"Warehouse efficiency at Topa verpakking"

topa verpakking

Master Thesis

UNIVERSITY OF TWENTE.

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August 2010

"Warehouse efficiency at Topa verpakking"

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Industrial Engineering & Management

Master Thesis
In order to obtain the Master degree of the study
Industrial Engineering & Management at the University of Twente

November 2009 – August 2010

topa verpakking

UNIVERSITY OF TWENTE.

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Summary

Topa verpakking is a specialist in the field of packaging and shipping. The distribution center of Topa is established in Lelystad. The distribution center had some rough changes during the last years. These changes resulted in a new layout and new processes. The question arises by the management of Topa if the right choices have been made. This research has focused on the main warehouse activities, receiving, storing, picking and shipping. Objective of this research was to expose the current bottlenecks and their performance and find solutions to improve the efficiency.

The problem definition of this research is: “*How can non value adding activities be reduced to improve the efficiency in the distribution center of Topa verpakking? “.* The word efficiency is defined as doing the thing right which is usually measured as the output per unit input.

Four bottlenecks were exposed after observing the current situation, interviewing employees and analyzing data from the ERP system.

Bottleneck 1: The receiving process
The sequences of the activities of the receiving process and the responsibility of two departments causes a lot of waiting time. Waiting time can be classified as waste in a process, a non value adding activity. The main problem is that stickers with the locations number on it are printed in a late phase of the process. This causes a delay in the whole process, a pallet can be stored in the locations only when the sticker is attached. The whole process is mapped with the tool Value Stream Map. The KPI (Key Performance Indicator) of this process is defined as the average total throughput time of a truck loading. Time is measured from the arrival of a supplier until the pallet is stored in the location. The current average total throughput time of the receiving process is 138 minutes for one truck loading.

A real life simulation was done for testing a desired situation. The stickers are printed in an early phase of the process and attached when possible. The storing of the pallets determines the rhythm and speed of the total process. The real life simulation of the desired situation has shown to be very effective. The total throughput time decreases to 88 minutes per truck load.

KPI	Current situation	New situation	Improvement
Average total throughput time in the receiving process	138 minutes per truck	88 minutes per truck	*50 minutes per truck* ***36.24 %***

Bottleneck 2: The forward-reserve problem
Topa has divided the warehouse in two different areas, the reserve area and the fast pick area. The fast pick area is used to speed up the order picking process for popular and small products. The reserve area is used for the bulk storage, picking big order quantities and less popular products. The allocation of SKUs (Stock Keeping Unit) to the fast pick area is done by plain thinking. An update of this allocation has never been done since the implementation. SKUs that have become popular are still picked from the reserve area and SKUs that have become less popular are still picked from the fast pick area. This problem results in labor intensive work in the reserve area and no advantage of savings of picking SKUs in the fast pick area rather than in the reserve area.

A literature study is done to find a suitable solution to allocate SKUs to the fast pick area. The model of Bartholdi & Hackman, 2010 described in their book “Warehouse & Distribution Science” is applicable for the case of Topa. It describes a heuristic and model to determine which SKU contributes net benefit of being picked from the fast pick area rather than from the reserve area.

The model of Bartholdi & Hackman is applied to the case of Topa. This resulted in an improvement of 66 minutes per day for a reach truck driver and an improvement of 133.9 picking hours per year of picking SKUs rather from the fast pick area.

KPI	**Current situation**	**New situation**	**Improvement**
Each picking time by reach truck drivers	232 minutes per day	166 minutes per day	*66 minutes per day* ***28.45 %***
Net benefit	1059.7 hours per year	1193.6 hours per year	*133.9 hours per year* ***12.63 %***

Bottleneck 3: The storage strategy in the reserve area
Topa has chosen in the past to implement a class based storage strategy. Products are categorized in classed regarding their popularity. The change of popularity resulted that SKUs are allocated in the wrong zones. The class based strategy has not been updated since the implementation. The management of Topa implemented the storage strategy without any thorough calculations and awareness of the travel distance and travel time for storing and picking the SKUs.

A literature study is done to determine the most suitable storage strategy in the reserve area. Random storage and different rules for class based storage are applied to the case of Topa. Studies have shown that an ABC classification regarding the 66.6-10 rule is the best option for Topa. The 66.6-10 rule means that 66.6% of the picks are caused by 10% of the products, these SKUs are allocated to zone A. The SKUs that are responsible for 66.6%-90% are classified in zone B and the rest in zone C.

The new storage strategy improves the efficiency with a decrease of the total travel time by 19.9%. An implementation plan is made with Excel lists with the SKU classification and blue prints of the new layouts.

KPI	**Current situation**	**New situation**	**Improvement**
Total travel time in reserve area	926.8 hours in 2009	742.8 hours in 2009	*184 hours per year* ***19.9 %***

Bottleneck 4: The storage strategy in the fast pick area
Dedicated storage strategy is used in the fast pick area in the current situation. SKUs are assigned to fixed locations regarding their popularity. The popularity is determined regarding customer demand. The allocations of SKUs to fixed locations has never been updated since the implementation of this area. SKUs are also assigned to locations without awareness of travel distance.

The current order picking equipment, storage space caused a lot of inefficiency in the fast pick area. A literature study was done to find a solution for the storage strategy in the fast pick area. Furthermore practical solutions have to be found to speed up the process. Dedicated storage strategy is shown to be the most suitable storage strategy in the fast pick area in combination with an allocation of the SKUs based on activity (popularity plus the number of restocks) regarding the travel distance to a location. Applying this method results in a decreasing of the travel distance by 52.84% in 2009. The order pick time in the fast pick area will decrease from 2 minutes and 40 seconds to 1 minute and 40 seconds when a new order picking vehicle is purchased that can also pick from the first level. The capacity in the fast pick area increases due to the elimination of the safety stock. SKUs from the 2nd to 6th locations are therefore stored on a ground or first level location.

KPI	Current situation	New situation	Improvement
Total travel distance in the fast pick area	2.803.776 meter in 2009	1.322.260 meter in 2009	***1.481.516 meter per year 52.84 %***
Average travel time 2^{nd} till 6^{th} location in the fast pick area	9 minutes per location	1 minute and 40 seconds per location	***7 minutes and 20 seconds per location 81.5 %***
Average travel time per ground and first level location in the fast pick area	2 minutes and 40 seconds	1 minute and 40 seconds	***1 minute 47.5 %***

This research can conclude that the efficiency can be improved for the distribution center of Topa by implementing the recommendations that are given. An implementation plan is made to implement the recommendations and to maintain the efficiency.

Preface

I would like to thank the company Topa verpakking who gave me the opportunity for this research. Topa gave me the possibility to work independently on my master assignment.

I had a great time at the distribution centre in Lelystad. I enjoyed my huge work place and the peaceful atmosphere it had. The location, next to the coffee machine and the view over the work area and the entrance to the company's site were a good combination for an excellent work environment.

I would like to thank the employees of the distribution centre who supported me in my assignment.
I would especially like to thank my supervisor, Barry, for his input and involvement in the assignment. I would also like to thank Dennis and Rudy, both responsible for the daily activities in the distribution center. Their input made me aware of the practical side of the assignment.

Also thanks to both supervisors from the University of Twente, Peter and Leo. The critical feedback sessions with both made me push my own boundaries to a higher limit.

Thanks also goes out to Anita Skelton for revising my English in this report. Her effort improves the readability of this report.

Finally I would like to thank Topa verpakking for offering me a job to implement my recommendations regarding this research. Moreover they are giving me the possibility to work on a new project.

The last three years during my study period and graduation assignment were very interesting but also very intensive. I'm therefore happy to close one chapter in my life and start a new one.

Gerben Stouwdam

August 2010

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1 Introduction

In order to obtain the master title Industrial Engineering & Management at the University of Twente I have researched the efficiency of the distribution centre of Topa verpakking.

The distribution center of Topa verpakking have some rough changes during the last years. The warehouse capacity had to be extended due to the increasing demand. This physical extension resulted in a new layout where a reserve area and a fast pick area are separated. The goal of this division of different areas was to speed up the pick process, provide more storage capacity and make the process safer.

The process also had to be adjusted because the physical layout changed. This new process had consequences in the way of working. The question arises by the management of Topa if the right choices have been made during this transition. Changes have been made on plain thinking without any based analysis. They wonder if other alternatives are applicable and more profitable for the distribution centre.

Goal of this research is to analyze the main warehouse activities, receiving, storing, order picking, and shipping. The current performance is analyzed for exposing the bottlenecks in the current process. Relevant literature is searched and practical solutions are thought of for solving these bottlenecks. New solutions are judged on the improvement of the efficiency of the distribution center. Finally conclusions and recommendations must form the base of a new implementation plan.

Next chapter gives an overview of the company Topa verpakking and their products. The third chapter describes the research structure with the problem definition, scope and approach. The current situation with the layout, processes and used warehouse strategies is described in Chapter 4. Chapter 5 contains the current performance and the bottlenecks with defined KPIs. Relevant literature regarding the bottlenecks is summed up in Chapter 6. Alternatives for the bottlenecks are given in Chapter 7 and the implementation plan for the chosen alternatives is described in Chapter 8. Finally Chapter 9 contains the conclusions and recommendations of this research. Common used terms and abbreviations are summed up in an enclosed Glossary. Used literature in this research is added in a reference list.

2 Topa verpakking

This chapter gives background information on Topa verpakking. The first section describes general information and history of the company. Second section describes the product groups and section three will outline the organization structure.

2.1 Topa

Topa verpakking or simply Topa, has been a specialist in the field of packaging and shipping since 1922. The name Topa originate from “**To**uw and **Pa**pier. Topa is a catalogue company who sells products regarding packaging and transportation materials. Customers can order their products on-line, by phone, fax or E-mail by use of the catalogue. Yearly Topa sends about 40,000 catalogues to their customers, but with the increasing usage of the World Wide Web this number is decreasing yearly.

Topa has a wide range of diverse customers. It varies from customers who only buy one article once, to big customers who purchase 20 full pallets of carton boxes every week. Some well known customers of Topa are: Medtronic, Nefit, Siemens, UPS, Yamaha Motor Distributie BV, Wehkamp postorders and Fetim.

The philosophy of Topa is translated into three statements, “a broad assortment”, “innovation and expertise” and “Customer specification and consulting”. Topa delivers direct from stock, an order before 12 a.m. means a delivery the next day, an order after 12 a.m. will be delivered the day after.

2.2 Products

Topa has a broad assortment with more or less 3000 articles such as carton boxes, tape, protection materials, diverse packaging materials etc. The core business of Topa is the carton packaging product group. In total there are sixteen main product groups which are shown with pictures added in Appendix I.

The mission of Topa is to deliver all products right from stock, which means that almost every article is stored in the warehouse. It is also the mission of Topa to make and develop to customer specific requirements regarding packaging materials; “*If we don’t have it, we will make it for you”.*

2.3 Organization

The company is divided over three places in the Netherlands. The headquarters and the Topa institute are established in Voorhout, the distribution centre and the carton box factory “Dopak” in Lelystad and the thermal packaging factory in Dronten. The organigram of the Topa group is added in Appendix II.

The Topa institute is an independent institute for the testing and development of packaging materials. With use of advanced test equipment it is possible to simulate the transportation of products. The institute can simulate product and packaging facing temperature exposure or movement during transportation such as pressure on the packaging, jerking movements and vibrations.

Topa started its own carton box production “Dopak” in 1976. Topa offers more flexibility to the customer and can reduce delivery times with the production under its own supervision. In 2000 the factory moved to Lelystad together with the distribution centre.

In the past year Topa made a strategic partnership with a thermal packaging producer from the U.S., Cold Chain Technology. Under license agreement Topa can produce and sell these products in Europe. The production of these thermal packaging products is established in Dronten.

The central warehouse of Topa was established in Lelystad in May 2000. Before this period the warehouse activities were located in Warmond and at other third parties. Because of the big growth of Topa a new central location was needed. After six years operating in Lelystad, the capacity of the 15.000 pallet places was reached and a new expansion was necessary. In the first quarter of 2008 the new warehouse extension was built with an extra pallet capacity of 7,000 pallet locations. Products from external suppliers, both factories and customers stock are now all stored in the distribution centre.

Main activities like purchasing, sales, engineering, management and administration also for the distribution centre and both factories, are established at the headquarters in Voorhout.

3 Research structure

The research structure of this project is added in this chapter. This chapter describes the problem definition (section 3.1) and scope (section 3.2) of this research. The project approach for solving the problem definition is added in section 3.3. The deliverables of this research are finally added in section 3.4.

3.1 Problem definition

Management of Topa wants to gain insight in alternative solutions for improving the efficiency of the distribution centre as mentioned in the introduction. The need for improvement is noted during an introduction period of this research. During an observation period of 3 weeks several time and labor intensive activities and waiting times were noted in the distribution center.

The first labor intensive activities and waiting times are noted at the receiving process. A lot of paper work has to be filled in for the dispatching process. Waiting time occurs in this process because another department has to execute ERP system activities before the goods can be placed in the storage locations. The supporting unit is responsible for printing the stickers. Pallets in the receive area can't be stored without these stickers.

The current storage strategies used by Topa are implemented by plain thinking. Time intensive activities occur because goods aren't stored efficiently. Long travel times occur because of inefficient storage. The current storage strategy also results in labor intensive activities. Labor intensive activities occur due to a wrong allocation of products to a location regarding the equipment restrictions. Some equipment is restricted to the ground level and other equipment can pick from the first level or all levels. Due to these equipment restrictions waiting time occurs because employees have to wait until the right equipment arrives.

These observations result in the problem definition of this research:

"How can non value adding activities be reduced to improve the efficiency in the distribution centre of Topa verpakking?"

The problem definition contains the term *efficiency.* The term efficiency is a vague and broad word and can be interpreted in different ways. To give answer to the objective of this research it is important to define the word efficiency.

The definition of efficiency by Jack R. Meredith from his book "The management of operations" (Meredith, 2006) is applicable in the case of Topa:

Efficiency is doing the thing right, which is usually measured as the output per unit input. Goal is to compare different transformation processes in choosing good measures for outputs and inputs. A good example is the number of goods made by one employee during one hour.

This definitions means that good defined measures are needed for the output and input for comparing different transformations of the process. A better input/output ratio can be achieved by doing things right the first time: improving the efficiency.

The term "value" in the problem statement refers to the activities that the customer is willing to pay for. Non value added activities are classified as *waste* of a process (Breyfogle, 2003). Waste is classified in

seven types: 1. Defects, 2. Overproduction, 3. Transportation, 4. Waiting, 5. Inventory, 6. Motion and 7. Processing.
The goal of this research is to eliminate or reduce the seven types of waste so the input/output ratio improves. A better output per input is an improvement of the efficiency.

3.2 Scope.

This research will focus on the improvement of efficiency of the activities between the processes "receiving of goods" and the process "making an order shipment ready". Included are the main activities described by Rouwenhorst et al (2000) : Receiving, storing, order picking and shipping.

The physical layout of the warehouse was recently implemented (2002) and hardware can't be changed. Management wants to gain insight in new alternatives given the fixed layout. The procurement of products, supplier agreements and stock management are processes dealt with by employees in Voorhout and therefore not included in this research. These processes can't be influenced by employees in the distribution centre.

The current ERP system is out dated and adjustments or improvements are difficult to make regarding this system. Management of Topa is gathering information and knowledge for purchasing a new ERP system. Therefore changes regarding the current ERP system AS 400 are excluded from this research.

3.3 Project approach

The main problem definition can be answered by use of several sub questions. Each sub question is described in this section. The approach for answering the sub question is also described briefly.

3.3.1 Current situation

First step of the research is mapping the current situation. Important is to know how processes are established in the organization. Secondly it is important to find out which decisions and underlying argumentations were made by management in the past. The first sub question:

1. *How is the current process established in the distribution centre?*

To answer this first question the process is observed at different moments. Information is gathered by use of interviews with the employees involved in the process. Processes are overviewed in schematic layouts and evaluated with employees and management. The total process in the distribution centre is described regarding the main warehouse processes: receiving, storing, order picking and shipping.

3.3.2 Current performance and bottlenecks

Second step of the research is to gain information of the current performance of the distribution centre. This performance must indicate the inefficiency in the current process. Two terms are important for this sub question: Bottleneck and KPI (Key Performance Indicator). A bottleneck is the slowest operation in a chain of operations; it will set the pace of the output of the entire line (Breyfogle, 2003). A KPI is a quantifiable measurement that reflects the critical success factors of an organization (Breyfogle, 2003). The performance of a bottleneck is expressed in KPIs. These KPIs are based on the output and input and therefore related to efficiency. A new alternative can be judged on the improvement of this KPI. Sub question 2 and 3 are:

2. *What are the bottlenecks in the current situation?*

3. *What is the current performance of these bottlenecks expressed in KPIs?*

Some performance indicators and KPIs are already maintained by Topa but are not related to this research. The performance of the bottleneck processes has to be measured. All bottlenecks are analyzed with use of cause and effect diagrams. Data for defining KPIs are gathered from the ERP system. Unknown data needed for the KPIs must be gathered by own measurements. Finally data have to be gathered from the pick lists and forms that are filled in by employees. For each bottleneck a KPI is defined regarding the collected data.

3.3.3 Literature study

The third step of the research is to develop a plan of approach to solve the bottlenecks. What information is needed and how to gather information to solve the bottlenecks. The next step is to find literature which can be used to improve the KPIs. Therefore sub question 4 is:

4. *How to find information for improving the KPIs and what is a suitable way for improving the KPIs of the bottlenecks?*

Per bottleneck a plan of approach is developed for improving the KPIs. Literature is searched for providing alternatives for each bottleneck. Information is searched by use of the databases Scopus and Web of Science. These two databases cover the top 33 rated journals in the field of Operations management according to Olson, 2005. The list of the ranked journals is added in Appendix III. For each bottleneck several possible alternatives are presented with pros and cons. The best alternatives are selected regarding these pros and cons.

3.3.4 Alternative assessment

The next step of the research is to give insight to what extent the alternatives are improving the current KPIs. Methods and theories from the literature study are adapted to Topa's situation to give answer to sub question 5:

5. *To what extent are the alternatives for the bottlenecks improving the KPIs of Topa?*

To answer this question calculations are made regarding the improvement of the KPIs. The constraints of the layout and type of products are taken into account for the adaption of the literature to Topa's specific case. The selected alternatives from sub question 4 are adapted to the case and calculations are made regarding the improvement of the KPIs. The new calculated KPIs are compared with the current KPIs. The alternatives are finally judged regarding significant improvement of the efficiency, easy implementation, simplicity, long period savings and savings in a short period of time. The efficiency improves if waste is eliminated and when KPIs improve significantly. The research question can be answered when other alternatives improve the efficiency. In this research efficiency is expressed in KPIs, if a KPI improves the efficiency improves. The possible improvement of the efficiency is presented to the management of Topa who can make the choice for implementing or not implementing one or more solutions.

3.3.5 Implementation

Step 5 of the research is to draw up an implementation plan for implementing the new solutions for solving the bottlenecks. A part of the implementation plan consists of a plan to maintain the efficiency. Which activities are needed to maintain the efficiency and in what kind of time window must this be done.

6. *How to implement the solutions at Topa and how to maintain the efficiency?*

This question is answered by making a structured implementation plan. The basic concept that will result in profitability is worked out in detail. This plan must be evaluated and established with the process owners/ employees and the management of the distribution centre. The next issue is to maintain the efficiency. Changes in customer demand can have influences in the KPIs. What actions does Topa have to take if demand changes or if KPIs change? A change in the KPIs can result in another strategic, tactical or organizational decision. The last sub question gives answer to what to do when demand or KPIs change to maintain the efficiency.

3.4 Deliverables

The deliverables of this research exist of a report, an implementation plan, a maintenance plan and an Excel model. The model is meant for calculating changes of the KPIs regarding the demand fluctuations. The maintenance plan takes into account how to maintain the efficiency related to the model.

The implementation plan consist of a step wise process on how to implement the new solution for the bottlenecks. The implementation plan is summarized in this report.

Last deliverable is this report. The reports contains relevance (Chapter 1) and structure (Chapter 3) of the research. A description of the company is given (Chapter 2) and an analysis of the current situation and performance (Chapter 4 & 5). The results of the literature study (Chapter 6) and important and summarized data of the analysis (Chapter 7) are also added in this report. The implementation plan is added in Chapter 8. Conclusions and recommendations for further research can be found in the last chapter. A glossary is added for abbreviations and common terms used in this research. Finally a list of literature is added for the references of the used literature.

3.5 Summary

The research structure is described in this section. The motive, objective and scope of this research are described in the first section. The approach of the research is divided into several sub questions that are answered in the report. The sub questions give answer to the problem definition:

1. How is the current process established in the distribution centre?
2. What are the bottlenecks in the current situation
3. What is the current performance of these bottlenecks expressed in KPIs?
4. How to find information for improving the KPIs and what is a suitable way for improving the KPIs of the bottlenecks
5. To what extend are the alternatives for the bottlenecks improving the KPIs of Topa
6. How to implement the solutions at Topa and how to maintain the efficiency?

4 Current situation

This chapter describes the current situation at the distribution center of Topa. The current situation gives answer to sub question 1."How is the current process established in the distribution centre?". The current layout of the building is added and described in the first section. In section 4.2 the main warehouse processes are described regarding receiving, storing, order picking and shipping. Per process the corresponding layout is added.

4.1 Layout

An overview of the layout of the distribution centre is shown in *figure 1*. The distribution centre is divided into two main areas: The reserve area and the fast (case) pick area. The reserve and fast pick area both have their own shipment and loading area. Topa works with several logistic service companies who deliver the orders to the final customer. The transport companies have placed two or more trucks in a dock at Topa, one truck at the reserve area for the bulk deliveries and one truck at the fast pick area for the case pick deliveries. For example, if a customer orders both bulk and pick quantities this order will be combined at the transporter's company who deliver the total order to the final customer.

There are two processes for incoming goods, one from the external supplier and the other one from the internal supplier, Dopak. These two deliveries are physically separated as shown in the layout.

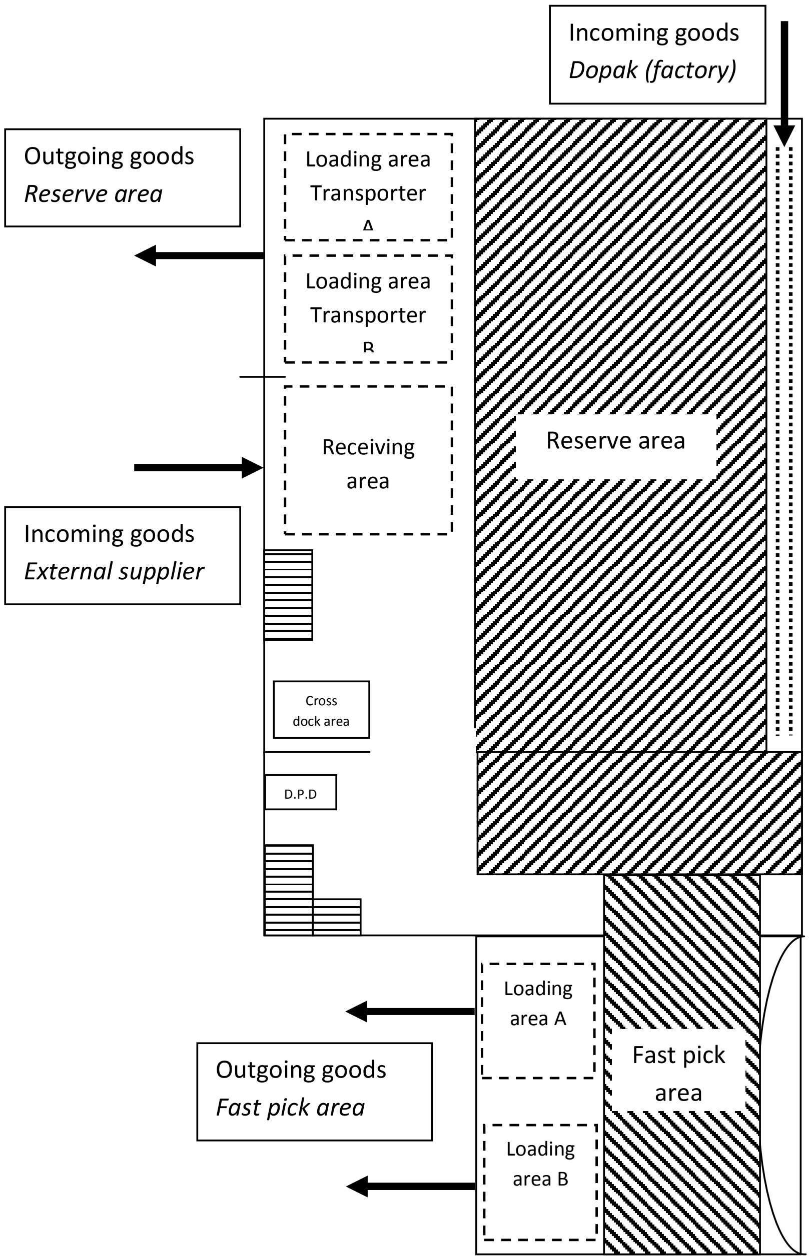


figure 1: Layout distribution center

Topa uses diverse material handling equipment for picking, storing and pallet movement see *figure 2*. In the reserve area Topa uses four reach trucks, in the fast pick area five low-level order picking vehicles. To support the whole process several electric fork and pallet trucks are used for pallet movement.

The warehouse is implemented with regular pallet racks for storing the goods. These racks are suitable for different kinds of pallets. Topa must be able to handle different kinds of pallet dimensions due to the wide range of suppliers.

Furthermore the warehouse has a cross-dock area for cross-dock products and a D.P.D. (small and special delivery service) area where products are made shipment ready for this special service. Above the loading areas a mezzanine has been built for storing rolls (see product group rolls in Appendix I).

Electric Fork truck

Electric Reach truck

Electric low-level order pick truck

Electric pallet truck

figure 2: Material handling vehicles at Topa (source www.toyota-forklifts.nl)

On average 25 employees work at the distribution centre. The organigram of the warehouse is added in Appendix IV. Topa has 20 employees on permanent basis and 5 employees on temporary basis. 16.5 FTE (Full-time equivalent) are assigned to physical work and 3 FTE are assigned to the supporting unit. *Figure 3* shows the division of labor time per warehouse activity.

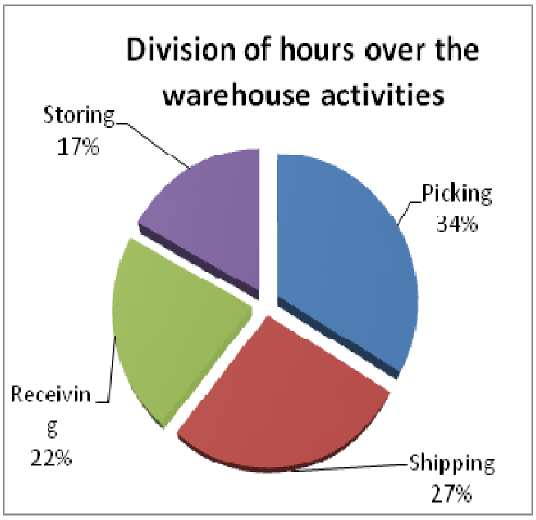


figure 3: Division of labor hours over the warehouse activities.

4.2 Receiving process

The first main process in a warehouse is the receiving of goods. The receiving of goods at Topa is split up in two processes: Goods from external suppliers and goods from the internal supplier, the factory Dopak (*figure 4*).

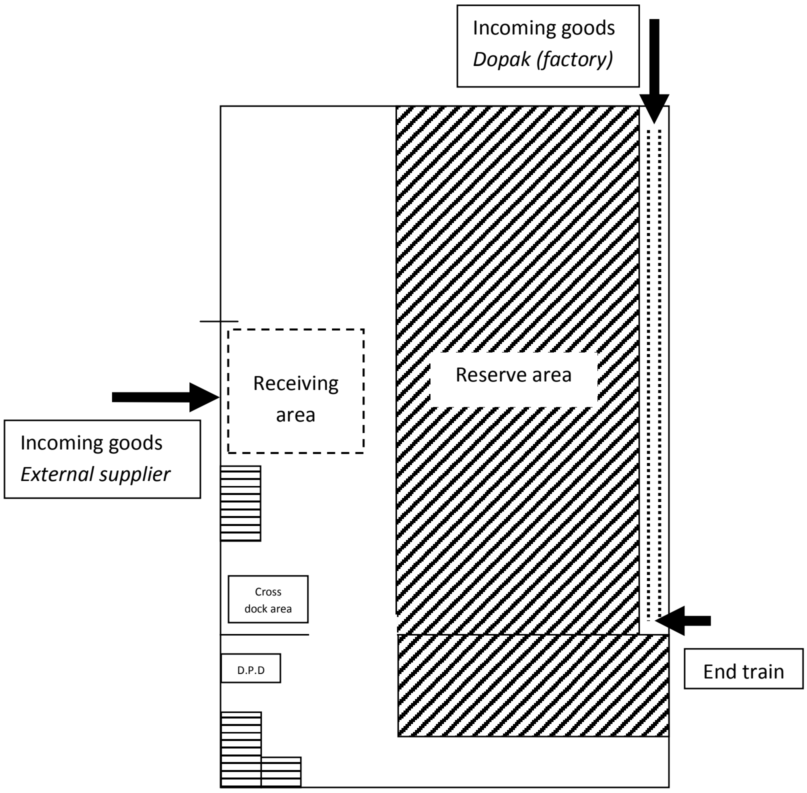


figure 4: Layout receiving process

External supplier:
A truck can be unloaded after the supplier places the truck in a loading dock. The unloaded goods are placed in the receiving area. The goods are first checked regarding the consignment note of the supplier. An internal document is filled in with the products delivered, quantities and pallet dimensions of the goods. The pallet dimensions have effect on the storage location later described in the storing strategy section 4.3. The internal document and consignment note are sent to the supporting unit. The supporting unit checks this list regarding the purchase order. The information from the checklist is entered in the ERP system. The stickers with the storage location and the article numbers are printed automatically when the information is entered in the ERP system. The stickers are attached to the pallets in the receiving area. The pallets are now ready for the storing process.

Internal supplier Dopak:
The factory places a full pallet on a roller lane when production is ready. The pallets are automatically transported to the entrance of the warehouse as the arc symbolizes. A small train picks up two pallets at a time and drives them automatically to the end of the warehouse. The pallets are moved into a buffer roller lane. The pallets are now ready for storing.

4.3 Storing process

The storing process can be divided into two main activities: the storing of the goods in the reserve area and the replenishment of the fast pick area. Both storing process are described in this section.

Storing in the reserve area:
The layout of the storing process in the reserve area is added in *figure 5*. The storing process can also be divided in two activities: storing a stock order or a cross dock order. A cross dock order is an order that is received at the warehouse but must be sent the same day or the day after to the customer. In this case it is unnecessary to place the pallet in stock and pick the same pallet some hours later. These orders are placed in the cross dock area. Cross docks can occur both for internally as well as for externally supplied goods.

A pallet from an external supplier is stored when a sticker is attached to the pallet at the receiving area. The sticker printed by the supporting unit contains the right location number.

A pallet from Dopak always contains an attached form. The supporting unit of Dopak reserves location numbers for their deliveries. This location number is attached to this form. When the pallet is at the end of the train it can be directly driven to the right stock location. The term cross dock is added to the form if this is applicable. In this case no location number is added.

A class based storage strategy is used for storing the products in the reserve area. Products are located in specific zones or areas in the warehouse. Frequently picked SKUs are randomly located in zone A. Zone A is a physical zone in the warehouse which is located nearby the I/O (Input/Output) point. Less frequently picked articles are randomly located in zone B, and slow movers are located in zone C. Furthermore products can have other categories due to their dimensions or other characteristics. Below an overview of the zones Topa uses.

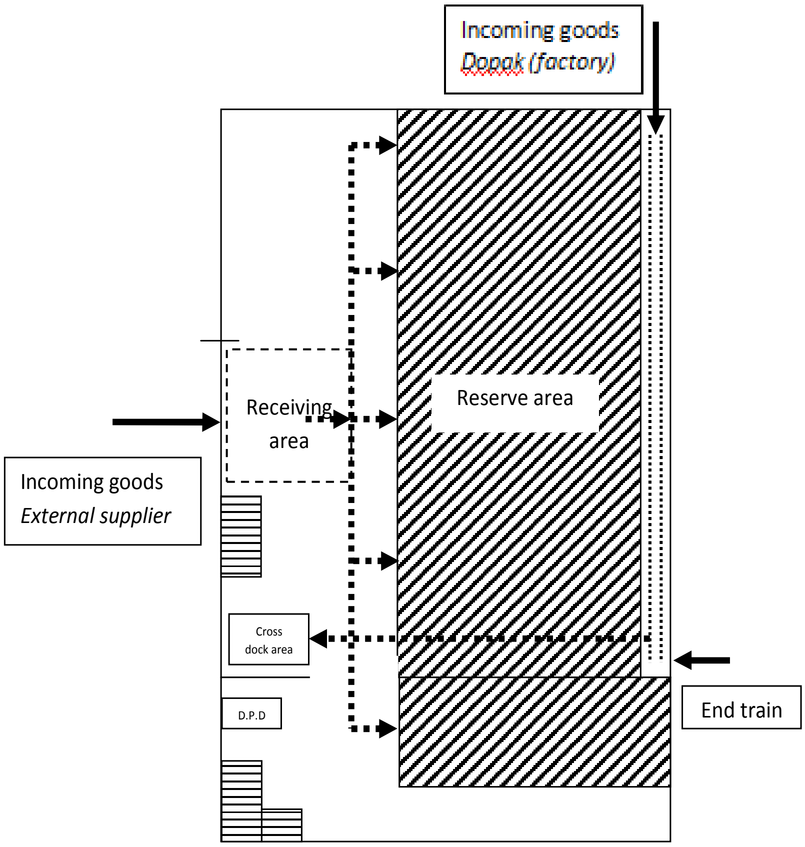


figure 5: Layout storing process

Zone A:	Fast mover
Zone B:	Middle fast mover
Zone C:	Slow mover

A single rack location has a dimension of 1.35 meter broad x 1 meter deep x 2 meter high. The dimension of the product and pallet must fit in these rack dimensions. Due to the type of product of Topa it can occur that the dimensions are bigger than a single rack space. These products are located in other zones:

Zone D:	Pallet needs a double rack location (Pallet and product are broader than 1.35 meter)
Zone E:	Product is a roll (Located at the mezzanine)
Zone J:	Product needs a double rack location and is a bit deeper then the rack (broader than 1.35 and a bit deeper than 1 meter to 1.2 meter)
Zone KL:	Product is stored in small shelf racks
Zone V:	Product needs a double location and is too deep for a regular rack (Pallet and product are broader than 1.35 meter and deeper than 1.2 meter)
Zone R:	Product is too heavy or has other restrictions and must be placed on a ground storage location

The zone division of the ground level of the reserve area is overviewed in *figure 6*. This is an example of the zones for only the ground locations. In total there are 6 different levels, each with a different zone division. The reserve area is divided into these nine zones, the ERP system randomly selects the first free space in the zone and allocates the products to this location.

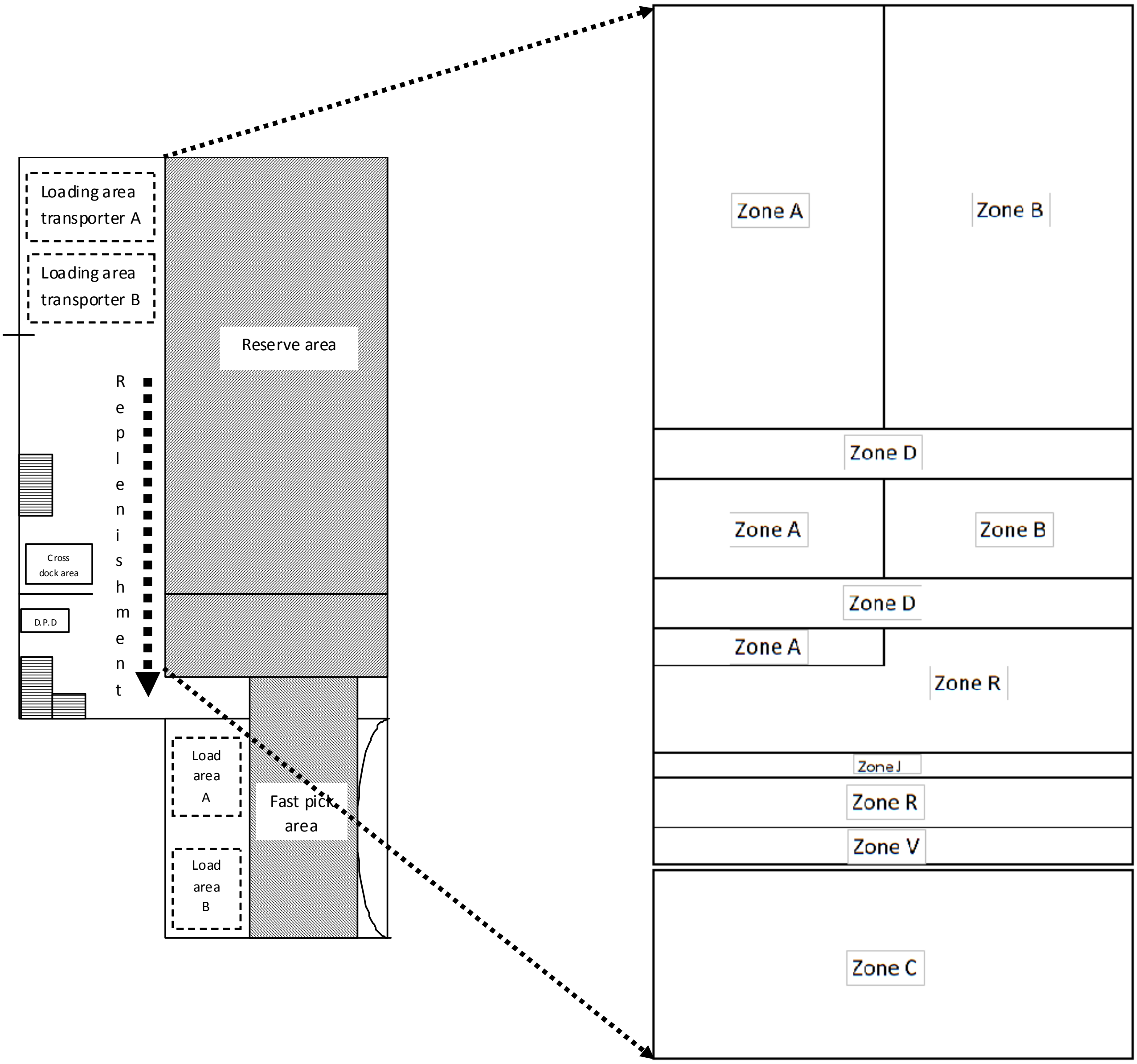


figure 6: Layout: Zone division in reserve area

Replenishment of the fast pick:
The replenishment process in the fast pick area is automatically generated by the ERP system. The ERP system checks the stock levels twice a day during the order pick wave. Stock quantities are reduced in the ERP system by closing customers orders. In the fast pick area each pallet has a replenishment level. Popular SKUs have two pallet places and are replenished when one pallet is empty. Less popular SKUs have one location and are replenished when the pallet quantity is zero. When the replenishment levels are reached the ERP system automatically generates a replenishment order. Internal movement stickers are printed that contain information of the old and the new location. The ERP system automatically allocates the quantities from the reserve area to the fast pick area. The location in the reserve area is released automatically. The pallet is picked in the reserve area and placed at the replenishment area. The fast pick area employees place the pallet in the right location in the fast pick area with a fork truck. (*see figure 7*)

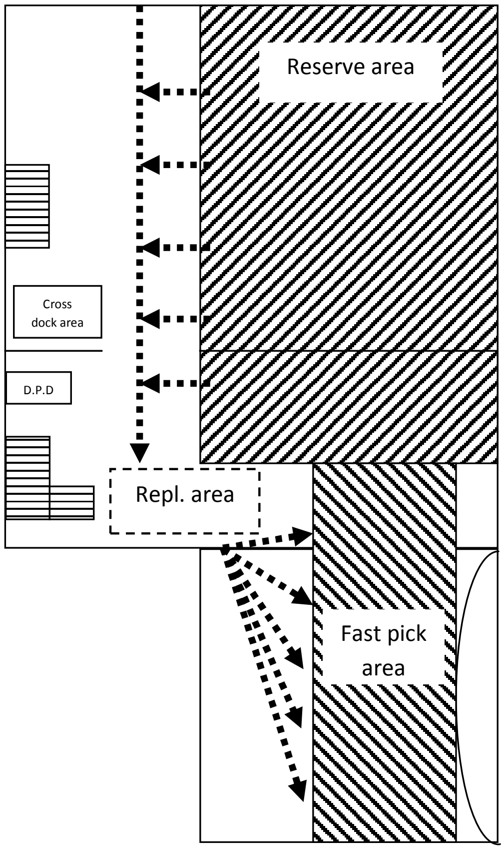


figure 7: Layout replenishment of fast pick area

Storage in fast pick area:
In the fast pick area a dedicated storage strategy is used. Each SKU that is stored in the fast pick area has a fixed pallet rack location. There are two divisions:

1. A fast mover with a double location:
A fast mover has an extra storage capacity above the ground storage location. An order picker picks from the ground location. When the ground location is empty the extra pallet on the first level is dropped to the ground location. The ERP-systems notifies that the pallet is empty and generates a replenishment order that is placed on the first level.

2. A slow mover with a single location:
A slow mover can have a ground location or can be located at the first level. The ERP system generates a replenishment order when the pallet is empty.
The layout of the fast pick is added in *figure 8*. The layout shows the division of the double locations and the single locations.

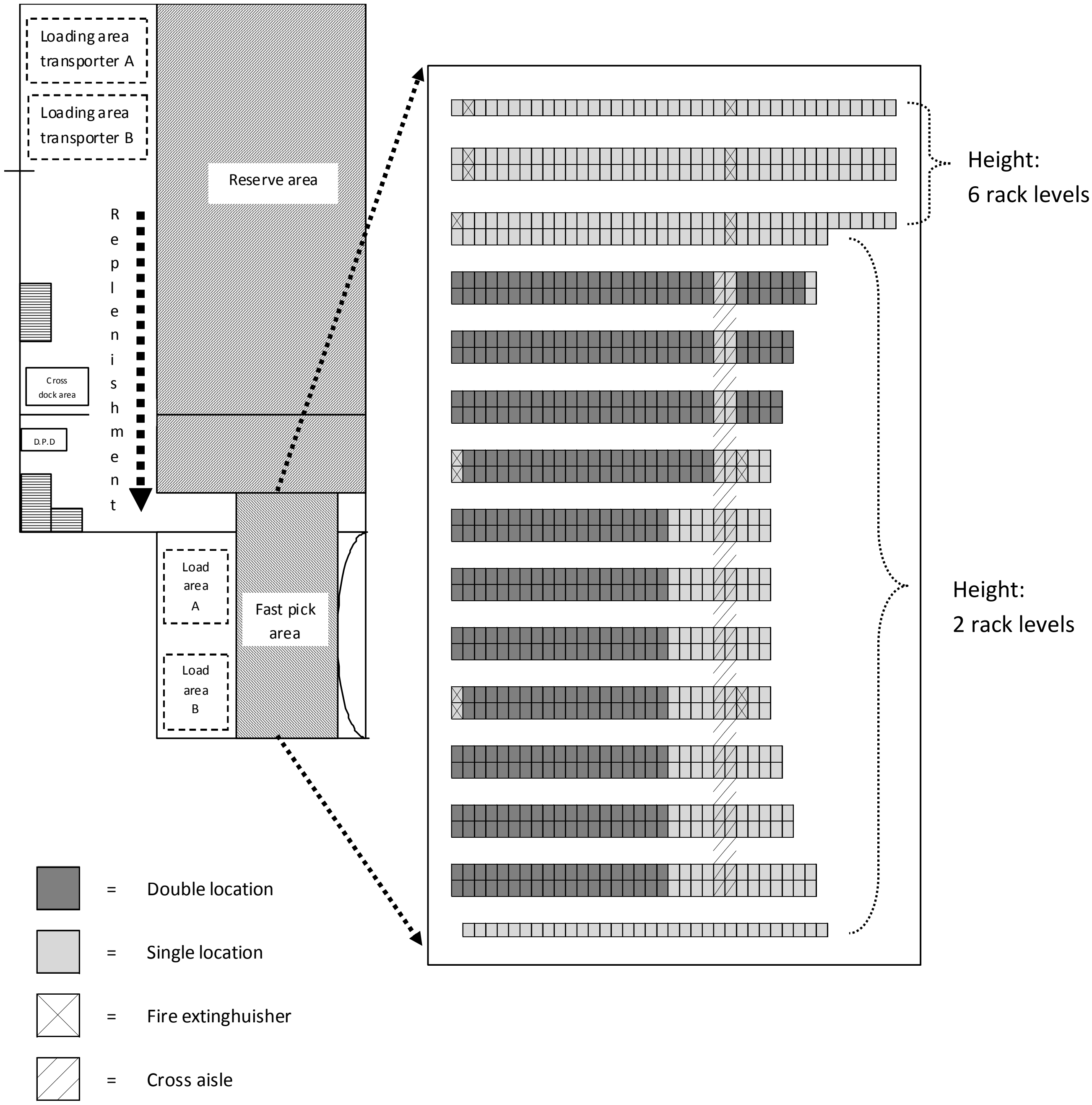


figure 8: Layout of the fast pick area

4.4 Order picking process

The order picking process is divided in four main activities: Order picking in the reserve area, order picking of rolls, order picking in the fast pick area and order picking of small goods (D.P.D.). The order pick process of rolls and small orders are relative small and simple order pick processes (*figure 9*). The management of Topa thinks these processes are efficient enough at the moment and are therefore not included in this research. The pick process in the reserve and fast pick area are described below.

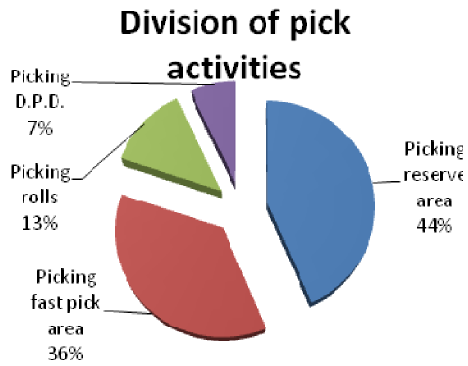


Figure 9: Divison of pick activities

Order picking in the reserve area:
The order pick process in the reserve area is viewed in *figure 10*. Topa uses wave picking. This means that twice a day the customer orders are released by the ERP system and printed on pick lists. The first wave starts at 8:30 am and the second wave at 1:00 pm. The pick lists contain information such as: customer name, article name, article number, quantity to pick and location number. Stickers are printed with the corresponding information of the customer.

Supporting unit employees take care of the cross dock products regarding the planning. An employee allocates the right pallet in the cross dock area and attaches the customer's sticker. A reach truck driver or fork truck driver places the cross dock pallet in the right loading area.

For picking the orders in the reserve area single order line picking (SOP) or also known as Single Command picking is used. SOP means that an order picker picks one order line at a time and places it at the I/O point. A reach truck driver picks an order, attaches the sticker to the pallet and places the pallet at the loading area.

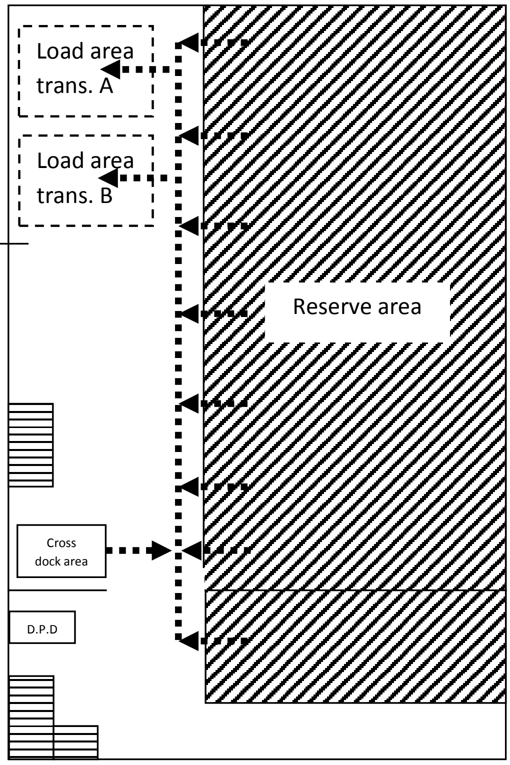


figure 10: Layout order picking in the reserve area

Three types of different orders can occur in the reserve area:

1. A whole pallet quantity
This is a simple pick process as described above. A reach truck picks a full pallet and places it at the loading area.

2. An order quantity with more than 75% of a full pallet loading
Topa made the division between an order line quantity with more than 75% of a full pallet loading and less than 75% of a pallet loading. An order line quantity below 75% of a loading is picked in the fast pick. An order line quantity with more than 75% of the loading is picked in the reserve area. This division is made due to the replenishment frequency.

A reach truck driver picks the pallet with the corresponding article number. He places the pallet near a seal machine. He picks an empty pallet and divides the right quantities over the pallets. Both pallets are sealed in so products can't fall off the pallet. The pallet with the order is placed in the loading area.

Two different situations can occur regarding the rest quantity of a pallet. With 3000 different articles it isn't possible to store each article in the fast pick area. Some articles are stored and picked only in the reserve area, others are stored in both pick and reserve area but picked in the fast pick area. The rest quantity is placed back in the reserve area if the same article isn't stored in the fast pick area. The remaining articles are added in the fast pick area if the product has a fixed location over there.

3. A case pick order
For some articles it isn't efficient to place them in the fast pick because they are picked only several times a year. It can occur that a reach truck has to pick less than 75% of a pallet loading in the reserve area. Rest quantities are always stored in the reserve area.

Order picking in the fast pick area
The order pick process in the fast pick area is schematically viewed in *figure 11*. The orders for the fast pick area are printed on separated pick lists. Customers information is printed on stickers. SOP is also used in the fast pick area. An order picker first picks an empty pallet, drives to the location and puts the corresponding quantity on the empty pallet. The sticker is attached to the pallet with the order. Finally the pallet with the order is placed in the loading area.

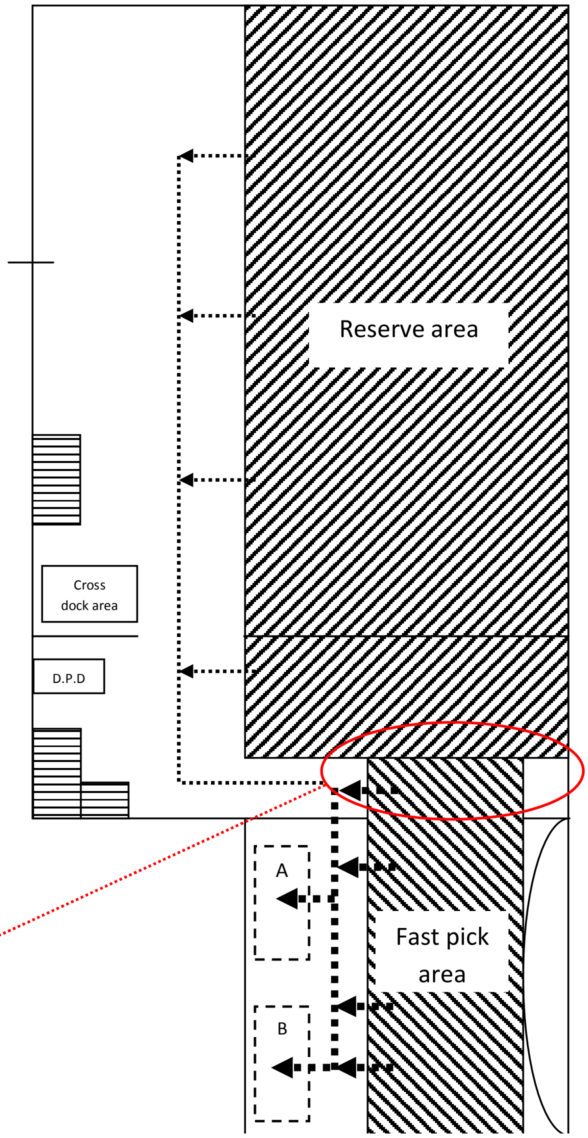


figure 11: Layout order picking in the fast pick area

Four different pick activities can occur in the fast pick area.

1. Ground location
A product is located in a ground location. An order picker can pick the products easily regarding their equipment.

2. First level location
A product is located on the first rack level. An order picker has to notify a fork truck driver to drop the pallet. The order picker can pick the quantity when the pallet is dropped to ground level. The fork truck driver places the pallet back in the rack location.

3. Second level to fifth level location
A product located between the second and sixth level is also named as a "reach location". An order picker has to inform a reach truck driver to drop the pallet.

4. Ground location in reserve area
A product is located at a ground location in the reserve area. These products are stored in the reserve area because of the dimensions of the product. Due to their popularity they are classified as fast pick SKUs.

4.5 Shipping process

The last process of the warehouse is the shipping process. Both reserve and fast pick area have their own shipping process (*figure 12*).

Shipping process in the reserve area
Check lists are printed at the same time the order pick lists are printed. One employee checks the picked orders regarding these check lists. Deviated quantities and pallet dimensions are filled in the checklists. This information is needed for the consignment note. Logistical companies need this information for planning in their own schedule. When an order is approved a green approval sticker is attached to the pallet. The pallet can now be placed in the truck. The check lists are returned to the supporting unit.

Shipping process in the fast pick area
Another employee checks the picked orders in the fast pick area regarding a check list. Deviated quantities and pallet dimensions are filled in and a green approval sticker is attached to the pallet. When the order is approved the pallet can be sealed in. Finally the pallet is loaded into the truck.

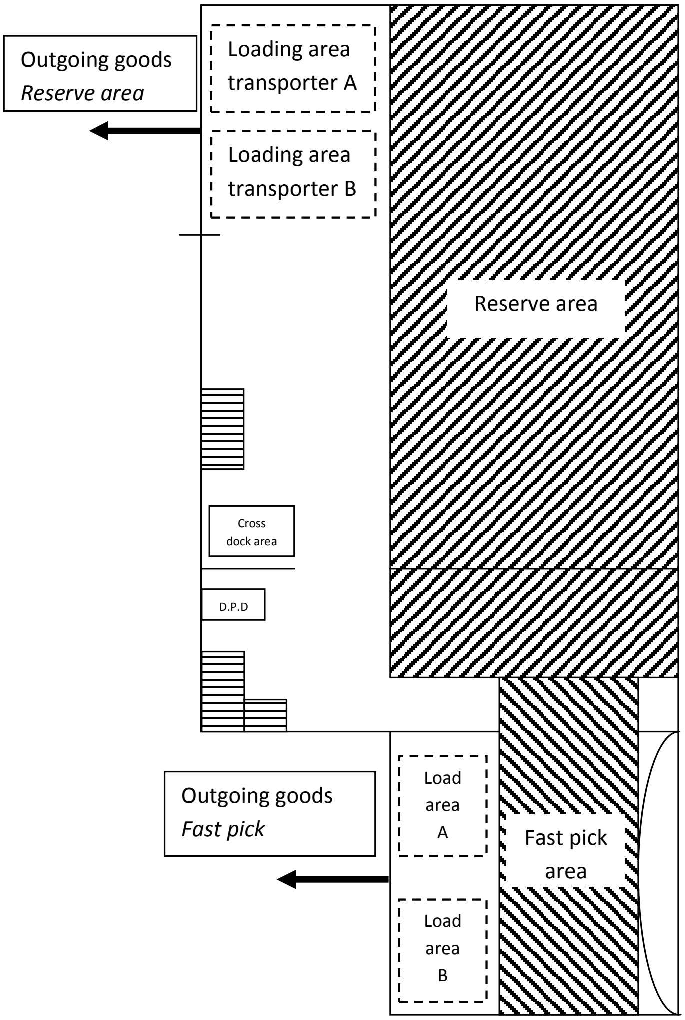


figure 12: Layout shipping process

Transportation
Orders are delivered to the final customer in five different ways:
1. International transportation
2. Topa has one truck and truck driver of its own
3. Special packaging service D.P.D., for small packaging
4. Customer can pick up their orders at Topa
5. The remaining orders are split up over two logistical companies (A&B).

4.6 Summary current situation

The current situation in the distribution center of Topa is described in this section. This chapter gives answer to the first question: “How is the current process established in the distribution center”. Layout of the building, the equipment that is used and employee occupation is described in the first section. The process of the distribution center is viewed regarding the main warehouse processes: receiving, storing, order picking and shipping. Each process is described briefly and a layout is added for illustration of the process. The processes give insight in the current way of working and reveal the decisions made by management in the past. The description of this chapter gives a clear insight of the current situation. This description of the current situation is a starting point for exposing the current bottlenecks. The next chapter deals with the question: what are the bottlenecks in the current situation and what is the current performance of the bottlenecks?

5 Current performance and bottlenecks

This chapter gives answer to sub question 2. "What are the bottlenecks in the current situation?" and 3. "What is the current performance of these bottlenecks expressed in KPIs?". Topa maintains two KPIs in the current situation, these will be described in the first section. The current KPIs are not suitable for exposing the bottlenecks regarding the problem statement. For a month data is gathered and analyzed and diverse measurements are taken for exposing bottlenecks described in section two. The last section contains the defined and calculated KPIs for the bottlenecks.

5.1 Current KPIs

Topa maintains two KPIs in the current situation: The costs per outgoing pallet and the service level rate of the distribution centre. The calculation and motive of the KPIs are given in this section.

Costs per outgoing pallet
The first KPI is the costs per outgoing pallet. Each day the outgoing pallets with orders are counted by the supporting unit and archived in an Excel sheet. The total outgoing pallets per month are divided over the total labor costs over that month. It is the perception of the management that the outgoing pallets represent the value adding activity for the customer. Second perception of management is that the number of outgoing pallets represents the workload of the distribution centre. The labor costs represent the total of employees that are needed to fulfill the demand of the customer.

In the month February 2010, 8336 pallets were sent to the customers. The labor costs of the warehouse were € 57,935.20 in the month February which resulted in a cost of € 6.95 per pallet. The outcome of this research can influence this KPI in a relatively small way. The outgoing pallets are related to the demand by customers which can't be affected by this research. The labor costs can only be affected if the waiting times, labor and time consuming activities decrease significantly. The labor costs only decrease if less hours and employees are needed for executing the daily activities. It can also be a goal if the same employee can execute the daily activities when demand increases. However this KPI can't be used as an indication regarding direct improvements in efficiency. The first KPI is not a strong KPI for this research:
KPI: costs per outgoing pallet February: € 6.95

Service level of the distribution level
The service level of the distribution is the second KPI that is maintained in the current situation. This KPI is calculated regarding the return of products from the customers. There are two types of mistakes: 1. Mistakes caused by the distribution centre and 2. Mistakes caused by factors that can't be affected by the distribution centre. The distribution centre has no influence in the mistakes made by Topa Voorhout, the customer or transportation companies. Mistakes that can't be affected are: miscommunication by representative and customer, wrong data entered in the ERP system, transportation damage, customer ordered wrong article etc. Mistakes made by the distribution centre are for example: Wrong article picked, wrong quantity, wrong customer sticker attached etc. Returns are listed per month in an Excel sheet with a mistake code.

The number of orders and order lines are counted every day by supporting unit. Numbers are archived in an Excel sheet. In total 37,246 orders were completed in 2009. Topa received 733 orders back from the customer. Only 93 of these 733 were caused by the distribution centre. The other 636 were caused by external factors. 93 divided over 37,246 is 0.25% which results in a service level of 99.75% for the distribution centre. Topa in general has a service level of 98.3%. This KPI shows that the service level of the distribution level is sufficient. There is no direct need for improving this KPI.
KPI: Service level of distribution center in 2009: 99.75 %

5.2 Bottlenecks and KPIs

The KPIs maintained in the current situation by management are not suitable for exposing the bottlenecks regarding the problem statement. KPIs that are needed in this research must indicate waste which results in inefficiency. The first step is to define the bottlenecks in the current situation. The second step is to measure the performance and calculate the KPI related to the bottleneck.

The bottlenecks in the current situation are exposed by analyzing data from the ERP system (*table 1*) and by observing the processes. By answering sub question 1: How is the current situation established at Topa (Chapter 4) insight is gained regarding the current process. Furthermore information, experience and knowledge is gathered from the employees and management of Topa.

The assumptions of the bottlenecks are made by observation and information gathered from the management and the employees of Topa.

Assumption 1: An inefficient receiving process. Several problems in the receiving process were noticed through observations and information gathered from management and employees. The receiving area is fully occupied almost every day. Employees have to work overtime because the floor must be emptied before the next day. The stickers with the identification numbers are printed late so pallets can’t be stored in the rack locations. These problems are in contradiction with the definition of efficiency. By solving these problems the efficiency can be improved in the receiving process. This assumption/ bottleneck is further analyzed in section 5.2.1.

Assumption 2: The allocation of SKUs to the fast pick area is not correct. The output of interviews with the management and employees was that the decision, which SKU to store in the fast pick area, is done by plain thinking. Also an update of the policy has not been done since the implementation of the policy. If this assumption is correct it can result in long travel distance and travel time which is also in contradiction with the definition of efficiency. This waste must be eliminated to improve the efficiency. This assumption is further analyzed in section 5.2.2.

Assumption 3: The storage strategy in the reserve area is not optimal. The management of Topa has chosen an ABC storage strategy in the reserve area. No update of this policy has been done since the implementation of the strategy. Employees suspect that the popularity of the SKUs has changed since the implementation and that certain SKUs are located in the wrong zones. If the SKUs are not stored optimally it can result in long travel distances. Travel distance is waste and must be minimized to improve the efficiency. This assumption is further analyzed in section 5.2.3.

Assumption 4: The storage strategy in the fast pick area is not optimal. During observations several inefficient activities were noted. Employees have to inform other employees due to equipment restrictions. The order pickers have to pick SKUs in the reserve area which has a long travel distance. Furthermore SKUs in the fast pick area are stored in high locations which can’t be reached by used equipment. Other employees must be noted to pick these SKUs. The layout of the dedicated fast pick area is also observed. It is noted that popular SKUs are stored in the back of the area and less popular SKUs in the front of the area. These problems cause long travel distance and waiting times in the fast pick area which cause waste and inefficiency. Solving these problems result in an improvement of the efficiency which is the goal of this research. This assumption is further analyzed in section 5.2.4.

The assumptions 2,3 and 4 are based on further analysis of the ERP data. The information gathered per SKU from the ERP system is added in *table 1*.

	Gathered data per SKU from the ERP system
1	Article name
2	Article description
3	Quantity sold in 2008
4	Quantity sold in 2009
5	Number of SKUs on one pallet (pallet quantity)
6	Number of full pallet picks in 2009
7	Reserve area category regarding the zone (A,B,C, et..)
8	Is the SKU stored in the fast pick area?
9	If stored in the fast pick area, what is the fixed location number?
10	If stored in the fast pick area, does it have a double or single location?
11	If stored in the fast pick area, what is the pick popularity in 2009?
12	If stored in the fast pick area, what is the number of restocks in 2009?
13	If stored in the reserve area, what is the pick popularity in 2009?

table 1: Overview of data that is gathered per SKU from the ERP system

The data from the ERP system, diverse interviews, observations and blue prints of the layouts are used for analyzing the assumptions that are described above. Per assumption a cause & effect analysis is used for exposing the problems and bottlenecks. A KPI per bottleneck is defined for indicating the performance of the bottleneck.

5.2.1 Inefficiency in the receiving process

The assumption of the inefficiency in the receiving process is further analyzed in this section. The receiving process is described in section 4.2. An overview of the activities in this process is added in *table 2*.

	Overview activities in the receiving process
1	Arrival of supplier
2	Unloading of the truck
3	Checking the quantity and quality of the goods
4	Filling in the internal document
5	Bringing the internal document and the consignment note to the supporting unit
6	Dispatching of goods in ERP system and printing of the stickers
7	Attaching stickers to the pallets
8	Storing of the pallets in the racks by reach trucks

table 2: Overview of the activities in the receiving process

Bottleneck

The process is observed for several days. Regarding this observation and interviews with the management and employees of Topa a cause & effect diagram (*figure 13*) is made for exposing the bottleneck in this process.

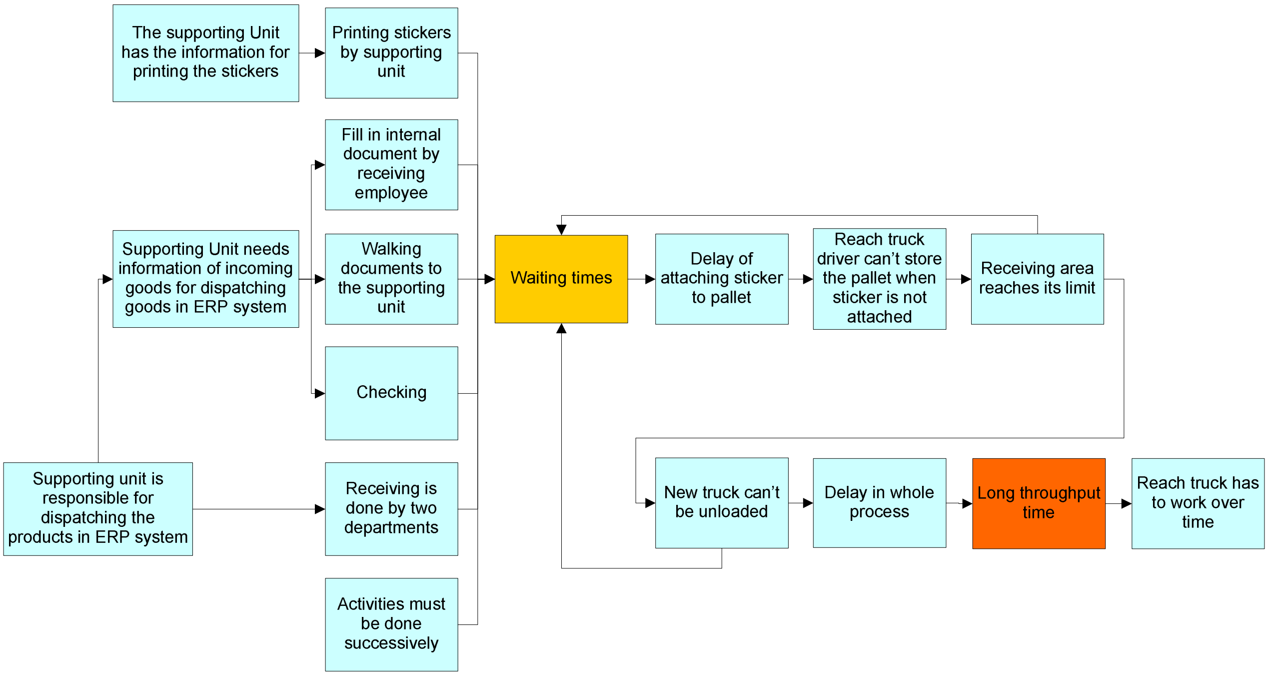


figure 13: Cause & effect diagram of the receiving process

The problems of the receiving process are viewed in the left boxes of the diagram. There are two departments involved in the receiving process, the receiving department and the supporting unit. Both departments are physically separated by a distance of 50 meters (*See layout receiving process figure 4*). The receiving department is responsible for the physical activities on the floor and the supporting unit is responsible for the dispatching process in the ERP system. The supporting unit needs the information gathered on the floor for executing their activities. The receiving department must therefore fill in an internal document. Goods have to be checked physically for possible mistakes and documents have to be brought to supporting unit. Filling in the internal document, bringing the documents to the supporting unit, printing of the stickers and checking of the goods causes waiting times. Successive activities have to wait because other employees have to execute the previous activity. These problems result in waiting times between the activities. The printing of the stickers is delayed because of the waiting times. Without these stickers, pallets can't be driven away by a reach truck driver. The stickers contain the important information of the location number where the pallet must be stored.

The loading area reaches its limit when a reach truck driver can't drive the pallet to the location. Not storing the products because of the unprinted sticker also causes extra waiting time. When the loading area is full another truck can't be unloaded. When a new truck can't be unloaded it results in a delay in the whole receiving process. The delay has an impact on the throughput time of the receiving process.

It happens on a frequent basis that reach truck drivers have to start earlier (overtime) because the loading area is still full. Throughput time can be reduced by solving the problems that cause the waiting times. All problems can have an influence.

VSM

The tool Value Stream Map (VSM) is chosen to expose waste and give insight in the time per activity. Timing the activities of processes gives insight in the total throughput time of the receiving process. A value stream is all the actions required to complete a product or service (Breyfogle, 2003). VSM is a tool that can be used for reducing lead times and eliminating waste.

The term value in VSM refers to the activities that the customer is willing to pay for. A customer is only willing to pay for the value adding activities. Activities can be classified in three types of values:

- Value adding activities (VA)
- Non-value adding activities (NVA)
- Necessary activities (NA)

The goal of VSM is to visualize the adding value activities, non-value adding activities and necessary activities. The waste (non-value adding activities) can be detected by this tool. Waste is a process that doesn't result in reaching the goal/output or a process which doesn't contribute to the output. There are seven types of waste (Breyfogle, 2003):

1. Defects
2. Transportation
3. Inventory
4. Processing
5. Overproduction
6. Waiting
7. Motion

Goal for this research is to improve the efficiency, doing the thing right. This means that we have to focus on the value adding activities and eliminate the non value adding activities.

The activities of the receiving process are mapped into a Value stream Map. For over a week the two employees at the receiving process are observed and timed for the duration per activity. This time is measured by stopwatch and listed on forms. The activities per truck are timed. The time starts when a truck arrives at Topa and ends when this same truck is unloaded and the goods are stored in the warehouse. At the end of the week an average of the time is calculated for the Value Stream of the receiving process. The VSM of the receiving process with the time per activity is added in *figure 14*.

On average 10 trucks arrive at Topa per day with 170 pallets, 80 rolls and 50 collies. On average a truck has to wait 20 minutes before an employee of Topa starts with unloading the truck. It takes 20 minutes on average to unload a truck. Then it takes on average 12 minutes before an employee starts to check the goods and fill in the internal document. After the document is brought to the supporting unit it takes on average 30 minutes before the stickers with the locations numbers are printed. From this 30 minutes are 20 minutes waiting time and 10 minutes to dispatch the goods in the ERP system. Furthermore it takes 7 minutes before the stickers are attached to the pallet. Finally after an average of 12 minutes waiting the pallets are stored by reach truck drivers.

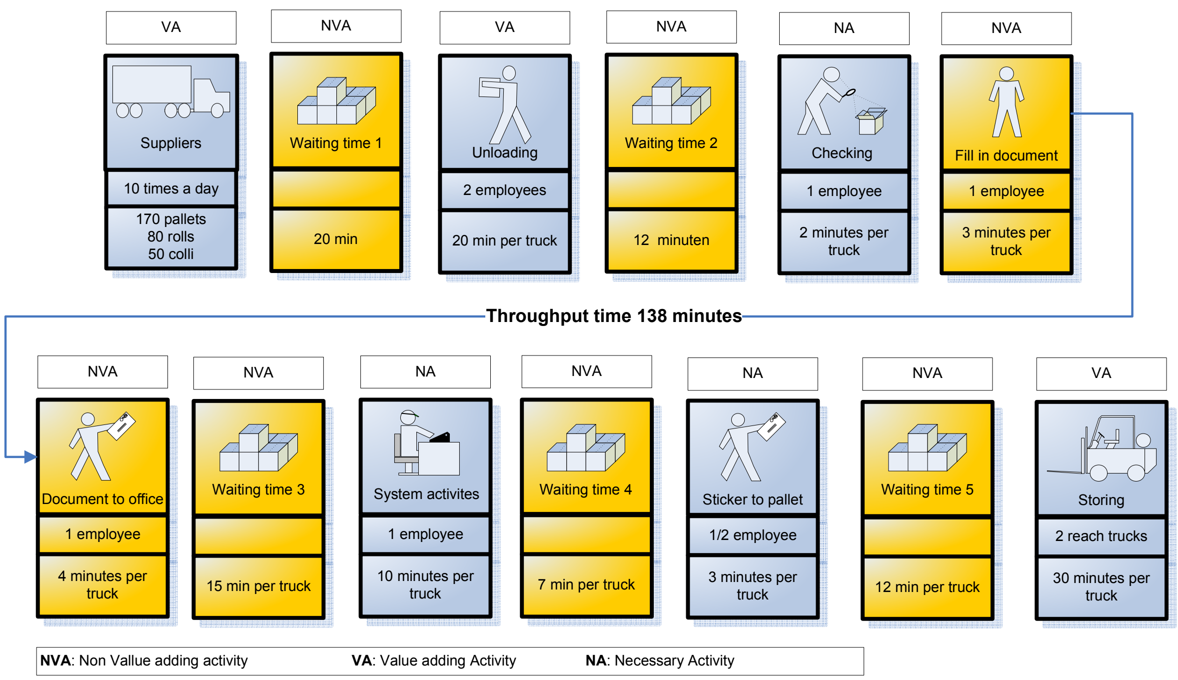


figure 14: Value Stream Map of the receiving process

The receiving activities are classified into the three categories: Non added value, non-value added or necessary activity. The waiting times in the VSM symbolize the waiting time for the pallet in the receiving area. The waiting times aren't physical waiting times for an employee. An employee will proceed with another activity if he can't proceed with his current activity.

In total there are 5 waiting time moments in the current situation. As mentioned earlier waiting times are one of the seven waste factors.

Waiting time 1: Occurs when the loading area is full and a new truck can't be unloaded. It is also possible that more than 3 trucks arrive at the same time. One truck has to wait until the other two trucks are unloaded first. The two employees each unload one truck.

Waiting time 2: Occurs when an employee is occupied with other activities. For example unloading another truck.

Waiting time 3: Occurs when the internal document and the consignment note of the suppliers are brought to the supporting unit. Information is not entered in the ERP system if the supporting unit employee is occupied with other activities. Miscommunication can also be a cause for the occurrence of this waiting time.

Waiting time 4: Occurs when stickers are printed but employees are occupied with other activities or are unaware that the stickers have been printed.

Waiting time 5: Occurs when reach truck drivers are occupied with other activities, like storing the loading of another truck or a reach truck driver is occupied with order picking. Most of the time a reach truck driver starts to store the products if a receiving employee gives a signal.

KPI bottleneck 1
The total average throughput time is chosen to be a suitable KPI for the receiving process in this research. The receiving process starts when a supplier arrives till the moment that the loading of a truck is placed at the receiving area. The total throughput time of this process is in the current situation 138 minutes. This is the total average throughput time of processing the load of one truck. The total time of the non value added activities is 73 minutes. Considering this amount of waste in the process, the assumption can be based that the problem is a serious bottleneck.

Improving this KPI will speed up the process and improve the pallet flow. Products can be stored faster by improving the pallet flow and the loading area occupation will decrease. Arriving trucks do not have to wait if the loading area still has free space. Finally employees don't have to work overtime because the loading area is empty or near empty at the end of the day.

Data Bottleneck 1:
Bottleneck: Non value adding activities that cause long throughput time in the receiving process

KPI : Average total throughput time of the receiving process: ***138 minutes***

Goal: Eliminate or reduce non value adding activities so the total throughput time will decrease

5.2.2 Allocation of SKUs to reserve area or fast pick area

The assumption that the allocation of SKUs to the fast pick area is not correct, is analyzed in this section. The management of Topa has chosen in the past to divide the warehouse in two parts: a reserve area and a fast pick area. The SKUs with a high case pick popularity are located in the fast pick area till the rack locations in that area were occupied. The remaining SKUs still have to be picked from the reserve area by reach truck drivers. Furthermore the distinction is made for picking almost full pallets. An order line quantity above 75% of the loading quantity of a pallet is picked in the reserve area and an order line quantity less than 75% of a pallet loading quantity is picked in the fast pick area.

Bottleneck
Management divided the SKUs over both areas by plain thinking. No calculations are done regarding savings that can be achieved by the use of a fast pick area. Furthermore if Topa adds a new article to the catalogue it is always stored in the reserve area. This article is not placed in the fast pick area if the pick popularity increases so significantly that it deserves a place in the fast pick area. A SKU is also not placed back in the reserve area if the pick popularity decreases significantly.

A case pick order in the reserve area that is supposed to be in the fast pick area results in a lot of labor intensive work for a reach truck driver. A reach truck driver has to perform more activities when picking a case pick order in comparison with a full pallet pick as described in section 4.4 Order picking process. These problems and bottleneck are viewed in a cause and effect diagram *figure 15*.

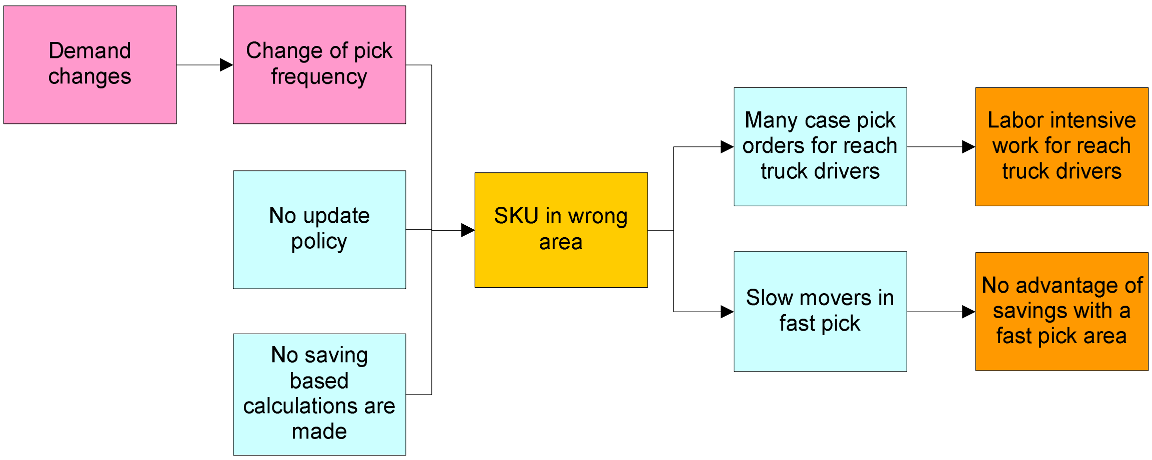


figure 15: Cause & effect diagram of the allocation process of SKUs

The problems are viewed in the boxes on the left side of the diagram. No update of the policy and the lack of saving based calculations result in the bottleneck: SKUs are stored in the wrong area. In the reserve area it results in many case pick orders that are labor intensive. In the fast pick area it results in less popular SKUs being stored in the fast pick. It has no benefit to store the less popular SKUs in the fast pick area.

Measuring the output
The output of the bottleneck is the labor intensive work and the savings that can be achieved with a fast pick area. The savings can only be measured with a costs saving formula. Literature must be searched for providing formulas for calculating the savings. Savings can be defined by the net savings per item i when item *i* is picked from the fast pick area rather than from the reserve area. The other output, labor intensive work for reach truck drivers can be expressed in a KPI.

The frequency of the case pick orders and the time it takes to pick such orders can be observed and analyzed. Recall that case picking by reach truck drivers requires more time and effort, which can be classified as waste. The frequency of the case pick orders is gathered from the picking lists. This list contains the information if a reach truck driver must pick a full pallet or a case picking order. From the month February the pick lists are gathered and the frequency of case picking orders by reach truck drivers are counted. On average 185 order lines have to be picked on a day by reach truck drivers. On average 32 of these order lines are case picking orders that have to be picked by reach truck drivers.

Next step is to measure the time that is needed for this activity. In total 30 case picking orders by a reach truck driver are timed. The time starts when a reach truck driver drives to the location from the I/O point. The time ends when the pallet is placed at the loading area and when the rest pallet is placed back in the rack. An average time is measured of 7 minutes and 15 seconds per case pick order. The average time of picking a full pallet is also measured for comparison. The average time for picking a full pallet is 1 minute and 35 seconds. This time is measured for 79 full pallet pick orders. In *figure 16* an overview is given of the comparison of full pallet picking and case picking.

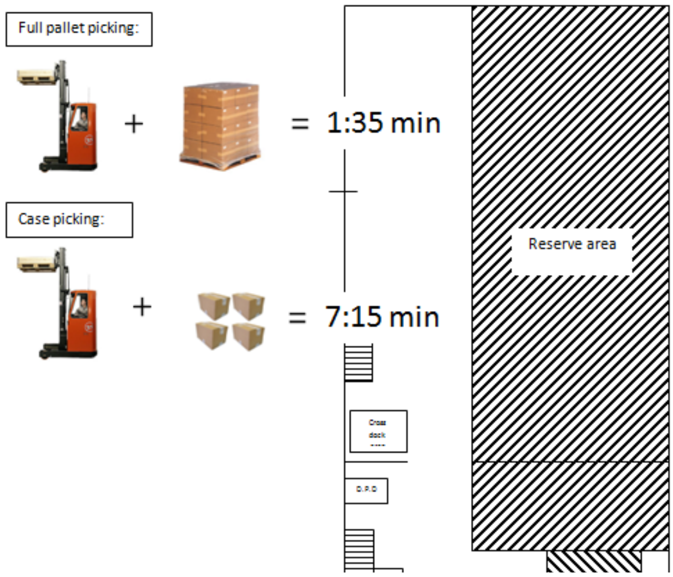


figure 16: Overview order picking times per order line

KPI bottleneck 2

In this research the total case picking order time per day is used for a KPI. Case picking for reach truck drivers is time and labor intensive. If a SKU can be picked faster and more efficiently from the fast pick area this will reduce case picking time in the reserve area. Reach truck drivers are occupied 232 minutes (32 * 7 minutes and 15 seconds) on average a day for picking case orders. Improving the bottleneck must decrease the number of case picking orders a day, which results in a decrease of the total labor time spent for this activity.

Data bottleneck 2:

Bottleneck: SKUs are stored in the wrong area

KPI 1: Case picking time in the reserve area by reach truck drivers: ***232 minutes*** *a day*

KPI 2: Benefit of storing SKU i rather in the fast pick area than the reserve area: To be determined in a later stage.

Goal: Calculate savings for storing a SKU in the fast pick area rather than in the reserve area. A new allocation of SKUs must decrease the case pick time in the reserve area.

5.2.3 Storage strategy in the reserve area

The third assumption, “the storage strategy in the reserve area is not optimal”, is analyzed in this section. Topa has implemented the ABC class based storage strategy as described in section 4.3 Storing process. The ERP data from the *table 2* is analyzed for this assumption. Data is analyzed in Excel and arranged regarding the popularity of the SKUs. From the data it can be concluded that the product classification is not accurate with the regard to popularity. This means that a product that is classified as zone C supposed to be in zone A. The popularity of the SKUs has changed since the first implementation of the zones. The classification was never been updated after the strategy was implemented. *Table 3* shows the classification of zone A,B and C and where the products are supposed to be.

Current Zone	Number of SKUs	Difference	Percentage
A	163	79 of 163 are located correct in Zone A	48.5 %
		83 of 163 should be stored in zone B	50.9 %
		1 of 163 should be stored in zone C	0.6 %
B	729	68 of 729 should be stored in zone A	9.3 %
		496 of 729 are located correct in zone B	68 %
		165 of 729 should be stored in zone C	22.7 %
C	515	12 of 515 should be stored in zone A	2.3 %
		150 of 515 should be stored in zone B	29.1 %
		353 of 515 are located correct in zone C	68.6 %

table 3: Classification of SKU to zones

The storage strategy is implemented with the assumption of an occupation rate of almost 90%. With the current occupation rate of 57% this results in many free locations between the zones. The occupation rate is decreasing because of the decreasing customer demand caused by the financial crisis. Reach truck drivers have to drive to zone C while zone A and B are just occupied for 57%. The question arises if the ABC storage strategy is the best strategy for Topa.

A third problem that emphasizes the bottleneck is the layout. The blue prints of the current layout are observed. The layout is made by plain thinking of management and not by thorough analysis. Management did not take into account the I/O point of the warehouse. They also didn’t calculate travel distance or travel time regarding the zones. There is also no based calculation for: How many products to store in zone A, B or C. or how many zones are optimal? Or what is the optimal zone dimension for zone A,B or C.

These problems emphasize the assumption of this bottleneck. Analysis reveals that the process contains waste that must be eliminated. The problems of this bottleneck are also viewed in a cause and effect diagram in *figure 17*:

The purple boxes can’t be influenced. Decrease of customer demand or change of customer demand can’t be influenced by the warehouse. Update of the policy, cost saving calculations and layout with awareness of an I-O point can be influenced. These three problems cause the bottleneck: Current storage strategy in the reserve area is not optimal. The bottleneck finally results in long travel times for reach trucks.

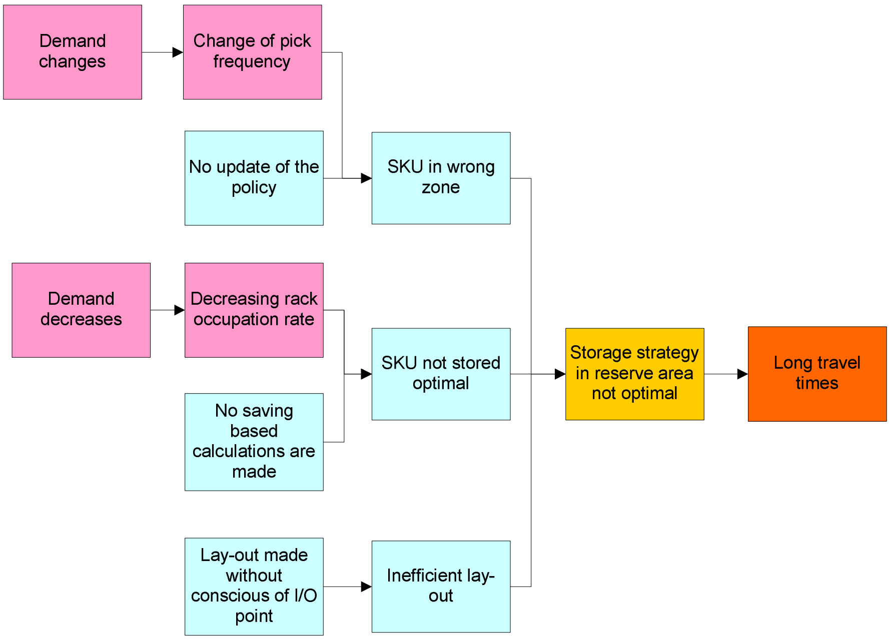


figure 17: Cause & effect diagram of the storage strategy in the reserve area

Measuring the performance

Travel time (transport) can be classified as waste in a process. Goal of this research is to reduce or eliminate the non value added activities. In this research the travel time is used as a KPI for this process. Due to the number of rack levels at Topa travel time is chosen instead of travel distance.

Before measuring the travel times an I/O point, a starting point, is fixed in the warehouse. The input and output of goods from the docks is viewed in the current layout. Considering the input and output of the warehouse the starting point for measuring is fixed at row 15 at the reserve area. From this point travel time is measured to every begin, middle and end of a path. With these measurements the average travel time for the ground locations is known. Next step is to measure the pick times for the higher locations. Five measurements are done for timing the pick process for the first till sixth level. An average of these five measurements is calculated. With these travel time measurements the average travel distance for the current zones is calculated. The zones D, J, R and V are out of scope for this bottleneck. These zones are fixed because of the dimensions and the characteristics of the products or racks. Further analysis must conclude if these zones can be located more efficiently than in the current situation.

The average travel time per zone in the current situation is given in *table 4*.

Zone	Average travel time
A	70.4 seconds
B	105.8 seconds
C	127.5 seconds

table 4: Average travel time per zone

KPI bottleneck 3:

The total travel time for each SKU in 2009 is calculated by use of the pick popularity. The following calculation is done: The popularity of a SKU is multiplied by the average travel of the zone in which the SKU is stored. The popularity of all SKUs that are stored in Zone A are multiplied by the average travel time of zone A (70,4 seconds). This same calculation is done for Zone B and C. The total travel time is calculated by summing up the total travel time per zone. The total travel time in 2009 was: 3,336,589 seconds. The seconds are converted in 926.8 hours travel time in 2009.

Data bottleneck 3:
Bottleneck: Current storage strategy in the reserve area is not optimal

KPI: Average total travel time of ***926.8 hours*** *in 2009*

Goal: Finding literature regarding the most suitable way for storing the SKUs in the reserve area. How many zones are needed, which SKU is located in which zone and what must the dimensions of a zone be if the ABC storage strategy is still the best solution. The new storage strategy and layout must decrease the total travel time.

5.2.4. Storage strategy in the fast pick area

The last assumption for a bottleneck, the storage strategy in the fast pick area is not optimal, is analyzed in this section. The current storage strategy of the fast pick area is also described in section 4.3. Analysis is done by interviews, observation and analyzing the ERP data (*table 2*).

Management implemented a dedicated storage strategy in the fast pick area. The SKUs that are responsible for 80% of the total picks in that year attained an extra safety stock (double location). The same problem is noted in the fast pick area as in the storage strategy of the reserve area: no update has been done since the implementation of the strategy. The popularity of the SKUs have changed due to changes in customer demand. The result is a wrong allocation of SKUs regarding the area as described in the second section above.

Second problem in the fast pick area is the layout. Management implemented the dedicated storage strategy without calculations regarding travel distance optimality. The location of the I/O point was also not taken into account when allocating SKUs to a dedicated storage strategy.

Third problem are picks of SKUs that are stored in the reserve area but must be picked by fast pick employees. These SKUs have a high popularity and are classified as a fast pick SKU. These SKUs are therefore listed on the picks lists of the fast pick department. Moreover these products are stored in the reserve area due to their characteristics and dimensions. Some of these SKUs can't be stored in a regular pallet rack location. This problem occurs on average 6 times a day. This number is attained from the daily picking lists of the fast pick employees.

Fourth problem is caused by the old storage strategy. Before the implementation of the fast pick area Topa had only one area where fast picking and bulk picking were combined. In that time it occurred that a fast pick employee faced an empty pick location and had to wait until a reach truck driver replenished the pick location. Management of Topa therefore decided to place an extra safety stock above the pick location. The safety stock only had to be dropped and fast picking could continue. At a later time the safety stock was replenished. By implementing the fast pick area this policy was copied. However the replenishment process was also programmed in the ERP system. When a stock level drops below the replenishment level the ERP system automatically activates a replenishment order. The replenishment is done at the beginning of pick wave in the current situation. An empty location isn't possible because replenishment is always done at the beginning of a wave, the safety stock is therefore not needed in the current situation. The filling and dropping of the safety stock are activities that can be eliminated. The current 452 double locations create less space in the fast pick area because the first level locations above the ground locations are reserved for the safety stock.

The fifth and final problem in the fast pick area is the restriction of the picking vehicles and the space in the fast pick area. Some of the SKUs are stored in high locations (first level till the sixth level of a rack) because not all the SKUs can be stored in the fast pick area. Layout of the fast pick area is added in *figure 11* in section 4.3 Storing process in the fast pick area. The area in the red circle symbolizes the reach locations (second till sixth level). Above the whole fast pick area a first level is available. The equipment that the order pickers are using is only suitable for ground locations. The fork truck driver must be notified if a SKU is stored in a first level location. First level locations occur with an average of 14 times a day. One employee gathers per pick wave the reach locations and notifies a reach truck driver. Reach truck locations (second till sixth level) also occur 14 times a day. (*figure 18*)

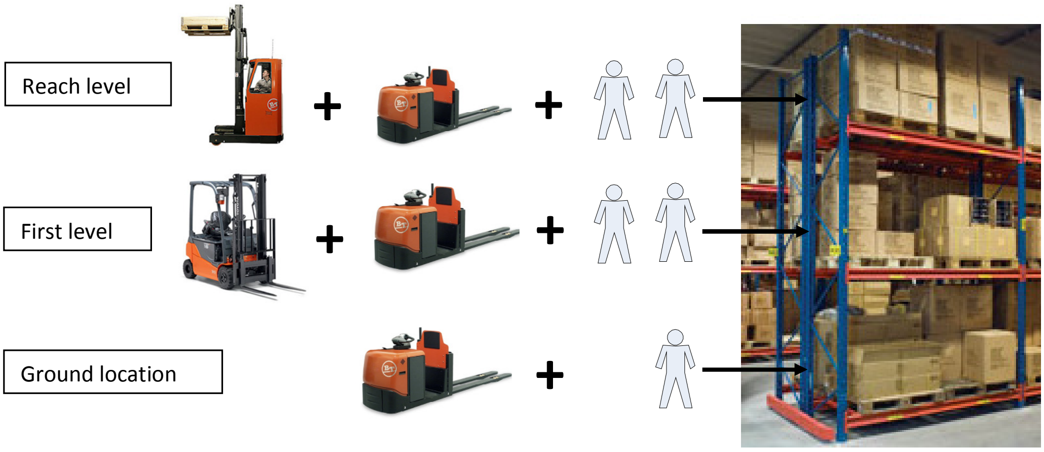


figure 18: Different pick levels in the fast pick area

All the above mentioned problems result in the bottleneck in fast pick area: The storage strategy in the fast pick area is not optimal. This bottleneck results in a long travel distance and in a high travel time. The cause and effect of the problems and the bottleneck are added in *figure 19*.

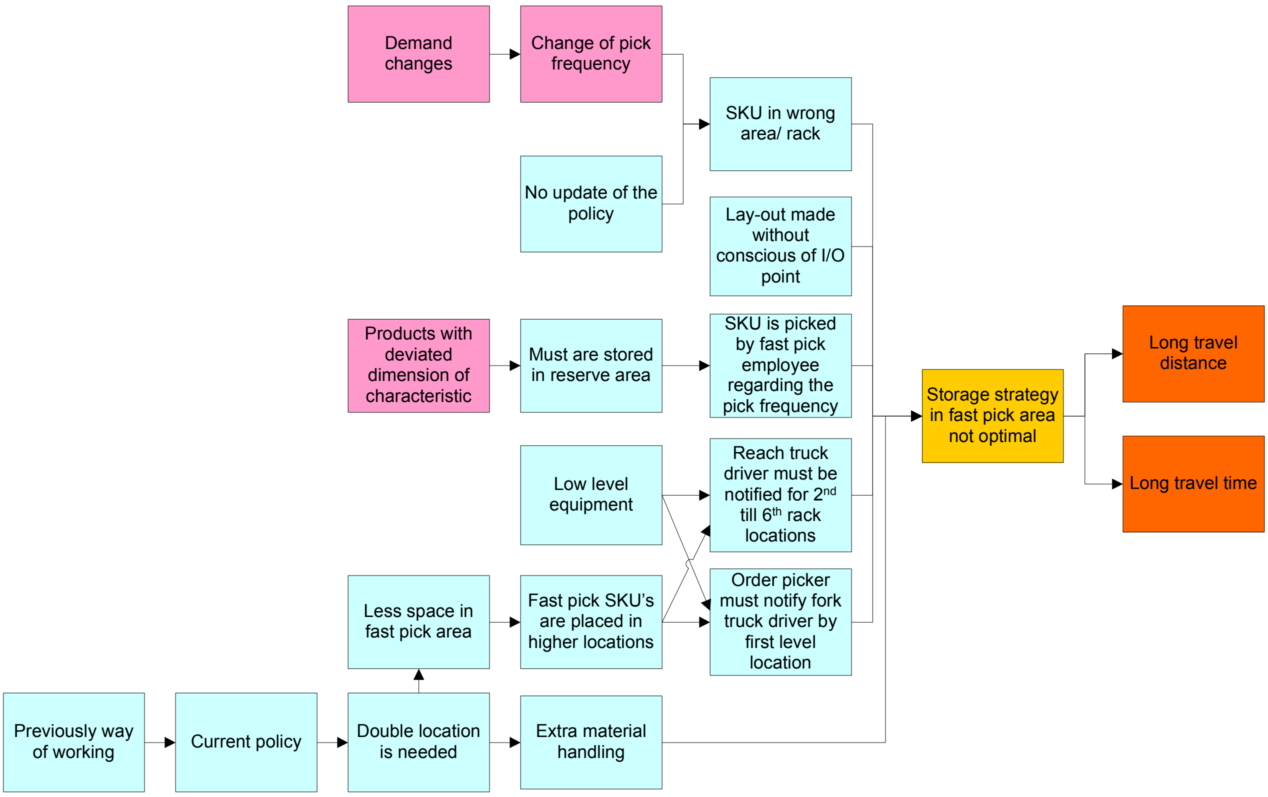


figure 19: Cause & effect diagram storage strategy in the fast pick area

The purple boxes can't be influenced. The demand of customers and pick frequencies can't be influenced by the warehouse. Also the deviated dimensions and characteristics of products can't be changed.

KPI

The chosen KPI for this process is divided over the travel distance and travel time. These KPIs are related to each other. Travel time decreases when travel distance decreases. However if travel time decreases this doesn't have to influence travel distance. Travel distance is used for calculating an optimal storage strategy considering a fixed I/O point, the extra time or distance for storing a pallet in the first level is negligible. Travel time is used for providing a KPI for the other problems.

The first defined KPI is the total travel distance in 2009. Distance between I/O point and locations are measured and filled in a layout. The I/O point is fixed in the middle of the layout. Next step is the calculation of the total travel distance. The popularity of a SKU and the number of restocks in 2009 are multiplied with the travel distance. This calculation results in a total travel distance of 2.803.776 meters in 2009.

The KPI, travel time in the fast pick area, is divided in two travel times: 1. The average pick time for picking a ground location, a high location or a case pick order in the reserve area. 2. The time for picking an order in a reach truck location is done by an employee in combination with a reach truck driver. The travel times are hard to combine and are therefore separated. The goal is to reduce both travel times.

Data for the first average travel time is achieved by Topa for two years. Each order pick employee writes down his start and end time and the number of visited locations. The time that was needed for picking all the orders on the picking lists are divided over the total locations that are visited. An order is picked in an average of 2 minutes and 40 seconds per location. This time includes a SKU that is picked in the reserve area, a first level location and a ground location. This KPI can be influenced by optimal placement in dedicated storage, solving the first level locations problem or the location of SKUs in the reserve area.

The second travel time is measured for only the time spent for the reach truck locations. Two employees, a fast pick employee and a reach truck driver are both occupied for picking these reach location orders. Both employees are occupied one hour a day for visiting on average 14 reach truck locations. This results of 4 minutes and 30 seconds minutes per reach truck location. Two employees are occupied for 4 minutes and 30 seconds, which result in an average time of 9 minutes per location.

Data bottleneck 4:
Bottleneck: Storage strategy is not optimal in the fast pick area

KPI 1: Travel distance of **2.803.776 meters** per year in 2009

KPI 2: Average travel time of **2 minutes and 40 seconds** per order line for a first level, ground and reserve area.

KPI 3: Average travel time of **9 minutes** per reach truck location

Goal: Searching relevant literature for an optimal storage strategy in the fast pick area. Second goal is the allocations of SKUs to a storage location by minimizing the total travel distance. Third goal is to find alternatives for the storing of products or equipment by minimizing the travel time per order line. Fourth goal is to reduce or eliminate the travel time for reach truck locations in the fast pick area.

5.3 Summary current performance and bottlenecks

The assumptions for bottlenecks in the current situation in the distribution center of Topa are validated in this chapter. The bottlenecks are exposed regarding observations, interview and analysis of ERP data. The bottlenecks and their performance are summarized (*figure 20*) in this section.

1 **Receiving process**
Bottleneck: Non value adding activities that cause waiting times in the receiving process

KPI :	*Average total throughput time of **138 minutes** before a load of a truck is unloaded and stored*

2 **Allocation of SKUs to reserve or fast pick area?**
Bottleneck: SKUs are stored in the wrong area

KPI :	*Case pick time in the reserve area: **232 minutes per day***

3 **Storage strategy in reserve area**
Bottleneck: Current storage strategy in the reserve area

KPI:	*Total travel time of **926,8 hours** in 2009*

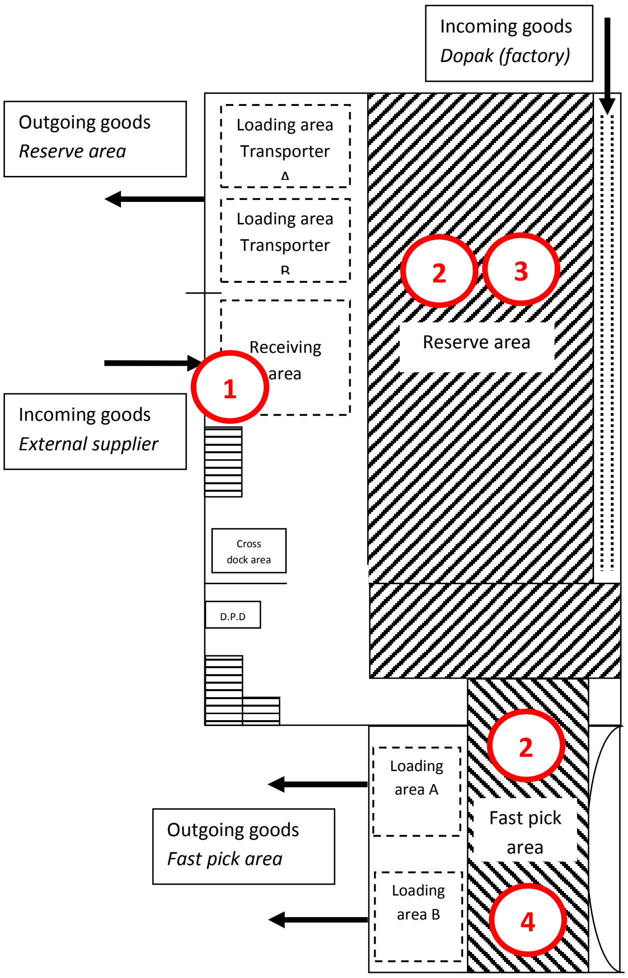


figure 20: Overview of the bottlenecks in the layout

4 **Storage strategy in fast pick area**
Bottleneck: Current storage strategy is not optimal in the fast pick area

KPIs:	*1.)Travel distance of **2,803,776 meters** per year in 2009* *2.)Average travel time of **2 minutes and 40 seconds** per order line for a first level, ground and reserve area.* *3.) Average travel time of **9 minutes** per reach truck location*

6 Literature study

This chapter gives answer to sub question 4."How to find information for improving the KPIs and what is a suitable way form improving the KPIs for the bottlenecks?" The first question is answered in section 6.1. An approach is given per bottleneck. Section 6.2 contains the execution of the plan of approach. Relevant information is searched for solving the bottlenecks and influencing the KPIs. Finally a summary is added in section 6.3 with the suitable alternatives for solving the bottlenecks.

6.1 Approach for solving the bottlenecks

This section contains information on how to find relevant literature or information to solve the bottlenecks. An approach is established for each bottleneck that is defined in chapter 5.

6.1.1 Receiving process

The root of the first bottleneck is caused by the current ERP system. Activities are embedded in the process due to the ERP system. The process can only change if the ERP program changes. This last point, changes in the ERP system are very difficult in the current situation. The current ERP is out dated and restricts changes in the current processes. Therefore the management of Topa decided to switch to another ERP system. This new system allows Topa to critically review the current process. Between the writing of this report and a year a new ERP system will be active. The same tool that is used for exposing the bottlenecks, VSM, can be used for mapping a future state. The root cause of this bottleneck is more a practical problem than a theoretical problem for which a possible solution can be found in the literature. No literature is searched for this bottleneck, but VSM and real life simulation is used for improving the KPI of this bottleneck in Chapter 7.

6.1.2 Allocation of SKU to reserve area or fast pick

There are two main problems that cause that SKUs are stored in wrong areas.

1. No savings based calculations for storing item *i* in the fast pick rather than in the reserve area.
2. No update policy

The solution of the problems must decrease the case order pick time by reach trucks and indicate savings per SKU *i* that is stored in the fast pick area rather than the reserve area.

Approach:
Literature must be searched regarding the problem which SKU to store in the fast pick area rather than in the reserve area. Goal is to find models and formulas for calculating the savings per item. The division of the SKUs over the two areas must be translated into a straight policy. When to place a SKU in the fast pick area and when to store a SKU in the reserve area. In a later phase a plan must be made for maintaining the policy for the solution.

6.1.3 Storage strategy in reserve area

There are three problems that can have an influence in solving the storage strategy in the reserve area.

1. No savings based calculations are made in the reserve area
2. Layout made without being aware of the I/O point
3. No update of the storage strategy policy

The solution for these problems must reduce the total travel time of 926,8 hours in 2009.

Approach:
Literature must be searched for several alternatives for storing SKUs in the reserve area. Goal is to find models and formulas for calculating the travel time regarding a storage strategy. The new storage strategy needs a new policy and a policy update plan.

6.1.4 Storage strategy in fast pick area

The problems for the storage strategy in the fast pick area are caused by six problems:

1. Layout made without awareness of I/O point
2. Fast pick employees still have to pick products from the reserve area
3. Low level equipment (time lost by waiting)
4. Less space in fast pick area due to current policy
5. Double location per SKU due to current policy
6. No savings based calculations are made for the storing strategy

Solving these problems must result in a decrease of the average order pick time, the total travel distance and the time spent by reach truck drivers in the fast pick.

Approach:
Searching storage strategies for storing SKUs the fast pick area in the literature. Goal is to find a new storage strategy policy for the fast pick area. The new policy must decrease the KPIs of this bottleneck. Second step is to find practical solutions for the fast pick process. Problem 2, 3 ,4 and 5 are more practical problems to solve. Plain thinking and try-outs must indicate improvements. Finally a new policy must be established with an update plan.

6.2 Literature review

The search strategy is mentioned earlier in the project approach section 3.4. Relevant literature is searched in two data bases: Scopus and Web of Science. These two databases cover the top 33 rated journals in the area of Operation Management (Olsen, 2005). Bottom up search is used for finding relevant literature. Papers are also found by use of backward searching; papers are looked up that are referenced by papers that are found by use of the databases. Finally information is gathered from several books in the area of warehouse management. The literature found per bottleneck is described in this section

6.2.1 Allocation of SKU to reserve area or fast pick area

The key words used to find literature for this bottleneck were among others: Fast pick area, forward pick area, forward-reserve problem, storage strategy, distribution center, warehousing, order picking. The key words are also used in combinations of them. The first part of this section described why and when to use a fast pick area. The next part of the section contains which information is needed to determine which SKU to store and pick from the fast pick area. The final part describes a model by Bartholdi and Hackman (2010) that can be used for calculating net benefits.

What is a fast pick area and why to use a fast pick area?
The fast pick area, also known as the forward pick area, is a “warehouse within a warehouse”: Many of the most popular SKUs are stored there in small amounts. Order picking can concentrate within a relatively small area (Bartholdi and Hackman, 2010). Primarily a fast pick area is used to reduce the travel distance and improve the order picking time. The reserve area is used for bulk storage and replenishment for the fast pick area and for picking the products that are not assigned to the fast pick area. The trade off

which SKU to store in the fast pick area is also known as the *forward-reserve problem (*van den Berg et al, 1998). A SKU is picked faster from the fast pick area but must be replenished from the reserve area. Among all warehousing operations, order picking makes up approximately 55% of the costs because it is a labor-intensive activity for traditional manual warehouses (Bartholdi and Hackman, 2010). A fast pick area allows order pickers to fill a large portion of the orders while traveling in a small space (Kong and Masel, 2008). This reduces the total travel distance and time.

How to attain information about which SKU to store in the fast pick area?
The use of a fast pick area is shown to be of great value in a distribution centre. A fast pick area reduces travel time and improves the efficiency of the picking process. The next step is to attain relevant information about when to store a SKU in the fast pick area. This part contains an overview of the literature found on this subject. The next part of the section contains the relevance and applicability at Topa.

The keywords are used for finding relevant articles regarding this topic. The articles found by the databases are scanned on the summary and the article title. When the summary contains relevance to the topic the whole article is read. In total five articles are found for this topic. Besides these five articles several articles are found that are related to the subject. Several authors adapted the forward reserve problem of Bartholdi and Hackman, 2010 for additional issues regarding the fast pick area such as, the size of a fast pick area (Frazelle et al. 1994, Gu, 2005) and limitations on restocking (Frazelle et al., 1994, van den Berg et al, 1998). Furthermore a wide range of authors pay special attention to automated warehouses. The five remaining articles are summarized in *table 5*.

1. Van den Berg et al, 1998: *Forward-reserve allocation in a warehouse with unit-load replenishments*
2. Bartholdi and Hackman, 2008: *Allocating space in a forward pick area of a distribution center for small parts*
3. Bartholdi and Hackman, 2010: *"Warehouse & Distribution Science" release 0.92*
4. Kong and Masel, 2008: *Methods for design and management of a fast-pick area in a warehouse*
5. Van den Berg and Zijm, 1999: *Models for warehouse management: Classification and examples*

	Author	Core
1	Van den Berg et al., 1998	Determine which replenishments minimize the expected amount of labor during the picking period. The focus is on the replenishment of SKUs from the reserve area to the fast pick area. Assumption is that replenishments take places in the evening or in the weekends, in idle periods.
2	Bartholdi and Hackman, 2008	Two stocking strategies that are commonly used in industry are analyzed and compared with the optimal stocking strategy for small parts in the fast pick area. The focus is to allocate the right amount of space in a fast pick area. The authors assume that SKUs already have been chosen for storage in the forward pick areas as in Hackman and Rosenblatt, 1990. The results of the article by Hackman and Rosenblatt, 1990, are used for the input of a book written by Bartholdi and Hackman, 2010.
3	Bartholdi and Hackman, 2010	Book in a concept phase, three chapters are devoted to layout of different areas; 1: A unit load area, 2: A carton pick from pallet area and 3: A piece pick from carton area. Area 2 & 3 are two ways of implementing a forward pick area. In area 2 cases are picked from a full stocked pallet. In area 3 a single piece (SKU) can be picked from a predetermined amount of stock. A heuristic is described for allocation SKUs to the forward area and gaining an optimal benefit for storing SKU *i* in the fast pick area rather than in the reserve area.

4	Kong and Masel, 2008	Heuristics are described to assign SKUs to zones and then to sequence the orders for picking so that the full benefits of the buffers can be obtained.
5	Van den Berg & Zijm, 1999	The authors discuss warehousing systems and present a classification of warehouse management problems. One of the topics they are dealing with in the article is the forward reserve problem. In a brief section a binary model is proposed for allocation SKUs to the fast pick area. Assumption is that more unit loads are located to the fast pick area. Model has a strong relation with the heuristic described by Bartholdi & Hackman.

table 5: Summary of relevant articles for a fast pick area

Van den Berg et al (1998) sums up the advantages of a fast pick area and refers to other relevant literature regarding the fast pick area. They also refer to Hackman and Rosenblatt (1990) which were the first to present a model for the forward-reserve problem. This model is described in the upcoming book "Warehouse & Distribution Science". Van den Berg et al (1998) are presenting a model for minimizing the expected amount of labor during the picking period. Goal is to replenish in idle periods like the weekend or in the evening and nights. The authors are extending the model by Hackman and Rosenblatt (1990) focusing on the replenishment period. The second article by Bartholdi and Hackman is also useful for general information regarding the fast pick area. Furthermore the article focuses more on small parts and is therefore not useful for Topa. However it can be noted in the article that the SKUs have already been chosen for storage in the forward pick area as in Hackman and Rosenblatt (1990). Kong and Masel (2008) also explain the usefulness of a fast pick area. However the focus is more on zone picking with conveyors and buffers. Finally van den Berg & Zijm, 1999, emphasize the use of a fast pick area to reduce the amount of work associated with order picking. The authors formulated the forward reserve problem as the binary programming problem. Two options are possible, 1: a product is assigned to the fast pick area or 0: product is assigned to the reserve area.

Applicability at Topa

Article	Applicable for Topa?
1 Van den Berg et al., 1998	No, some of the assumptions of the model are in contradiction with Topa. Model is focuses more on replenishment in idle periods like the evenings and the weekends. Furthermore the focus is more on the replenishment costs instead of which SKU to store in the forward area.
2 Bartholdi & Hackman, 2008	No, model is aimed on small parts and the assumption is made that the SKU are allocated to the fast pick area regarding Hackman and Rosenblatt 1990. The definition of small parts is that a single SKU is very small, like a pencil or small box. Furthermore the article refers to piece picking. Topa has almost no small parts, most parts at the forward area are transported on pallets. The next issue is that Topa almost only picks collies and no pieces.
3 Bartholdi & Hackman, 2010	Yes, model is general applicable the assumptions are in line with Topa's situation. The heuristic is based on assigned SKU regarding a net benefit.
4 Kong & Masel, 2008	No, model is aimed on zone picking with conveyors and buffers.
5 Van den Berg & Zijm, 1999	The binary model could be used for Topa's bottleneck. Model is related to the model of Bartholdi and Rosenblatt. Disadvantage of the model is the brief description and calculations with more than one unit load replenishment. The model also does not take into account that a full bulk pallet can be sold and picked.

table 6: Applicability of the articles for Topa

Several articles (van den Berg et al, 1998 & 1999, Bartholdi and Hackman, 2008 and diverse literature reviews) refer to the forward-reserve model presented by Bartholdi and Hackman, 2010 in their book "Warehouse & Distribution Science". Three chapters are dedicated to the layout of a warehouse. Two chapters are fully dedicated to a fast pick area. In chapter 7 the layout of "*a carton pick from pallet area*" is discussed and in chapter 8 the layout of "*a piece pick from carton area*". Chapter 7 contains a heuristic when to store a SKU in the fast pick area and when not. This heuristic is applicable when full cartons or collies are picked from full pallets. This layout type corresponds exactly with the situation of Topa. Chapter 8 contains a heuristic when we have to determine how many SKUs to stock in the fast pick area if piece picking is applicable. Piece picking isn't applicable in the case of Topa.

Chapter 7 contains a formula to calculate the net-benefit for picking SKU *i* in the fast pick area rather than the reserve area. The model will be used to determine if a SKU must be stored in the fast pick area.

Model

Bartholdi and Hackman (2010), divides the layout of a warehouse in three types: a unit load area (chapter 6) and case pick from pallet area (chapter 7) and a piece pick from carton area (chapter 8). The three layouts are viewed in *figure 21*.

Unit load area:

Only a single, common "unit" of material is handled at a time. A typical unit load is a pallet. At Topa this is the reserve area where almost only full pallets are handled.

Case pick from pallet area:

A carton box or case refers to a rectangular box that can be handled by one person and be stored on a pallet. The carton boxes are typically stored on pallets, restocking is a unit load process and picking not. This creates additional complexity in the calculations of savings. At Topa case picking is done in the fast pick area and less popular SKUs are picked in the reserve area.

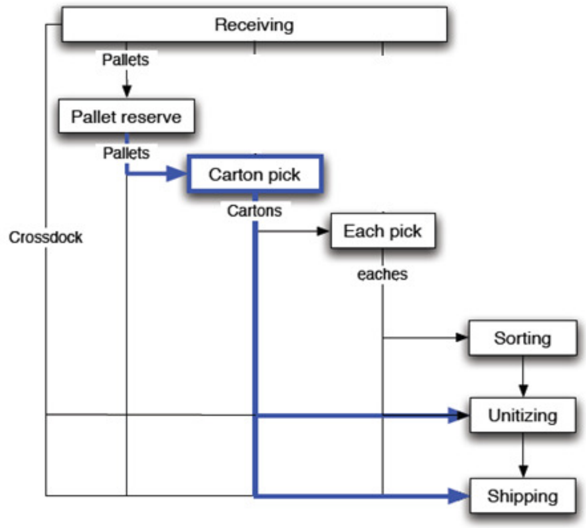


figure 21: Typical flow of cartons through a warehouse (Source Bartholdi & Hackman, 2010)

Piece pick from carton area:

Piece picking is the most labor intensive activity in a warehouse because the product is handled at the smallest units-of-measure. Its customers demand that items can be ordered at a SKU level. If a customer wants to order only one carton box or one roll of tape it is possible while for several years only minimum order quantities were allowed. Piece picking isn't a common process at Topa, and occurs on a less frequent basis. Piece picking is done at a special rack only for special products. Restocking is not a unit load process and the order frequency is very low. Some piece picking is done in the fast pick area.

Chapter 6 is focuses on the reserve area which is out of scope of this bottleneck. Chapter 8 focuses on piece picking which is not applicable for Topa. The focus of Chapter 7 carton pick from pallet area is applicable on the case. In the next part of this section the model of Chapter 7 is described.

Bartholdi and Hackman, (2010) describe two typical configurations of a fast pick in a case-pick area of a warehouse. 1. Pick from pallets at bottom of rack and replenish from above and 2. Pick from carton flow rack to conveyor.

Two important assumptions are made by the model for analyzing the fast pick configuration.

Assumption 1: All locations in the fast pick area are dedicated storage locations, randomized storage strategy is used for the unit load area.

Dedicated storage has the advantage to support rapid order picking. Employees learn easily where a product is stored. The reserve area is generally devoted to bulk storage and is much larger. Randomized storage ensures high space utilization.

Assumption 2: At any time each SKU has a single location from which to pick all less-than-pallet quantities; furthermore, that location will remain within a single area, either forward or reserve.

When a SKU is stored in both areas it makes economic sense to pick a full- quantity pallet from the reserve area. If a full pallet is picked from the fast pick area it must be replenished from the reserve area.

Now the question arises: Which SKUs should be stored on the fast pick locations? The authors of the book state that only three are worth considering storing: no pallets, one pallet or all pallets.

Any SKU that is picked from pallets should either not be in the fast pick area at all; or it should have one pallet; or it should have all of its on-hand inventory in the fast pick area.

In the case of storing only one pallet a safety stock can additionally be stocked. The option, placing all of its-on-hand inventory in the fast pick area isn't possible for Topa. A SKU can be sold in a full pallet quantity and as a case pick quantity. A certain SKU can have an inventory of 20 full pallets. The advantage of a fast pick area will disappear when storing all pallets in the fast pick area. Furthermore Gu et al, (2007) states that assuming that the forward area can be replenished instantaneously there is no need to assign more than one unit to the forward area.

The authors express the net benefit per SKU per year in a formula of storing a SKU in the fast pick area rather than in the reserve area. Let p_i be the number of less than 75% of a pallet quantity pick (popularity) per year and d_i the number of restocks by such picks per year. Suppose that, on average, it saves *s* minutes when a pick is made from the forward area rather than from reserve area; and that each restock of the forward area (that is, each move of a pallet from reserve to the forward area) requires c_r minutes. The net benefit in minutes per year of SKU i in the fast pick area is:

Formula:
Net benefit per year per SKU $i = sp_i - c_r d_i$

s = Savings in minutes of pick a SKU from the fast pick area instead of the reserve area
p_i = *Number of less than 75% of a pallet quantity per year (popularity)*
c_r = *Minutes of restock*
d_i = *Number of restocks per year*

The net benefit per year per SKU i is 0 when no items are located to the fast pick area. Some SKUs could negative influence efficiency if they were stored in the fast pick area. The net benefit for this SKU is negative if:

$(p_i / d_i)s < c_r$

For the effectiveness of the model one SKU is tested for savings. Consider the most popular SKU of Topa in the current fast pick area: Topafix (*figure 22*)

Example SKU 1: Topafix (Tape)

s = 2 minutes and 20 seconds = ***140*** *seconds*
p_i *=* ***500*** *picks in 2009*
c_r *= 6 minutes =* ***360*** *seconds*
d_i *=* ***32*** *restocks in 2009*

figure 22: Picture of Topafix the most popular SKU that is picked in the fast pick area (Source: www.topa.nl)

The savings, *s* are calculated regarding the average pick time in the reserve area and the average pick time in the fast pick area. Recall that it takes 7 minutes and 15 seconds to pick a case order in the reserve area. However the time for making the order shipment ready is included. The time for sealing must be subtracted from the pick time. An average of 5 minutes remains for case picking in the reserve area. Recall that the average pick time in the fast pick area is 2 minutes and 40 seconds. The saving is 5 minutes minus 2 minutes and 40 seconds = 2 minutes and 20 seconds = *140 seconds*.

*Net benefit for picking Topafix from the fast pick area rather than the reserve area = 140*500-360*32 = 58,480 seconds = 16 hours and 14 minutes in 2009.*

In this example the model is shown to be effective for this SKU. 16 hours and 14 minutes in 2009 were saved by picking this SKU in the fast pick area rather than in the reserve area. The model is worked out for all SKUs in chapter 7. The model of Bartholdi and Hackman, 2010 also discusses which storage strategy to use in the forward area. This topic will be discussed in section 6.2.3.

6.2.2 Storage strategy in reserve area

Key words to find information relevant to storage strategies in the reserve area were among others; storage strategy, reserve area, bulk area, ABC storage, random storage, zone storage, order picking, warehouse management, logistics, distribution center, warehouse. Goal of this section is to review relevant literature for storage strategy in the reserve area.

Storage policy
Many authors have written about the subject storage strategy in warehouses. Solutions and suggestions vary from simple rules of thumb to complicated simulations and programming models. The same search strategy is used as mentioned in the previous section. Articles are scanned by titles and summary. For this subject eleven articles are read fully. Two articles (van den Berg, 1999 and Hausman et al,. 1976) are not useful after reading the whole article. An overview and summary of the remaining nine articles is given in *table 7*.

Author	Article title	Relevance
Gu et al, 2010	*Research on warehouse design and performance evaluation: A comprehensive review*	Article summarizes important literature for diverse storage strategies. A summary for several possibilities and authors is given.
Larson et al, 1997	*A heuristic approach to warehouse layout with class-based storage*	Articles focus on three phases, 1 the layout assignment of material to a storage medium and 3 allocation of floor space.
Petersen & Aase, 2004	*A comparison of picking, storage, and routing policies in manual order picking*	Several picking, storage, and routing policies are evaluated to determine which process decision provides the greatest percent savings relative to the current policies.

De Koster et al, 2006	*Design and control of warehouse order picking: a literature review*	Article gives a literature overview on typical decision problems in design and control of manual order-picking processes. Paper gives a broad overview of the diverse storage possibilities.
Rouwenhorst et al., 2000	*Warehouse design and control: Framework and literature review*	Article gives a literature overview of storage policies.
Gu et al., 2007	*Research on warehouse operation: A comprehensive review*	An extensive review on warehouse operation planning problems is presented. The problems are classified according to the basic warehouse functions.
Dekker et al., 2004	*Improving order-picking response time at Ankor's warehouse*	Authors adapt existing solution techniques for improving order picking response time. A good combination of policies for storage assignment and routing is determined.
Petersen, 1999	*The impact of routing and storage policies on warehouse efficiency*	Article provides volume based storage strategies policies layouts.
Roodbergen & Petersen, 1999	*Order picking 401: How to improve order picking efficiency with routing and storage policies*	Article proved several layout possibilities regarding a volume based storage strategy.

table 7: Summary of the articles found for a storage strategy in the reserve area

The article by de Koster et al. (2007) provides the most useful overview of the storage strategies. The author describes five frequently used storage assignment strategies: Random storage, closest open location storage, dedicated storage, full turnover storage and class based storage. These storage strategies can be adapted for both areas: reserve area and fast pick area. The storage strategies are each described briefly. Relevant literature from other articles is combined per subject. In *table 8* a summary is given of the advantage disadvantage and applicability for Topa per storage strategy.

Random storage:
Every incoming pallet is assigned to a location in the warehouse that is selected randomly from all eligible empty locations with equal probability (Petersen, 1997). Advantage of this strategy is the high utilization rate of the warehouse. The disadvantage is the possibility of large travel times from having to traverse the entire warehouse. However random storage is the most common storage policy used in warehouses today (Petersen, 1999). Randomized storage policies can be calculated by calculating the average travel time per location regarding the uniform probability (Petersen, 1997).

Closest open location storage:
An order picker can choose the location for storage themselves. The first free location is allocated for storage. Hausman et al. (1976) argue that this storage strategy and random storage has similar performance if products are moved by full pallet only. The disadvantage is that the storage policy is driven by the employees and not by system. When an employee is not accurate or forgets where the SKU was stored it could provide serious problems.

Dedicated storage:
For every quantity of a SKU a dedicated storage location is reserved. A disadvantage of dedicated storage is that a location is reserved even for products that are out of stock. Moreover maximum inventory must be reserved for each SKU. The space utilization is much lower than random storage. The advantage of dedicated storage is that the order pickers get familiar with the location of the SKUs.

Full turnover storage:
Products are assigned to location regarding their turnover. Products with a high turnover rate are stored nearby the I/O point and slow movers are stored in the back of the warehouse. This strategy has a big overlap with the COI rule Cube per order index (de Koster et al, 2007). While the full turnover storage strategy only focuses on the turnover rate does the COI rule combines the demand rate with the required space. The COI of an item is defined as the ratio of the item's total required space to the number of trips required to satisfy its demand per period. Items with the lowest COI are placed closest to the depot (see Heskett 1963, 1964 and Kallina and Lynn, 1976). The ratio is defined of the item's space to the number of trips required to satisfy its demand per period. Disadvantage of this strategy is the change of ratio. Each change would require a new ordering of products in the warehouse resulting in a large amount of reshuffling of stock. (see also in section 6.2.3 on page 55)

Class based storage:
Products are grouped into classes in such a way that the fast moving class contains a certain % of the products contributing a significant % to the turnover. Pareto's analysis describes 15% of the products which contribute 85% of the turnover. Each class is then assigned to a dedicated area of the warehouse. The storage within these classes is random (de Koster et al 2007). The advantage of the class based storage is the less time to administer the policy regarding dedicated storage. Second advantage is the gain of travel time regarding the randomized storage strategy. The disadvantage is the reserving of extra locations in a zone, however this is less than with the dedicated storage policy.

There are diverse ideas about the class division in a class based storage strategy. De koster et al, 2007 describes the 15-85 rule, 15% of the SKUs contributes to 85% of the picks. The classes are mostly restricted to three but more can be implemented if this affects the travel time positively. Most importantly the author states that in the warehousing literature, no firm rule exists to define a class partition (number of classes, percentage of items per class, and percentage of the total pick volume per class) for low-level picker to part systems. Dekker et al, 2004 advice performing experiments with the percentage of picks allocated to Class A. In the same article Dekker et al (2004) uses 70% of the picks or at most 15% of the SKUs to allocate in Class A. The next 20% of the pick popularity (to 90%) or at most 50% of the SKUs are assigned to Class B. The rest of the SKUs must be assigned to Class B.

Other commonly used Classed based strategies are, 20% of the SKUs that correspond with 80% of the picks in Class A, the next 15% of the picks (30% of the SKUs) in Class B and the remaining 5% in Class C. Or 66,6% of the picks (10% of the items) in Class A, 23,3% of the pick in Class B and the rest in Class C.

The storage space needed by each class is determined by calculating how many locations are occupied by the products assigned to each class. Each zone must contain safety stock locations to cover peaks.

Layout policy for class based storage
When implementing the class based storage policy the layout can have significant impact on the travel time. Three layouts are commonly used for class based storage (Petersen, 1999, Petersen & Aase, 2004 and Roodbergen & Petersen, 1999) Diagonal, Within-aisle and cross aisle storage, *figure 23 and figure 24.*

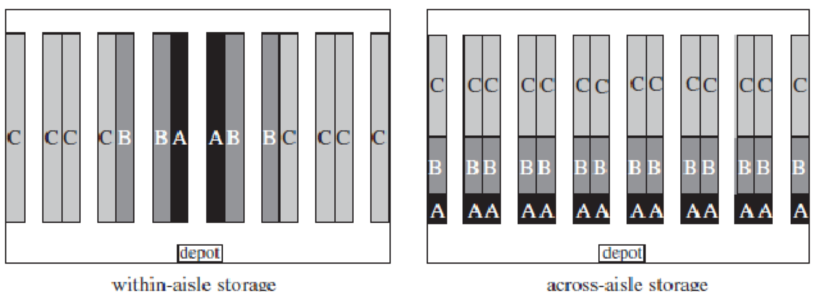


figure 24: Illustration of two common way to implement class-based storage (source: de Koster et al., 2007)

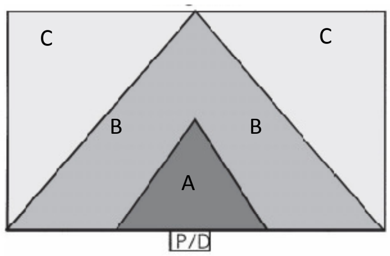


figure 23: Diagonal volume based storage strategy (source: Petersen, 1999)

The highest volume items are stored in the aisle closest to the I/O point with the “Within aisle storage”. In combination with routing policies this can be an attractive storage policy. The highest volume items are stored in the “area” closest to the I/O point with the across-aisle storage. This area is fixed across the aisles (Roodbergen & Petersen, 1999). Diagonal storage involves having the items stored in the warehouse in a diagonal pattern with the highest volume item in the location closest to the I/O point (Petersen,1999). Tompkins et al. (1996) states that this type of storage strategy is the “optimum”.

Method	Advantage	Disadvantage	Applicable in reserve area?	Applicable in fast pick area?
Random storage	- High utilization rate of warehouse - Not information intensive - No update needed	- Possibility of long travel time - System driven	Yes	Yes
Closest open location storage	- Order picker can chose location	- Employee driven - Human mistakes	No	No
Dedicated storage	- Familiar with locations - Positioning of products	- location reservation even for SKUs that are out of stock - administer intensive	No	Yes
Full turnover storage	- High rated turnover close to I/O point - High sale rate = easy accessible	- Data intensive approach - Demand rate changes - products assortment changes - update intensive policy - Loss of flexibility	No, (in combinatio n with dedicated storage)	Yes
Class based storage	- Combination of random and dedicated - Flexibility - less time to administer regarding dedicated	-update of policy (new ranking) - more space needed than randomized storage	Yes	Yes
Within Aisle storage	- Efficient in combination with routing policies	- Less efficient with single command picking	Yes	
Across aisle storage	- Easy implementation - Efficient with single command picking	- Less efficient than diagonal aisle storage	Yes	
Diagonal aisle storage	- Optimum	Difficult to program in Warehouse system	Yes	

table 8: Applicability of the storage strategies for a reserve or fast pick area

Applicability of the storage strategy at Topa

In this section several alternatives are considered for the storage strategy in the reserve area. The storage strategy in the fast pick area is discussed in the next section. *Table 9* gives an overview of the discussed storage strategies and their advantages and disadvantages. The first discussed storage strategy, random storage is suitable for implementing at Topa. The disadvantages and advantages of this storage strategy will be shown using calculations in the next chapter. The closest open storage is not a suitable storage strategy for Topa. The picker chooses the closest location for storage. The chance of making mistakes is too high regarding the high pallet movement at Topa. Moreover Topa has an ERP system which eliminates manual activities and can allocate the closest location. The closest open storage strategy will not be worked out for the Topa case. Dedicated storage strategy is also not suitable for Topa in the reserve area. However this strategy could be a good strategy in the fast pick area, which will be discussed in the next section. With a large number of SKUs and high change of assortment dedicated storage is not suitable for the Topa case. Full turn over strategy is also not suitable for the reserve area at Topa. A rate is established regarding the turnover. This rated is ranked and products are located regarding this rank, most of the time in combination with dedicated storage. This policy is a high information intensive approach and each change in demand or assortment requires a reshuffling of stock. The full turnover strategy is not further discussed as an alternative for Topa. The last storage strategy, the class based storage, is a suitable storage strategy for Topa. Topa uses this strategy in the current situation. Trial and error will expose the best division of the zones and pick percentages. Diverse policies and rules must be applied to the case for comparison. The across-aisle layout is a common used strategy in combination with the ABC storage strategy. The within aisle is a common used layout in combination with routing policies. Topa uses single command picking in the reserve area. The within aisle layout gains no extra benefit. The diagonal layout will be taken into account but can't be implemented in the current ERP system of Topa. The across aisle layout is a straight layout that can easily be adapted.

6.2.3 Storage strategy in fast pick area

Key words to find information relevant to storage strategies in the fast pick area were among others; fast pick area, storage strategy, forward area, dedicated storage, order picking, warehouse management, logistics, distribution center, and warehouse.

The first bottleneck, which SKU to store in the fast pick area, is related with the storage strategy that is used in the fast pick area. The same articles found for the first problem, discusses also the storage strategy in the fast pick area. Five articles are fully read for the storage strategy in the fast pick area. Bartholdi and Hackman, 2008 and 2010, De Koster et al., 2006 and Gu et al., 2007. The article of Malmborg, 1995 was not found relevant to the case after fully reading.

Hackman and Bartholdi, (2008, 2010) states using dedicated/ reserved storage in the fast pick area to support rapid order picking. When storage is reserved it can be assigned based on activity rather than mere availability, and order-pickers can learn more easily where a product is. The disadvantage of dedicated storage strategy is not applicable for the fast pick area. Recall that space inefficiency is the biggest disadvantage of dedicated storage strategy. In the fast pick area only one pallet will be assigned to this area, so no extra space has to be reserved for safety stocks. Furthermore only frequently picked SKUs are allocated to the fast pick area.

De Koster et al, (2006) states that dedicated storage can be applied in pick areas, with a bulk area for replenishment that may have, for example, random storage. In this way, the advantages of dedicated storage still hold, but the disadvantages are only minor because dedicated storage is applied only to a small area.

Two commonly used policies for dedicated storage are: Popularity and Cube per Order Index (COI). Popularity, defined as the number of storage/retrieval operations per unit time period. The items are ranked regarding the popularity and the item with the highest popularity is assigned to the most desirable location (Gu et al, 2007). The COI is defined as the ratio of the maximum allocated storage space to the number of storage/retrieval operations per unit time. The COI policy takes into consideration both the SKUs popularity and its storage space requirement. The storage space requirements depend on the stock per SKU and the number of locations the stock requires. Items are ranked by increasing COI value, the lowest value is assigned to the most desirable location (Gu et al, 2007). The author also states that since a unit load occupies the same amount of storage space, the popularity policy is essentially the same as the COI policy.

Applicability of the storage strategy in the fast pick area at Topa

All four read articles state that dedicated storage strategy is the best solution for the fast pick area. Topa uses this strategy in the current situation. The disadvantages of dedicated storage strategy are minor in such a small area. Assigning the most popular SKU to the best locations is a strategy that is not used at Topa. Both strategies are worked out in the next chapter.

6.3 Summary literature study

6.3.1 Which SKU to store in the fast pick area

A literature review regarding the forward reserve problem concluded that the model by Bartholdi and Hackman, (2010) a case pick from pallet area can be used to determine savings for storing item i in the fast pick area rather than in the reserve area. A fast pick area is used for reducing the travel distance and travel time. A SKU must therefore be placed in a fast pick area if this SKU is picked from the fast pick area rather than from the reserve area. Bartholdi and Hackman (2010) formulated the following formula to determine the savings for SKU i per year:

Net benefit per year per SKU i= $sp_i - c_r d_i$

If the net benefit per year for SKU i is positive the SKU should be stored in the fast pick area. An example of a SKU at Topa is shown to be effective. The model is adapted in the next chapter for effectiveness for all SKUs

6.3.2 Storage strategy in reserve area

Several storage strategies are discussed: random, closest open location, dedicated, full turn over and class based turnover. Closest open location, dedicated and full turn over are not applicable for the case at Topa in the reserve area. Further calculations of the storage strategies must reveal if random or class based storage is the best alternative for the case of Topa. Diverse methods are described for determining the zones. Experiments regarding the dimensions of the zone and which SKUs to place in which zone must indicate savings for this alternative. Finally three layouts are discussed when adapting the class base storage strategy. Across aisle, diagonal and within aisle can be used for the class layout in the reserve area. The across aisle layout is used for locating the zones in the warehouse while diagonal is not easy to implement and within aisle only has extra benefit regarding routing.

6.3.3 Storage strategy in the fast pick area

The same discussed storage strategies are applicable on the fast pick area. However the model for allocating the SKU to a fast pick area advises dedicated storage strategy. Only one unit load is located to the fast pick area when a SKU is picked from the fast pick area rather than the reserve area. The number of SKUs and number of locations needed in the fast pick area are equal. Dedicated storage strategy is therefore the best option. Moreover it’s possible to rank the SKU on popularity and reduce the travel distance and time regarding this method. Applying this method and storage strategy must improve the KPIs in the case of Topa.

7 Alternatives

This chapter gives answer to sub question 6: "To what extent are the alternatives for the bottlenecks improving the KPIs of Topa? ". The relevant literature found in chapter 6 is applied in the case of Topa. The constraints of the practical situation are taken into account. The alternatives are tested as to what extent they improve the KPIs. The alternative solutions for the four bottlenecks are each discussed. The first section applies VSM to improve the total throughput time of the receiving process. The second section contains the application of the model of Bartholdi and Hackman for allocation of SKUs to the fast pick area. The third section contains the calculations of the diverse storage methods in the reserve area. The last section contains alternatives for the storage strategy in the fast pick area.

7.1 Improving the total throughput time in the receiving area

This section contains an alternative for the receiving process. Chapter 5 concluded that the receiving process is a bottleneck due to the long throughput time. This long throughput time is caused by the delay of printing the location stickers. The incoming pallets can't be stored in the racks when there are no location stickers. The delay of the printing of the stickers is caused by the division of the incoming goods processes. The root of this problem is caused by the current ERP system.

The incoming goods process is mapped with use of the VSM tool. Each activity is timed and categorized as value adding, non value adding or necessary activity. The goal is to eliminate or reduce the non value adding activities. The total throughput time will decline when the waste is eliminated or reduced.

It is not possible to make changes in the current ERP system. The ERP system is even out of the scope of this research. A proposal of a desired situation can be used for input of a new ERP system. Between the writing of this report and a year from now a new ERP system should be active. The rest of this section discusses a new desired situation mapped with VSM and a real life simulation.

Desired situation at the receiving process

The goal for improving this bottleneck is to reduce the waste in the receiving process. Recall the causes for waste in the receiving process.

1.) Fill in internal document
2.) Checking
3.) Walking documents to supporting unit
4.) Printing stickers done by supporting unit
5.) Activities in receiving process are successive
6.) Different departments are responsible for different activities in one process

These causes result in several waiting times in the current process. A new situation must decrease or eliminate these waiting times.

The proposed situation for reducing the total throughput time of an incoming pallet is viewed in *figure 25*. The sequence of activities is changed and non value added activities are as good as eliminated.

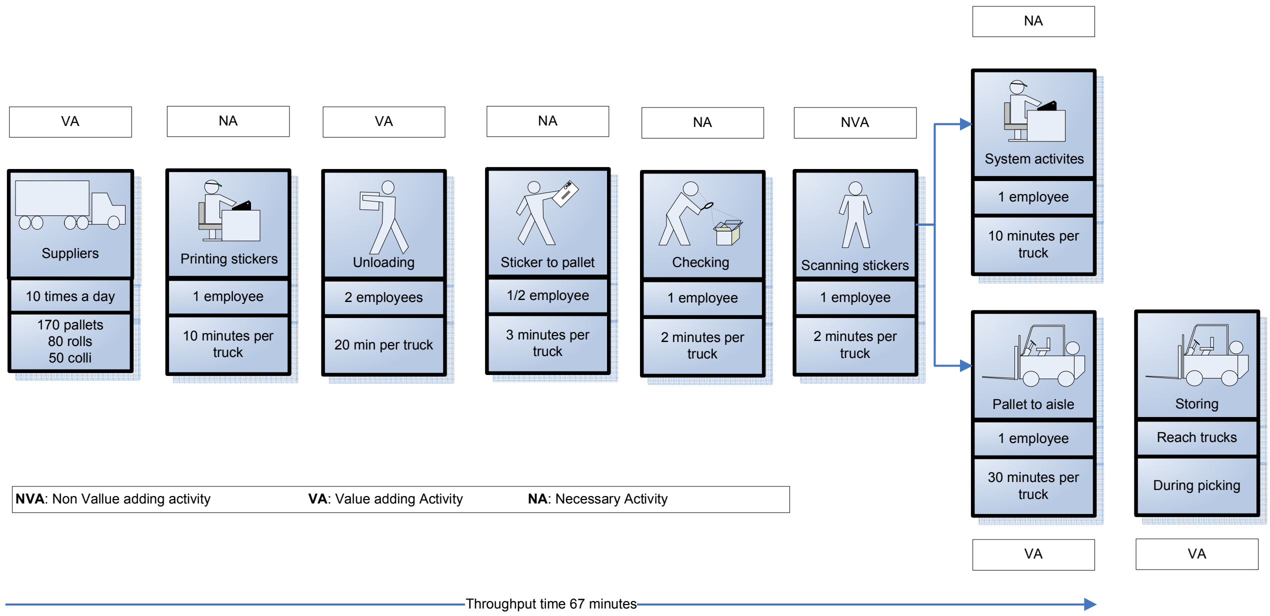


figure 255: Value Stream Map of the desired situation of the receiving process

A truck driver reports his arrival to the supporting unit. A supporting unit employee receives the consignment note and administrates the order in the ERP System. The stickers can be printed immediately. The receiving department receives the stickers at the time that the truck driver is driving his truck to a dock. Employees can unload a truck and stickers the pallets. These stickers contain a barcode with the corresponding data of the article. The sticker is attached to the pallet when the pallet is unloaded. A quality check is performed regarding the quantity and quality of the incoming goods. The employee scans the pallet and can adjust the quantities and pallet dimensions in a mobile scan device. The system receives the information that the article is approved with the corresponding quantity and the pallet dimensions. The incoming goods worker places the pallet in the aisle where it must be stocked. A reach truck driver places the pallet in the right location when he has to pick a pallet in the same aisle. During breaks the employees can bring the consignment notes to the supporting unit. The supporting unit checks the data with the corresponding purchase order. When the data is correct they can complete and close the customer’s order in the ERP system.

Real life simulation of the desired situation

The desired situation is simulated in real life for one day. This real life simulation must reveal if the KPI of the process, the total throughput time, will decrease. Recall that the current total throughput time is 138 minutes before one truck load is processed. The activities sequence as shown in *figure 25* is done for one day. Barcode scanning is out of the scope of the simulation. This new technology will be tested in a later stage at Topa. The testing of combining storing and picking will also be done in a later stage. This change in the process can only be done if the layout changes. Results of the real life simulation are shown in *figure 26*. During the simulation day 9 trucks arrived at Topa with 140 pallets, which is comparable with a regular day.

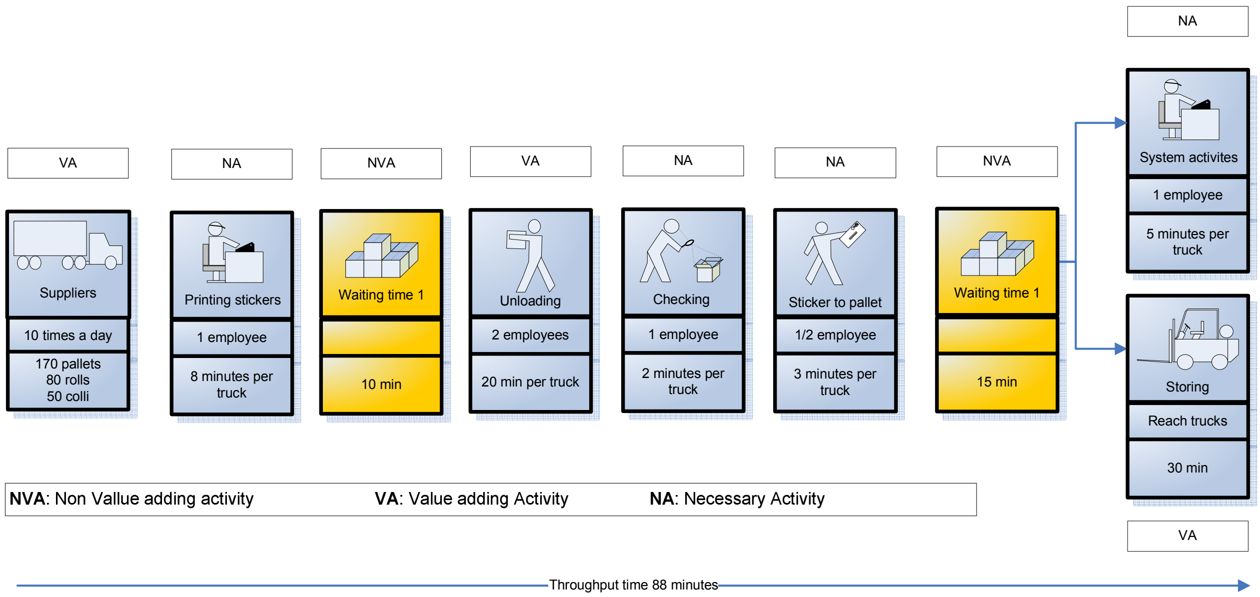


figure 266: Results observation of the real life simulation

Waiting times

Waiting times also occur in the desired situation. It can occur that two or three trucks arrive at the same time. The last truck has to wait until the other two are emptied. A second waiting time occurs when the stickers are attached to the pallets of two truckloads. A reach truck driver can start with storing the next truck load when the first truck load is finished storing.

Other findings

During the experiment various findings were noted. At the beginning of the day it was noted that a reach truck driver could immediately start storing the pallets. In the current situation a reach truck driver can start after an hour when the first stickers are printed and attached. In the experiment the receiving area was almost empty before the next truck arrived. At the end of the day the receiving area was totally empty all incoming pallets of that day where stored. The foreman of the receiving department noted that he had more time to spend on other activities. He was mostly responsible for checking the goods and filling in the internal document.

Conditions

Some conditions must be taken into account for the success of the new situation. The reach truck that stores the pallets is the last activity in the sequence. This activity determines the beat of the process. If the storing begins a half hour later the whole process is delayed with a half an hour. The new situation is successful if the receiving employees make sure that the stickers are attached to the pallets when this is possible. When the stickers are printed and the truck is unloaded the receiving employees must have the discipline to first sticker the pallets before starting a new activity, for example unloading a next truck. The receiving employees also have the responsibility to communicate possible changes in the loading to the supporting unit. For example, a pallet quantity is given on the consignment note. When the pallet is checked at the receiving area and the quantity is not correct it is up to the employees to communicate this with the supporting unit. The supporting unit can adapt these changes in the ERP system.

Improvement in the receiving process

The time measures during the real life simulation reveals that the total throughput time will decrease after implementing the desired situation. Measurements of one day concluded in an average total throughput time of 88 minutes per truck. In total 9 trucks arrived during the experiment. The total throughput time decreased from 138 minutes per truck in the current situation to 88 minutes per truck during the experiment. This is a decrease of 50 minutes. This saving is achieved over the whole process, in the supporting unit, in the receiving area and for the reach truck drivers. A note can be made regarding the improvement. One employee of the receiving process was on holiday and a new employee was learning the process. The improvements can increase when all employees are working.

Current KPI	**Goal**	**Action**	**New KPI**	**Improvement**
Average total throughput time	*Reducing and eliminating the waste in the process*	*New sequence of the process.*	*Average total throughput time*	
138 minutes			**88 minutes**	***50 minutes 36.24 %***

table 9: Summary improvement in the receiving process

7.2 Which SKU to store in the fast pick area?

This section discusses the model of Bartholdi and Hackman (2010) that is applied to Topa's case. Let us first recall the restrictions of the current fast pick area at Topa.

The fast pick area has 817 ground locations and 884 first level locations. The higher locations (2^{nd} till the 6^{th} level) will not be used for fast picking. The current equipment can't pick from these levels. It gains therefore no extra benefit for picking orders from those locations. The total fast pick locations available are 817 + 884 = 1701 single locations. At most 1701 SKU can be allocated to the fast pick area. Remaining SKUs are located to the reserve area if more than 1701 SKUs are profitable to locate them to the fast pick area.

The previous chapter concluded that the model of Bartholdi and Hackman, 2010 from their book "Warehouse and Distribution Science" is an efficient method to determine which SKUs to store in the fast pick area. The authors state a formula which determines the net benefit per year per SKU for storing SKU i in the fast pick area rather than in the reserve area.

Formula:
Net benefit per year per SKU $i = sp_i - c_r d_i$

Net benefit per year per SKU $i = V_i$
$V_i = sp_i - c_r d_i$

s = Savings in minutes of pick a SKU from the fast pick area instead of the reserve area
p_i = *Number of less than 75% of a pallet quantity per year (popularity)*
c_r = *Minutes of restock*
d_i = *Number of restocks per year*

Recall that s is set at 140 seconds and c_r is set on 360 seconds. A critical note can be placed by comparing the pick times of both areas. A pick time of the reserve area can be more expensive for Topa than for example the pick time in the fast pick area. The equipment and labor costs are more expensive in the reserve area compared with the fast pick area. However the model uses time for comparison.

The p_i's, pick popularity per item i per year and the d_i's, the number of restocks, are gathered out of the ERP system. The data of 2086 different SKUs from 2009 is listed in an Excel document.

Each restock of the forward area requires c_r minutes. Bartholdi and Hackman, advises using an average restock time. However a note can be placed by taking an average restock time. The start of a replenishment is never fixed due to the random storage strategy in the reserve area, while the fast pick area location is dedicated. The time to restock a SKU at the front of the fast pick area deviates from the back of the fast pick area. Observation concluded that this deviation is minimal (30 seconds), which is relative small. Furthermore it is a lot of work to gain an explicit overview of the restock time per SKU. An average restock time is a good representation of the reality. On average it takes 360 seconds for replenishing a pallet in the fast pick area. This time is observed and measured for an average of 100 replenishments.

Two different kinds of calculations are done for giving insight in the improvement of the current situation. First the current sum of V_i is calculated regarding the SKUs that are located to the fast pick area in the current situation. The sum of these net benefits (positive and negative) per SKU are summed over all SKUs that are stored in the fast pick area.

The second calculation is done for all SKUs. SKUs that gain no net benefit are removed from the fast pick area list and SKUs that gain net benefit but are stored in the reserve area are located to the fast pick area list. The sum of V_i is compared for the current situation and only the positive net benefit.

Calculating the current sum of all net benefit: $\sum V_i$
Let us give an example of the calculation of the current situation. 1354 SKUs are located in the fast pick area in the current situation.

	Article name	**s in minutes**	**p_i Popularity**	**c_r in minutes**	**d_i number of restocks**	**Net benefit in minutes in 2009 (V_i)**
1	TOPAFIX 50/66 TRANSPARANT	2.2	500	6	32	908
2	INKAPALLET 60X80 F66 MAX.500KG	2.2	245	6	104	- 85
3	Doos 70015	2.2	268	6	73	151.6
..	..	..	..	..	..	..
..	..	..	..	..	..	..
1354	Mail block standaard	2.2	1	6	0	2.2
					Sum V_i	**63,582.8 minutes 1059.7 hours**

table 10: Examples of the net benefit formula of Bartholdi & Hackman, 2010 for several SKUs

Article number 1 is a SKU that is placed in the fast pick area in the current situation. The total net benefit of storing this SKU in the fast pick area rather than in the reserve area is 908 minutes per year (2009). This saving is already achieved in the current situation.

Article number 2 is also a SKU that is placed in the fast pick area in the current situation. The total net benefit of storing this SKU in the fast pick area rather than in the reserve area is -85 minutes per year (2009). This means that it has a negative net benefit, this SKU should rather be stored in the reserve area and be picked by a reach truck. The number of restocks and time per restock contribute more than the advantage of picking from the fast pick area.

Sum of net benefit of all SKUs in the current situation:
$\sum V_i$ = 63,582.8 minutes = 1059.7 hours per year

Calculating the optimal sum of the net benefit: $\sum V_i$
The calculation for the new situation is done over all SKUs, including the SKUs that are stored in the reserve area in the current situation. The list with the SKUs and net benefit is ranked regarding the net

benefit. In this case more than 1701 SKUs have a positive net benefit and should be stored in the fast pick area. The sum of all benefits, $\sum V_i$,over these 1701 SKUs is: 1193.6 hours.

Sum of net benefit of all SKUs in the optimal situation:
$\sum V_i$ = 71623.8 minutes = **1193.7 hours** per year

Sum of net benefit of 1701 SKUs in the optimal situation:
$\sum V_i$ = 71616.6 minutes = **1193.6 hours** per year *i= 1 till 1701*

There is only a small difference between storing all SKUs with a positive net benefit and storing the highest ranked 1701 SKUs. In total 1720 SKUs have a positive V_i. Only 19 SKUs with a relative small positive net benefit can't be stored in the fast pick area. 1227 SKUs are already placed in the fast pick area which should be stored in the fast pick, this is 72.13%. This means that 27.87% is currently stored in and picked from the reserve area. 370 SKUs that are stored currently in the fast pick area must be removed from this area and be stored and picked from the reserve area.

A critical note can be made for the variable s. The formula by Bartholdi and Hackman, contains four variables, s, p_i, c_r and d_i. The p_i and d_i are data gathered out of the ERP data and depends on customers demand. The c_r, the minutes for restocks is also a " fixed" average time. The savings are based on the order pick time in the reserve area and the order pick time in the fast pick area. This research also focuses on improving these picking times. Changes in the pick times result in another s for the formula. The results of the net benefits will be different. If s increases more benefit will be gained for storing the SKUs in the fast pick area. If s decreases less benefits will be gained and certain SKUs can contribute negative net benefit and should therefore be stored in the reserve area.

A second note can be made in the relation between the popularity and the number of restocks. The ratio of these two parameters has a big influence on the net benefit. For SKU 1 in *table 9,* the ratio of the popularity and number of restocks is (32/500)*100= 6.4%. This means that a restock takes place after an average of 15.6 time of picking. For SKU 2 in *table 9*, the ratio is (104/245)*100= 42.45%. This means that a restock takes place after an average of 2.3 time of picking. In this case the number of restocks and restock time outweigh the benefit of picking the SKU from the fast pick area.

Improvement of the KPIs

This research focuses on improving the efficiency at the distribution center. In Chapter 5 are KPIs defined for indicating the current performance. Recall that for this bottleneck one KPI is established: 232 minutes of case picking per day by reach truck drivers.

For over a month pick lists were analyzed regarding the case pick orders. The case pick orders were looked up in the new fast pick area lists. This list contains the information if the SKU is stored in the reserve area or in the fast pick area in the new situation. 13 case pick orders would be picked from the fast pick area instead of the reserve area in the new situation. However 4 case pick order would be picked from the reserve area instead of the fast pick area. This is a difference of 9 case pick orders. This means that the 32 case pick order will decrease to 23 case pick order in the new situation. This would take 23*7 minutes and 15 seconds ≈ 166 minutes per day. The KPI would decrease from 232 to 166 by 66 minutes. This result that it would save the reach truck drivers an hour per day.

The second KPI, the savings of a fast pick area, is not defined in the current situation. Chapter 5 concluded that a new model or formula must indicate savings. The sum of the net benefit in the current situation is 1059.7 hours per year. A new situation is proposed by allocating only the SKUs with positive net-benefit in the fast pick area. The sum of the net benefit of these SKUs is: 1193.6 hours per year. An improvement of 133.9 hours a year (12.63%).

Conclusion

Current KPI	Value KPI	Goal	Action	New value KPI	Improvement
Case pick time	*232 minutes per day*	*Reduce case pick time*	*Reshuffling of SKUs*	*166 minutes per day*	***66 minutes per day 28.45%***
Current $\sum V_i$	*1059.7 hours per year*	*Improve the net benefit*	*Applying the model of B&H*	*1193.6 hours per year*	***133.9 hours per year 12.63%***

table 11: Summary improvement in the forward reserve problem

7.3 Storage strategy in the reserve area

This section discusses several alternatives for storing strategies in the reserve area. Recommendations for the new storage strategy are done without use of the new capacity of the reserve area. The current warehouse capacity is only 57%. We advise to fill first to old reserve area and then use the new capacity. The new capacity is situated further from the I/O point (*see figure 25*).

Storage strategy
Two different storage strategies are applicable for the reserve area at Topa, random storage and class based storage. In this section we will compare 5 different strategies. 1. An update of the current policy, 2. Random storage, 3. Class based storage 80-20 rule, 4. Class based storage 66.6-10 rule and 5. An own Class based storage strategy.

1. Update current policy.
The current storage strategy described in section 4.3 Storage was implemented 2 years ago. In the meantime the policy has not been updated as mentioned in section 5.2.3. Products with a high pick popularity can be classified as a C and a less popular SKU in an A Zone. To compare a possible new storage strategy we have to know the performance of the current updated storage policy. The physical zones A,B and C are not updated, only the SKU ranking is updated regarding their popularity.

Strategy	Total travel time in 2009 in hours	Percentage difference
Current storage strategy	926.8	100%
Updated storage strategy	811.1	87.5%

table 92: Total travel time of current and updated storage strategy

By only updating the current strategy an improvement of 12.5% can be realized.

2. Random storage
Recall that every incoming pallet is assigned to a location in the warehouse that is selected randomly from all eligible empty locations with equal probability (Petersen, 1997). The ERP system randomly selects the first free pallet rack and assigns an incoming pallet to that location. No division is made between popularity of the SKUs. This strategy is applied to the Topa case. The average travel distance for the reserve area is calculated first.

The average travel time in the reserve area from row 1 to 46 (old area), without Zone R, D and V is 94.2 seconds. In comparison if we use the extra pallet capacity where Zone C was stated the travel time will increase to 107 seconds per location. The average travel time only to the new area is 127.2 seconds. The assumption is made that we only need the old reserve area without the new extra capacity for the current stock. The average travel time of 94.2 seconds is taken for calculating the total travel time for random storage.

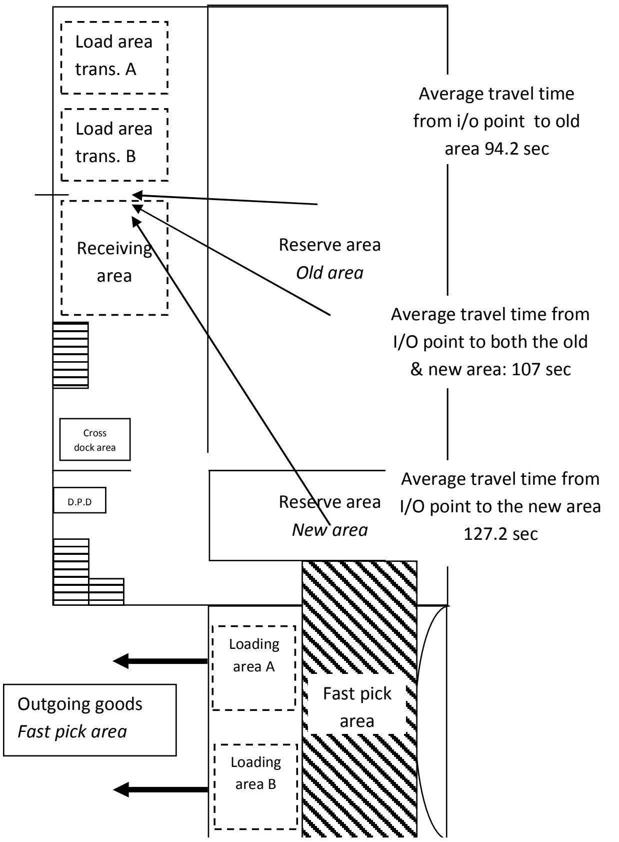


figure 277: Overview of the average travel time with or without the extra area.

Strategy	Total travel time in 2009 in hours	Percentage difference
Updated storage strategy	811.1	100%
Random storage strategy	913.3	112.6%

table 103: Total travel time of the updated and random storage strategy

When random is compared to the update current storage strategy no improvement can be made. The travel time increases with 12.6%.

3. Class based storage strategy 80-20 rule

The next strategy that is applied to the storage of the reserve area is the class based approach regarding the 80-20 rule. On average 20% of the items are responsible for 80% of the picks, the next 30% of the items 15% of the picks and finally the remaining 50% of the products are responsible for 5% of the picks.

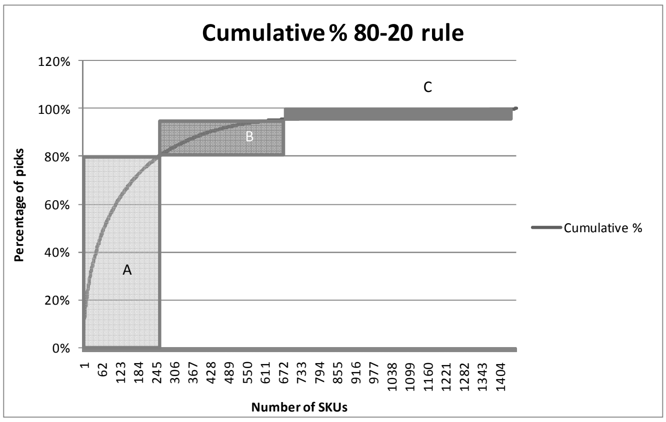


figure 28: Graph with the cumulative % of picks of all SKUs divided over zones. 80% of the picks 20 % of the SKUs

At Topa 17.7% of the products are responsible for 80% of the picks. The next 25.3% for 15% of the picks and finally 57% of the products are responsible for the last 5% of the picks. The new zones are established regarding the article quantities and average stock per year. Per zone the average travel time is calculated and multiplied with the corresponding average travel time for that corresponding zone.

Strategy	Total travel time in 2009 in hours	Percentage difference
Updated storage strategy	811.1	100%
Random storage strategy	913.3	112.6%
ABC 80-20	759.6	93.7%

table 114: Total travel time of the updated, random and ABC 80-20 rule storage strategy

When the Class based storage strategy is applied regarding the ABC 80-20 rule an improvement of 6.3% can be achieved.

4. Class based storage 66.6-10 rule

Another common used ABC strategy is the 66.6-10 rule. 10% of the items are responsible for 66.6% of the picks. The next 20% items for 23.3% and the remaining 70% of the items for 10.1% of the picks. This strategy is also applied to the Excel data. Zone dimensions are established regarding the storage history and average travel distance is calculated regarding these zones.

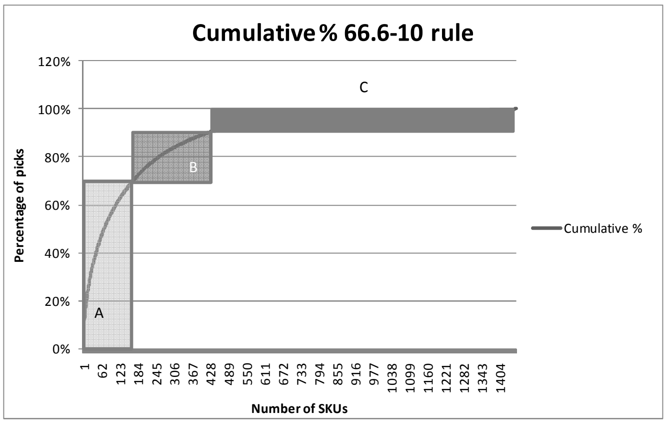


figure 299: Graph with cumulative % of picks of all SKUs. 66.6% of the picks 10% of the SKUs.

Strategy	Total travel time in 2009 in hours	Percentage difference
Updated storage strategy	811.1	100%
Random storage strategy	913.3	112.6%
ABC 80-20	759.6	93.7%
ABC 66.6-10	742.8	92.02%

table 125: Total travel time for the updated, random, ABC 80-20 rule and ABC 66.6-10 rule storage strategy

5. Class based storage own rule

Finally an own rule is proposed and applied to the case. By making calculations and analyzing the ERP data it was noted that the first 20 articles are responsible for 25% of the picks. A relative small group of SKU is responsible for a great amount of picks per year. A proposal is done for putting the first 25% in zone A, 55% of the picks in zone B and the rest in Zone C. The graph of this cumulative number of picks is presented in *figure 30*.

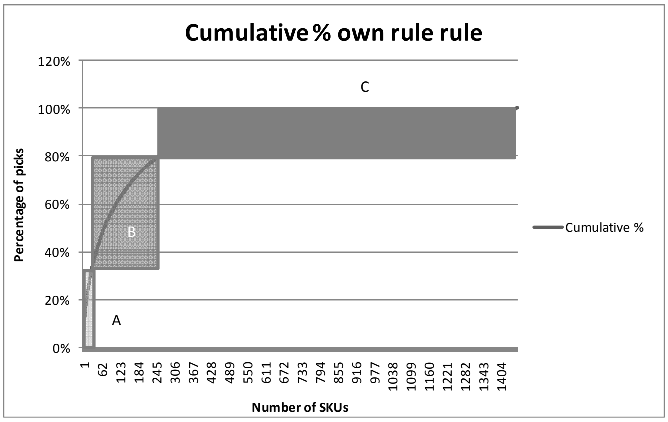


figure 30: Graph with cumulative % of picks for all SKUs. Own rule

Strategy	Total travel time in 2009 in hours	Percentage difference
Updated storage strategy	811.1	100%
Random storage strategy	913.3	112.6%

ABC 80-20	759.6	93.7%
ABC 66.6-10	742.8	92.02%
ABC own rule	778.3	95.6%

table 136: Total travel time of the updated, random, ABC 80-20, ABC 66.6-10 and ABC own rule storage strategy

The own rule gives an improvement of 4.4% in comparison with the update storage strategy. In the time of calculating this strategy is shown to be ineffective. The 6 SKUs of the top 20 are generated by one big customer of Topa. In the meantime this customer left Topa. The storage strategy collapsed to a percentage equal to the update storage strategy.

Improving the KPI
The starting point for this research is the current situation. The new strategies are compared regarding the total travel time in 2009.

Strategy	Total travel time in 2009 in hours	Comparison current situation	Comparison updated strategy
Current situation	926.8	100%	114%
Updated storage strategy	811.1	87.5%	100%
Random storage strategy	913.3	98.5%	112.6%
ABC 80-20	759.6	81.9%	93.7%
ABC 66.6-10	**742.8**	**80.1%**	**92.0%**
ABC own rule	778.3	84.0%	95.6%

table 147: Comparison of the storage strategies with the current and updated strategy

Let us recall the KPI defined at chapter 5 of this bottleneck. The bottleneck was the current storage strategy in the reserve area with an average total travel time of 926.8 hours in 2009. Goal was to find relevant literature to improve the total travel time.

If the ABC 66.6-10 rule is implemented at Topa an improvement of 19.9% can be achieved in the total travel time in comparison with the current situation. This is a reduction of 184 hours per year.

7.4 Storage strategy in the fast pick area

This section discusses a new alternative for the storage strategy in the fast pick area. The goal is to improve the current KPI of this storage strategy. The first part contains practical issues and the preconditions of the fast pick area. The second part contains a new proposal of the allocations of products and a new layout.

7.4.1 Practical issues

In the fast pick there are also some practical issues that must be solved first. 14 times a day it occurs that an order picker has to pick a SKU at a reach truck level (2^{nd} to 6^{th} level height). The average time is 9 minutes to pick such an order. The question that arises is why are these SKUs stored in these high fast pick locations. The fast pick employees don't have the equipment to pick those products. A SKU is replenished from the reserve area in these high locations, when a fast pick employee has to pick such a SKU they must inform a reach truck driver to drop the pallet. These products have no advantage in being stored in these locations, it only makes extra work because people have to notify each other and two people are picking one order which is not efficient.

Second practical issue is the first floor locations. Order picking equipment allows order pickers in the fast pick area only to pick from ground floor. A fork truck driver must be notified to lower the pallet from the first floor. When these locations are still needed in the new situation it is advisable for Topa to purchase new equipment that can easily pick products from the first floor. A small market search is done to order pick equipment and the equipment in *figure 31* is found to be suitable for picking orders from first floor locations.

figure 30: First level order picking vehicle (source: www.toyota-forktrucks.nl)

Both pallet and employee are lifted up by the vehicle. When the vehicle is lifted up to the desired height the employee can pick the needed quantity and place it on the pallet. When the right quantity is picked the employee can lower the vehicle and can continue order picking. The employee doesn't have to wait or inform a fork truck driver but is able to pick the SKUs by himself.

Third practical issue is the double locations in the fast pick area. These double locations aren't needed in the new situation. A safety stock isn't needed in the fast pick area. Replenishment is done before the wave picking starts. A pallet is placed in the replenishment area if a location in the fast pick area is empty. When only 30 SKUs are on stock in the fast pick and the demand in the pick wave is 50 SKUs the system activates a full pallet replenishment. The ERP system also generates a replenishment order when demand is higher than the stock. Moreover the most frequently replenished SKU is replenished 73 times a year. An average of a replenishment of once in three days. It is almost unlikely that a pallet is empty in one day. In the current situation 450 SKUs have a double location in the fast pick area. This means that 450 extra pallet locations are available in the fast pick area on the first floor.

The fourth practical issue is the products with deviated dimensions of characteristics. These products are automatically stored in the zone of their characteristics. However some of these products are classified as fast pick products and printed on the pick list of the fast pick area but not physically stored in the fast pick area. A fast pick employee has to travel to the corresponding location in the reserve area to pick that SKU. These products must be picked by the reach truck drivers in the reserve area or must be stored in the fast pick area. This situation is taken into account when calculating the savings for storing a SKU in the fast pick rather than in the reserve area.

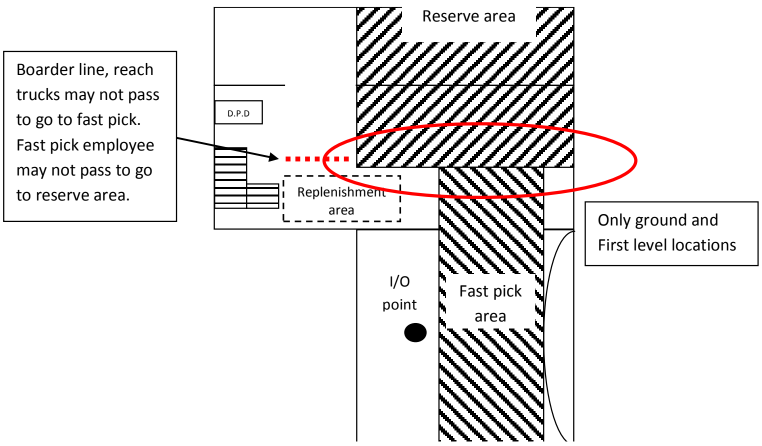


figure 31: Practical issues in the fast pick area

The fifth practical issue is the current layout. Between the reserve area and the fast pick area there is a "grey" area where both reach trucks and order picking vehicles are driving. In the current situation it is not clear to which department this area belongs. This area contains racks locations to the 6th floor which is why it makes sense to restrict this area to the reserve area. However these locations are used to store fast pick area products mentioned in the first practical issue. The reserve area has a low occupation rate so it doesn't need extra space. As an assumption for the calculations this area is allocated to the fast pick area also due to the short travel distance to this area. The locations from 2nd to 6th are blocked so no products can be stored and no reach truck has to be there. A safety assumption has been made that no reach truck drivers have to be in the fast pick area and no fast pick area employees have to be in the reserve area.

The sixth practical issue is the I/O point that must be fixed before calculating the travel distance. Over the entire breadth of the fast pick area docks are stationed. This means that the products can leave the building over the entire breadth of the area. Therefore the I/O point is fixed at the middle of the front of the fast pick (*see figure 32*).

7.4.2. Storage strategy in the fast pick area

In section 7.2 we have solved the problem of which SKU to store in the fast pick area. The current fast pick area has 817 ground locations available and 884 first level locations. These locations can be filled with the SKUs that have been shown to contribute positive savings when they are stored in the fast pick area.

The geographical representation of the fast pick area must be made first before allocating SKUs to a storage location. An overview of the best spots regarding the I/O point is give in *figure 33*.

The black point symbolizes the I/O point of the warehouse. Each location has a rank number. This rank number is based on the distance from the I/O point to the location. The four places in front of the I/O point are the most popular places because the travel distance is short, and therefore ranked with rank number 1. The yellow places with a popularity rank of 28 are presented with the collar yellow in the figure. A V shaped area is the result of the ranking. More locations are available on the first floor due to the cross aisles and fire extinguishers. The ranking of locations of the first floor is almost the same as the ground floor. The ground locations are more popular places due to the equipment. The first floor locations are allocated next.

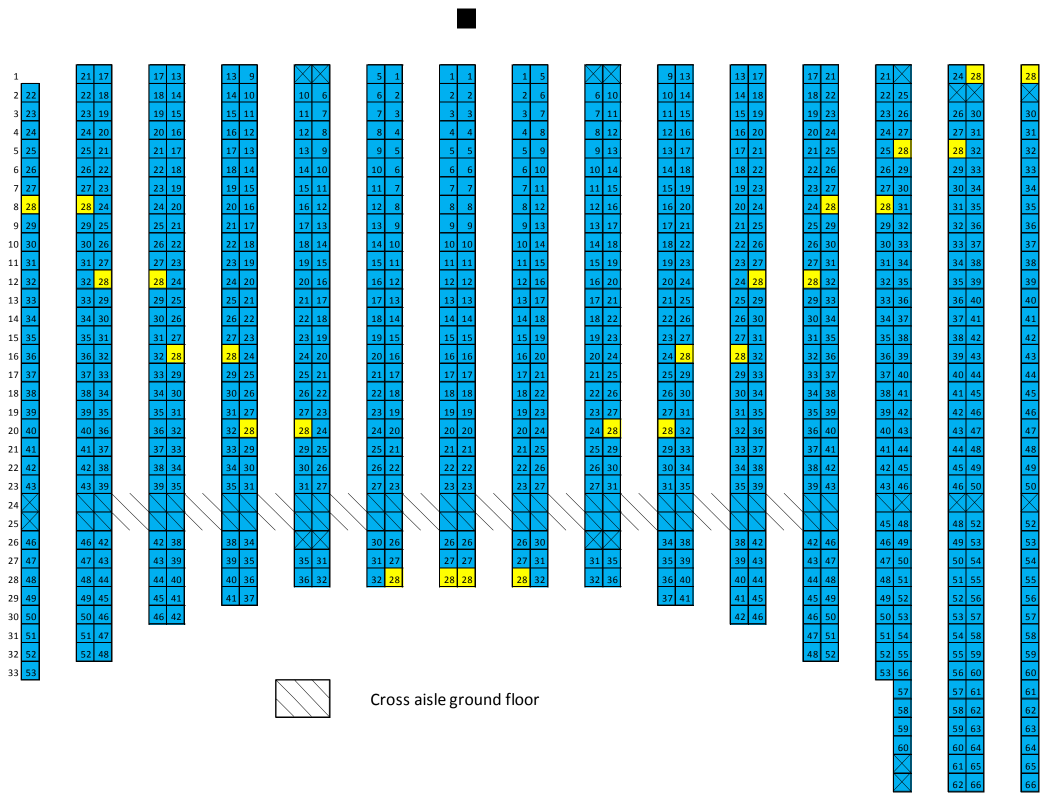


figure 323: Ranked ground locations regarding the travel distance in the fast pick area

Bartholdi and Hackman (2010) assume that all locations in the fast pick area are reserved locations to which specific SKUs will be assigned. SKUs can be assigned based on activity rather than mere availability, and order pickers can learn more easily where products are located. Each SKU that is stored in the fast pick area will have one single location from which to pick. A frequently used storage policy for dedicated storage is COI but because each SKU has only one single location we can assign the SKUs regarding the activity. The popularity of a SKU and the replenishment determines the travel distance per year. The popularity plus the replenishment represents the number of times the location is visited. The popularity per year plus the replenishment per year will be used to assign SKUs to a single location.

Article	Popularity	Replenish-ment	Activity	Old distance	Total distance old	New distance	Total distance new	Savings
Topa-fix	500	32	532	35 meter	18,620 meter	6.5 meter	3454 meter	15,166 meter

table 158: Example of the improvement of travel distance of one SKU

The product in the table is the most popular SKU in the fast pick area. In the current situation this product is stored with a distance of 35 meter from the I/O point (*see figure 34*). The popularity plus the replenishment is 532 visits per year with a total distance of 18,620 meter. Because the activity is the highest of all SKUs we store the Topa fix in a location that is ranked with 1. The distance for the most popular single rack location is 6.5 meter with a total distance in 2009 of 3454. A saving can be achieved of 15,166 meter per year.

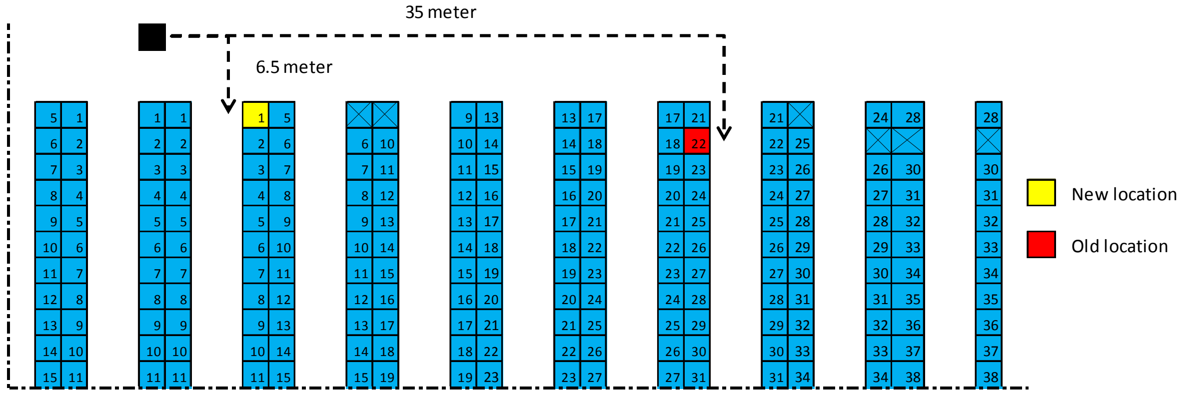


figure 334: Example of the improvement of travel distance of one SKU

Assumption for this improvement is that only the SKUs with positive savings are placed in the fast pick area. Second assumption is that the area is implemented with the layout in *figure 33*. Ground locations are assigned first before the first level locations. First level locations have the same popularity ranking of the single ground locations. The vehicle in *figure 31* must be purchased for picking the orders from the first level. The total orders per pick wave that must be picked from a first level location must be combined on one separate pick list. This list is picked by the employee in the new vehicle. In this case a regular ground vehicle can't have a pick location on his list for a first floor location. A pick location in the reserve area is also taken from the fast pick list. A fast pick employee only can pick a product in the area of *figure 33*. A regular ground order picker gets only a list with ground locations.

Improvement of the fast pick area

Let us recall the bottleneck and the performance of the fast pick area. The storage strategy in the fast pick area is not optimal for several reasons. Fast pick employees must pick products from the reserve area, the current equipment can only pick from ground locations, other equipment must be notified if products must be picked from a higher level. The extra safety stock causes extra material handling and extra space capacity in the fast pick area. Three KPI are determined in chapter 5. The travel distance in 2009: 2.803.776 meters. The average travel time in the current situation: 2 minutes and 40 seconds per location and the average travel time of a reach truck location: 9 minutes per location.

The goal was to find literature that provides alternatives to improve the efficiency at the fast pick area. The travel distance and pick times must decrease.

Several solutions are provided that decrease the total travel distance by 52.84%. This result is calculated in an Excel sheet with the data of more than 2000 SKUs. The double locations are removed which results in more capacity in the fast pick area. The products that are stocked at reach location can therefore be stocked in a ground or first level location. The 9 minutes per reach truck location will decrease to a regular pick location: 1 minutes and 40 seconds per location. Recall that the 2 minutes and 40 seconds pick time per location is composed of a ground location, first level location and a reserve area ground location. This time includes travel time to the reserve area which is eliminated in the proposal. Furthermore this KPI includes waiting time for the fork truck for a first level location, which is also eliminated in the proposal. The average travel time for picking an order at a ground level location is: 1 minutes and 40 seconds. Picking a products from a first level location with the new equipment will take a bit more time but is faster than a fork truck.

Conclusion

KPI	Current situation	New situation	Improvement
Total travel distance in the fast pick area	2.803.776 meter in 2009	1.322.260 meter in 2009	**1.481.516 meter per year 52.84%**
Average travel time 2nd till 6th location in fast pick area	9 minutes per location	1 minute and 40 seconds per location	**7 minutes and 20 seconds Per location 81.5%**
Average travel time per ground and first level location in the fast pick area	2 minutes and 40 seconds	1 minute and 40 seconds	**1 minute 47.5%**

table 19: Summary improvement in the fast pick area

7.5 Summary alternatives

This section contains the summary of the alternatives of the bottlenecks. Alternatives per bottleneck are discussed regarding the improvement of the KPIs.

7.5.1 Improving the total throughput time in the receiving process

A new desired situation is proposed for the receiving process. The sequence of the activities is changed. The possibilities of a new ERP system and the intention of investment in technologies by Topa are taken into account. The new process is divided in such a way that the stickers with locations numbers are printed as soon as possible. In this way the pallets can be stored faster in comparison with the current situation. Real life simulation proved that the new situation improves the KPI.

Current KPI	Value KPI	Goal	Action	New value KPI	Improvement
Average total throughput time of a truck	138 minutes per truck	*Reducing and eliminating the waste in the process*	*New sequence of the process.*	*88 minutes*	***50 minutes 36.24%***

table 20: Summary improvement in the receiving process

7.5.2 Which SKU to store in the fast pick area?

The model of Bartholdi & Hackman (2010) of a case from pallet pick area is used to determine which SKU to store in the fast pick area. The model proposes a net benefit formula to detain the net benefit for SKU i that is stored in the fast pick area rather than in the reserve area. Calculations are done regarding this formula.

Current KPI	Value KPI	Goal	Action	New value KPI	Improvement
Case pick time	*232 minutes per day*	*Reduce case pick time*	*Reshuffling of SKUs*	*166 minutes per day*	***66 minutes per day*** ***28.45%***
Current $\sum V_i$	*1059.7 hours per year*	*Improve the net benefit*	*Applying the model of B&H*	*1193.6 hours per year*	***133.9 hours per year*** ***12.63%***

table 21: Summary improvement of the forward reserve problem

7.5.3 Storage strategy in the reserve area

Several alternative storage strategies are applied in the case of Topa. Random storage strategy is applied but concluded not to be profitable for Topa. The average total travel time per year increased regarding this strategy. Furthermore three variants of the ABC storage strategy are applied. The 80-20 rule, the 66.6-10 rule and an own rule. The 66.6-10 rule seems to be improving the average total travel time the most. In comparison with the current situation the average total travel time will decrease by 19.9%

Strategy	Total travel time in 2009 in hours	Comparison current situation	Comparison updated strategy
Current situation	926.8	100%	114%
Updated storage strategy	811.1	87.5%	100%
Random storage strategy	913.3	98.5%	112.6%
ABC 80-20	759.6	81.9%	93.7%
ABC 66.6-10	**742.8**	**80.1%**	**92.0%**
ABC own rule	778.3	84.0%	95.6%

table 22: Summary improvement in the reserve area

7.5.4 Storage strategy in the fast pick area

Several practical solutions are proposed for improving the efficiency in the fast pick area. A new situation allows order pickers to pick from only the first and second level. The higher locations are blocked and not used anymore. A recommendation is done to a new order picking vehicle that can pick also from the first level. The pick locations in the reserve area are eliminated. These locations are picked by reach truck drivers in the new situation. An I/O point is established in the middle of the fast pick area. Regarding this point the locations are ranked on the minimal travel distance. The SKUs that are located to the fast pick area are ranked on activity. The activity is the sum of the popularity of a SKU and the number of restocks. The SKU with the highest activity is allocated to the location with the minimal travel distance.

KPI	Current situation	New situation	Improvement
Total travel distance in the fast pick area	2.803.776 meter in 2009	1.322.260 meter in 2009	**1.481.516 meter per year** **52.84%**
Average travel time 2^{nd} till 6^{th} location in fast pick area	9 minutes per location	1 minute and 40 seconds per location	**7 minutes and 20 seconds Per location** **81.5%**
Average travel time per ground and first level location in the fast pick area	2 minutes and 40 seconds	1 minute and 40 seconds	**1 minute** **47.5%**

table 23: Summary improvement in the fast pick area

8 Implementation and maintenance

This chapter gives answer to the last question "How to implement the solutions at Topa and how to maintain the efficiency?". A stepwise implementation plan is made how to implement the new alternative. The implementation plan consist with a plan how to maintain the efficiency.

8.1 Implementation receiving process

The real life simulation proved that the total throughput time decreases significantly. At the start of the experiments were the employees of Topa critical regarding the bugs in the ERP system. The experiment concluded that the desired situation is causing no extra problems for the ERP system. The management of Topa therefore decided to continue the proposed situation. The proposed situation has such a benefit and almost no disadvantages. In a later phase the process can be extended with barcode scanning. The dispatching process of the goods into the ERP system requires a lot of manual work. These manual activities can be critically considered during the programming of a new ERP system. Management of Topa is currently brainstorming how to implement the new ERP system. For Topa a new ERP system provides possibilities of reviewing the process critically. The new ERP system can be programmed regarding the desired requirements of Topa. The proposal for the new receiving process is input for programming the ERP system.

8.2 Implementation: Which SKU to store in the fast pick area

An overview for the management of Topa is made with the positive or negative benefit per SKU. The 1701 SKUs that contribute the most savings are made into a list and a list is made with the remaining SKUs. The SKUs that are currently stored in the fast pick area but contribute negative savings are removed from the fast pick area and stored in the reserve area. The SKUs with positive savings can be located to the fast pick area regarding the storage strategy described in 8.4. The maintenance of this new strategy must be done twice a year. New data must be gathered from the ERP system for updating the policy. The same formula can be used to determine if a SKU still is picked from the fast pick area rather than from the reserve area. Important is to give attention to SKUs that are not sold anymore or SKUs that are new in the assortment.

8.3 Implementation: Storage strategy in reserve area

The management of Topa has proposed to work out an implementation plan of the 80-20 rule. This is in contradiction with the best solution, the 66.67-10 rule. The gap between the improvement between these rules is however very small. The management of Topa has the perspective that the 80-20 rule is more familiar and easier to maintain. The following new strategy is proposed:

Zone A: 80% of the picks
Zone B: 80% to 95% of the picks
Zone C: Rest of the picks
Zone D: Two single locations with a max depth of 1.1 meter
Zone R: SKU must be stored on the ground
Zone V: Two single locations wide and two single locations deep.

For each layout level of the reserve area a new layout has been made. The next page represents the layout of the ground locations (*figure 35).*

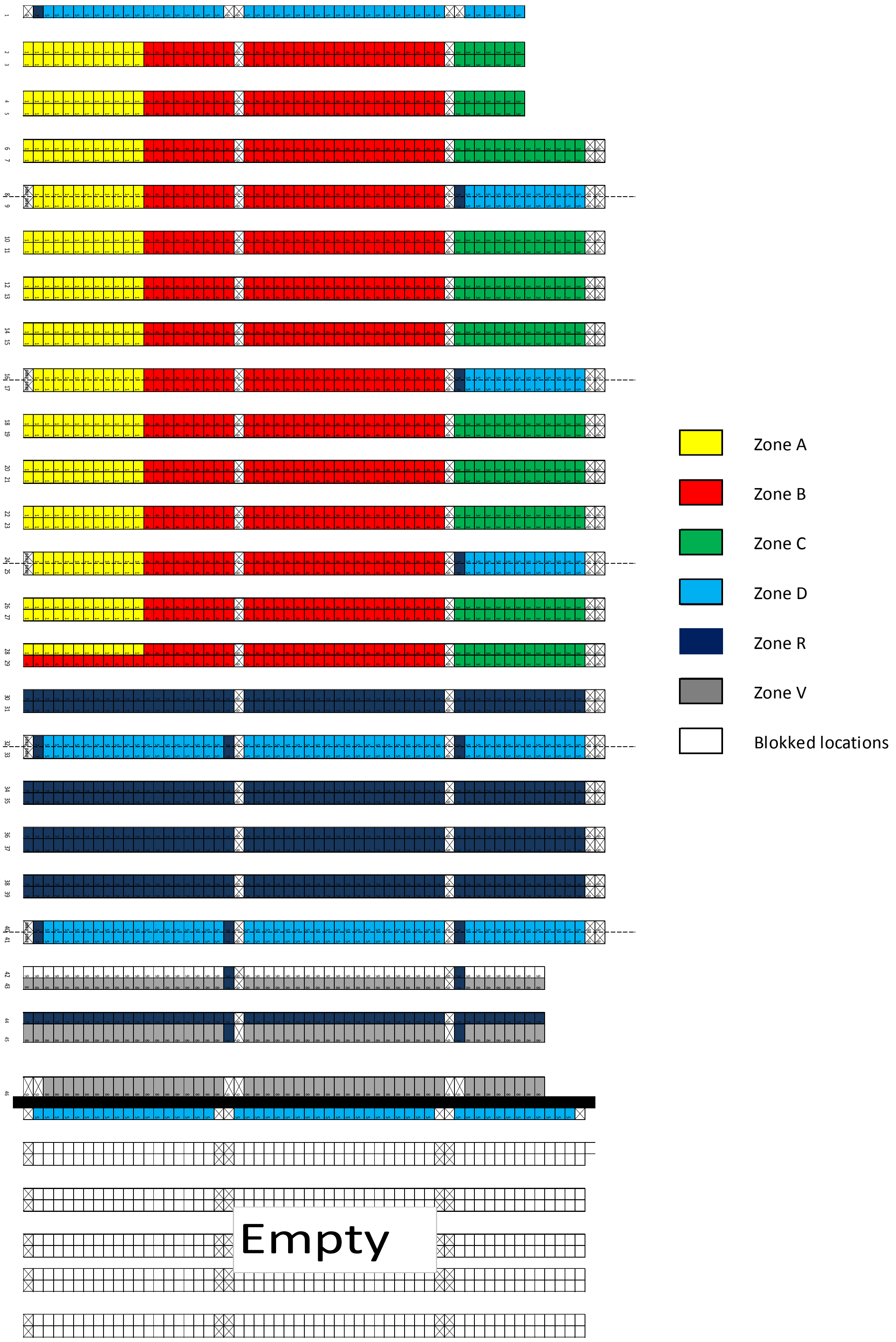


figure 34: New layout of the reserve area

The blue area, zone D, is stationed at the building pillars. Zone A and B are 4 layers height, the fifth and the sixth layers are located to Zone C and D. The new area, the old C zone, will be emptied and not used. This area will be assigned to zone C if the occupation rate of the warehouse increases.

The next step of the implementation is to categorize the SKUs in the predetermined zones. For each zone a list is made with the SKUs that are assigned to this zone. The list contains per SKU, the article number, the article description, the old zone and the new zone. The supporting unit can changes the categories of the zones regarding this information.

Stepwise approach for the implementation:

Step 1:
Convert the current category J to D and eliminate the zone J in the ERP system

Step 2:
Adjust the physical zone in the ERP system regarding the layout from *figure 34* and the other layers.

Step 3:
Adjust the new category per SKU. The ERP system locates the SKUs to the right zone when new SKUs are ordered.

Step 4:
The capacity per zone can be monitored by the ERP system. A tool is been built in the ERP system that automatically counts the occupations rate per zones. Monitoring this parameter may result in small changes of the layout.

Step 5:
SKUs, mostly slow movers (zone C), have to be moved manually after two months.

Updating the policy
This new policy must be updated twice a year. New data per SKU (*table 24*) must be gathered from the ERP system. This new list of data per SKU must be ranked regarding the new popularity. The SKUs must be switched between the zones regarding the new ranking. This update results that the SKUs are allocated to the right zones regarding the customer demands fluctuations.

	Gathered data per SKU from the ERP system
1	Article name
2	Article description
3	Quantity sold
4	Number of SKUs on one pallet (pallet quantity)
5	Number of full pallet picks in 2009
6	Reserve area category regarding the zone (A,B,C, et..)

table 24: Data per SKU needed for updating the storage policy in the reserve area

8.4 Implementation of the storage strategy in the fast pick area

This section contains an overview of the activities that must be done for implementing the solutions given in chapter 7. The implementation of the recommendations has a big impact on the current process. The new dedicated storage strategy results in a movement of hundreds of pallets. This section describes a stepwise approach for implementing these solutions.

Step 1:
The SKUs that are stored in the 2nd till 6th level must be located back to the reserve area. The empty locations must be blocked in the ERP system so no new SKUs can be located to these racks.

Step 2:
The double locations (safety stock) in the fast pick area are also not needed in the new situation. A solution could be to store the double locations back in the reserve area. A better solution is to set back the replenishment quantity to one pallet in the ERP system. The ERP system will only generate a replenishment order when the pallet quantity is zero. The safety stock will disappear automatically.

Step 3:
Eliminate the pick locations in the reserve area in the ERP system. The EPR system will not assign an order to the fast pick area if this location is eliminated as a fast pick location. These orders must be allocated to the pick list of a reach truck driver.

Step 4:
Testing and purchasing the new order picking vehicle. Testing must conclude if a fast pick employee can pick a SKU easily from the first level.

Step 5:
The list with the ranking of the popularity of the SKUs assigned to the rank order of the most popular location is input for the allocations of SKUs to the fast pick area. This list contains the following information per SKU: Article name, article description, old location and new location. The new locations number of the SKUs must be entered in the ERP system. The SKUs with an old location in the reserve area will be located in a later step. The SKUs that are currently stored in the fast pick area but do not contribute savings to the fast pick area a removed first. The movement of these pallets can cause interference on a regular working day. We advise to execute the movement of pallets during a weekend. In such a way it can't interfere with the daily activities.

Step 6:
SKUs from the reserve area can be moved to the fast pick area after the SKUs within the fast pick area are moved.

Step 7:
The orders that contain a SKU from the first level must be assigned to a separate pick list. This pick list is assigned to the employee that is driving the new order picking vehicle.

Updating the policy
The update of the forward-reserve problem results in an update of the fast pick storage strategy. A SKU must be stored back in the reserve area if the net benefit is negative of a SKU. A SKU that is stored in the reserve area that results in a positive net benefit must be stored in the fast pick area rather than in the reserve area. This switching of products must also be done twice a year. The popularity and restocking must be taken into account when switching the SKUs. It is a lot of work to move and switch the SKUs in the fast pick area twice a year because the popularity ranks changes. A few changes can be made during the switching of SKUs. A SKU that is new in the catalogue but increases its popularity in halve year significantly it must be allocated to a "low distance" location. The management of Topa can choose to move all SKUs again if the ranked list of popularity is far from efficient.

8.5 Summary implementation

8.5.1 Implementation in the receiving process

The experiment of the desired situation worked out very well. The management of Topa decided to work with the changes that have been made during the experiment. The process is still working regarding the recommended solution since the experiment. Improvement in the receiving process can increase with use of barcode scanning which can be implemented at the same time of the new ERP system. The new ERP system can also eliminate manual activities.

8.5.2 Implementation of the allocations of SKUs

A list is made which consist with the information of the SKUs that contribute net benefit. This list is needed for the implementation of the storage strategy in the fast pick area. Twice a year the list must be updated regarding new information out of the ERP system.

8.5.3 Implementation of the storage strategy in the reserve area

Several practical solutions must be implemented first. Zone j must be eliminated and products must be assigned to zone D. Furthermore is chosen to empty the current zone C. This zone will be used when the occupation rate increases. Three lists are made, each list contains the information of the SKUs that are assigned to zone A, B or C. Layouts are made per layer of the reserve area. This allocation of zone must first be changed in the ERP system. Second step is to assign the SKUs to the right zone. The new storage strategy is changing automatically due to the random allocation of SKUs in the zones. After a month several pallets must be moved manual. Twice a year this storage strategy must be updated regarding new input from the ERP system. SKUs must be switched between the zones regarding the popularity.

8.5.4 Implementation of the storage strategy in the fast pick area

The implementation of the storage strategy in the fast pick area causes the biggest change. The movement of the SKUs in the fast pick area must be done in a weekend so it can't interfere with the daily activities. Several practical issues must be implemented first. SKUs located on the 2nd to 6th level are moved back to the reserve area first. These high locations must be blocked in the ERP system so no new SKUs can be located to these locations anymore. Next step is to eliminate the fast pick orders in the reserve area. The new order picking vehicle must be tested. A list with the ranked SKUs on popularity regarding the ranked locations on distance is used for input for the movement of pallets. The safety stock must be eliminated in the ERP system. SKUs that are located in the fast pick area in the current situation and are still located in the fast pick area are moved first. The last step is to assign the SKUs from the reserve area to the fast pick area. The storage strategy in the fast pick area must be updated twice a year, when the allocations of SKUs to the fast pick area of reserve area are updated. Allocation all SKUs to a new dedicated location is too much work if this must be done twice a year. Proposed is to make small changes if the popularity has great differences. The management of Topa can chose to update the whole strategy if the strategy is far from optimal.

9 Conclusions and recommendations

This last chapter of this report describes the conclusions and recommendations of this research. The objective of this research was to improve the efficiency in the distribution center. This research had to give insight in the current bottlenecks and performance and come up with solutions. The objective was formulated as: "How can non value adding activities be reduced to improve the efficiency in the distribution center of Topa Verpakking. This research exposed four bottlenecks in the current situation at Topa. These bottlenecks are observed and their performance is measured and calculated. Each bottleneck is expressed in one or more KPIs which are indicating the performances of the processes. Per bottleneck a literature study is done to find solutions for the bottlenecks. The solutions are applied to the case of Topa. This chapter describes if the objective is reached.

9.1 Receiving process

9.1.1 Conclusions receiving process

The activities of the receiving process were observed, timed and schematically viewed in a Value Stream Map. The total throughput time in the current situation was 138 minutes before a truck loading was fully processed. The activities were measured from the arrival of a truck until all incoming pallets are stored in the racks. The VSM exposed a lot of waste mostly caused by waiting times. The waiting times were caused by the sequences of the activities and the two departments involved. The sequence of activities and the division of responsibilities was partly caused by the current ERP system. A real life simulation was done for a new sequence of activities in the process. The main problem of the long throughput time was caused by the delay of attaching the stickers to the pallets. The sequence is switched in such a way that the stickers are printed in an earlier phase of the process. The real life simulation resulted in a saving of 50 minutes of the average total throughput time per truck load. The new sequence has been maintained since the real life simulation, due to the high improvement.

Conclusion: A new sequence of the receiving process improves the efficiency with 36.24% of the total throughput time of a truck load.

Current KPI	Value KPI	New value KPI	Improvement
Average total throughput time of a truck	*138 minutes*	*88 minutes*	***50 minutes*** ***36.24%***

table 25: Conclusion of the improvement in the receiving process

9.1.2. Recommendation receiving process

The total throughput time can decrease a lot due to the solutions given by this research. This solution can only be successful if both departments follow the new process. The total throughput time depends on the responsibility of both departments. A reach truck driver still can't store the pallets if an employee of the receiving area doesn't attach the sticker to the pallet but first unloads a new truck. The employees at the receiving area are also responsible for the physical control of the goods. If quantities deviate from the consignment note they must communicate this with the supporting unit. It is important for the management of Topa to communicate this to the employees.

A second recommendation is done to the new ERP system. A new system allows Topa to make use of barcode scanning as mentioned earlier in this report. Barcode scanning can speed up the process and decrease the total throughput time of a pallet in the receiving area. A new ERP system can also simplify the activities that are done in the ERP system.

9.2 Forward reserve problem

9.2.1 Conclusion forward reserve problem

The second bottleneck was exposed regarding observations and analyzing data from the ERP system. Unawareness of the net benefit of storing a SKU in the fast pick and not updating the strategies causes labor and time intensive work for the reach truck drivers. The KPI of the current performance was set on 232 minutes of case picking by a reach truck driver per day. The goal was to find a solution in the literature to allocate SKUs to the fast pick area. The model of Bartholdi & Hackman in their book "Warehouse and Distribution Science" provides a net benefit formula. The formula calculated the net benefit per SKU of being stored in the fast pick area rather than in the reserve area. Adapting this model and formula to the case of Topa resulted in an improvement of the case pick time of 66 minutes per day. In the current situation a net benefit of 1059.7 hours per year is achieved by use of the fast pick area. A new allocation of SKU regarding the model of Bartholdi & Hackman increases this net benefit to 1193.6 hours per year. This new solution will improve the efficiency of the distribution center. An implementation plan is made to allocate the SKUs to the fast pick area.

Conclusions: An allocation of the SKUs to the fast pick area regarding the model of Bartholdi & Hackman decreases the case picking time with 66 minutes per day and increases the net benefit with 113.9 hours per year.

Current KPI	Value KPI	New value KPI	Improvement
Case pick time	*232 minutes per day*	*166 minutes per day*	***66 minutes per day*** ***28.45 %***
Current $\sum V_i$	*1059.7 hours per year*	*1193.6 hours per year*	***133.9 hours per year*** ***12.63%***

table 26: Conclusion of the improvement of the forward reserve problem

9.2.2 Recommendation forward reserve problem

The method provided by Bartholdi & Hackman has shown to be a sufficient method for allocating SKUs to the fast pick area. The recommendation can be given that Topa uses this method in the future for a new allocation. We propose to update this new policy twice a year. A SKU that is added in the catalogue can be placed in the fast pick area in such a way. A SKU with a decreasing popularity or even removed from the catalogue can be removed from the fast pick area. Topa can only maintain this efficiency by updating the policy twice a year.

9.3 Storage strategy in the reserve area

9.3.1 Conclusion storage strategy in the reserve area

Observation and analysis of the strategy, blue prints and data from the ERP system exposed the bottleneck in the reserve area; the storage strategy. The used storage strategy was never updated since the implementation of the strategy and the management of Topa never calculated travel time regarding the I/O point of the distribution centre. The change in the demand resulted in a change in the popularity of SKUs. A SKU that was very popular was stored at the back of the warehouse and a less popular SKU at the front. These problems resulted in long travel times for the reach truck drivers in the reserve area. The current travel time was calculated for indicating the current performance: 926.8 hours in 2009. A literature study is done to find a better solution for a storage strategy. Class based storage strategy with a across aisle storage was concluded to be the best solution for Topa. Several practical issue are solved first before allocation the zones in the layout. The 66.63-10 rule improves the total travel time with 19.9% in comparison with the current situation. A new layout with the new zone division is made and an implementation plan is established for Topa. An Excel sheet is made with a division of the SKUs per zone.

Conclusion: The class based storage strategy with the 66.6-10 rule improves the total travel time in 2009 with 19.9%.

Strategy	Total travel time in 2009 in hours	Comparison current situation
Current situation	926.8	100%
ABC 66.6-10	**742.8**	**80.1%**

table 27: Conclusion of the improvement of the storage strategy in the reserve area

9.3.2 Recommendation storage strategy in the reserve area

The recommendation can be given to update the storage strategy in the reserve area twice a year. The popularity can be attained from the ERP system. The SKUs can be categorized regarding the new popularity. The management of Topa received an Excel sheet with the calculations and procedure of the classification in this report. We also advise to supervise the occupation rate per zone weekly. The dimensions of the zones can easily be adjusted in the ERP system. The extension that is advised to be empty can be used when the total occupation rate of the warehouse increases. Considering the travel time it is advisable for Topa to not use this area with the current occupation rate.

9.4 Storage strategy in the fast pick area

9.4.1 Conclusions in the fast pick area

The last bottleneck was exposed by observations of the process and data from the ERP system. The allocation of SKUs to the fast pick area is not based on the I/O point but on plain thinking by management. The current picking vehicles, no update of the policy, the allocation of SKUs to the storage locations and previously way of thinking causes long travel distance and long travel time in the fast pick area. Three KPIs are defined for this bottleneck. The travel distance in 2009, the average travel time per ground, first level and reserve area location and the average travel time for reach locations. A literature study is done to research the best storage strategy in the fast pick area. Dedicated storage strategy is concluded to be the best solution for Topa in the fast pick area. SKUs must be ranked on activity (popularity plus the number of restocks) and allocated to a sequences of the location ranked on the distance. Several practical issues are proposed first. SKUs that are assigned as fast pick SKUs may not be located to the 2nd to 6th level. The SKUs that are assigned as fast pick SKUs but located in the reserve area must be assigned to the reserve area, picked by reach truck drivers. A new order picking vehicle is proposed that can also pick order from the first level. The double safety locations in the fast pick must be eliminated. The SKUs that contribute net benefit, calculated at the second bottleneck are assigned to the locations regarding the activity and distance. This results in an improvement of the travel distance of 52.84%. The average travel time of a ground and first level location decreases to 1 minutes and 40 seconds when a new vehicle is purchased. An implementation plan is made with new layout, an Excel list with the SKUs located to fixed locations and the other practical issues.

Conclusions: A dedicated storage strategy with an allocation of SKUs based on activity per SKU and distance of a rack location will improve the efficiency in the fast pick area.

KPI	Current situation	New situation	Improvement
Total travel distance in the fast pick area	2.803.446 meter in 2009	1.322.260 meter in 2009	**1.481.186 meter per year** **52.84 %**
Average travel time 2nd till 6th location in fast pick area	9 minutes per location	1 minute and 40 seconds per location	**7 minutes and 20 seconds Per location** **81.5 %**
Average travel time per ground and first level location in the fast pick area	2 minutes and 40 seconds	1 minute and 40 seconds	**1 minute** **47.5 %**

table 28: Conclusion of the improvement of the storage strategy in the fast pick area

9.4.2 Recommendation in the fast pick area

It is advisable for the management of Topa to test the advised order picking vehicle, proposed in this report. This vehicle can pick orders from the first level in the fast pick area. In such a way an order picker employee doesn't have to inform a fork truck driver. The second recommendation is given to the high locations. The 2nd to 6th rack levels are not needed and gain no benefit in the fast pick area. A reach truck driver can only store and pick from these levels. Regarding the safety issue it is not advisable that both reach truck drivers and fast pick employees are working in the same area. An update of the storage policy must also take place twice a year. SKUs can be located to new locations regarding the forward-reserve problem. SKUs that gain no benefit from being picked from the fast pick area rather than the reserve area must be eliminated and new SKUs that gain net benefit must be stored in the fast pick area. A total reshuffling of the SKUs to new locations is labor and time intensive work. We advise review the dedicated locations after one year. A new reshuffling of the SKUs can be done if it results in a significant decrease of the travel distance.

9.5 Recommendations regarding further research

It is advisable for the management of Topa to put a lot of effort in the new ERP system. The current ERP system causes a lot of manual work while an ERP system must simplify and support the activities. Many manual activities can be eliminated or reduced with a better programmed ERP system. It is also advisable for Topa to combine the new ERP system with new technologies like barcode scanning. Barcode scanning is an example to reduce the amount of paper and speed up the receiving, storing, picking and shipping process. Further research can be done with regard to picking with the use of computers.

Further research can provide insight in the possible benefit of combining storing and picking. Separate reach truck drivers are responsible for the storing and picking processes. A reach truck driver that is responsible for storing the products in the racks is traveling full to the locations and drives back empty. A reach truck driver that is responsible for the order picking is travelling empty to the location and back full. Combining those processes can reduce the travel time significantly.

Further research can be done to the storage of SKUs that are only picked from the fast pick area. Certain SKUs are only sold per full pallet. Others are sold as a full pallet and per cases. Some SKUs are only sold in a smaller amount of quantity than a full pallet. The bulk location of this SKU is in the reserve area. It can occur that this full pallet of this SKU is stored at the other side of the warehouse. Further research can provide insight if these SKUs can be stored more efficiently and nearby the fast pick area.

Glossary

Bottleneck	The slowest operation in a chain of operations; it set the pace of output of the entire line
COI	Cube per Order Index
Consignment-note	A document issued by a carrier giving details and instructions related to the shipment
Cross dock	Distribution method in which the goods flow in an unbroken sequence from receiving to shipping, thus eliminating storage.
D.P.D.	Logistical transport service for small packages
Efficiency	Doing the thing right, usually measured as the output per unit input
ERP system	Enterprise resource planning system. An ERP system is a software that is used to support the processes in a company
Fast pick area	An area where a certain number of SKUs with a high pick density are stored to obtain savings instead of picking those SKUs from the reserve area
Forward area	See fast pick area
I/O point	Average input & output point of the goods in a warehouse
KPI	Key Performance Indicator: Quantifiable measurements that reflect the critical success factors of an organization
Loading dock	A recessed bay in a building or facility where trucks are loaded and unloaded
Reach truck	A warehouse vehicle that can pick pallets from rack levels to 8 meter.
Reserve area	Area that contains the bulk stock of a company. This area is used for “bulk” picking, full pallet quantities and to restock the fast pick area
Single command	Picking one order line at a time
SKU	Stock Keeping Unit: A unique identifier for each distinct product and service that can be purchased
S.O.P.	Single Order Picking: Picking one order at a time. The picked SKUs are brought to the loading area after completion of one order
Supporting-unit	A department at Topa that supports the daily activities by planning and administrative activities
VSM	Value Stream Mapping: Methods that can be used for exposing and elimination of non value added activities.

Formula

Net benefit per year per SKU $i = sp_i - c_r d_i$

Net benefit per year per SKU $i = V_i$

$V_i = sp_i - c_r d_i$

s = Savings in minutes of pick a SKU from the fast pick area instead of the reserve area

p_i = *Number of less than 75% of a pallet quantity per year (popularity)*

c_r = *Minutes of restock*

d_i = *Number of restocks per year*

References

References that are cited in this research:

Articles:

Bartholdi, J.J., Hackman, S.T., (2008): *Allocating space in a forward pick area of a distribution center for small parts,* in: IIE Transactions, Vol 40, 1046-1053.

De Koster, R., Le-duc, T., Roodbergen, K.J., (2007): *Design and control of warehouse order picking: A literature review,* in: European journal of operational research, Vol 182, 481-501

Dekker, R., Koster, de M.B.M., Roodbergen, K.J., Kalleveen, van H., (2004): *Improving order-picking response time at Ankor's warehouse,* in: Interfaces, Vol 34(4), 303-313

Gu, J.X., Goetschalckx, M., McGinnis, L.F., (2005): *Warehouse design and performance evaluation: a Comprehensive review,* in: Working paper, Virtual factory laboratory, Georgia Institute of Technology.

Gu, J., Goetschalckx, M., McGinnis, L.F., (2007): *Research on warehouse operation: A comprehensive review*, in: European Journal of Operational Research, Elsevier Vol 177, 1-21.

Gu, J., Goetschalckx, M., McGinnis, L.F., (2010): *Research on warehouse design and performance evaluation: A comprehensive review*, in: European Journal of Operational research, Vol 203, 539-549.

Hackman, S.T., Rosenblatt, M.J., (1990): *Allocating items to an automated storage and retrieval system*, in: IIE Transactions, Vol 22 (1), 7-14.

Hausman, W.H., Schwarz, L.B., Graves, S.C., (1976): *Optimal storage assignment in automatic warehousing systems,* in: Management Science, Vol 22 (6), 629-638

Heskett, J.L., (1963): *Cube-per-order index a key to warehouse stock locations*, in: Transportation and Distribution Management Vol 3, 27-31.

Heskett, J.L., (1964): *Putting the cube-per-order index to work in warehouse layout,* in: Transportation and Distribution Management Vol 4, 23-30.

Kallina, C., Lynn, J., (1976): *Application of the cube-per-order index rule for stock location in a distribution warehouse,* in: Interfaces, Vol 7 (1), 37-45

Kong, C., Masel, D., (2008): *Methods for design and management of a fast-pick area in a warehouse,* in: Proceedings of the 2008 industrial engineering research conference J. Fowler and S.Mason, eds.

Larson, T.N., March, H., Kusiak, A., (1997): *A heuristic approach to warehouse layout with class-based storage,* in: IIE Transactions, Vol 29, 337-348.

Malmborg, C.J.,(1995): *Optimization of cube-per-order index warehouse layouts with zoning constraints,* in: International Journal of Production Research, Vol 33 (2), 465-482.

Olsen, J.E., (2005):*Top 25 business school professors rate journals in operations management and related fields,* in: Interfaces, Vol 35 (4), 323-338.

Petersen, C.G., (1997): *An evaluation of order picking routing policies,* in: International Journal of Operations & Production Management, Vol 17 (1), 1096-1111.

Petersen, C. G., (1999): *The impact of routing and storage policies on warehouse efficiency,* in: International journal of operations & production management, Vol 19 (10), 1053-1064

Petersen, C.G., Aase, G., (2004): *A comparison of picking, storage, and routing policies in manual order picking,* in: International Journal of Production Economics, Vol 92, 11-19.

Rouwenhorst, B., Reuter, B., Stockrahm, V., Houtum van, G.J., Mantel, R.J., Zijm, W.H.M., (2000): *Warehouse design and control: Framework an literature review*, in: European journal of operational research, Elsevier Vol 122, 515-533.

Van den Berg, J.P., Sharp, G.P., Gademann, A.J.R.M., Pochet, Y., (1998): *Forward-reserve allocation in a warehouse with unit-load replenishments,* in: European journal of operational research, Vol 111, 98-113.

Van den Berg, J.P., (1999): *A literature survey on planning and control of warehousing syste*ms, in: IIE Transactions, Vol 31, 751-762.

Van den Berg, J.P., Zijm, W.H.M., (1999): *Models for warehouse management: Classification and examples,* in: International Joural of Production Economics, Vol 59, 519-528.

Books:

Bartholdi, J.J., Hackman, S.T., (2010): “*Warehouse & Distribution Science” release 0.92, downloaded from: www.warehouse-science.com.*

Breyfogle III, Forrest W. (2003): “*Implementing Six Sigma”,* second edition, John Wiley & Sons, inc., New Jersey, *waste: p859, value stream: p858*

Frazelle, E.H., Hackman, S.T., Passy, U., Platzman, L.K., (1994): *The forward-reserve problem,* in: Optimization in Industry 2, Ciriani, T.A. and Leachman, R.C. (eds.), Johan Wiley, 43-61.

Meredith, J.R., Shafer, S.M., (2006): “The management of operations”, Wiley, 3rd edition.

Roodbergen, K.J., Petersen, C.G., (1999): *How to improve order picking efficiency with routing and storage policies,* in: Progress in material handling practice: 1999, G.R. Forger et al. (eds), Material handling institute, Charlotte, Noth Carolina, 107-124.

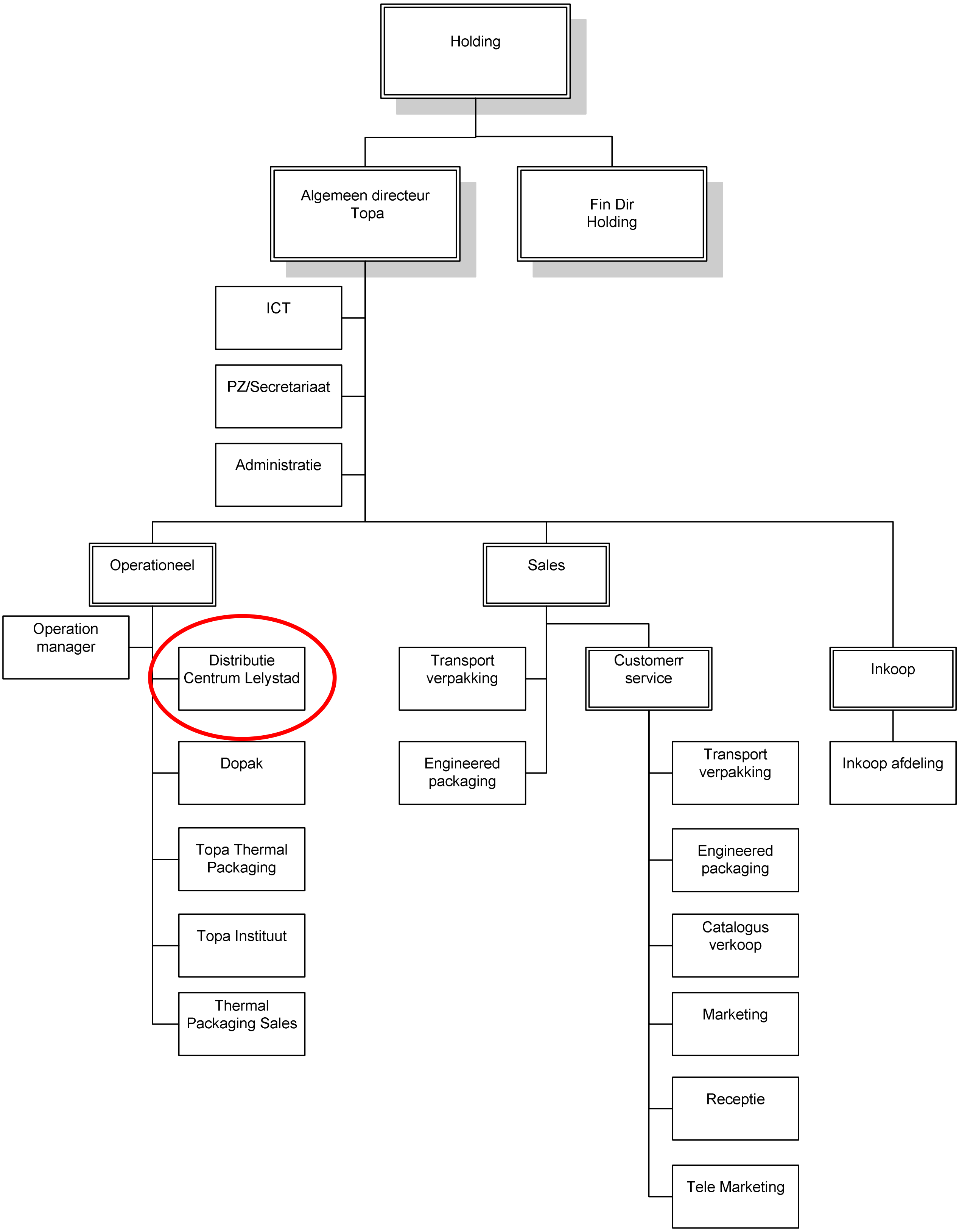
Tompkins, J.A., White, J.A., Bozer, Y.A., Frazelle, E.H., Tanchoco, J.M.A., Trevino, J. (1996): *Facilities Planning,* John Wiley, New York, NY.

Appendix I: Main product groups

1. **Carton boxes** 	2. **Rolls (Protection materials)** 	3. **Plastic bags** 
4. **Tape** 	5. **Document, envelopes and labels** 	6. **Pallets** 
7. **Foils** 	8. **Equipment** 	9. **Insulation packaging** 
10. **Archiving** 	11. **Envelopes and mail boxes** 	12. **CD and DVD packaging** 

13. **Books and clutch boxes** 	14. **Long packaging** 	15. **Dossier boxes** 	16. **Bottle and gift packaging** 

Appendix II: Organigram Topa group



Appendix III: Ranked Operation and Management journals

Journal	Operations management		Operations research		Other fields		Journal rankings by field		
	Number of OM raters	OM quality means	Number of OR raters	OR quality means	Number of other raters	Other quality means	OM ranking	OR ranking	Other ranking
Management Science[1]	119	1.03	28	1.14	24	1.38**	1	2	1
Operations Research[2]	115	1.08	29	1.03	21	1.52**	2	1	2
Mathematics of Operations Research	90	1.40	29	1.28	15	1.53	3	4	3
Manufacturing & Service Operations Management[3]	110	1.50	16	2.63	8	3.13**	4	13	12
Mathematical Programming[4]	69	1.67	29	1.24	11	2.18*	5	3	5
Journal of the American Statistical Association	30	1.73	11	1.64	10	1.70	6	5	4
IIE Transactions[1]	105	2.27	18	2.78	15	3.33**	7	14	16.5
Naval Research Logistics	105	2.28	24	2.54	16	2.75	8	12	8
Transportation Science	74	2.34	25	2.36	11	3.00	9	11	10
SIAM Review[4]	25	2.36	13	1.92	7	3.43*	10	6	18
Interfaces	114	2.61	28	2.04	18	2.83*	11	7.5	9
Operations Research Letters[4]	82	2.62	26	2.35	13	3.31*	12	10	14
European Journal of Operational Research[1]	113	2.73	28	2.86	21	3.33*	13	15	16.5
Networks[2]	39	2.79	22	2.32	7	3.86**	14	9	22
INFORMS Journal on Computing[5]	49	2.80	25	2.04	9	3.22*	15	7.5	13
Annals of Operations Research	78	2.86	26	3.12	13	3.31	16.5	18	15
Production and Operations Management	106	2.86	13	3.69	9	3.56	16.5	22	20
Journal of Combinatorial Optimization	13	3.00	8	3.00	3	4.00	18	16	24
Journal of Operations Management	93	3.04	15	3.13	10	2.70	19	19	7
Decision Sciences	99	3.25	19	3.63	20	3.05	20	20	11
Journal of the Operational Research Society	81	3.28	23	3.04	13	3.54	21	17	19
International Journal of Production Research[1]	82	3.76	12	4.17	8	4.88*	22	27	30.5
Journal of Supply Chain Management	24	3.83	2	5.50	3	3.67	23	32	21
Journal of Business Logistics	25	3.92	4	3.75	4	2.25	24	25	6
International Journal of Production Economics	79	3.95	9	4.67	6	4.67	25	29.5	28.5
Mathematics and Computer Modelling	30	3.97	10	3.70	8	3.88	26	23	23
Computers and Operations Research[4]	60	4.05	19	3.68	7	5.00	27	21	32
International Journal of Operations and Production Management	41	4.07	3	4.67	3	4.33	28	29.5	25
Decision Support Systems and Electronic Commerce	41	4.27	15	3.73	9	4.67	29	24	28.5
Omega	66	4.33	16	4.31	12	4.50	30	28	26.5
Production and Inventory Management	35	4.34	2	6.00	4	4.50	31	33	26.5
Computers and Industrial Engineering	49	4.53	13	4.15	6	5.00	32	26	33
American Journal of Mathematical and Management Science	27	4.85	8	4.88	8	4.88	33	31	30.5

Appendix IV: Organigram Central Warehouse Lelystad