data and on the fact that nearly no articles differ by five or more, the stock managers and fill-up persons work without support by the system nearly like the different approaches. The different approaches reflect the work of the responsible persons very well.

Nevertheless, the stock management system can improve and automatise the work, which is now done by the stock managers. This leads to a stock that is not managed by experience. The semi-automated system at the fill-up process can improve the optimization potential of the daily work, and save costs by storing the right articles near the packing tables and reduce the ways of the workers.
The optimization potential can be shown by comparing the current data from the productive system to the data which the prototype can apply. At the fill-up approach, the saved ways at the picking process later are important. Every stock location has an order number, which is also used as the way through the stock. This order number can be used to calculate saved ways from the stock location where the good is currently located to the stock location, which the prototype would apply. The applied stock location will be a random location in the area of the result of the ABC-XYZ analysis. When the actual stock location is in the partition BZ, and the ABC-XYZ analysis will rank the article as a BX article, the difference between a random stock location of BX and the current stock location in BZ will be calculated. When calculating the random stock location in the destination partition will be done, the article must be stocked in the same height

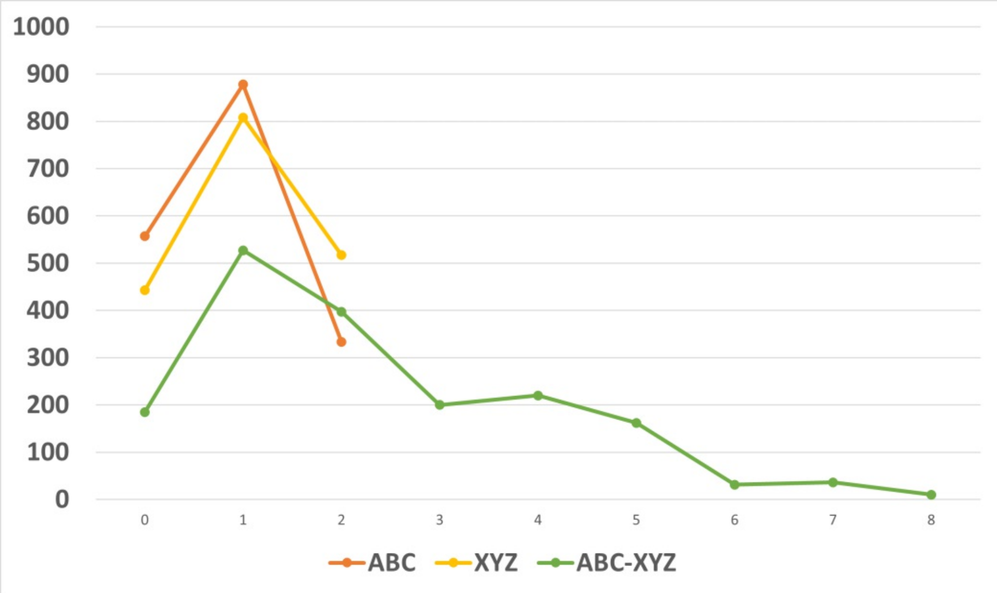


Figure 4.18: Differences of the actual stock and the specific approaches

level as in the actual stock location. This needs to be done because the order numbers define the costs to reach a specific stock location. A stock location in level A or B costs less than a stock location in level D or E. Therefore, the level of the stock locations must be at the same level to get a useful result of the optimization potential.
For the calculation of the optimization potential, a query is created, which calculates the difference based on the order numbers and calculates the difference out of this in seconds, minutes and hours. Therefore, the average walking speed of 3 kilometers per hour or 0.83 meters per second is assumed. Every pallet or stock location has an average width of 1 meter. The actual data include all picking processes of the 1,620 lots, which are currently free to sell to the customers at the warehouse of Sonnentor. The author of this thesis decided to use this type of evaluation because a lot of data is needed to get a meaningful factor of optimization. Several test data which would be created by users would be too less and just give a direction how the potential can look like.
Thereby, the data of the stock location given by the ABC-XYZ approach are randomly generated, the testing environment runs 20 times to get a dataset that can be analysed. Table 4.4 shows the result of all 20 runs of the evaluation algorithm.

The given data in Table 4.4 can be seen as the potential of improvement by the life cycle of a batch of a selling product. This life cycle is defined as the difference between the date the lot is entered into the stock and the date where this lot is removed from the stock completely. The calculation takes working days into account to have a useful result. Based on the data from the productive system of Sonnentor, there is an average batch life cycle of 15 days. This means that the improvement potential of the ABC-XYZ analysis is 4.2 hours every 15 days.

Number of	Difference by		
Run	Seconds	Minutes	Hours
1	17,499.75	291.6625	4.861041667
2	15,063	251.05	4.184166667
3	10,689	178.15	2.969166667
4	9,537.75	158.9625	2.649375
5	15,909	265.15	4.419166667
6	7,524	125.4	2.09
7	15,879.75	264.6625	4.411041667
8	22,545.75	375.7625	6.262708333
9	11,000.25	183.3375	3.055625
10	16,280.75	271.3458333	4.522430556
11	12,693.75	211.5625	3.526041667
12	13,708.5	228.475	3.807916667
13	20,817.75	346.9625	5.782708333
14	12,518.25	208.6375	3.477291667
15	22,671	377.85	6.2975
16	15,506.25	258.4375	4.307291667
17	10,620.75	177.0125	2.950208333
18	17,314.5	288.575	4.809583333
19	25,593.75	426.5625	7.109375
20	10,047.5	167.4583333	2.790972222
Average	**15,171.05**	**252.8508333**	**4.214180556**

Table 4.4: Saved time of a life cycle of a lot when follow the ABC-XYZ approach

4.2.4 Optimized ways through the stock

The reduction of the ways based on the new stock locations of the articles can not be seen at every fill-up action but has an impact on the picking process. But there is an optimization potential at every fill-up process available when guiding the workers through the stock, which is described in Section 3.3.2. In the stock a lot of people work together. Therefore, it is necessary to have a real-time optimization without any pre-calculation. This will be done by minimizing the way between every article within one fill-up action.

4.3 Picking process

The picking process is the second part to be optimised in this thesis. After the fill-up process, all goods should be stored in the most optimal stock location with a view of the picking process. Therefore, the fill-up process should optimise the daily work of the workers, and the picking process should increase the number of picked goods. The critical path of the picking activities is the distances a picking person has to walk through the warehouse. Therefore, the optimised picking process creates one batch order so that a picking person picks more than one customer order at once and optimises the way through the stock. A batch order aims to find a way to group those orders together which have a high similarity of articles. This leads to short ways for the picking persons. For that batch order, the seed orders indicate the basis to find four similar orders. After selecting a seed order, four accompanying orders will be grouped to this seed order. These four orders should be similar to the seed order in the perspective of minimizing the way through the stock for the picking person. In the following sections, the different approaches to find a seed order and the accompanying orders will be evaluated.

4.3.1 Batch orders

There are different approaches available in the literature to select a seed order. In Section 2.4.1, all possible approaches are shown. The most suitable approaches are implemented to the test system of Sonnentor and are described in Section 3.4.2. At first, every approach to select the seed order will be evaluated with the "GPLSR" approach to batch orders together. This is necessary to have the same basis for comparing the results. At 9 am, noon and 3 pm the five different approaches "Random", "Greatest number of picking locations", "Smallest number of picking aisles", "Greatest number of picking aisles" and the new "Oldest order" approaches are executed, and the data is written into a file. The data is collected from the productive system of Sonnentor to have a high turnover of new orders in the system. The evaluation results are shown in the following sections.

Random selection

At the random approach, the seed order will be chosen randomly based on all open selling contracts in the system which are untouched at the moment. The system can not influence to find a similar batch order or the part of the picking warehouse which will be focused on. Based on the 65 orders which are batched to the seed order, on average 12.4 percent of the articles of the accompanying order were equal to the seed order. At the investigated orders, there was in average, 10.3 different articles. Therefore, on average only 1.29 articles per order were equal to an article in the seed order. Also, an important factor of a method is the average number of articles in the seed order. At the "Random" approach, there are 8.8 articles per seed order. Compared to the other methods, this is an average value.
Figure 4.19 shows the ratio of the average number of articles to the equal articles in the accompanying orders against the seed order. The seed order is selected by the random selection approach and the accompanying orders are batched with the "GPLSR" approach.

Greatest number of picking locations

Another approach is the "Greatest number of picking locations (GNPL)". This approach counts all different stock locations of an order. The higher the amount of different picking locations is, the higher the rating is. An advantage of having a high amount of different

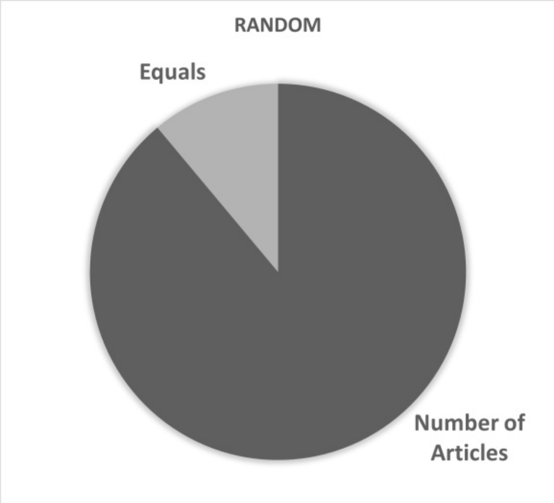


Figure 4.19: Ratio of equal articles using the random selection approach compared to the “GPLSR” approach

picking locations is that the batch order can be found easier. When the seed order contains just one article, the batch order has a smaller similarity to this than to an order with many different stock locations. Also, the probability of batching an order with a high amount of different stock locations to a seed order is low.
When selecting the seed order with the “GNPL” approach, 3.55 articles are the same in the accompanying orders, which are 25 percent. On average, an order of the data examined has 13.7 articles. At the “GNPL” approach, the seed order has, with an average of 25.8, the highest number of different articles. Figure 4.20 shows the ratio of equal articles of the accompanying orders to the seed order.

Smallest/greatest number of picking aisles

The “Smallest/greatest number of picking aisles (SNPA/GNPA)” is another way to find a seed order. This approach counts the different aisles a picker has to walk when the investigated order is used as seed order. At the “SNPA” approach the smallest and at the “GNPA” approach the highest number of different picking aisles will lead to a high rating. Based on this decision, the system can manage whether just a small or a big part of the warehouse should be focused on. When deciding to find a seed order based on the “SNPA” approach, the picking action will be focused on a picking process at a small part of the warehouse. When deciding to select this based on the “GNPA” approach, the picking activity will be spread through a bigger part of the warehouse.
The “SNPA” approach is the worst approach regarding similarity to the accompanying orders. Only 0.28 articles in the accompanying orders were the same as in the seed orders, which are just 3.55 percent. One reason for that is that at this approach, orders with just one article are selected as seed orders. Based on 20 selected seed orders, the average

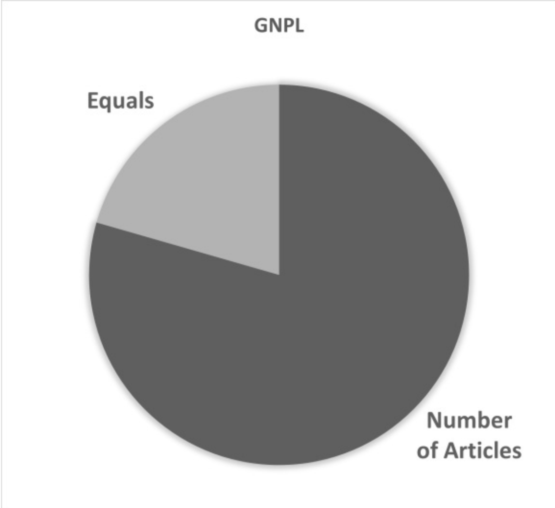


Figure 4.20: Ratio of equal articles using the "GNPL" approach compared to the "GPLSR" approach

number of articles of such an order is 1.8 articles. When selecting the accompanying orders with the "GPLSR" approach, the similarity ratio is high because there is a high probability of finding the same article in another order. The number of equal articles in the orders is low when there is just one article to compare with. The average number of articles of the whole batch order is also just 7.86. Therefore, the "SNPA" approach is the worst of all selection methods examined.
Figure 4.21 shows the ratio of equal articles of the batch order to the seed order.

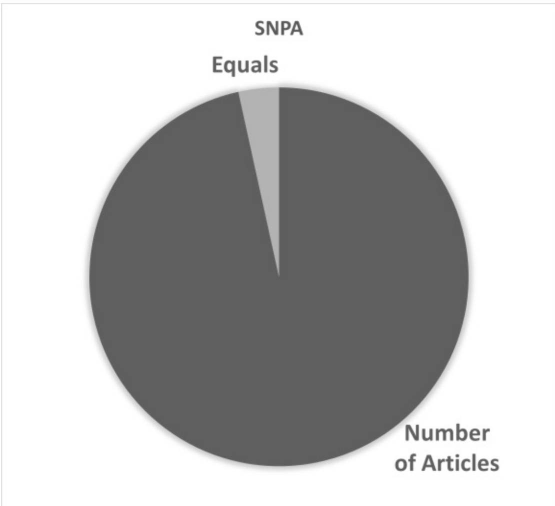


Figure 4.21: Ratio of equal articles using the "SNPA" approach compared to the "GPLSR" approach

The other aisle-based approach is called “GNPA”. This approach selects the seed order based on the highest number of different picking aisles. The “GNPA” approach has the highest number of articles of a batch order. A batch order selected with the “GNPA” and “GPLSR” approaches includes, on average, 15 different articles. On average 18 articles are in the seed order which is also very high. After the “GNPL” approach, this method has the highest amount of equal articles in the accompanying orders. On average, 2.35 articles or 15 percent of the articles are equal in the seed order and the accompanying orders.
In Figure 4.22, the ratio of equal articles of the batch order compared to the seed order is shown.

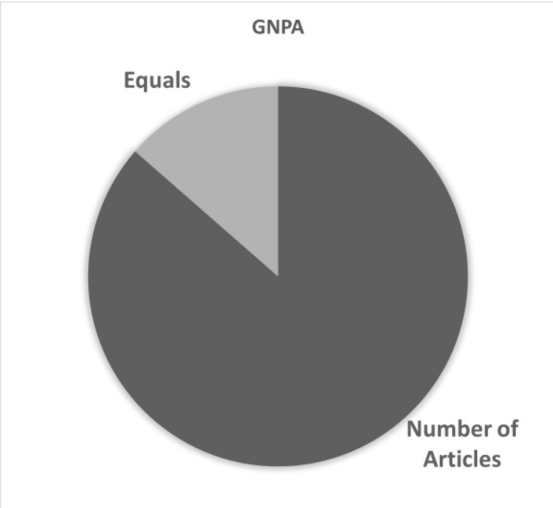


Figure 4.22: Ratio of equal articles using the “GNPA” approach compared to the “GPLSR” approach

Oldest order

The author of this thesis described a new approach. The “oldest order approach” just takes the oldest order in the system as seed order. This is done because with this approach no order can be lost in the high amount of selling contracts in the system. The oldest order approach will be needed when the pickers can not pick all open orders within one day. In the system, the number of orders will increase and stays in the system. With this approach, every customer gets his/her goods as fast as possible. When not taking the incoming date of order into account, it can happen that an order can stay in the system for a long time. At this approach, there are only 4.6 articles in the seed order, which is the second-lowest value. Also, seven different articles of the batch order are one of the lowest values. Therefore, it is not surprising that only 0.48 articles or 6.8 percent of the articles of the seed order and the accompanying order are the same.
Figure 4.23 illustrates the number of equal articles of the seed order to the accompanying orders graphically.

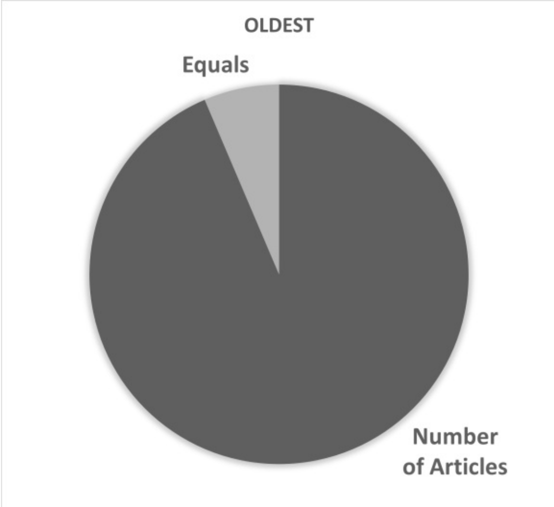


Figure 4.23: Ratio of equal articles using the "oldest order" approach compared to the "GPLSR" approach

Overall result to find a batch order

In Table 4.5, the differences in the approaches to create a batch order are shown. All values in this table are based on calculating the different approaches within one week and are average values. The best method to create a batch order concerning the similarity of the articles is to use the "GNPL" approach, followed by "GNPA", "Random", "Oldest order" and "SNPA". Based on the data, it can be seen that a high similarity of the different orders depends on the number of articles in the seed order. The more articles the seed orders have, the higher the ratio of equal articles to the accompanying orders is. A high number of different articles can explain this as the basis of the selection of the accompanying orders. The number of articles in the seed order and the number of articles in the accompanying orders have no impact on the similarity of the orders, which can be seen by the fourth line of Table 4.5.

4.3.2 Way through the stock

Based on the new "GNPL" approach and the "GPLSR" approach with a priority of the oldest orders, a batch order consisting of 5 orders is created. The seed order and four accompanying orders are included in this batch order. Based on this order, there are different ways to walk through the stock. This should be done in an optimized manner. Therefore, the "S-shape" and the "Mid-point" heuristic will be compared. This should lead to the decision, which type of order numbers and walking strategies will be applied in the future at Sonnentor when the batch orders are created. The data of all different approaches was the same, just the ordering of the stock locations was different. This ordering guides the picking person through the warehouse. At the different evaluation steps, the average walking speed of 1 meter per second is assumed. This is a bit slower

	Random	GNPA	GNPL	SNPA	OLDEST
Average number of articles in seed orders	8.8	18	25.8	1.8	4.6
Average number of articles in accompanying orders	10.35	14.97	13.72	7.86	7
Different number of articles between seed and accompanying orders (in percent)	17.61	-16.83	-46.82	336.67	52.17
Equal articles in accompanying and seed orders	1.29	2.35	3.55	0.28	0.48
Equal articles in accompanying and seed orders (in percent)	12.48	15.72	25.89	3.52	6.81

Table 4.5: Comparing of investigated approaches to create a batch order

than at the fill-up part because at the fill-up process, the person is machine supported, and at the picking process, he/she walks through the warehouse.
For the first evaluation step, the picking processes, which were done without a batch order, are grouped together, and the way is calculated in the order the picking person picked the goods. The average picking time without any way strategy is at about 1 hour. Within this hour, on average, 65.9 articles were picked by one person. Without any way strategies, every picker needs about 57 seconds to pick an article. In table 4.6, the data of 20 picking processes will be shown. Every picking process will be done by one person in this scenario.

S-shape with skipping heuristic

The next step is to guide the picking person through the stock. This is done by the scanner, which shows up the next optimized article regarding the minimum way. For the S-shape heuristic, the picking persons walk in S-shapes through the stock and skips the aisles where no article is located. The same picking processes as in the evaluation without any logic will be taken into account. As a result, the author of this thesis get an average picking time of 0.225 hours or 13.5 minutes also for on average 65.9 articles per picking process. With this way strategy, every picker picks every 12.3 seconds one article from the stock. Table 4.7 shows the same 20 picking process data, which are already stated without any way strategies.

Mid-point heuristic

The last investigated heuristic is called “midpoint”. At this heuristic, the picking person is just allowed to pick just one half of the aisle at a time. When there are articles in the other half of the hallway, he/she will come back to that when changing the side of the aisle at the end of the warehouse. The picking persons are allowed to skip aisles where

Number of picked items	Time per picking process		
	Seconds	Minutes	Hours
64	4230	70.500	1.175
118	4824	80.400	1.340
74	5356	89.267	1.488
64	1778	29.633	0.494
94	5072	84.533	1.409
96	4392	73.200	1.220
64	2329	38.817	0.647
60	5145	85.750	1.429
40	2386	39.767	0.663
56	3297	54.950	0.916
66	3902	65.033	1.084
60	4110	68.500	1.142
68	6264	104.400	1.740
48	4194	69.900	1.165
54	3695	61.583	1.026
48	2296	38.267	0.638
44	2242	37.367	0.623
76	4343	72.383	1.206
60	1064	17.733	0.296
64	4948	82.467	1.374
Average	**3793.350**	**63.223**	**1.054**

Table 4.6: Time per picking process without any way strategy

no article can be picked. At this approach, the average picking time per process will be decreased to 0.118 hours which is about 7 minutes. This means that a picking person will pick an article every 6.5 seconds. Table 4.8 shows the data of the 20 investigated picking processes.

Based on this data, the optimization potential for a company can be shown. In the last year, the employees of Sonnentor started 99 picking processes per day. This was done by an average of ten different picking persons. On an average day, they picked 6,016 articles all in all. All this data is based on persons without any guidance from the IT system. Based on the "GNPL" approach to select a seed order and the "GPLSR" approach to find an appropriate accompanying order, then full-time picking persons could pick over 670 picking processes per day when they have no waiting times. This can not be compared one by one to the 99 picking processes of the past year because the people at Sonnentor split the batch order into the five customer orders when picking all goods. Also, the number of packing tables is limited. Due to space limitations, there are only eight packing tables available for up to 15 picking persons. After the picking process, the picked goods will be packed and sent to the customer on average within

Number of picked items	Time per picking process		
	Seconds	Minutes	Hours
64	926	15.433	0.257
118	888	14.800	0.247
74	759	12.650	0.211
64	783	13.050	0.218
94	929	15.483	0.258
96	876	14.600	0.243
64	903	15.050	0.251
60	595	9.917	0.165
40	762	12.700	0.212
56	880	14.667	0.244
66	928	15.467	0.258
60	738	12.300	0.205
68	773	12.883	0.215
48	771	12.850	0.214
54	735	12.250	0.204
48	920	15.333	0.256
44	823	13.717	0.229
76	989	16.483	0.275
60	477	7.950	0.133
64	765	12.750	0.213
Average	**811.000**	**13.517**	**0.225**

Table 4.7: Time per picking process with the S-shape heuristic

twenty minutes. Twenty minutes is an average value because there are goods that need more time to be packed and sent, like glasses or individual gift boxes. When this aspect is not changed, the overall picking and packaging time of goods will increase to 27 minutes for five customer orders. A team of five full-time picking persons can pick, pack and send 177 picking processes per day. This is an improvement of 78 percent.
Another improvement of the optimization of the ways is that the box-plots, which are shown in Figure 4.24, look more compact at the "S-Shape" and the "Midpoint" heuristic. This means that there are not that many spikes in the data. The x in the figures shows the average of the data, the lower line of the box is the first quartile, and the top line of the box shows the third quartile. The line within the box illustrates the median value of the data. Therefore, when the box is small, the time per picking process has a small variation. This leads to better scalability when hiring new employees.

Number of picked items	Time per picking process		
	Seconds	Minutes	Hours
64	471	7.850	0.131
118	480	8.000	0.133
74	397	6.617	0.110
64	416	6.933	0.116
94	468	7.800	0.130
96	468	7.800	0.130
64	490	8.167	0.136
60	401	6.683	0.111
40	460	7.667	0.128
56	468	7.800	0.130
66	429	7.150	0.119
60	383	6.383	0.106
68	417	6.950	0.116
48	428	7.133	0.119
54	351	5.850	0.098
48	405	6.750	0.113
44	443	7.383	0.123
76	424	7.067	0.118
60	316	5.267	0.088
64	394	6.567	0.109
Average	**425.450**	**7.091**	**0.118**

Table 4.8: Time per picking process with the Mid-point heuristic

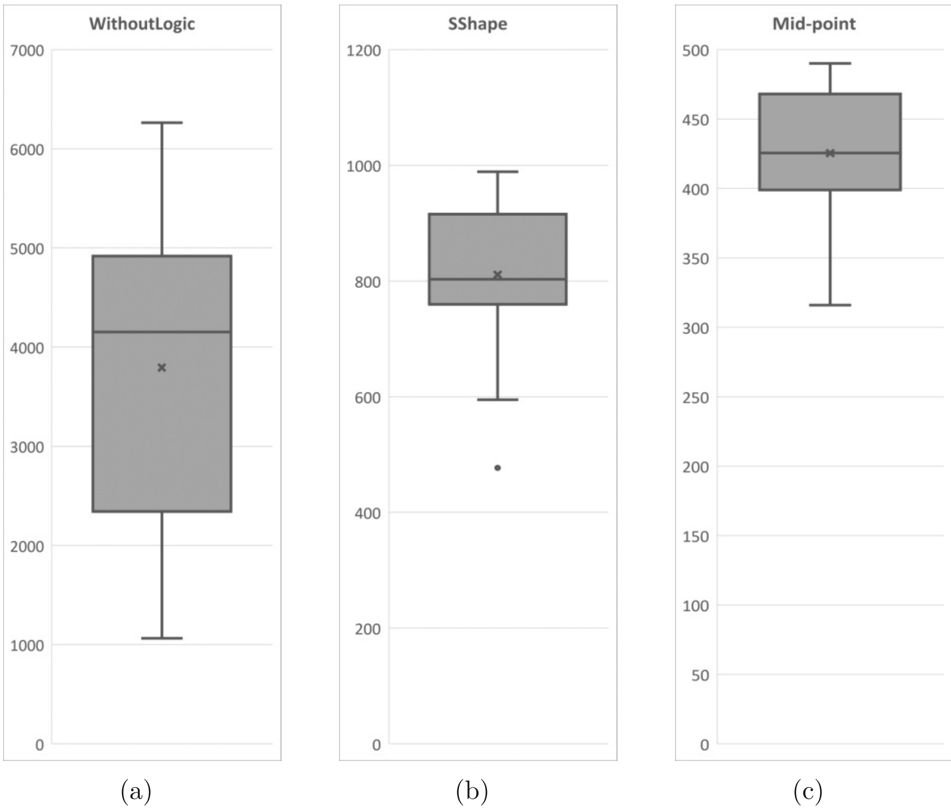


Figure 4.24: Box-plots of the different way optimization strategies

CHAPTER 5

Conclusion and future work

This thesis aims to create a dynamic fill-up and picking process for small and middle sized companies in the food market industry. Therefore, it was shown in detail how the different methods work and can be implemented into an ERP system. For a dynamic stock management system, it is important to have a look at all workflows. Also, in this thesis, it is shown that one workflow depends on another one in the same system. The picking process can be more optimal when there is an underlying fill-up process before. This means, when a fill-up process is accessing the best selling goods near the packing tables, the picking process can be more optimal because of the short ways between the stock locations and the packing tables.

When optimising the workflows, the same question arrives every time: "Is this possible in real-time or should the data be pre-calculated?". Most workflows in this thesis are in real-time. With an increasing number of customer orders, simultaneously working people, size of the warehouse and more complex workflows, the number of pre-calculated steps will also increase. The only reason why the pre-calculation is not wanted is the quality which may decrease.

It is hard to create one description, how to create a dynamic stock management system for a company in the food market industry because every company is different and has other requirements and circumstances. With the prototype described in this thesis and the implementation shown, some parts can be used for every company. The fill-up approaches ABC, XYZ or the combined ABC-XYZ approach which are described in [Nev14] are the same for different companies, but how to work with the results can differ. Also, the investigated companies work differently and would need different approaches. Kiennast and Kastner would need the ABC analysis which is described in Section 2.2.1 to fill up the stock locations because they have the goods ordered on stock. At Sonnentor, the combined ABC-XYZ approach which is described in Section 2.2.3 is needed because they have to forecast the amounts [SRHMB12] of the future periods because they also work as a producer. This forecasting is implemented in Section 3.3.3 and is necessary to buy the

ingredients from suppliers and farmers and produce them before the main season starts for the specific product without knowing how much they will sell in the main season. The forecasting amounts from the system can be seen as approximate values and can differ to the real sales amount. This can seen in Figure 4.12 where the deviation is between -1.1% and +11.3% compared to the real selling amounts.
In the future, the functionality should be provided where a specific ratio of the stock locations should be free and available for the fill-up process every time. This is necessary because the different approaches to fill up articles, which are shown by Listings 3.9, 3.11 and 3.13 return one stock location per article. If there is no empty stock location available for an article in a specific sector of the stock, the approaches can not work in an optimal manner. Also to fill up new articles, empty stock locations must be available. When it is impossible to apply a functionality like this, the fill-up process must find a stock location in the next part of the warehouse. If there is no empty stock location within class A available, the stock management system must store it in a stock location with classification B. For the implementation of such a fill-up process, it is advisable to create the article classification first and the classification of the stock locations later on. As my evaluation has shown in Section 4.2.3 123 stock locations are applied to the class AX. When classifying the articles, only 4 articles are grouped as an AX article. On the other hand side, 301 stock locations are classified to the group AZ. The implemented prototype classified 617 articles to class AZ. When knowing the distribution of the articles through the classes in advice, the classification of the stock locations can be done with the same distribution. Figures 4.13 and 4.14 show the distributions of stock locations and articles through the classes graphically.
When analysing the processes within a company and choosing the right approaches, a lot of optimization potential is available. At Sonnentor, the optimization potential at the fill-up process is not that high as expected but leads to a more optimized picking process. The picking process can be improved by about 78% to the current state at Sonnentor. This factor is possible with the current circumstances of picking persons, the given number of stock locations and packing tables. The actual bottleneck at Sonnentor is the amount of packing tables. There are just eight packing tables available for up to 15 picking persons where the picker and goods wait several minutes for packing and sending to the customer. When this waiting time is decreased, the optimization potential will increase automatically. The most important part to create a high optimization factor is to apply several unique order numbers to every stock location. At the fill-up process, this order number is necessary to find the next optimal stock location to fill up an article as described in Section 3.2.1 and shown in Figure 3.3.2. At the picking process, the order number defines the way through the stock for the picking person. These order numbers are different from each other and can differ between the different approaches as seen in the implemented prototype when applying the order numbers for the different way strategies through the stock in Section 3.4.4.
Also, some limitations were detected when implementing the prototype on the stock management system from Sonnentor. The forecasting method works better if it has a specific continuity or seasonality. This is not the case when the main part of the customers

are private persons or smaller shops. When detecting this circumstance, it is not useful to create forecasting for a short period in time, like hours or days. This limitation of the forecasting is shown in Section 3.3.3. When implementing a dynamic fill-up approach based on forecasting values, it is necessary to check if there is any continuity available by comparing the selling articles of specific weeks in different years.

The final prototype offered the fill-up process that calculates the ABC analysis [Nev14] based on the access frequency from the previous year in Listing 3.8 and the XYZ analysis [Nev14], which calculates the prediction accuracy done by calculating the forecasting demand [SRHMB12] of every article. The combination of both approaches was implemented in Section 3.3.3 and evaluated in Section 4.2.3. The responsible stock managers and the fill-up persons work similarly to the prototype as shown in Table 4.3. This table identifies the differences of the prototype to the actual distribution of the articles to the stock locations. Out of 1,768 articles more than half of the articles are placed in the same class, in the next class or two classes away of the results the prototype returns. Therefore, the optimization factor of just 4.2 hours every 15 days which is shown in Table 4.4 is quite modest.

For the picking process, the creation of a batch order [HT06] was done. This creation of a batch order starts by selecting a seed order. The different approaches to select a seed order are shown in Section 2.4.1. As my evaluation has shown, the selection of a meaningful seed order is crucial for the accompanying orders. The best approach to select the seed order is the "Greatest number of picking locations" (GNPL) [HT06] approach which leads to the accordance of the same articles in the seed order and the accompanying orders of 25%. This result is shown in Section 4.3.1. Based on the seed order, four accompanying orders are selected which are similar to the seed order. As the literature shows, the "Greatest picking location similarity ratio" (GPLSR) [HT06] approach to batch orders is the best one. Therefore, all different approaches to select a seed order are compared to the GPLSR approach. The result that the combination of selecting the seed order with the GNPL approach and selecting the accompanying orders with the GPLSR approach is the best one as shown in Table 4.5.

After that, two different way heuristics [ADO09] are implemented to evaluate the most optimal way through the stock. As my evaluation has shown in Section 4.3.2, the implemented Mid-point heuristic which is described in Section 2.6 creates an optimization potential of about 78%.

In summary, the fill-up process does not improve the daily work that much. Nevertheless, it is necessary for an optimal picking process with the highest optimization potential of the investigated processes. When optimizing these processes, it is essential to have a good insight into the processes to choose the right approaches for the requirements of the investigated company.

List of Figures

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Appendix A

Sonnentor

Sonnentor[1] is an Austrian company which was founded in 1988 from Johannes Gutmann as a sole trader business. Nowadays, they are producing herbage, tees, spicery, coffee or cacao. They have more than 400 employees and sell about 900 different products. Sonnentor works based on the "welfare economy" strategy. This means to work for the welfare and surrounding instead of optimizing their profit. They have their own farmers to produce the regional goods. For all products which are not available in Austria they have a network of suppliers from Romania, Albania, Nicaragua, Tanzania, China, New Zealand, Spain, Kosovo, Greece, Germany and Czech Republic. They sell their products in 25 shops in Austria, Germany and Czech Republic and on-line in more than 50 different countries.

[1] https://www.sonnentor.com/de-at

Appendix B

Interview with SONNENTOR Kräuterhandels GMBH

1. **Which properties can your articles have?** Sonnentor only work with spice, teas, snacks and herbages so they don't have any cooled products. This type of products can be strong smelling and can accept the aroma of other goods. So they have to find a way to store these types of products that a product doesn't influence another product. This will be ensured by spatial distribution of such products. There is also a restriction of stacking goods. It's not possible to stack big bags or 50 kg bags over each other in a structural way.

2. **Do you trade your product to different countries with different languages?** The teas, herbages, spice and snacks from Sonnentor will be traded to 50 different countries. Product description and ingredients will be translated into 23 different languages. They have their products in german, which are the main language and without any description. When they receive orders from different countries they print the new descriptions and ingredients in their own printing office and label their products right before shipping.

3. **Which package types do you have in your company?** The main packaging units are 1, 6 and 42 pieces. But for special products it can happen, that there are other sizes of the packaging units are available.

4. **Which packaging units did you have in your company?** This depends on the article. Products will be packed in different box sizes. There are single packaging units for B2C customers and there are boxes with e.g. 24, 40, 60 up to 1200 packages inside for bigger orders.

5. **Do you have any special products like vouchers which are not on stock?** Yes, there are also individual products available in the shop (e.g. vouchers, individual teas, products with personal dedication). These types of products will be printed in the office. The stock management system has to ensure that the picker gets this orders with a delay of 1-3 hours that the printing office can prepare these products.

6. **Which types of storage racks do you have?** Different parts of the stock has different types of racks. The picking part of the stock has flow racks which holds

the demand of one day. This racks will be taken for B2C customers and includes just smaller packaging sizes. The second type is the pallet shelf. This part of the stock only holds the articles for B2B customers and to fill-up the flow racks. The last type is the rack for small part articles. Products in this part of the stock are for example single pieces of a product to fill-up the shop or marketing stuff like posters.

7. **Do you have shifts for your stock employees?** No. Fill-up and picking persons have a predefined working time. When the main season in winter starts it may happen, that persons have to do some overtime.

8. **Is there a relation between number of orders and number of pickers?** When the main season around Christmas starts some seasonal workers will help our fill-up and picking persons.

9. **Do you have different types of stocks? (e.g. Stock for picking, external stock, main stock, ...** Yes, there are 3 different types of stores. For picking the B2C orders the pickers have the picking store. This type of store is next to the packaging tables and ensure short ways of the pickers when they collect the B2C orders which are the main part of the orders. The second type is the pallet store. This is the main stock and contains the a high amount of the articles for B2B orders and fill-up of the picking store. The last type is the small part articles which is just for fill-up purposes of the store and marketing articles like posters. There is also an external warehouse in Waldhausen. This warehouse is just a few minutes away from Sprögnitz and is for fill-up of the main stock.

10. **When do you fill up the stock?** The stock at Sonnentor will be filled up when a processing step finishes or goods arrive from the external warehouse in Waldhausen. A processing step can be cleaning after delivery from the farmers, drying, mixing or packing.

11. **Do you have a processing/production hall next to the storage?** Yes there is a production hall next to the stock. At this production halls there will be different activities. After the delivery of the farmers the goods will be give on stock for drying. When the goods are dry enough the laboratory tests the goods which quality die farmers delivered. Based on that laboratory report the goods will be cleaned, mixed and packed in predefined packaging units.

12. **Is it usual to have different articles at one stock place?** No. Every article has his own stock place. This type of data will be stored at the article master data.

13. **Which types of customers do you have? (B2B, B2C or both?)** Sonnentor trades with B2C customers in their own Shops and the Webshop. Before the picker can start to collect the goods for B2C there is an other department which checks the customer. They also have B2B customers like bigger companies and also the 25 franchise shops which orders a high amount of the goods.

14. **Which picking type do you prefer in your company?** Picking and fill-up processes will be by terminal. All involved persons has a handheld device where they get all important information.

15. **Are you differentiating between orders to give them a different priority?** Not directly a priority. Some orders just have to wait until a specific action. If there is a voucher at the order, this will be printed in the office. So order has to wait some time until the voucher is printed to pack all goods together. Currently there is a delay of about 3 hours until the order will be grouped together to a collection order.

16. **Are there some corridors for a specific value?** There are experiments to define driving directions and corridors for a specific purpose. At the picking stock, the fill-up persons will be separated from the picking persons. Every group of persons must use the specific corridor. This is possible because at this part there are flow shelves.

17. **How does picker and fill-up persons carry their articles?** The Fill-up process and picking of B2B orders will be handled with a stacker because of the high amount of the articles. B2C orders will be collect by hand or with smaller shopping carts.

18. **Are there different persons for picking and fill-up process?** No. If the amount of a good is low within a stock place, every person can start a fill-up process.

19. **How often do you receive articles for fill-up of the main stock?** This differ every day. One fill-up activity can have more than one article.

20. **Information about the company**

    - Name of the company: SONNENTOR Kräuterhandelsgesellschaft mbH
    - Number of employees in the company: There are about 320 employees in Austria. Sonnentor plays also attention to hire people with a disability or permanent unemployed persons.
    - Number of orders per day: Sonnentor have on average 215 orders per day (B2B and B2C).
    - Number of articles on stock: There are 1800 active products on stock. This number includes all variants of a product (e.g. spicery with 50 g and 100 g are 2 products). Sonnentor have about 800 base articles.

Appendix C

Interview with KASTNER GroßhandelsgesmbH

The interview was held with Franz Vogler stock manager of fresh goods in the central stock in Zwettl on 27th of February.

1. **Which properties can your articles have?** At Kastner Gruppe are many different types of articles. There are different categories of products with similar properties. The categories are deep frozen, dry products, fruits and vegetables and the category "fresh" which means meat and sausages. This categories are separated to guarantee the different properties (e.g. the different degrees of cold). The articles can be cooled, strong smelling, accept the aroma of other goods, easily perishable, article aren't allowed to stack, touch-sensitive, toxic, acidly and have sometimes statutory regulations. Regulation by law can be for example to cool the fish down to one degree Celsius or to cool the fresh assortment to six degrees Celsius.

2. **Do you trade your product to different countries with different languages?** Not now. The Kastner Gruppe has plans to label their products in different languages because they have also customers in different countries. Because they have no own machine for labelling, they will send the labels in the different languages to the customers to source that part of work out to the customer.

3. **Which package types do you have in your company?** This is completely different and depends on the product and the customer. They have sacks, pawn boxes, single-use boxes or loose items. If the customer orders a different packaging size than a usual unit, the article will be packed in pawn boxes.

4. **Do you have any special products like vouchers which are not on stock?** They call this type of products "providers" which means, that these type of products are not on stock like a special kind of a good. The Kastner Gruppe orders these special goods at their suppliers and send them to the customer. This process will take more time than the normal orders so the customer will get an information when the articles will be delivered.

5. **Which types of storage racks do you have?** At the whole store they have different rack systems. They have a flow rack for smaller products with a high turnover ratio like meat, a pallet storages for products with a bigger amount and a high turnover ratio like fruits and vegetables, a high rack storage area for the dry assortment with a big amount and buffer and a stock for small pieces for articles which will be sold in small amounts.

6. **Do you have shifts for your stock employees?** There are two shifts. The first starts at 6 am and ends after 8 hours when they achieve the aim to pick all specified customers. Shift two starts at 4 pm and ends also after 8 hours. About 25 persons works per shift to collect all orders of the customers. At the two shifts the pickers collect nearly the same amount of orders.

7. **Do you have a incentive system for your pickers and fill up persons?** Yes, every person has his own scanner which is directly connected to the IT-System. The system can create a statistic to show, how much picks a picker accomplish per minute in one month. If the picker manage to pick more than 2 goods per minute he will get a financial reward. There are different buckets of classes where the reward will increase.

8. **Is there a relation between number of orders and number of pickers?** The responsible persons have the experience, that Mondays and Tuesdays are worse than the other days. On the basis of customer orders they also can regulate the number of pickers and fill-up persons.

9. **How many orders do you have on average and how many articles does an order have (average)?** The number of orders has a seasonal deviation. On 20th of February they had 344 orders from customers which a overall amount of articles of 35748. For this amount of articles they need roll containers.

10. **Do you have different types of stocks? (e.g. Stock for picking, external stock, main stock, ...** The different types of stocks in central stock in Zwettl are based on the different product categories like in question one described. Kastner also has external warehouses in Vienna (South and North), Eisenstadt, Jennersdorf, Krems, Amstetten and a envelope stock in Wallern.

11. **Do you have packaging tables/areas?** Yes at this predefined areas the picker registers all roll containers and pawn boxes which will be sent to the customer and control and finish the goods.

12. **When do you fill up the stock?** The racks will be filled up when the goods arrive at the landing area or if the picking racks has no goods available. To order the right amount of goods the IT-System will create a suggestion and the authorised agent can overrule the system.

13. **Do you have a processing/production hall next to the storage?** No.

14. **Is it usual to have different articles at one stock place?** Yes it's possible to store at one pallet store two or more different products. This will be ensured by the bar code at every stock place.

15. **Which types of customers do you have? (B2B, B2C or both?)** Only B2B customers. On the one hand the shops which are integrated in the Kastner Gruppe and on the other hand gastronomy.

16. **Are you differentiating between orders to give them a different priority?** No every order has the same priority. The only thing is, that orders with articles from the small articles stock has to wait until this articles are picked. This is caused by the layout of the stock.

17. **Which picking type do you prefer in your company?** Every picker and fill up person has his own scanner. So the preferred picking method is "pick-by-terminal". The system automatically sort the goods of an order from heavy to light and group the goods based on the product families.

18. **Are there some corridors for a specific value?** No. Pickers and fill-up stacker are working in the same corridors.

19. **Is there a standard place for the articles?** Yes every article has his own place. The places changes over time by the experience of the managing people. How often the standard places change will be decided regarding the seasonal availability of the products and the turnover ratio. Articles of fresh assortment will be changed every month and the dry articles will change just once a year.

20. **How does the picker carry the goods?** The picker use rolling containers and picking vehicles.

21. **How does fill up persons carry the goods?** Fill-up persons use forklift to carry the pallets from the goods entry zone to the stock place.

22. **Are there specific persons for picking and fill-up?** Yes the teams are separated. One team are the pickers and do only picking the whole day. The other team only fill-up the racks. There are more pickers than fill-up persons.

23. **How often do you get goods for fill-up?** This depends on the product family. The fresh articles will be delivered once a day, fruits and vegetables twice a week and the dry goods once a week. This depends on the demand of articles and seasonal deviations.

24. **Does the Kastner Gruppe also have a production hall?** No there is no production hall. All articles will be delivered packed.

25. **Is is possible to store more than one article at a stock place?** Yes this is possible. At the pallet stock there are also pallets with different articles on it.

26. **Which types of customers do you have? (B2B, B2C or both?)** Kastner Gruppe only deliver their goods to B2B customers. The customers are gastronomy, hospitals, hotels, shops and other medical institutions.

27. **How orders the customer the goods?** There are different ways to order goods from Kastner Gruppe. The customer can order via webshop, phone, mail or MDE-Devices. MDE means mobile data acquisition devices which are used by shops.

28. **Information about the company**

    - Name of the company: KASTNER GroßhandelsgesmbH
    - Number of employees in the company: about 900 from 13 different countries. In Zwettl there are 185 people working in the logistics.
    - Number of orders per day: 334 (based on data from 20th February 2019)
    - Number of articles on stock: 60000 articles (about 14000 organic products)
    - Number of customers: 33000 pick up customers and 9500 delivered customers
    - Number of pallet storage: 42000 (total number of all stocks)
    - Revenue (2018): about 225 million Euro

Appendix D

Interview with JULIUS KIENNAST LEBENSMITTELGROSSHANDELS GMBH

The interview was held with Thomas Vit assistant of the stock manager at the logistics center in Gars am Kamp on 21st of March.

1. **Which properties can your articles have?** Kiennast trade with all levels of tempered goods started from -22° Celsius frozen products up to the dry products which will be on stock at about +20° Celsius. They also trade with easily perishable products which can stacked over each other because Kiennast just acts as a trader and will sell all products (except meat) as they get it. Some products are touch-sensitive so they have to take care when they give these type of products on stock. They also have non-food articles like cleaning powder or laundry detergent. These products are at a separate part of the stock.

2. **Do you trade your product to different countries with different languages?** Yes. They have to fulfil some regulations to have different levels of tempered stocks. The different tempered stocks are -20° Celsius for frozen products, 0° Celsius for fresh meat, +2° for leafy vegetables, +11° for fruit and vegetables, +15° Celsius for exotic fruits and +20 degrees for their dry assortment. Another regulation are the different certificates. Regarding their MSC (certified sustainable seafood MSC) and ASC (aquaculture stewardship council) they have to stock the certified fish not next to the fish without a certificate.

3. **Do you sell the articles in different languages?** All articles will be sold in German. They also sell 4 articles with Turkish language but these articles aren't available in German. So no special requirement are given for stock management.

4. **Which package types do you have in your company?** Kiennast sell their products in bags, boxes, cans and loose products packed in boxes.

5. **Do you have any special products like vouchers which are not on stock?** Not all products are on stock because this would be too much. In Gars there are about 12500 different products and other 20000 products can be ordered. These

products are rare or ordered just a few times per month. This products will be ordered by the suppliers of Kiennast and will be delivered after some days.

6. **Which types of storage racks do you have?** They have different stock types. The most important are pallet storages, flow racks for meat and high rack storages.
7. **Do you have shifts for your stock employees?** No.
8. **Do you have a incentive system for your pickers and fill up persons?** Yes. The system calculates the time for every order which a picker has to handle and add a default value for printing the documents and packaging. When the picker undercuts a specific value, he or she gets a bonus. This will be calculated per order.
9. **Is there a relation between number of orders and number of pickers?** When they know there are many orders per day, they have the possibility to have more people for picking and fill-up.
10. **Do you have different types of stocks? (e.g. Stock for picking, external stock, main stock, ...** There is just the main stock in Gars. This logistics center will be split up into two halls. One hall is for packing the orders from judicial institutions and the main stock is for gastronomy, gas stations and shops.
11. **Do you have packaging tables/areas?** This will be handled directly at the goods issue place. At this area the goods will be packed at the roller containers and labelled for the customer.
12. **When do you fill up the stock?** At Kiennast this task is a challenging one. On the one hand they must look at past orders from the last years and on the other hand based on the open orders.
13. **Do you have a processing/production hall next to the storage?** They get all articles packed and they just act as a retailer. The only exception is the butcher department. The whole killed animals arrives at this department and the butcher disperse these into smaller pieces for the customers.
14. **Is it usual to have different articles at one stock place?** Yes this is possible at the logistics centre Kiennast in Gars. At one stock place it's possible to store more than one article at the same time.
15. **Which types of customers do you have? (B2B, B2C or both?)** The main customers are B2B. For judicial institutions they pack all goods for every person in a separate box.
16. **Are you differentiating between orders to give them a different priority?** Yes the IT-System has a priority function implemented so the departmental manager can give different customers different priority. At Kiennast the own shop in Gars am Kamp is every day the first customer which gets the goods. So the priority from this shop is the highest one.

17. **Which picking type do you prefer in your company?** They have two different picking types at the same time. Pick-by-terminal for scanning the product and feed the IT-System and Pick-by-document for an overview of all goods which will be picked. The picker can decide with which article he or she will start because the IT-System don't know which articles are heavy and should be picked at first.

18. **Are there some corridors for a specific value?** No every person can use every corridor. They just have a driving direction.

19. **Is there a standard place for the articles?** Every article has his standard place and if there are new goods they will be placed at the first free place. This is like a chaos approach but with a standard place if the article has his fixed place.

20. **How does the picker carry the goods?** With picking vehicles and a roller container.

21. **How does fill up persons carry the goods?** With a stacker.

22. **Are there specific persons for picking and fill-up?** There are predefined teams for picking and fill-up. When there are vacations or if persons are ill the team can vary for a specific time.

23. **How often do you get goods for fill-up?** It depends on the goods which are needed. The goods receiving starts at 8 am and ends at 4 pm.

24. **How orders the customer the goods?** This will be handled in different ways. The selling department accept E-Mail, Fax, Webshop orders or orders via the Best-friend order system.

25. **Information about the company**

    - Name of the company: Julius Kiennast Lebensmittelgroßhandels GmbH
    - Number of employees in the company: there have about 220 employees overall. Of theses 220 employees there are about 130 at the logistics center.
    - Number of orders per day: They supply about 1100 customers per day.
    - Number of articles on stock: 12500 articles overall (8200 dry assortment, 4300 fresh produce) and over 20000 additional special products
    - Number of customers: 2400 customers and their own shop with about 1700 customers per day
    - Number of pallet storage: 10000 pallets spaces in the stock
    - Revenue (2018): 82.5 million Euro