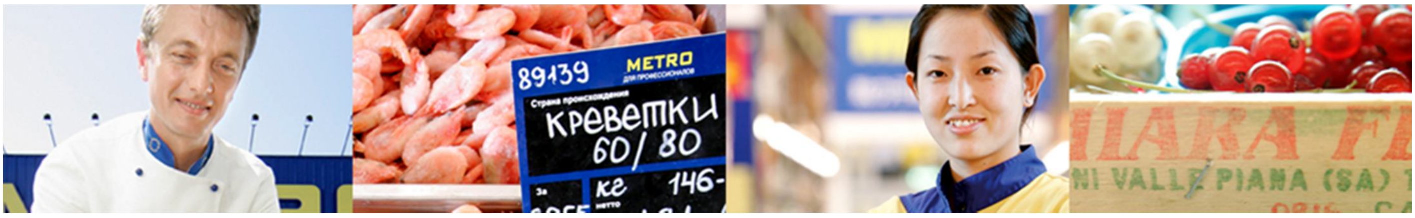
makro

UNIVERSITY OF TWENTE.

The combination of ‘Bricks&Clicks’:

An investigation into warehousing efficiency improvements for the E-Commerce fulfillment processes at Makro Cash & Carry.

Master thesis Industrial Engineering and Management by
P.J.J. Reiche



March 2014

This research is confidential, therefore this public version only contains the management summary, introduction and conclusions & recommendations. All figures are excluded, and replaced by ‘X’.

General information

The content of this report is designated as confidential. The content is not for public distribution. Any form of reproduction should be with the explicit permission of Makro Cash & Carry.

Author
P.J.J. Reiche
Jacob Catsstraat 37
3521 VE Utrecht
p.j.j.reiche@alumnus.utwente.nl

Educational institution
University of Twente – The Netherlands

Faculty
School of Management and Governance

Educational program
Industrial Engineering and Management – Production and Logistics Management

Committee

University of Twente

Dr. P.C. Schuur
School of Management and Governance
University of Twente, Ravelijn (RA3422)
p.c.schuur@utwente.nl

Dr. ir. L.L.M. van der Wegen
School of Management and Governance
University of Twente, Ravelijn (RA3355)
l.l.m.vanderwegen@utwente.nl

Makro Cash & Carry Nederland B.V.

Ir. J.P. de Craen
Fulfillment Manager
jens.decraen@makro.nl

Management Summary

Two of the main goals of Supply Chain Management in general are to increase efficiency and remove bottlenecks from operations. The highly competitive and transparent E-Commerce market, with corresponding fulfillment costs and low margins, forces companies operating in this market to effectively pursue and achieve these Supply Chain Management goals. This paper reflects the findings from a research conducted for Makro Cash & Carry, to improve the efficiency and remove encountered bottlenecks from E-Commerce fulfillment activities.

About eighteen months ago, Makro Cash & Carry Netherlands entered the online sales market for 'office supplies and general needs'. Customer orders are fulfilled from the conventional Makro store in Vianen and shipped to the customer by a third party logistics provider. The advantage of this so called 'Brick-&-Clicks model is that inventory is centralized, and strong inventory pooling effects are realized via the multiple channels. This enables the company to maintain a large assortment, and reduce inventory costs compared to an individual 'Brick' and individual 'Clicks' fulfillment model. However, it also incorporates some inefficiency in for example the order picking process. In the current situation, the capacity of the E-Commerce order fulfillment process is sufficient to deal with the current demand, but the amount of slack is negligible.

Research motivation

In the first six months of 2013, the average number of orders per month has been doubled. This growth rate seems to continue, due to investments in the visibility and usability of the online shop and the expansion of the range of products which are online available. Therefore, the capacity of the fulfillment process has to be increased to deal with this increasing demand.

Research goal

From a Supply Chain Management perspective, the main focus of all operations should be on *efficiency*, whereby bottlenecks must be removed and costs must be lowered throughout the chain, by driving out unnecessary expenses, movements, and handling (Hines, 2004). Therefore, the goal of this research is to identify opportunities to improve the efficiency of the order fulfillment process to increase the capacity of the E-Commerce department. Moreover, the efficiency improvements need to decrease the average operational costs per order. The increased capacity enables Makro to deal with the increasing demand.

Research design

For identification of possible solutions, the current situation is assessed. Using warehouse activity profiling (Bartholdi & Hackman, 2011), we assess the current fulfillment process with its individual activities. Next, an extensive literature research is conducted to identify suitable solutions for the Makro case specifically. The main focus areas of research are the picking strategy and storage applications in the order fulfillment process. After identifying the possible solutions, the current situation is redesigned to achieve an increase in efficiency. The impact of the proposed order picking strategy is empirically measured using a case study. The order throughput time quantifies the impact, and is measured before and after implementation of the suggestions. The impact of the proposed solution in the field of storage applications is assessed using a benchmark analysis. This research ends with the conclusions and recommendations to improve the fulfillment efficiency.

Conclusions and recommendations

The store in Vianen is characterized by wide pick facings and spacious aisles, to allow for convenient conventional customer shopping in a wholesale environment. The store is not optimized for E-Commerce fulfillment activities, but both order picking and conventional shopping are performed in parallel in Vianen. In general, order picking accounts for at least 50% of the operational costs of a warehouse, and order picking itself consists of 50% travel time, a reduction in travel time will have major impact on the order throughput time and operational costs. By increasing the pick density of a picking tour, the total distance traveled (and travel time) is reduced, the average throughput time of an order is thereby reduced, and consequently, efficiency is increased (Kämäräinen et al., 2001). Solutions in the field of order picking strategy and storage applications are proposed to achieve an increased pick density. Based on the empirical time study, we realize a decrease of X% in the average picking time per order, and a decrease of X% in the average packaging time per order. The savings as a result of an improved picking strategy account for € X on labor costs, based on the budgeted sales of 2014. The savings as a result of a new storage application are estimated on € X. The total annual savings are therefore estimated on € X.

In the field of picking strategies, we recommend Makro to implement batch picking. Batch picking is the process of combining multiple orders in one picking tour. Batch picking can decrease the total picking time significantly due to the increase of the pick density. The store is naturally split up into two zones, namely Dry and Home (on the first floor) and Office/Media (on the second floor). We recommend Makro to only batch orders from the same zone to ensure a learning effect of the SKU positioning on the shelves by the employees. The total distance travelled can further be reduced by only combining orders from the same area within a zone. The best way to form batches is by creating multiple batches concurrently, to enable the employee to add a randomly selected order to the most suitable batch under construction. The most suitable batch to add a randomly selected order to is the batch in which the number of additional aisles that has to be entered due to the new order is minimized. These choices require quite some intellect from the employee forming the batches. The ultimate recommended variant of batch picking which suits the situation of Makro is ***sort-while-pick parallel wave picking*** whereby:

- only orders for one of the two zones are batched together (wave),
- the two individual zones in the store are picked at the same time to prevent too much work in process, which could lead to mistakes in the fulfillment process (parallel),
- individual customer orders are separated on the picking cart while picking to maintain order integrity and prevent sortation effort after picking (sort-while-pick),
- the maximum batch size for orders picked in the first floor zone is five orders and in the second floor zone is 10 orders. We empirically determined that this enables the order picker to keep track of all orders in the batch, and leads to an acceptable risk of picking mistakes. Moreover, this equalizes the average time to pick a batch in both different zones.

A heuristic has been developed for the batch formation process. After a warm-up period in which step 1 is executed 4 times, the pseudo code to form a batch with batch size i for the first floor zone is as follows:

1. Apply Seed Selection rule
   Select the order with the largest number of SKUs
2. Apply Order Addition rule
   Select a random order with an average order size or smaller (so no outlier)
   a. *If order is not available, proceed to step 4*
   b. *If cart capacity including selected order is not violated, add order to most suitable batch under construction and proceed at the beginning of step 2 if i<5 , or to step 4 if i=5*
   c. *If cart capacity including selected order is violated, proceed with step 3*
3. Select order with the smallest number of SKUs
   a. *If cart capacity including selected order is not violated, add order to batch and proceed at the beginning of step 3 if i<5 , or to step 4 if i=5*
   b. *If cart capacity including selected order is violated, proceed to step 4*
4. Send batch to order picker and proceed at step 1

In the field of storage applications, we recommend Makro to include the top X fast-moving SKUs to a fast-pick area which has to be newly designed at the central depot. This particular set of items is concentrated in a small physical space, which results in an increased pick density for this set of items. These X items enable Makro to pick all non-promotional items from at least X% of the orders. We provided a sensitivity analysis which indicates the impact of an increased amount of SKUs in the fast-pick area on the average amount of order lines that can be fulfilled per order from this fast-pick area. Besides the reduction in average travel time per order as a result of the increased picking density, another advantage of the fast-pick area is an increase in service level for online customers. The service level is increased since conventional customers are not able to collect items from the fast-pick area. This increases the availability of this specific set of SKUs and reduces the chance of out of stock issues. Moreover, the fast-pick area reduces the amount of traffic in the conventional store, which results in fewer disturbances of conventional shopping activities. Based on a benchmark with a comparable fast-pick area in the Makro store Amsterdam, we estimate the benefits of a pick from the fast-pick area and the costs of restocking this area. The annual net savings for the proposed fast-pick area containing the X fastest moving items in regular sales are estimated on € X. A sensitivity analysis is provided to indicate the impact of an increased amount of SKUs in the fast-pick area compared to the annual benefits. The savings optimum appears to be at X SKUs, but Makro should consider the increase in complexity due to such an amount of SKUs in the fast-pick area. We conclude that Makro should consider the trade-off between the annual benefits and increased service level on the one hand, and the required space, increased complexity and increased inventory level, all depending on the number of SKUs, on the other hand.

Other recommendations to eliminate observed waste are:

- Confidential

Preface

Dear reader,

The previous few months have been challenging, inspiring and most of all, a lot of fun. Makro gave me the opportunity to conduct my master research to obtain my master's degree at their headquarters in Amsterdam, and the store in Vianen. I am grateful for this opportunity as a stepping stone to my future career. It has given me lots of insights in business and operations, which were all enriching experiences and a valuable contribution to my personnel and professional development. After all the work that has been done, I am proud to present my master thesis to you.

This report was partly created by the help and commitment of employees of Makro Cash & Carry and the University of Twente. I would like to thank everyone that put effort in my research. Without your effort and advice, the required insights would not be obtained. I would like to say thanks to some people in particular:

Jens, it was a pleasure to work with you. We had lots of fun during day to day business, but you had always time for serious topics and guidance. I was fortunate that you completed the same master program at the same University as I do now. Your knowledge of the study program and expectations of both the University and Makro guided me in the right direction.

Peter, thanks for your always open en honest comments on my delivered work. I admire your extremely diverse topics of interest and your reaching knowledge in so many research areas. This allowed me to explore my own topics of interest at Makro and gave me lots of freedom to deliver a custom made solution.

Leo, thanks for your critical and constructive comments during the feedback sessions at the UT. Although your schedule was most of the time overbooked because of the educational reforms, the time you invested in my research was of great value. Your comments helped me to improve the quality of my work significantly.

Have fun reading!

Best regards,

Peter Reiche

Utrecht, March 2014

Table of Contents

Definitions and abbreviations

Pick density: The number of picks per unit distance traveled

$$pick\ density = \frac{\#\ picks}{unit\ distance\ travelled}$$

Picking density: The number of picks per unit volume stored (e.g. # picks / m^3)

$$picking\ density = \frac{\#\ picks}{unit\ volume\ stored}$$

Efficiency: The ratio of output (like fulfilled orders per day) to input of, for example, effort, time, resources or cost (Ostroff & Schmitt, 1993)

- **SKU** Stock Keeping Unit
- **3PL** Third Party Logistic Provider

1. Introduction

This report is written to obtain my Master's degree in *Industrial Engineering and Management* at the University of Twente, in the research field of *Production and Logistics Management.* The research focusses on the optimization of the order fulfillment processes of the online customer orders at Marko Cash & Carry Netherlands. In September 2012, Makro started online sales and initially introduced a limited number of articles in their online shop, from now on called 'Webshop'. The aim of this research is to analyze and optimize the order fulfillment processes to enable Makro to expand the volume and increase online turnover.

The research has been conducted from an Operations Management perspective, in which is focused on ensuring that business operations are efficient in terms of using as few resources as needed, and effective in terms of fulfilling all incoming orders. The premise of the entire research is to come up with solutions of practical relevance. Optimality in an ideal world falls outside the scope of this research.

In Section 1.1 of this chapter, the research goal is identified based on interviews with stakeholders within Makro. In Section 1.2, the relevance of the research is outlined. In the third section of this chapter, a general introduction into Makro is given. *(Last two sections not included in this confidential version)*

1.1 Problem introduction

This research is conducted on behalf of the E-Commerce department of Makro Cash & Carry Netherlands. E-Commerce can be defined as the buying and selling of information, products and services via computer networks (Daniel, Wilson, & Myers, 2002). This department started in September 2012 with the online offering of a selected number of articles from the standard assortment. In the following months, the range of products has been expanded to about X items in September 2013. Makro aims to increase the amount of customers in the Webshop in various ways and thereby increase the sales volume. This requires Makro to adjust and to be ready for the future situation. The assignment provided by Makro can be summarized by:

Design a roadmap to successfully cope with future demand

Makro foresees its future in a multi-channel supply chain with the combination of **'Bricks&Clicks'**. 'Bricks&Clicks' is defined as the integration of E-Commerce activities into the conventional store shopping activities. The advantage of this system is that inventory is centralized, and strong inventory pooling effect are realized via the multiple channels, which enable the company to maintain a large assortment, because demand reaches beyond the boundaries of an individual conventional store (Agatz, Fleischmann, & Van Nunen, 2008).

The E-Commerce industry is a highly competitive and transparent market, since every consumer can compare multiple suppliers with a few mouse clicks. Customers are highly price sensitive, since it costs almost no effort to switch from supplier (Tarn, Razi, Wen, & Perez Jr, 2003). On top of that, consumers demand the lowest price, high quality and fast delivery. Not available items or an incorrect delivered item directly results in a dissatisfied and, most probably, lost customer. Therefore, the product availability needs to be high, which requires high stock values.

In the current situation, the capacity of the **E-Commerce** order fulfillment processes (Clicks) is sufficient to deal with the current demand, but the amount of slack is negligible. An increase in demand directly requires an increase in workforce deployment. The fulfillment activities take place in the conventional Makro store in Vianen. Order pickers pick the orders which are placed online from the shelves in the store in Vianen during daytime, where conventional customers are shopping. All warehousing and fulfillment activities are performed in parallel with the conventional 'Bricks' activities of Makro Vianen. This creates challenges for both the conventional and online activities in this Makro store in Vianen.

This research is conducted to deliver an advice to deal with the expected upcoming increase in volume and the resulting need for extra capacity. There are generally two options to cope with a lack of capacity. The first is to increase the capacity by acquiring extra (human) resources and the second is to increase efficiency to *create* extra capacity and reduce operational costs. From a Supply Chain Management perspective, the main focus of all operations should be on *efficiency*, whereby bottlenecks must be removed and costs must be lowered throughout the chain, by driving out unnecessary expenses, movements, and handling (Hines, 2004). Therefore, this research focusses on efficiency improvements in the order fulfillment process to increase the capacity of the E-Commerce department, and concurrently decrease operational costs.

The research goal can be formulated as follows:

Identify opportunities to improve the efficiency of the E-Commerce fulfillment process in Vianen, to enable Makro to deal with an increasing demand and concurrently decrease operational costs.

Before we continue, we clarify what we mean by *efficiency.* Efficiency is the relation between (1) the accuracy and completeness with which users achieve certain goals and (2) the resources expended in achieving them (Frøkjær, Hertzum, & Hornbæk, 2000). In other words, it is the ratio of output (like fulfilled orders per day) to input of, for example, effort, time, resources or cost (Ostroff & Schmitt, 1993). The research goal includes the objective to lower the operational costs. In the remainder of this research we will assume that efficiency improvements result in the decrease of operational costs. Of course not in absolute terms but in relative terms per order. In the case of Makro, we will find out later in this report that the efficiency of the fulfillment process is determined by the throughput time per order. An increase in efficiency lowers the average throughput time per order, and thereby the average operational costs.

In pursuing the research goal, we strive to get insights in the following aspects:

- The required time per activity in the fulfillment process;
- Possible solutions to decrease the order throughput time;
- Possible solutions to increase the picking productivity;
- Options to eliminate waste/ remove bottlenecks from operations.

2. Conclusions and recommendations

In the introduction of this research we mentioned the reason for starting up this research and the problem encountered by Makro:

To deal with the expected increase in demand, changes in the fulfillment process are required to obtain the required capacity. Makro wants an advice on the steps to be undertaken to cope with future demand.

In consultation with stakeholders within Makro, we decided that efficiency improvements are necessary to increase the capacity of the system to be able to deal with the expected increase in demand. Therefore, we formulated the following research goal:

Identify opportunities to improve the efficiency of the E-Commerce fulfillment process in Vianen, to enable Makro to deal with an increasing demand and concurrently decrease operational costs.

The Key Performance Indicator that quantifies the extent to which the efficiency is improved is the 'average throughput time' of an order.

2.1 Conclusions

To achieve the research goal, we formulated the following main research question:

What improvements can be realized to increase the efficiency of Makro's E-Commerce fulfillment process?

In general, order picking costs account for at least 50% of the total warehouse operating costs. Order picking, in turn, consists of about 50% travel time. Therefore, a reduction in travel time per order will relatively have a major impact on operations and the order throughput time. By increasing the pick density, less time is wasted on traveling between individual picks, since the average number of picks per traveled meter is increased. This results in a reduction of the average order throughput time per order. Solutions in the field of order picking strategy and storage applications are proposed to improve the pick density, which decrease the order throughput time and consequently increase the fulfillment efficiency.

An empirical time study in the field of picking strategy is conducted to test the implementation of batch picking. The average time to pick an order using batch picking is reduced by X% compared to the currently used pick-by-order strategy, which is a reduction of X minutes per order. Moreover, batch picking results in a X% reduction in the time to pack an order, since all shipment documentation is already included on the picking cart, along with the picking list. This prevents the need to search for these documents after the order is picked. The total annual savings due to the implementation of batch picking are forecasted on € X, based on the sales targets for 2014.

The proposed solution in the field of storage applications to increase the pick density is the introduction of a fast-pick area containing X SKUs. This fast-pick area enables Makro to pick all regular sales order lines of X% of the incoming orders. Based on a benchmark with a comparable fast-pick area, we determined the benefits of a pick from such an area, and the costs of restocking it. The annual savings are estimated on € X. Besides the increased pick density for these X selected fast moving items, another benefit is an increase in the service level for online customers. Conventional customers are not able to collect items from the fast-pick area, so the availability of the items in the fast-pick area is more secure and better predictable for online sales. Therefore, less out of stock issues occur and online customer satisfaction increases. Moreover, less picking activities take place in the conventional store, which leads to less disturbance, so an increased conventional customer satisfaction. Inventory for the fast-pick area is provided by increasing the reorder points in the conventional store for the X SKUs. Makro should consider the trade-off between the annual benefits and increased service level on the one hand, and the required space, increased complexity and increased inventory level, all depending on the number of SKUs, on the other hand.

Sub research questions are formulated to support answering the main research question:

1. *How is the current E-Commerce fulfillment process organized, and what is the performance?*

In the current process, the vast majority of orders is picked one-by-one, based on a first come first serve policy. Orders are picked in the conventional Makro store in Vianen, which is characterized by spacious aisles and wide pick facings. This results in high travel distances per picking tour. An order picker collects an individual picking list, and travels along the relevant aisles to pick the items on the list, in a conventional shopping cart. The store is naturally split up into two zones which are separated by a floor. Orders containing two zones are sometimes split up, but a clear policy is not in place. A small fast-pick lane is situated at the central depot at the E-Commerce department. The variety and storage volume of the products in the fast pick lane are based on common sense of fast moving items in regular sales, and promotional items in a particular week.

Besides the high travel distances, we identified multiple other forms of waste within the fulfillment process. Examples are X, X and X.

2. *What are possible improvements in the order fulfillment processes according to the literature, and what are the pros and cons?*

Much has been written about warehousing (re)design and optimization. An extensive literature research has given us insights in order picking strategies and routing policies, as well as various storage modes and policies. The main focus of the literature research was on solutions which can increase the pick density, to lower the time wasted on travel between individual picks. An increased pick density leads to a lower average picking time per order and consequently an increased fulfillment efficiency.

In the field of order picking, we reviewed picking strategies like pick-by-order, batch picking, zone picking and wave picking. Moreover, routing policies like S-Shape strategy, Return Strategy, Largest Gap strategy, Combined strategy and Midpoint strategy have been identified. A complete overview with corresponding pros and cons is composed in the summary section of chapter 4 *(not included in this confidential version).*

In the field of storage applications, we reviewed the application of a fast-pick area to increase the pick density for a specifically selected set of fast-moving SKUs. The methodology to design this fast-pick area, with corresponding decisions about the choice for the different SKUs to store against individual volumes, have all been discussed in Section X. For these items, multiple storage modes have been discussed, like shelf storage, palletized storage and automated storage. Within the fast-pick area, a choice can be made between multiple storage policies, which are dedicated storage, random storage or class-based storage.

3. *Which improvements are suitable for Makro, based on their properties?*

In the field of order picking, we suggest Makro to implement batch picking. Batching is the clustering of orders together in the picking process to form a single picking tour. This increases the pick density and thereby decreases the average picking time per order. We suggest the variant whereby only orders from the same zone are batched, which is called wave picking. To prevent a high amount of work in process, we suggest to pick the two different zones in parallel. We suggest to separate individual orders while picking to maintain order integrity and prevent sortation effort after picking. The ultimate picking strategy is called ***sort-while-pick parallel wave picking.*** We formulated a greedy heuristic for the batch formation process. This heuristic maximizes the pick density per tour and conforms to multiple operational restrictions as formulated in consultation with Makro. Multiple batches should be formed concurrently to enable the administrative employee to add a randomly selected order to the most suitable batch under construction. This is the batch in which the number of additional aisles to be visited after inclusion of the extra order is minimized.

In the field of storage applications, we suggest Makro to implement a fast-pick area containing the proposed list of the X top fastest moving items as indicated in *(not included in this confidential version)*. This enables Makro to fulfill **all** non-promotional order lines of at least X% of all incoming orders from this area. This saves travelling time to the conventional picking area in the store and thereby decreases the average picking time per order. Next to that, it enables Makro to minimize the risk of out of stock for this particular set of SKUs, since conventional customers cannot collect items from the fast-pick area. Moreover, less traffic in the conventional store results in less disturbance of the conventional shopping experience. We provided two sensitivity analyses which indicate the impact of an increased amount of SKUs in the fast-pick area on the annual benefits, and on the average amount of order lines that can be fulfilled per order. Within this fast-pick area, the storage mode per SKU depends on multiple variables like the size, the volume, the throughput, the fragility, the weight of a box and handling effort. Dedicated storage appeared to be the most suitable storage policy. We recommend slotting SKUs based on the volume-based slotting technique, in which the most requested SKUs are located at the most convenient locations of the fast-pick area.

4. *How can the improvements successfully be implemented?*

The implementation of wave picking starts with the investment in new picking equipment to acquire the minimum required capacity for a picking cart. Based on the experience from an empirical test phase to test wave picking, it is determined that X trolleys are sufficient to process the current order volume. The total costs for these X trolleys is € X and result in a payback time of X days. The formation of batches should be executed by the administrative employee in the order preparation phase of the fulfillment process. Complete batches with corresponding invoices and shipment labels are sent to order pickers which divide them over the individual shelves in the trolley, to maintain order integrity. Completely picked trolleys are returned to the central depot, where the orders are packed from the trolley to prevent unnecessary product handling.

The implementation of the fast-pick area depends on the decision of the store manager in Vianen. Makro should consider the trade-off between the annual benefits and increased service level on the one hand, and the required space, increased complexity and increased inventory level, all depending on the number of SKUs, on the other hand.

2.2 Recommendations

The recommendations are split up in three different parts. In Section 2.2.1 *Implement wave picking,* we summarize all recommendations in the field of the proposed picking strategies. In Section 2.2.2 *Design of the fast-pick area*, we do the same, but now for the proposed solutions in the field of storage applications. Both Section 2.2.1 and 2.2.2 concern the increase of the pick density to decrease the time spent on travel to increase the efficiency. In Section 2.2.3 *Recommendations for the elimination of waste*, *(not included in this confidential version).*

2.2.1 Implement wave picking

Wave picking lowers the average picking time per order and thereby increases the efficiency of the fulfillment process. The batches of orders should be formed in the 'order preparation phase' and should be sent along with all other order documents to a dedicated order picker of the particular zone. It is empirically established that the maximum batch size for the first floor zone is 5 and for the second floor zone is 10. After a warm-up period in which step 1 is executed 4 times, the following heuristic should be followed to form the batches with batch size i (example for first floor zone):

1. Apply Seed Selection rule
   Select the order with the largest number of SKUs
2. Apply Order Addition rule
   Select a random order with an average order size or smaller (so no outlier)
   a. *If order is not available, proceed to step 4*
   b. *If cart capacity including selected order is not violated, add order to most suitable batch under construction and proceed at the beginning of step 2 if $i<5$, or to step 4 if $i=5$*
   c. *If cart capacity including selected order is violated, proceed with step 3*
3. Select order with the smallest number of SKUs
   a. *If cart capacity including selected order is not violated, add order to batch and proceed at the beginning of step 3 if $i<5$, or to step 4 if $i=5$*
   b. *If cart capacity including selected order is violated, proceed to step 4*
4. Send batch to order picker and proceed at step 1

Further recommendations for the implementation of wave picking are:

- Only orders from the same zone (first or second floor) should be batched to increase the learning effect of SKU position by the order picker (wave).
- The two different zones should be picked concurrently to prevent too much work in process, which could lead to mistakes in the fulfillment process (parallel).
- Individual customer orders are printed on separated picking lists to be able to store them separately on the picking cart while picking, to maintain order integrity and prevent sortation effort after picking (sort-while-pick).
- Multiple batches should be formed concurrently to enable the employee to add a randomly selected order to the most suitable batch. This is the batch in which the number of additional aisles to be entered after inclusion of the extra order is as small as possible. The entire batch under construction should be considered to determine the most suitable batch (dynamic).

- The maximum batch size for orders picked in the first floor zone is five orders and in the second floor zone is 10 orders. We empirically determined that this enables the order picker to keep track of all orders in the batch, given the particular order profile of orders in these zones. More orders in a batch would lead to an unacceptable risk of picking mistakes. Moreover, this equalizes the average time to pick a batch in both different zones.

- The maximum number of orders with an above average order size in a batch is one. Empirically is established that it is hard to keep track of all order lines if more than one order in a batch has an above average order size, which leads to an unacceptable risk of picking mistakes.

The ultimate picking strategy is called ***sort-while-pick parallel wave picking.***

2.2.2 Design of the fast-pick area

To increase the pick density for a particular set of SKUs and concurrently enable Makro to pick all non-promotional items from at least 10% of the orders from the fast-pick area, we suggest Makro to install the generically designed fast-pick area containing the top X fastest moving SKUs. This can result in a decrease in the average picking time per order, and the ability to minimize the risk of out of stock for this particular set of SKUs, since conventional customers cannot collect items from this fast-pick area. The increased service level results in an increased online customer satisfaction.

Depending on the size, weight, throughput and storage volume, Makro should consider either shelf storage or palletized storage for individual SKUs. The most requested SKUs should get the most convenient locations in the fast-pick area. Since we recommend Makro to implement a fast-pick area, we feel the need to sum up all advantages and disadvantages of this fast-pick area. This enables Makro to make a well informed decision.

The main advantages resulting from the installation of a fast-pick area are as follows:

- Decrease of the order throughput time, since picks from the fast-pick area reduce the time to pick the particular SKU by X%. This ultimately results in an increased fulfillment efficiency and annual benefits of € X

- More secure availability of the X fastest moving items since conventional customer cannot collect items from this area. This increases the service level for online customers, which leads to an increased customer satisfaction.

- Less traffic in the conventional store leads to less disturbance of conventional customer shopping. This increases the conventional customer satisfaction.

The main disadvantages resulting from the installation of a fast-pick area are as follows:

- A fast-pick area containing X SKUs requires space in the store in Vianen.

- An increased number of SKUs in the fast-pick area increases the complexity of picking and replenishment. The provided sensitivity analyses from Section **Fout! Verwijzingsbron niet gevonden. *Fout! Verwijzingsbron niet gevonden.*** should provide insights. *(not included in this confidential version)*

- The inventory level of Makro Vianen increases, which costs money and incorporates risk.

2.2.3 Recommendations for the elimination of waste

Confidential