A New Framework for Designing and Developing Cost-Effective Logistic Chains for Long Items

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I. Abstract

In this thesis, a new framework has been proposed, designed and developed for creating efficient and cost effective logistics chains for long items within the building industry. The building industry handles many long items such as pipes, profiles and so on. The handling of these long items is quite complicated and difficult because they are bulky, unstable and heavy. So it is not cost effective and efficient to handle them manually. Existing planning frameworks ignore these special requirements of such goods and are not planned for handling these goods. That leads to that many additional manual handling steps are currently required to handle long items. Therefore, it is very important to develop a new framework for creating the efficient and cost-effective logistics chain for long items.

To propose such a new framework, the expert interviews were conducted to gain the fully understanding about the customer requirements. The experts from all stages of the building industry supply chain were interviewed. The data collected from the expert interviews has been analysed and the meaningful findings about the customer requirements have been applied as the valuable inputs for the proposition of the new framework.

To have fully knowledge about current practices, all existing planning frameworks have been analysed and evaluated using SWOT analysis. The strengths, weaknesses, opportunities and threats of the current planning frameworks have been comparatively analysed and evaluated. The findings from SWOT analysis have been used for proposing, designing and developing the new framework.

The great efforts have been made during the implementation stage. The six different key parameters for a successful implementation have been identified. They are:

- Improvement Process with Employees
- Control of the Improvements

- Gifts/Money for the Improvements and Additional Work
- KAIZEN Workshops
- Motivation of the Employees for Improvements
- Presentation of the Results

Among these six parameters, it has been found that KAIZEN workshops is a very effective way for creating an efficient and cost-effective logistics chain for long items.

It is believed that the new framework can be theoretically used for the planning of logistics that handle long items and commercial goods. This framework can also be used to plan all kinds of in-house logistics processes from the incoming goods, storage, picking, delivery combination areas and through to the outgoing goods area.

The achievements of this project are as follows (1) the new framework for creating efficient and cost-effective logistics chains for long items, (2) the data collection and the data evaluation at the preliminary planning, (3) the decision for one planning variant already at the end of the structure planning, (4) the analysis and evaluation of customer requirements, (5) the consideration and implementation of the customer requirements in the new framework, (6) the creation of figures and tables as planning guideline, (7) the research and further development of Minomi with regards to long items, (8) the research on the information flow, (9) the classification of the improvements and the improvement handling at the implementation, (10) the identification of key parameters for a successful implementation of the planning framework.

This framework has been evaluated both theoretically and through a case study of a logistics system planning for handling long items and commercial goods. It has been found that the new framework is theoretically sound and practically valuable. It can be applied to creating the logistics system for long items, especially for building industry.

II. Declaration of Original

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas.

Any views expressed in the thesis are those of the author and in no way represent those of the University.

Signed: [redacted] Date: 03.06.2014

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IV.List of Abbreviations

Variables	Meanings	Unit
a	Acceleration	[m/s²]
A_{CP}	Expanse of the commercial Pallet	[m²]
AG	Joint-Stock Company	[-]
A_{LIP}	Expanse of the Long Item Pallet	[m²]
A_{SELIP}	Shelf Expanse of the Long Item Pallet	[m²]
A_{SECP}	Shelf Expanse of the Long Item Pallet	[m²]
B_i	Inventory	[€]
CG	Commercial Good	[-]
CP	Commercial Pallets	[-]
d	day	[-]
DC	Delivery Combination	[-]
$\boldsymbol{\delta_i}$	Time Effort	[s]
$\boldsymbol{\delta_p}$	Time Effort Packing	[s]
$\boldsymbol{\delta_{pr}}$	Time Effort Pre - Packing	[s]
$\boldsymbol{\delta_s}$	Time Effort Sorting	[s]
$\boldsymbol{\delta_u}$	Time Effort Unpacking	[s]
e	Edge	[-]
EP	Euro-Pallet	[-]
EPEI	Every Part Every Interval	[-]
ERP	Enterprise-Resource-Planning	[-]
$\varepsilon_{\boldsymbol{high}}$	High Effort per Activity	[s/piece]
ε_i	Effort per Activity	[s/piece]
$\varepsilon_{\boldsymbol{max}}$	Maximum Effort per Activity	[s/piece]
ε_{min}	Minimum Effort per Activity	[s/piece]
$\varepsilon_{\boldsymbol{mid}}$	Moderate Effort per Activity	[s/piece]
$\varepsilon_{\boldsymbol{s}}$	Slight Effort per Activity	[s/piece]
FIFO	First In First Out	[-]
GmbH	Limited Liability Corporation	[-]
I	Inventory	[Pallets]
IGA	Incoming Goods Area	[-]

Variables	Meanings	Unit
k	Amount of all Different Combination	
	of Two Locations	[-]
K_B	Customer Demand	[piece/day]
kpi	Key Performance Indicators	[-]
L	Sum of Length of the Locations in One Aisle	[m]
LI	Long Item	[-]
LIFO	Last In First Out	[-]
LIP	Long Item Pallet	[-]
$\lambda_i^{in}(t)$x	Input Material Flow	[piece]
λ_i^{out}(t)	Output Material Fflow	[piece]
m	Storage Area, Square Metres	[m^2]
MTM	Methods - Time Measurement	[-]
μ_i	Limiting Performance	[piece/hour]
n	Number of Order Positions	[piece]
n_a	Number of Going to Starting / Ending Points	[piece/order]
n_{CP}	Number of Commercial Pallets	[piece]
n_i	Number of Activities	[piece]
n_{LIP}	Number of Long Item Pallets	[piece]
n_p	Number of Positions per Order	[piece/order]
p_{ij}	Picking Performance	[piece/hour]
P_K	Picking Performance	[piece/hour]
P_P	Picking Performance per Picking Order	[piece/hour]
ppm	Part Per Million	[-]
P_{sort}	Sorting Performance	[piece/hour]
	e.g. from a Sorting Machine	[piece/hour]
REFA	Committee for Working Time Investigation	
	(Reichsausschuss für Arbeitszeitermittlung	
	und Betriebsorganisation)	[-]
RQ	Research Question	[-]
s_n	Picking Distance for One Order	[m]
s_p	Picking Distance	[m]
t_B	Operation Time	[s]

Variables	Meanings	Unit
t_{basic}	Basic Picking Time	
	e.g. Starting a Picking Order on a Computer	[s]
$t_{basic,n}$	Basic Picking Time for n Order Positions	
	e.g. Starting a Picking Order on a Computer	[s]
T_C	Customer Cycle	[s/piece]
t_K	Picking Time	[s]
TMU	Time Measurement Unit	[-]
t_n	Time that is Need for the Driving or Going	
	of a Distance Between Two Locations	[s]
t_{pick}	Pick Time (Time form the Picking	
	by Hand Until to Taking in the New Cargo)	[s]
ts	Time for Driving or Going a Distance	[s]
t_{sort}	Time for Sorting	[s]
τ_t	Time for Performance	[s]
t_W	Working Time per day	[s/day]
t_{waste}	Time that is Use for Waste e.g. Counting,	
	Unpacking	[s]
t_{ZAZ}	Time Between Two Arrival Goods	
	that are Direct in Sequence Goods	
	that are Direct in Sequence from	
	the Material Provision e.g. Storage	[s]
t_{ZAZ-FT}	Time Between Two Arrival Goods	
	that are Direct in Sequence from	
	the Replenishment e.g. Forklift	[s]
t_Z	Combination Time	[s]
v	Vertex	[-]
ϑ	Speed	[km/h]
z	Amount of Combination from Locations	
	(Normally Two)	[-]
ZZ	Cycle Time	[s]

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Chapter 1 Introduction

1.1 Overview

The term, ‘long item’ is used in the logistics sector for all materials that are longer than 2.5 metres, require individually packaging, and have a relatively small cross section (Martin, 2009, p. 63) (SSI Schäfer Noell GmbH, 2012, p. online lexicon key word "Langgutlagersysteme"). Some examples of long items are demonstrated in Figure 1.1 and Figure 1.2.

Figure 1.1 Studwall Profile
(Welser Profile GmbH, 2014, p. 2)

Figure 1.2: Installed Pipes (Viega GmbH & Co. KG, 2014, p. 14)

The current logistics processes of long item products have been designed and developed for the pallet-based logistics, especially for euro-pallets and handling parcels (Dittrich, 2002, pp. 37-38). Every truck trailer, container and pallet rack etc. can be used to handle goods with a length of 2.5 metres or longer (Rail Cargo Austria Group, 2012). However, these processes are inappropriate and inefficient due to the facts that these processes are not designed using a proper method from the systematically theoretical study but mainly adapted through evolution process based on the practical experiences (Dickmann, 2009, pp. 254-261). Logistics planning methods have the focus on the flexible adaptability. The aim of a current logistics planning method is to use the logistics planning method for all kind of goods and for all kind of logistics planning tasks. However, with a wide range of adaptability of a planning method details of planning requirements from industries (see Chapter 4 “Expert Interview”; one requirement is the transparency of the order process) and goods get lost. In case of exotic goods and an industry with a lot of own characteristics, the effect to plan a logistics system that is not effective and efficient rises.

In the long item logistics, the number of different products is very big and they are normally ordered in different quantities, in combination with different products, to different time slots. Thus, current methods for planning logistics processes are not effective and efficient (Gschwend & Schimmelfennig, 2007, p. 15). Therefore, it is both theoretical and practical important to study, propose, design and develop a new framework for designing and developing logistics chains for long items.

So it is necessary to research, propose and develop a framework for designing and implementing logistics processes for long items. From logistics management point of view, the difficulties are often faced in handling long items during the in-house operation (Koether, 2007, pp. 114-117). So, the focus of this study will be on all kinds of in-house logistics chains for long items. It is well-known that it is routine work to handle long items in the building industry. Therefore, the proposition of the framework is mainly based on the case studies in building industry though the underlying principle of the framework can be applied to the logistics management of long items in the other industries.

1.2 Motivation

The motivation for the research about a framework for planning long items processes arose at the work as expert for the logistics building industry. At the building industry, many different products have to be handled in the same processes. Most of these goods are cheap, so that investing in expensive machines to handle goods in an ideal way is not cost effective. Therefore, it needs many tricky ideas to handle all goods in one logistics system efficient and effective. These ideas are often created by the method “try and error”. However, this method is not usable for complex logistics tasks like at the building industry. The results of using current planning frameworks were not satisfactory. The current logistics planning frameworks are excellent usable for planning logistics for commercial goods. However, in case of a “logistics-niche” industry like the building industry the customer requirements are not considered. Beyond this the long items that are widely-used at the building industry are difficult to handle. This was the motivation to create a new framework that helps to plan efficient and effective processes for long items in the building industry.

1.3 Research Questions, Overall Aims and Objectives

The overall aim of this project is to research, propose, design and develop an efficient and effective framework for planning complex long item logistics chains based on the analysis and evaluation of existing logistics planning models. The models describe the different stages of a planning method (e.g. preliminary planning). The framework describes the content of these stages (e.g. at the preliminary planning, one content is the analysis of the basic data). The interview findings of the industrial experts will be comprehensively analysed, evaluated and integrated into the new framework.

1.4 Contribution to the New Knowledge Generation

The contribution to the new knowledge is the creation of a new framework that is applicable on planning long item logistics processes in the building industry. To create this new framework, the customer requirements from the supply chain of the building industry are analysed. These customer requirements are considered at the development of the new framework at every planning stage. Furthermore, the implementation of a framework is rarely researched. But the implementation is also important. However, a complex logistics system has to be implemented precisely that it works like it has been planned. Therefore, the complex implementation stage is also researched.

1.5 Thesis Structure

This thesis is divided into eight chapters (see Figure 1.3). Chapter 1 serves as an introduction. In Chapter 2, I conduct a literature review with the focus on long items logistics. In Chapter 3, the research methods are described. Chapter 4 focuses on the data research. With the help of an expert interview, the customer requirements within the building industry are identified. Chapter 5 deals with an analysis and evaluation of current planning frameworks. In Chapter 6, a new planning framework for the long item logistics is presented. Chapter 7 contains the case study in which this framework is tested. Furthermore, in this chapter, the key parameters for a successful implementation are identified. Chapter 8 contains the conclusion and suggestions for further research in areas that have been identified in this PhD project.

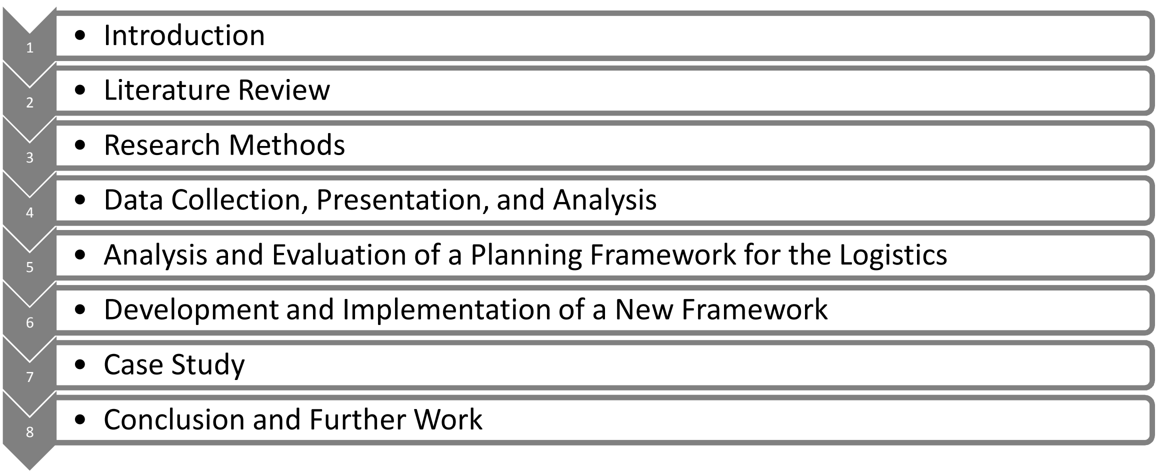


Figure 1.3: Thesis Structure

Chapter 2 Literature Review

2.1 Introduction

In the literature review, two areas are reviewed. The first area is about the history and the current logistics planning approaches. The second is about the two questions regarding long items. What are long items and how can they be classified?

2.2 Logistics Management of Long Items

Long items are used in many different industries (see Figure 2.1). In particular, these industries are the building industry, the steel industry, wood industry and the nuclear industry.

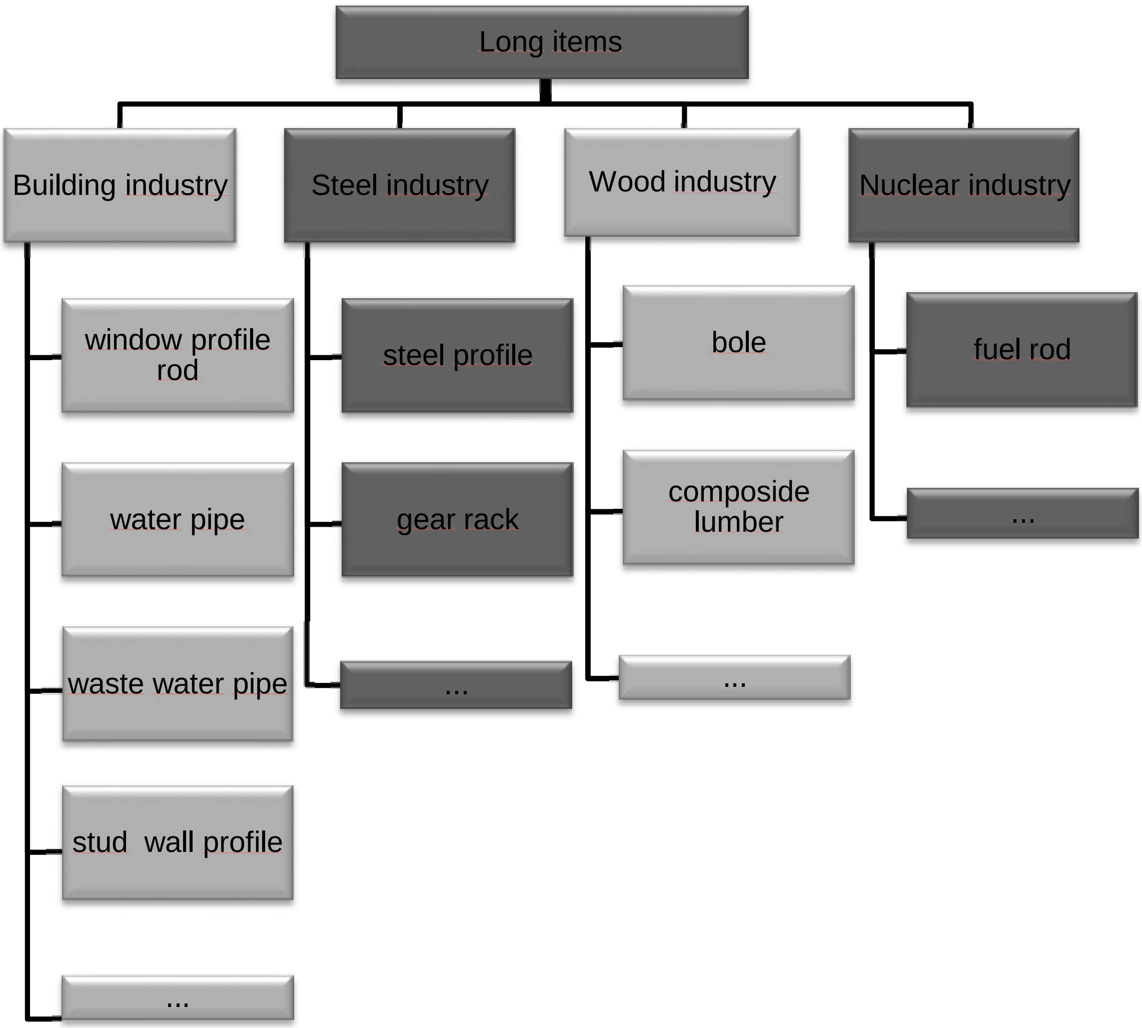


Figure 2.1: Long Items in Different Industries

The **nuclear industry** is the most exotic industry that handles long items (see Figure 2.2). The nuclear fuel rods are long items that must be handled with care (EnBW Kernkraftwerk GmbH, 2014). In addition to the dimension and the weight of the nuclear fuel rods, the nuclear radiation is the biggest problem at the handling (RWE AG, 2014).

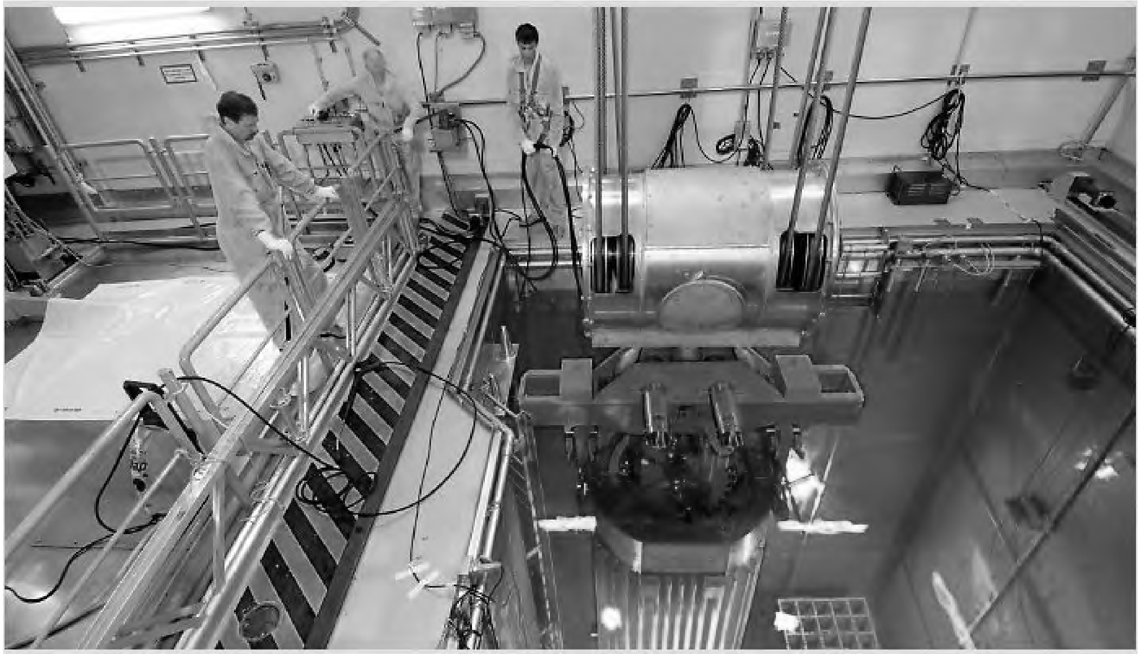


Figure 2.2: Nuclear Fuel Rod
(EnBW Kernkraftwerk GmbH, 2014)

The **wood industry** is the industry dealing with raw materials (= trees). The trees are cut in the forest and stored on a forest track until they are transported to the sawmill or the paper industry. The maximum length of the stocks of the trees is 6 meters because a commercial truck can only load 6 meter trees (Holztransporte Muffler, 2014). If it is necessary to handle longer stocks of trees than 6 metres, a lumber truck is needed (DOLL Fahrzeugbau AG, 2014, p. 2). This lumber truck has also a crane with high power to load the heavy weight stocks of trees, see Figure 2.3. The stocks of trees are not packed. Thus, the loading equipment touches directly the surface of the stocks of the trees. At this process the stocks of the trees can be damaged (EPSILON Kran GmbH, 2014, pp. 14 - 19). Furthermore, the storage in the forest is a block storage at which the surfaces of the trees touch are in contact. The stocks of the trees are stored outside a building. But in most cases, the weather conditions have no influence on the product quality. Only if the goods are stored for months or years on a block storage of the field, they have to water the stocks of the trees so that they do not dry-out. Furthermore, the stocks of the trees have to be protected against vermin, if the stocks of the trees are stored outside a building for months or years (Sägewerk Wiedemann, 2014). Damages on the stocks of the trees are accepted from the customer because in the next supply chain stage the goods are processed from raw materials to industry goods. For instance the saw-mill processes the stocks of the trees to boards. Another problem is, that the single goods are not labelled. Only the whole woodpile is labelled. Thus, the single traceability is limited.

Figure 2.3: Outdoor Wood Storage

(Holztransporte Muffler, 2014)

In the **steel industry**, many different long items exists. These are for example steel pipes and gear racks. Both goods are combined to an axis, see Figure 2.4. These goods are heavy.

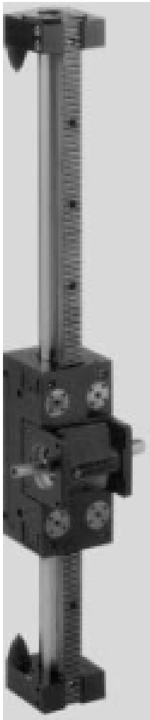


Figure 2.4: Gear Rack on a Handling System
(Zollern Vertriebs-GmbH + Co., 2014, p. 2)

Precision parts like the gear rack have to be handled carefully because they can be damaged or persons who handle these goods can be hurt (ThyssenKrupp AG, 2014). Especially if these goods are transported at the production no package is used and the danger to hurt a person or damage a good is much higher. In case these goods are packaged in a wood frame, the danger to hurt an employee or to damage the product decreases (Zollern Vertriebs-GmbH + Co., 2014). However, often these goods are not packaged since the packaging is unwieldy and difficult to transport. The problem at the transportation of the packaged goods is that the balance point of a packaged good is not directed viewable. Furthermore, the package is not transportable with all kind of transport equipment, e.g. commercial forklift. In some cases, the safe transportation can only be managed by the help of a crane. But not all logistics stages have this special transport equipment. Therefore, the danger of a wrong handling rises. Thus, high precision goods have also high requirements on the storage. These goods can only be stored in-house because of the risk of corrosion, the sensitivity to dirt, and the weather conditions. Therefore they to be specially protected (Bücheler, 2014).

The **building industry** is also a sector of industry where many different long items exist. But the long items at the building industry are quite different. One example are water pipes (see Figure 2.5). Water pipes are made of copper and cannot corrode. But water pipes are pressed at the installation. Thus, the geometry must not be deformed at the handling (Geberit AG, 2003). If the geometry is deformed the pressing at the installation does not work precisely and a water leak can arise. Stud wall profiles are not so sensitive. In case the geometry is deformed, parts of the stud wall profiles can still be used. Only the deformed part is waste. Many long items in the building industry are not robust but can be used with little damages (Viega GmbH & Co. KG, 2014). Thus, many goods with little damages are not waste for customers. Furthermore, they do not complain about these damages, since this is an accepted quality.

The handling of the goods in the building industry is similar to the handling in the steel industry. Many logistics do not have special equipment such as a four-way forklift for transporting long items. They use commercial forklifts for the handling. The advantage of the handling of long item pallets at the building industry is that the goods are not packaged in wood boxes like in the steel industry. The building industry uses simple wood frames for packaging. Therefore the person transporting the goods can see which products are in the wood frame. Thus, the employee can transport the goods more carefully. Furthermore, the employee handling the package can estimate the balance point of the load.

Mostly goods from the building industry are stored in cantilever racks, partly outside a building in case the goods cannot corrode (Mitter, 2014).

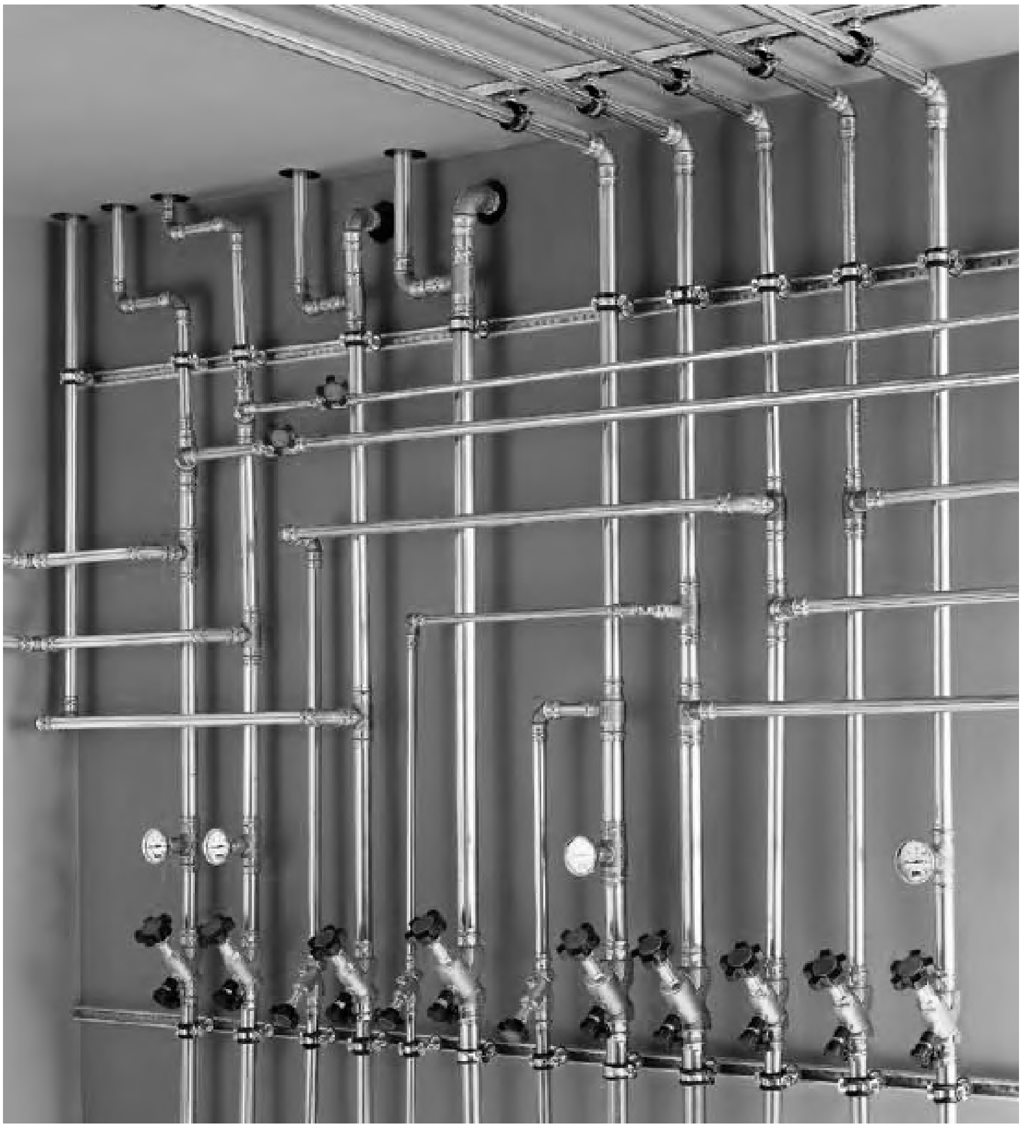


Figure 2.5: Water Pipes
(Viega GmbH & Co. KG, 2014, p. 8)

2.3 Long Item Logistics Management in the Building Industry

The long items handling in the building industry differs from the long item handling in the nuclear, steel and wood industry in essential aspects.

The first essential aspect is that in the building industry all goods are consequently labelled. Therefore, every good can be identified. In the wood industry not all goods are labelled. The second essential difference is that goods that cannot corrode can be stored outside a building. At the steel industry, high precision goods cannot be stored outside a building because of the danger sensitivity to dirt is much higher at these products (Mitter, 2014).

Long items are packed so that they can be handled by forklifts and cranes. The package has to be designed in a way that a storing at the building side is possible. In case of waste water pipes for example the tube ends have to be closed, that no dirt can come into the good (Geberit AG, 2003).

Another important aspect is that in the building industry long items are delivered to the craftsman or the end customer. In this sector of industry the products are ordered only a few days before the installation. Because many different long items producers exist it is necessary to deliver as fast as possible. Otherwise a competitor will receive the order the next time. In the steel industry longer delivery times are possible, because precision goods are adapted on a machine. Thus, to produce a new one, time is needed. In the building industry, the delivery time is a reason for purchase. In the steel and nuclear industry not the deliver time is a main reason for purchase. In the building industry the delivery time is a reason for purchase. This is because many long items can be combined with the same goods from competitors. For instance this is possible at water pipes and waste water pipes. So if the delivery time is too long the customer buys these products from a competitor (Viega GmbH & Co. KG, 2014).

Another important aspect is that the craftsman measures the required goods directly on the building site and orders the goods afterwards. Thus, no long planning in advance is possible. Already on the next day he wants to start with the installation. So the ordered goods have to be delivered as soon as possible (Waldvogel, 2012).

On the building site are limited transportation possibilities. Most buildings sites have a crane or a wheel loader. If no transportation equipment is on the building site, the goods have to be transported manually.

Another important aspect of the long item building industry is that in the building industry many different goods (long items and commercial goods) are handled in the processes. At the wood industry only stocks of trees are handled. In the steel industry mostly long item steel products are handled separately because these goods have a heavy weight and require big cranes for handling and trucks that can handle heavy-weight products. Because of the loading and unloading of the goods from the top by crane, the truck trailer has to be opened on the top. At the building industry products do not weigh so much, so that a commercial truck trailer is not on the loading limit.

Nevertheless customers at the building industry order different products. A plumber who needs for example a pipe needs also connectors for the installation. Both goods have to be delivered in one delivery so that the plumber can install both goods at the same time.

Classification of the Long Items

The term ‘long item’ is used in the logistics sector for all materials that are longer than 2.5 metres, require individual packaging, and have a relatively small cross section (Martin, 2009, p. 63). However, Martin only has one definition for long items. A detailed classification is implemented within this thesis. Table 2.1 shows a more detailed approach to classify long items. One important classification characteristic is the length of a long item. Goods are considered long items at a length of 2.5 metres. The length of 2.5 metres is a common length in the logistics because every standard truck has a width of 2.5 metres. A commercial euro pallet has a width of 0.8 metres. Thus, three pallets can be loaded into one truck (3 x 0.8 metres = 2.4 metres) beside each other. Another example is a commercial rack, which has a width of 2.5 metres, and so on. Therefore, the first length category starts at the length from 2.5 to 4 metres. Four metres is not a common length in the logistics sector but this kind of long items can be found in the building industry (Geberit AG, 2003, pp. 385 - 579). Pipes for example have a length of 2 metres, 4 metres, 5 metres, and 6 metres. Therefore, the second category considers all long items that are longer than 4 but less than 6 metres in length. The third category starts at long items that are longer than 6 metres, though long items that are longer than 6 metres are handled very seldom in the building industry. Nevertheless, it is important to consider these long items, if a company gets in touch with them. It is so important to consider these long items, because they often cannot be handled with normal equipment (Mitter, 2014). Thus, all logistics processes have to be adapted, in case such long items are used. The classification ends at this point. Currently at the building site, there are no long items that are longer than 6 metres. Only in special cases of customer-made products can such longer items be found, as the length of industrial produced long items is a maximum of 6 metres.

In the second classification stage, the characteristics of long items are named. The first two characteristics deal with corrosion. Thus, long items can be characterised according to whether or not they can corrode. This characterisation is important since the goods have to be handled outside of a building or in case the products are stored outside of a building. If products that can corrode are stored outside of a building, the quality of the surface will be damaged (Seidel, 2001, p. 239). For some long items, this is not a problem. For example, iron steel rods can be used inside of concrete to generate composites, but, if the steel is used for plumbing, the corrosion has to be removed.

The third classification stage deals with the stability of the dimensions. At this point, the stability of an item’s length is considered, which is an important factor when it comes to the handling and storage of the goods (Bücheler, 2014). Instable products can be handled manual by an employee on a limited basis. If it is a short long item between 2 to 4 metres in length, it could be possible to handle it manually. If it is a long item of more than 4 metres in length, additional man power or further assistance is needed to handle the goods in most cases.

The fourth classification deals with the sensitivity of the item’s surface. This characteristic is also important when it comes to the handling and storage of the goods with the surface that is an important characteristic for the end customer, particularly if the long item is used as visible part (Bücheler, 2014). Besides, the quality of the surface can have a technical importance, for example if the surface is used as mating face of a water pipe.
The last characteristic is the item’s sensitivity to dirt. This is related to handling and storage (Bücheler, 2014). Dirty goods have to be cleaned before they are installed. If they are not clean, problems with the installation could arise, e.g. dirt can cause leaks due to breaks in the seal. Or dirt can “produce” bacteria that

are dangerous for humans. It is particularly important that new water pipes do not have dirt in the pipe upon installation, for example.

Table 2.1: Classification of Long Items (Unit: metre)

Length /	>2.5 < 4	>4 < 6	>6 metres
Characteristics	Examples of the long items		
No Corrosion	waste water pipes …	waste water pipes …	waste water pipes …
Corrosion Possible	steel pipes steel profiles …	steel pipes steel profiles …	steel pipes steel profiles …
Dimensionally Stable	water pipes waste water pipes steel profiles …	water pipes waste water pipes steel profiles …	water pipes waste water pipes …
Sensitive surface	waste water pipes window profiles …	waste water pipes window profiles …	waste water pipes window profiles …
Sensitivity to dirt	water pipes …	water pipes …	water pipes …

2.4 Framework for Designing and Developing Logistics Chains for Long Items

Because of globalisation, the framework conditions of the market have changed (Dombrowski & Hennersdorf, 2010, p. 234). Customers' requirements change at a faster rate than they did years ago (Huang, et al., 2011, pp. 2413 - 2419); thus, companies have the challenge to adapt themselves to such changes. Beyond this, the planning periods for companies were shortened from long and middle term planning periods to short and middle term planning periods (Dombrowski & Hennersdorf, 2010, p. 234). Short term periods have a range of 2 to 3 years; middle term periods last up to 5 years. In the logistics area, only a limited number of methods for planning logistics systems exist. These methods can be used for and adapted to many different logistics requests. Most of the logistics planning methods neglect special requirements like such for long items, which is problematic because processes are only planned for products with high demand. In case of exotic products like long items, the entire logistics system is limited because the planning typically does not consider the strong fluctuation in demand. In planning long item logistics processes, the dimensions of long items in particular have to be considered. Hence, the process design can be very different from logistics processes of commercial goods (Geberit AG, 2003). That is why the adaption of existing logistics processes on long item logistic process planning is so difficult, if not impossible. In practice, customers often need a large number of “normal” goods and only some long items (Viega GmbH & Co. KG, 2014). Moreover, the amount of long items that are needed at the building site in comparison to the amount of small goods is not very high. This is why many companies do not plan long item logistics processes. Often, they simply try to adapt the logistics processes for “normal” goods. But because of the special requirements of long item logistics processes, the adaption is not successful. Because of these weaknesses of the logistics system, many companies find the handling of long items to be very cumbersome (Geberit AG, 2003). Nevertheless, the existing logistic processes have to be analysed to find out where exactly improvements are necessary. The consequence of this is the limitation of the door-to-door time by the performance of the long item processes. Moreover, companies run the risk of making errors if changes have to be made regarding products or processes, for example, as these changes could be implemented with false rearrangements of the processes if the rearrangements are not documented properly (Bornhäuser, et al., 2003, p. 172). In case the changing customers’ requirements are profound, the danger arises that the wrong activities are used, therefore the efficiency of a logistics model decreases. For that reason, it is important to gain clarity as to why and at which stage of the logistics system problems surrounding use of the current planning method exist.

At first, an evaluation of the planning models has to be done. As only a few different methods for planning logistics systems exist, the methods that might be useful for the company and process planning have to be evaluated.

The roots of the logistics system planning are found in the company planning. Company planning goes back to the 17th century (Schenk & Wirth, 2004, pp. 3 -

4). The scientific research of company processes began in the 20th century. A famous father of the current company planning is Rockstroh, who used the approach to describe a functional technological planning process in a holistic way (Rockstroh, 1980, p. 9). An important and famous initiator of the creation of a logistics planning process is Isermann. He describes logistics planning in a holistic way from the logistics company to the logistics services and to the logistics supply chain. Isermann describes all of the planning processes of a complete logistics supply chain, including the elements like layout planning that have to be implemented at the same time as the initial planning. The logistics unit planning is based on the company planning and Isermann uses the company planning process to plan logistics systems, thus demonstrating the similarity to the company planning (Isermann, 1998, pp. 321 - 337). Therefore, the planning processes of company planning are also relevant for this evaluation. Schmigalla describes the term “company” in a short sentence: “A company is a unit that has the task to produce and use goods and services to supply the customers’ wants” (Schmigalla, 1995, p. 33). To analyse and evaluate current planning processes, we need a structured method. The choice of the methods is described in the following chapters.

2.5 Performance Measurement Criteria of the Framework

Several aspects to measure, if the performance of the framework is fine, exist. The first aspect is if the framework is helpful to plan the target.

One type of performance measurement is to compare the results of the original planning targets with the targets that are achieved at the end of the planning (Kessler & Winkelhofer, 2004, pp. 130 - 131) (Litke, 2007, pp. 33 - 39) (Olfert, 2010, pp. 125 - 126). The disadvantage of this method is that the controlling of the results takes place at the end of a planning stage. To have effective performance measurement criteria the controlling of the achieved targets to the planned targets has to be done more than one time in a planning stage (Kessler & Winkelhofer, 2004, p. 129).

A further performance measurement criterion of the framework is the schedule. This performance criterion is measurable in case that at the start of the planning project the project schedule is made (Litke, 2007, pp. 102 - 105). The schedule is divided in some little parts so it is possible to control all activities. A time delay of a planning stage is an indicator for a problem at the planning stage. To identify problems as far as possible it is necessary that the time table divided in many activities (Litke, 2007, pp. 31 - 32). So performance problems from the framework can early identified.

Another way of the performance measurement is to check the quality of the findings. An example of a quality check is to compare the findings of each planning checked by the bench market (Litke, 2007, pp. 153 - 160). At the storage planning for example the storage equipment that is chosen to be used has to be double checked with different suppliers if the equipment is usable to generate the high effectiveness.

Another aspect to measure the effectiveness of the framework is to control the investments and the costs (Kessler & Winkelhofer, 2004, p. 136) (Litke, 2007, pp. 154 - 160). At the beginning of the framework the costs and investments have to be defined and divided in every stage of the framework. Thus a comparison of the allocated costs and investments to the reached costs and investments is possible (Olfert, 2010, pp. 120 - 123) (Litke, 2007, pp. 154 - 160).

A soft aspect for the performance measurement is to interviewing the employees that are involved at the planning (Olfert, 2010, pp. 158 - 163). If the employees are satisfied with the planning results and the planning progress, this is an indicator that the planning framework works well.

Methods for Analysing Planning Processes for Company and Logistics Planning

A variety of different models exist for analysing the planning processes companies and logistics use. The requirements for analysing the systems are, that at the end the task, the planning process and the strengths and weaknesses of a system are clearly described (Olfert, 2010, pp. 88 - 91). Moreover, it is interesting to find out if the systems have limits and whether these limits are firmly set limits or if they can be extended. In addition, a method that helps to create inputs and possibilities for a new long item planning process would be nice. It would make it easier to create efficient and effective processes. The following methods can be used for analysing and evalutaing mehtods and systems (Schawel & Billing, 2009, p. 20):

- Ansoff Matrix
- BCG Matrix
- Business Plan
- Three Generic Strategy (Porter)
- Five Forces Model
- Portfolio Analysis
- Strategy development
- SWOT Analysis
- 4-C Analysis Concept
- Value Added Chain
- 7-S Model
- System Analysis

Because of the requirments regarding analysing and evaluating planning methods, two methods have been chosen from the previous list to be evauated in greater detail for use in the current study: the SWOT Analysis and the System Analysis. These methods have been chosen because they are applicable for analysing and evaluating processes and methods. These two methods are compared in the following in order to decide which is the best suited for analysing process planning models.

System Analysis

System Analysis is a method which is applicable in many different disciplines and areas like physics, biology, economics, and also technical fields (Greiner, et al., 2005, pp. 297 - 300), (Visser, 2007, pp. 213 - 217). The method is divided in seven steps.

1. Analysis and detection of a problem or a system
2. Concrete description of the problem or system
3. Definition of the system borders
4. Identification of the system elements that are relevant to reach the target
5. Analysis of the network and how the subsystems are connected
6. Evaluation of the system performance with top level key performance indicators
7. Evaluation of the interfaces to other systems

The advantage of the system analysis method is that these seven steps can be used to analyse a logistics system (Niemes, 2012, p. 11). Each stage can be minimised or enlarged so that it is suited to analyse and evaluate a company or logstics system. The disadvantage is that this method has a limited focus on the description of the borders of the system, such as property borders. The analysis does not consider any procedures outside of these borders, so no findings about how processes could be connected are included in the analysis.

SWOT Analysis

The SWOT Analysis method is flexible. With this method, it is possible to analyse a company and the market environment of the company's scope. Furthermore, it is possible to create strategies for the product portfolio or the career management (Schawel & Billing, 2009, p. 182). SWOT Analysis is usually used to evaluate the economic direction of a company (Wagemann, 2004, p. 390). This analysis supports identifying factors of success and economic opportunities. Furthermore, it is used to create the basic strategy of a company (Kraus, et al., 2007, p. 375). On the one hand, the analysis can examine internal aspects, such as the strengths and weaknesses of a company, and on the other hand external aspects, such as the company's opportunities and possible threats to the business. This analysis method is also applicable on the logistics planning. It is important to use this analysis method from different perspectives. For example, when analysing internal aspects, the method includes three different perspectives that help to locate the company's strengths and weaknesses (Schawel & Billing, 2009, p. 183).

The three perspectives are:

- The company itself: Why do we think that we do a good job at what we do?
- The competitor’s perspective: Why do the competitors respect us?
- The customer’s perspective: Why do customers prefer our products?

After defining the strenghts, weaknesses, opportunities, and threats, strategies for improving the company processes are created. By doing this, new possibilities are generated.

Choosing a Method of Analysis

In order to choose the most applicable method, we have to compare the System Analysis and the SWOT Analysis. The appoach is to use these types of analysis to evaluate the SWOT and the System Analysis methods. In detail, the types of analysis examine:

1. Purpose
2. Subsystems
3. Elements, processes, or relations
4. Scope
5. Range
6. Source
7. Necessary tools
8. Schedule

Table 2.2: Choosing the Method of Analysis and Evaluation

	System Analysis	SWOT Analysis
1. Purpose	10	10
2. Subsystems	5	7
3. Elements, processes, or relations	7	7
4. Scope of analysis, the length and width	7	10
5. Range	7	7
9. Source	5	7
10. Necessary tools	7	7
11. Schedule	5	5
Sum of classifications	53	60

Classifications

10 = excellent *7 = very good* *5 = good*

3 = satisfying *0 = dissatisfying*

In Table 2.2, the SWOT Analysis and the System Analysis methods are compared with the help of Schmigalla's criateria. Five levels of classification exist; these are excellent (10 points), very good (7 points), good (5 points), satisfying (3 points), and dissatisfying (0 points). If the evaluation criteria are fulfilled completely, an item is rated "excellent" and awarded 10 points.

In the following, two significant characteristics are described. The second evalution criterion deals with the analysis of the subsystems. The SWOT Analysis was awarded 7 points for this criterion and the System Analysis 5 points. The reason that the SWOT Analysis was awarded more points is because of the four quadrants included in its research (strengths, weaknesses, opportunities, and threats). By specifically analysing the four quadrants, subsystems are also evaluated in detail because of the different views. In System Analysis, the subsystems are also identified, but the depth of the analysis is not regulated by the analysis method.

The fourth evaluation criterion deals with the “scope of analysis, the length and width.” The scope of the SWOT Analysis is described by the four quadrants. In the System Analysis, the scope is determined and set by the analyst, so that there are no fixed criteria. Hence, the results of the System Analysis can only be compared with other System Analyses to a certain, limited extent. With the help of the four quadrants from the SWOT Analysis, the findings can be compared with other SWOT Analyses. Therefore, the SWOT was rated with 10 points and the System Analysis with only 7 points.

At the end of the table, the points are added up for a total score. The method with the largest number of points is the best suited for evaluating the planning processes. After the evalutation, the SWOT Analysis method earned a total of 60 points, 7 more points than the System Analysis method. So, the SWOT Analysis method is chosen for further steps of the evaluation.

2.6 The SWOT Analysis Background and Application

The SWOT Analysis has developed from the martial arts (Yoffie & Kwak, 2001, pp. 1 - 7). The first application was in the military (500 B.C.) (Clavell, 1988, p. 39). SWOT Analysis is an empirical method, which is used by companies to clarify the new strategic adjustment. Companies use it also for the strategic product planning, to determine which products customers actually need in comparison to their own assumptions (Wolters, et al., 2013, pp. 1 - 11). SWOT analysis is also called an internal analysis because the internal strengths and weaknesses become very apparent in detail through the analysis.

The second part of the SWOT Analysis deals with external aspects, focusing on the analysis of the opportunities and threats (see Figure 2.6). The SWOT

Analysis can be repeated from time to time, to control the company's development. Products can also be services (Pelz, 2004, p. 8). In the special case of my thesis, the products are logistics services.

Adaption of the Concept behind SWOT Analysis

In this research, the concept of the SWOT Analysis is used as method to evaluate current planning models. To gain detailed results, it is necessary to divide every model into different stages. The SWOT Analysis itself is divided into two parts. The first part deals with the internal requirements of the long items processes. Furthermore, strengths and weaknesses are in the foreground in the first part of the analysis. By regarding currently existing processes for other logistics chains, the second part, the external analysis, has to be conducted. The second part contains the discussion of the external requirements, which involves examining the influences from the planning horizon.

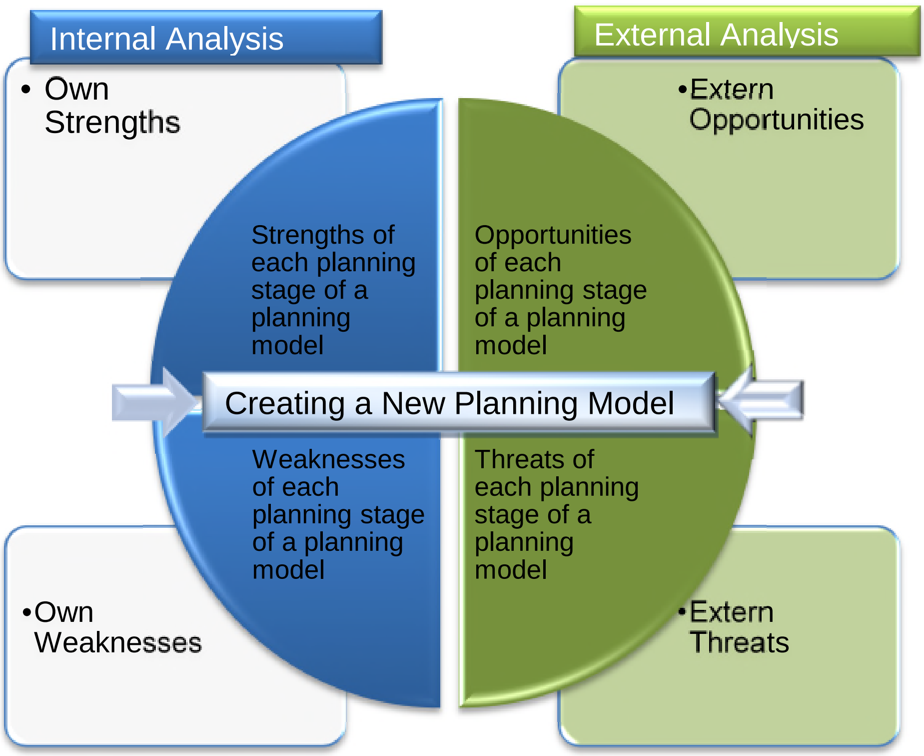


Figure 2.6: SWOT Analysis

Source: Author's design in analogy to (Pelz, 2004)

Structure of Internal Analysis

The internal parts of the analysis are the individual requirements with the strengths and weaknesses of the planning model. Strengths could be, for example, an easily applicable planning model. One of the important steps in identifying requirements is the identification of the critical and successful factors. These are factors of disappointment or of success (Lipps, 2006, p. 3).

Structure of External Analysis

The second part of the SWOT Analysis deals with the external processes, including all other logistics chains which are installed in this logistics system and external aspects that can influence the planning process, such as suppliers. In general, logistics centers handle thousands of different articles and use a lot of different processes (Martin, 2009, p. 344). These processes are connected in a network and influence each other (Krampe & Joachim Lucke, 2006, pp. 49 - 54).

To describe and evaluate the requirements of these thousands of goods is not efficient or useful. Identifying the processes used for the handling of these goods is much more effective and useful in analysis, particularly the opportunities and threats of these processes. The challenge is to locate important process key figures and evaluate them correctly. These factors have to be applicable in case a company has to change or implement new products and services (Pelz, 2004, p. 8).

The logistics and company planning models include five planning stages. SWOT Analysis is used to identify why the existing planning methods cannot be used to plan effective and efficient long items processes.

2.7 Problem Discussion

The long items industries are quite different from each other. The nuclear industry is the exotic one, because of the nuclear radiation a big danger at the handling of these goods for employees exists (RWE AG, 2014). Nevertheless the wood industry is also different, because of the heavy weight of the stocks of the trees and the different dimension of the stocks of the trees manual handling is impossible furthermore the product quality and the packaging quality at the handling are imprecise. The wood industry uses robust processes and robust equipment for the handling of the trees (Holztransporte Muffler, 2014).

Much more similar to the building industry is the steel industry. The difference to the building industry is the value of the goods and the weight of the goods. This is because of the high weight the goods are handled in separate processes. In the building industry the weight of the goods is low and customers order bundles of long items and commercial goods in one order. So the problem exists that these goods have to be handled parallel in processes or in the same processes. But the long items processes are not separately treated at the current planning frameworks. The consequences of the inefficient framework are noticeable in daily work. Because of the inefficient processes the door to door time is too long and the order schedule gets a delay. Thus, customers have to wait for the goods. Furthermore, the order level at the logistics company is not easy viewable. Moreover, the handling of the goods is complicated because goods often have to be buffered and transported. So the processes comprise a lot of waste.

Chapter 3 Research Method

3.1 Introduction

In this chapter, the research progress is described with the research methods. Furthermore, the research and evaluation methods are presented.

3.2 Evaluation and Selection of Research

In this section, the evaluation methods will be discussed against each research question and objective.

3.2.1 RQ 1 and RO 1

RQ 1 deals with the question if customers do have any special requirements for the logistics of long items. Corresponding to RQ1, RO 1 is designed to identify, analyse and evaluate the special business requirements of the long items logistics. To achieve this research objective, the data will be required for finding out the current situations of long item logistics. The data will be analysed to generate the knowledge why current logistics planning methods are not applicable for long items logistics planning. These data are not available from the previous publications. Therefore, they are the primary data.

The primary data are requirements of the customers concerning the goods and logistics processes. This kind of data is not measurable. It can be only analysed because the requirements often base on subjective preferences that occur in the practical work life. Because of this subjective aspect, this data is not measurable. Thus, the quantitative methods are not suitable. It is expected that rational and non-rational input factors are necessary in the first planning stage. Since qualitative methods are suitable to identify non-rational inputs, so qualitative method is used for RQ1 and RO 1. To obtain the customers' requirements, a customer survey will be carried out. Another data collection method is to monitor the customers' behaviours. The disadvantage of the monitoring is that results have to be created by self-estimation. In the social science, there are a lot of different guidance's for the self-estimation of behaviours. But the findings are not always precise (Doblhammer, 2004, pp. 7 - 30). Therefore, a customer survey is the preferred data collection method. A number of different survey techniques exist. To obtain reliable survey results, only the persons with expertise knowledge at the research area should be surveyed. In this project, a specific personal group with the expertise knowledge of the long items in the building industry will be selected as the experts for the interview. Besides, to achieve reliable results it is necessary to carry out multiple interviews in every stage of each supply chain. The findings of the interview will be used to propose a planning framework for long item logistics systems. The framework describes the groundwork of every logistics system. It describes the constraints of the model. The model contains the whole planning phases.

As presented in Chapter 1, each research objective is planned corresponding to a research question, so in this section, the research objectives will be evaluated based on their corresponding research question.

A survey can be done "one by one" or by paper, phone or e-mail with open or closed questions. Closed questions have multiple-choice answers. Open questions do not have answers to choose (Liebold & Trinczek, 2009, p. 38). That means the interviewed persons can answer the questions in the way they like. The answers are usable if they are only from persons that are really involved in the long item handling or have expertise knowledge. Thus, persons from the whole supply chain have to be asked.

It is understandable that all interviews cannot be carried out in the same day but they have to be done in short schedule. The short schedule is necessary since the knowledge level of the experts is roughly the same (Liebold & Trinczek, 2009, pp. 35 - 42). The presentation of the findings will be shown in a spider chart. Two different types of spider charts will be created, as shown in Figure 3.1. The first type of spider chart handles inputs from the answers of each supply chain stage. The second type of spider chart cumulates all answers of each supply chain stage. Thereby differences and similarities will be identified.

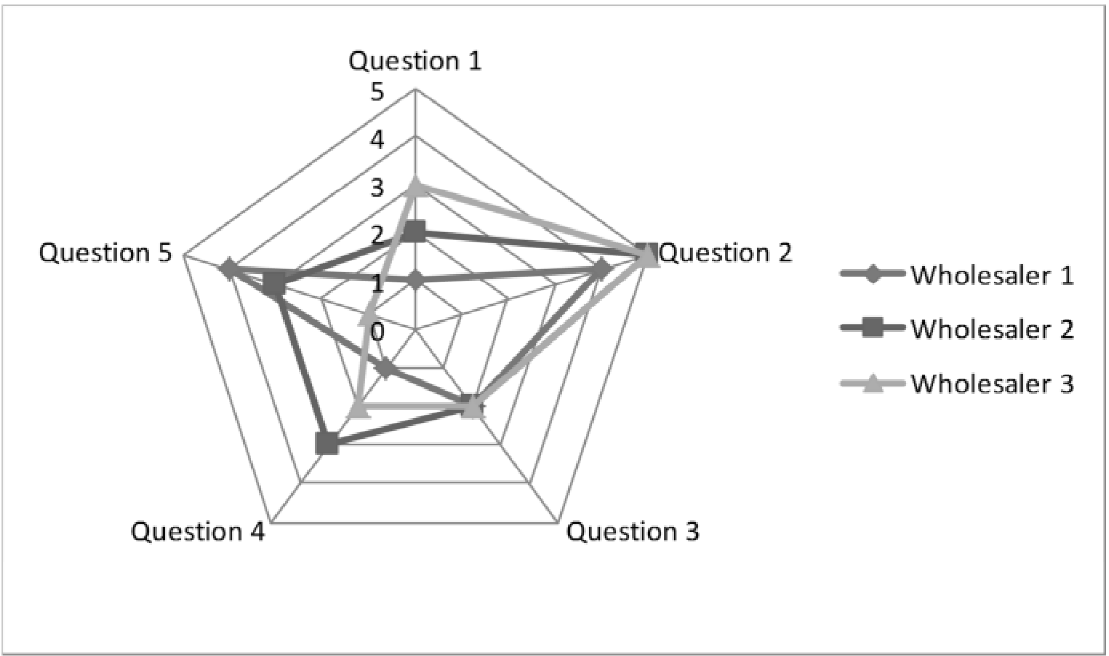


Figure 3.1: Example Spider Chart

The interview contains test questions that have to be answered in the same way. The evaluation of the expert interview is used to find out if one expert answers all questions in the same way. If yes, that means that the answers are stringent, which is a first indicator for the good quality of the expert interview. The second stage of the evaluation is to check if all supply chain stages are answered in the same way. If considerable differences in the way of answering the questions can be identified, the differences have to be analysed and evaluated.

A further evaluation method of the interview itself is to examine the personal conditions of the interview partner. Besides general excellence criteria e.g. the documentation of the interview exist for the qualitative research from Mayring (Mayring, 2003, pp. 111-154). With these excellence criteria the interview can be evaluated (see Chapter 4).

3.2.2 RQ 2 and RO 2

RQ 2 deals with the question what the most sustainable method for designing a new, cost-effective long item in-house logistics process is.

To answer this question, a new framework for the planning of long items logistics processes has to be proposed in this project. This is only possible by using the primary data that are collected, analysed and evaluated at RQ1 and by using the secondary data. The secondary data are collected by reviewing literature that describes models for company and logistics planning. The aim is to gain the knowledge about the structure of the models to which application the current planning models are usable and where the limitations of the existing planning models for meeting the requirements of non-long item goods (commercial goods) are. As far as the author is aware, the study of logistics planning frameworks is fairly new though there have been the efforts of some industrial applications (Nyhuis, 2008, pp. 2 - 4). There have not been many reports on systematic studies of the logistics planning frameworks for long items. Thus, it is both theoretically and practically important to study the planning aspects that are not covered by the current existing planning models.
One example for a planning model is shown in Figure 3.2.

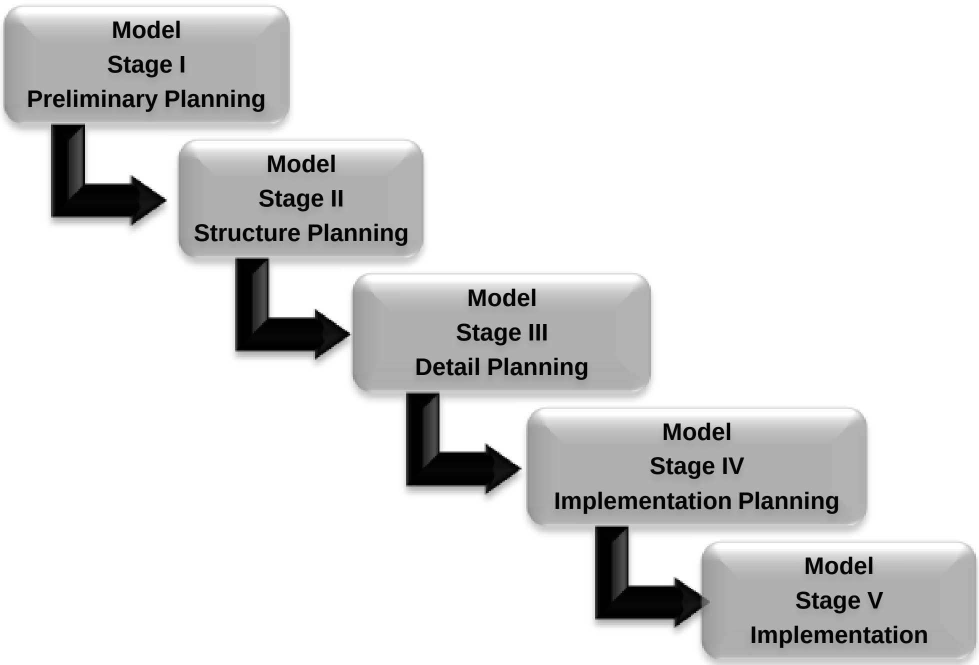


Figure 3.2: Example of a Model (Felix, 1998, p. 37)

The findings of the second research question are presented in a stage model (see Figure 3.2) and a framework (see Table 3.1). The stage model shows the planning processes of a logistics system. The framework and the model are closely connected. The framework is defined by the attributes and the organisation (see Table 3.1). The attributes of the logistics include eleven subcategories of attributes. Within these eleven subcategories, the work of a logistics system can be described.

For describing a logistics system, the questions depending on the organisation of the logistics are important. This part has five sub questions.

To answer these sub questions correctly, the logistics supply chain has to be divided into stages (“Attributes of the Logistics System” and “Organisation of the Logistics”) as shown on the top of the framework because all of these stages have different attributes and organisations of the logistics. All attributes are described in detail in Chapter 6.

Table 3.1: Example of a Framework

Source: Based on (Gudehus, 2005, p. 568)

		Intra - Logistics	External - Logistics	Internal - Logistics
Attributes of the Logistic System	Description			
	Location			
	Network			
	Source			
	Sink			
	Operating System			
	Material Flow			
	Information Flow			
	It - System			
	Improvement Process			
	Products			
Organisation of the Logistic	Logistic Operator			
	Owner of the Operating Equipment			
	Transport Service			
	Owner of the Transport Equipment			
	Owner of the Stock			

The evaluation of the present planning framework is carried out with the SWOT analysis as shown in Figure 3.3. The SWOT analysis method is a qualitative research method. This analysis method compares internal and external aspects and creates new possibilities to develop new planning methods. By this comparison, important aspects can be evaluated. These aspects are the strengths, weaknesses, opportunities, and threats. Thus, the evaluation of e.g. strengths like a clear focus on the planning task is done. So it is necessary to identify key structures and characteristics that help define the planning framework of logistics. By the application of different strategies, new possibilities in the planning process will identified. With these new possibilities and the evaluated customer requirements from RQ 1, a new planning framework for the long items, planning process can be defined and proposed at this stage in this project. To evaluate the created planning framework it is necessary to test it in the case studies.

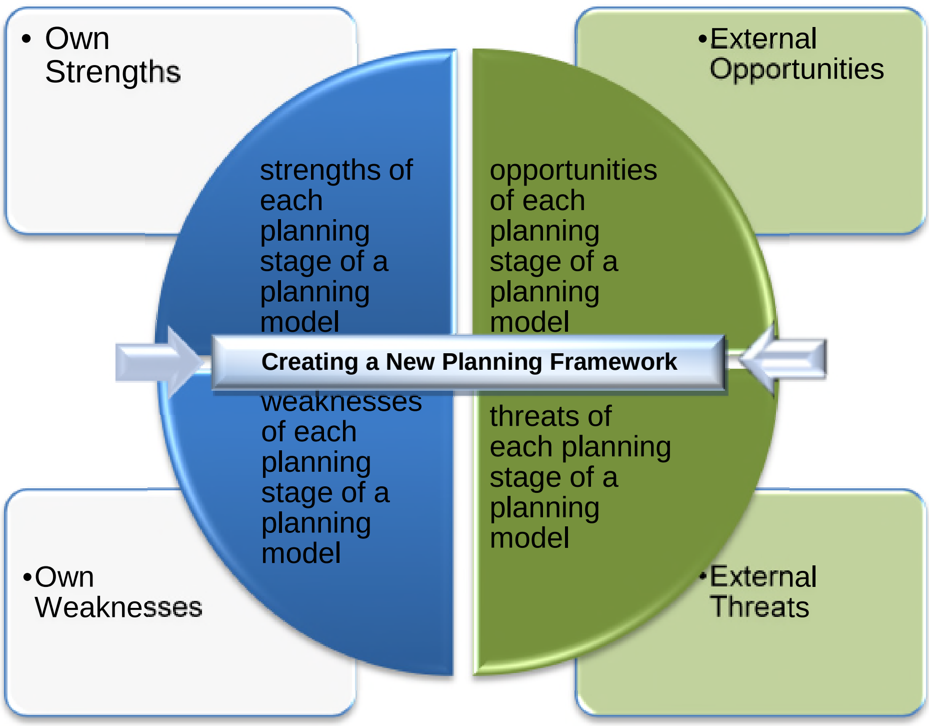


Figure 3.3: Evaluation by the SWOT-Method

The second possibility of evaluating a logistics planning framework is to use criteria as listed in Table 3.1.

The columns of Table 3.2 show the variants 1 to n and the rows list the design criteria. These criteria are described in detail at chapter 6. The first design criterion is the work-effectiveness. The work-effectiveness can be defined in different ways. It can be analysed for example by measuring the processing time or the door to door time. A further method for evaluation is to compare the measured results. For example, the process costs in the incoming goods area can be compared with different planning variants to find out which variant is most cost-effective variant.

Table 3.2: Evaluation Criteria of Logistics Frameworks

Design Criteria	Variant I	Variant II	Variant n
Work - Effectiveness			
Cost - Effectiveness			
Flexibility			
Usability			
Expandability			
Information - Flow			

The second design criterion is the cost–effectiveness. To measure the cost-effectiveness economic criteria are usually used. For example, the return on invest. The third design criterion is the flexibility. It is important to develop a flexible framework, because when the customers' requirements change, the framework has to be flexible enough to handle this change. However, the framework should not be too complicated. Otherwise, the applicability of the framework is limited. The design criterion of expandability describes to what level the system can be expanded. That means that if further long items are handled in the processes, the framework has to be flexible enough to handle these long items as well. The last design criterion is the information flow. The

information flow describes how the information flows from one process to another process.
The third way to evaluate the results from RQ 2 is to evaluate the new framework for the long item logistics chain planning by a case study. The case study has to be done in a logistics company that handles long items in the building industry. Above all, the chosen company has also to handle other small items. This is because it is necessary to handle long items together with commercial goods in the daily work of long item logistics. For example, a plumber needs a fitting to connect pipes. The results are evaluated to find out if the framework is suitable to plan long item logistics chains.

The last possibility for the evaluation of the results of RQ 2 is to examine the criterion information flow. It is important that during the whole framework continuous information flow exists.

3.2.3 RQ 3 and RO 3

Research question three deals with the question what the key factors for the implementation of a cost-effective, sustainable in-house logistics system for long items are. In my thesis, the key factors for the implementation of a cost effective and sustainable in-house logistics system for long items are identified.

The data collection for RQ 3 is divided into three parts (see Figure 3.4). To solve this research question, the primary and secondary data about the customer requirements will be used. The primary data are collected using the developed planning framework from RQ 2 by a case study. The case study has two tasks. The first task is to evaluate the framework. The second task is to collect primary data for RQ 3. The secondary data are collected by the critically review of the methods for the handling of continuous improvements in daily work life.

By considering the key factors, the improved handling should be more cost-effective and sustainable.

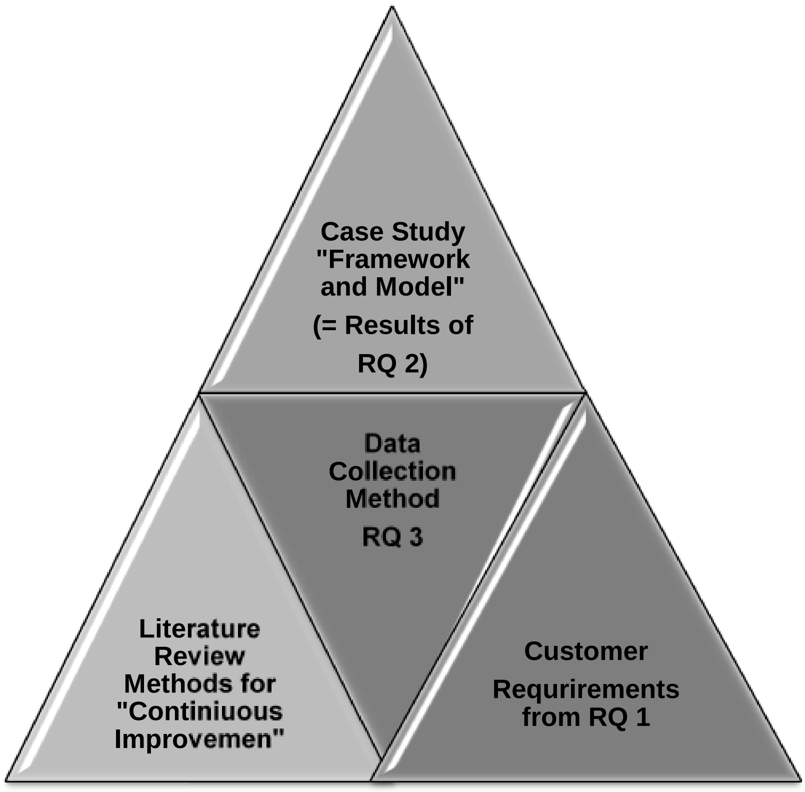


Figure 3.4: Data Collection RQ 3

The planning of a continuous improvement process can be divided into four stages. One common continuous improvement process is shown in Figure 3.5. This improvement process handles four different stages: the sensitising, start, implementation, and stabilisation stage. In the sensitising phase, the targets of the management board, the continuous improvement process and the company targets are analysed. At the start phase, the continuous improvement method is used. Also in this stage, resources like employees, time schedules, and costs are planned.

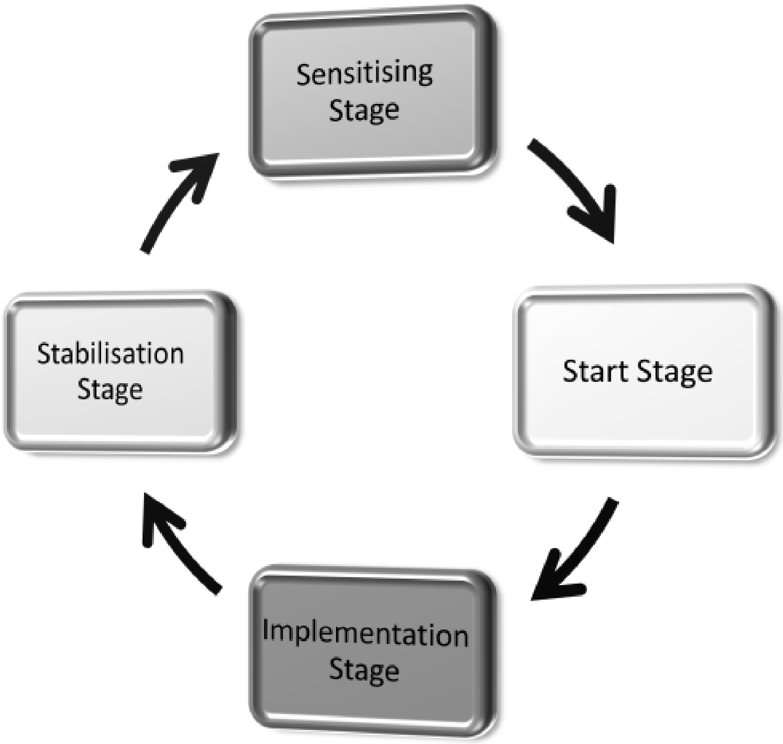


Figure 3.5: Example of a Continuous Improvement
(based on (Ohno, 2009), (Schlott, 2012))

At the implementation stage, the waste has to be identified and analysed (Schlott, 2012, p. 140). The wastes can be divided in two main parts. The waste that is not necessary for operation processes and the waste that is necessary for operation processes. The waste that is not necessary (e.g. overproduction) has to be eliminated as soon as possible. The waste that is necessary to use processes has to be reduced stage by stage. One example of this type of waste is the transportation of goods. Products have to be transported from one process to the next process. However, the distance between the processes should be minimised so that the waste is reduced. Beside the transportation, other types of waste exist. In whole, 7 types of waste exist (Ohno, 2009, pp. 91 - 93). In the last stage, the stabilisation, the processes should be optimised and made as efficient as possible so that they can be used in daily work life. After this stage, the improvement process is finished. At the implementation of a new logistics system, a large number of improvements will be identified. Therefore, it is expected that the improvement process in the implementation stage is very important. A lot of logistics companies have a functional improvement handling installed but they also have problems with the implementation of a new logistics system. Thus, it is necessary to identify further key parameters that have influences on a frictionless implementation of a new logistics system.

To evaluate the key factors from RQ 3 the same evaluation criteria for RQ 2 are used (see Table 3.3). But there are two additional criteria. The first additional criterion is the “number of improvements”. For this evaluation, the registered improvements at the implementation are investigated. The second additional criterion is the “number of implemented improvements”. It is important that improvements are identified and developed further and that the solutions are integrated at the implementation as soon as possible.

Table 3.3: Evaluation Criteria of RQ 3

	Developed Framework
Work - Effectiveness	
Cost - Effectiveness	
Flexibility	
Usability	
Expandability	
Information - Flow	
Number of Improvements	
Number of Implemented Improvements	

3.3 Procedure of Research

The research consists of three parts (see Figure 3.6). The first part is to carry out an expert interview. Through the one to one face expert interviews, the customer requirements are collected, analysed and evaluated for all stages of the whole supply chain in the case study. As discussed in Chapter 1, in this project, the building industry is chosen for the case study since in this industry many different long items are used and handled.

To make the collected data and hence, the analysed results representative, it is necessary to investigate every stage of the supply chain stages. Besides, it is necessary to carry out multiple interviews in every stage to find out which requirements are important on every stage. The quality of the data collection will be maintained to make sure the findings from the interview are meaningful. One method for achieving this is the comparison analysis of the answers of different interviewees. The analysis will deal at each research area with the question, if the similarities and differences between the answers of the interviewees are coherent. That means it is reliable to use the interview findings to obtain the customers' requirements of the logistics chain process design of long items and to design the process planning framework of a new in-house logistics system for the building industry.

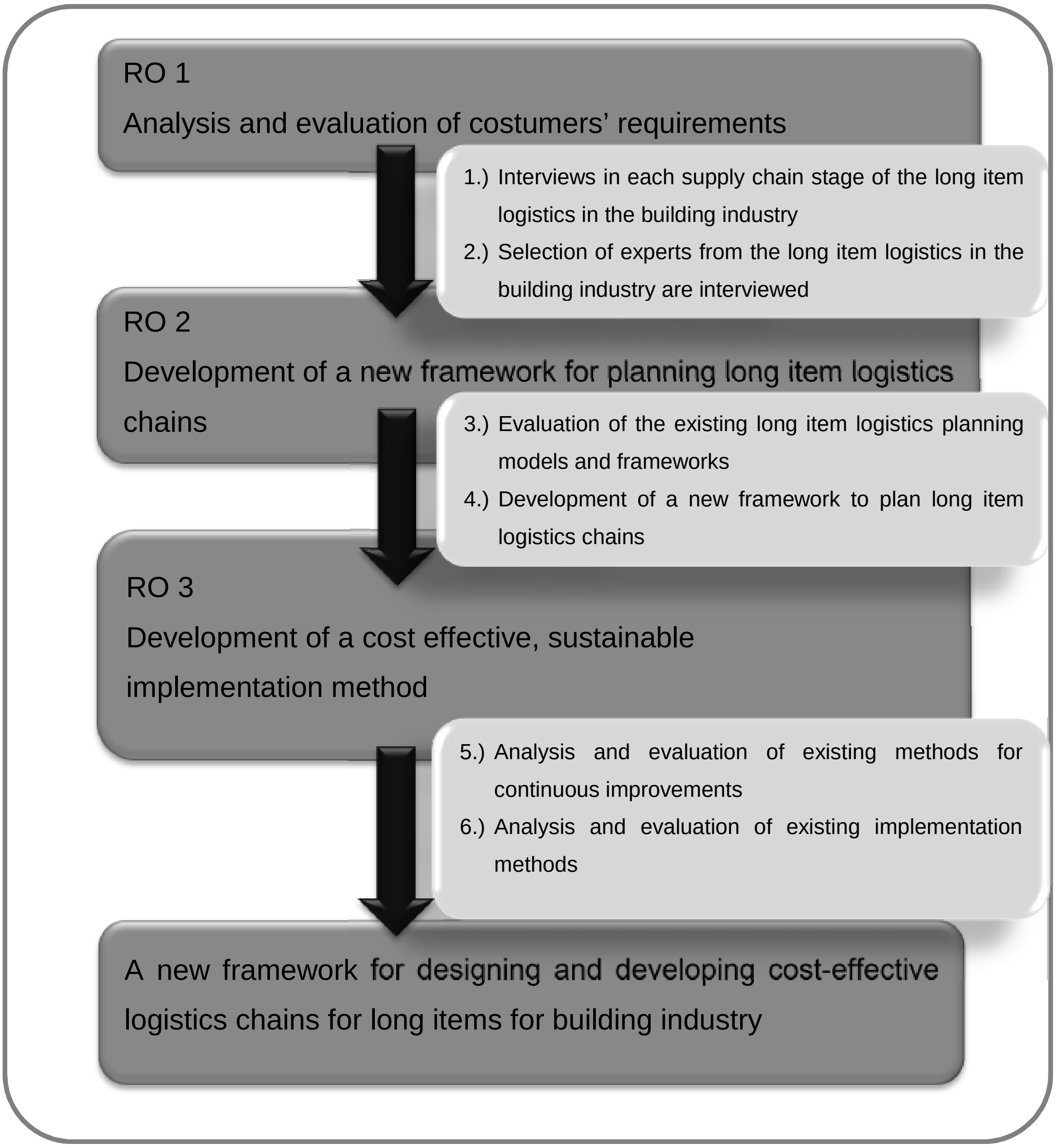


Figure 3.6: Research Design

The customer requirements are used as the inputs for solving the second research question hence to achieve the second research objective. To solve this research question, the logistics and company planning methods have to be analysed and evaluated. Through the Strength, Weaknesses, Opportunities and Threats method (SWOT-method), the existing planning frameworks will be evaluated. The results from SWOT analysis will be used to propose and design a new planning framework for the long items.

To evaluate the new long item logistics planning framework, the case study method will be used. The case study has two targets. The first target is to find out if the framework is applicable to plan cost effective and efficient long items logistics processes. The second target is to find out which requirements are necessary for a successful implementation. Furthermore, this is an iteration process of optimising the proposed and designed framework using the findings from the case study. Through this iteration process, a new cost-efficient, sustainable implementation method will be proposed, designed and developed.

At the end, when all three research questions are solved, a new framework for designing and developing cost effective logistics chains for long items can be designed and developed.

3.4 Ethical Issues

In this PhD project, the required data are colected from the existing literature or generated by the author's own design. The data from third parties are only collected with their permission. The interviews of experts are one to one interviews. To ensure the security of the confidential data of the participants, all individual data are treated strictly confidential. The agreement of all planned interviewees will be obtianed before interviews.

Chapter 4 Data Collection, Presentation, and Analysis

4.1 Introduction

The expert interview is also called a non-standardised interview or qualitative interview (Kühl, et al., 2009, p. 37). The expert interview has clear and specific content and a clear structure (Meuser & Nagel, 2009, p. 465) (Spath & Walter, 2012, p. 33). An advantage of the expert interview is that once the interview questions and the expert who will be interviewed have been chosen, the field of knowledge is also defined (Ahlrichs, 2012, pp. 107-109). An expert interview is usually an open interview with open questions. This is advantageous because it allows both the researcher and the interviewee to come up with completely new ideas over the course of the interview process. This can mean that the research may take a different direction than initially assumed, depending on the findings in the interview (Sapsford, 2007, pp. 3 - 4). Because it combines open questions with the specific structured questionnaire and the specific choice of experts, the expert interview is also said to offer a closed or semi-structured openness (Liebold & Trinczek, 2009, p. 37).The expert interview is one of the most widely used methods in the empirical social sciences. It can be used as independent method or in combination with other methods (Pickel, et al., 2009, pp. 519-522). The expert interview is rarely considered in the sciences. The reason for this is that it is a mixed form of research interviews. On the one hand, it has a focused content that has been structured by the interviewer. Thus, the researcher gains access to the interview partner's knowledge step-by-step over the course of the interview. The questions are asked in an open manner, which allows the interviewee to answer freely in his or her own words. In practise. a semi-structured interview is often used. In a semi-structured interview, the research designs questions in advance that provide a general structure for the interview (Pöchtrager, 2011, p. 283).

On the other hand, the choice of experts and the choice of the questions in the questionnaire help to determine the general direction of the interview. The open questions can also lead to the development of a new conceptual framework (Liebold & Trinczek, 2009, p. 37). To counteract simply following the main stream research, it is necessary to interview experts who have experience using and applying different methods of problem solving or who represent different segments in a logistics chain.

4.1.1 Identification of the Experts and their Levels of Knowledge

Experts are persons who have specific knowledge in a given area (Meuser & Nagel, 2009, pp. 466-470). To identify experts, you must first define the area of knowledge you would like to pursue. For any concepts that reach beyond this area, the knowledge of the experts is not specific (Kühl, et al., 2009, pp. 33-34). Experts have obtained a specific level of knowledge in their job, scientific work, or other professional experiences, and their knowledge is recognised by other people. Moreover, it would be extremely difficult if not impossible for other people to solve problems in a specific area of knowledge without such expertise.

There are two ways to define the knowledge level of an expert through an interview.

The first way to identify an expert is to find a person who would like to develop a specific research area. That means he/she is working on a problem and is looking for a solution. In this case, the expert could also possibly be a scientist working in this area. The respondents for this expert interview were found at a colloquium in which they presented their research findings as well as through careful analysis of publications in the scientific area at hand, e.g. long-item logistics.

The second way to identify an expert is to identify a potential expert who has specific knowledge and access to knowledge in this specific area (Meuser & Nagel, 1997, p. 484). Thus, the interview partners are persons who have the knowledge and the ability to design, implement, and control a problem in their area of expertise. This means that it is not the personality or the biography of a person that defines him or her as an expert (Kühl, et al., 2009, p. 35), (Rottbeck, 2013, p. 160). For the expert interviews, business partners with expert knowledge have been found. Their level of knowledge was evaluated before the interview by checking their publications and comparing them with other scientific approaches.

Experts are located in all stages of the supply chain (Klare, 2010, pp. 139 - 140). The supply chain in the building industry is divided in to five stages. At the beginning, the definition of the supply chain step is set. A producer is a person who manufactures articles (Bünting & Karatas, 1996, p. 890). The production is a technical procedure to manufacture goods (Brockhaus_a, 1972, p. 159). Goods in the building industry are for example pipes, window profiles, fittings, and so on. Especially producers of long items face the challenge that long items are extruded. They need very long machines, which can be longer than 100 metres.

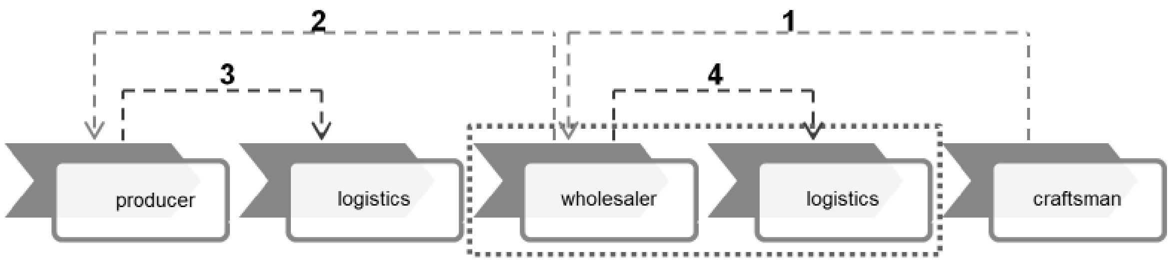


Figure 4.1: Supply Chain of Long Items in the Building Industry
Source: Author's design in analogy to (Corsten & Christoph, 2004, p. 60)

Wholesalers are salesmen who buy goods and sell them again (Bünting & Karatas, 1996, p. 475). Wholesalers sell goods directly to the customers or only with little improvements (Brockhaus_b, 1969, p. 708). In the building industry, wholesalers offer the whole range of building products and customers can buy all products which are needed at a building site from one salesman.

A craftsman is a person who has learned a specific trade (Bünting & Karatas, 1996, p. 353) (Brockhaus_c, 1968, p. 10). In the building industry, craftsmen include plumbers, carpenters, electricians, and so on.

The producer is placed at the first stage of a supply chain, as he/she is getting an order from the wholesaler. The wholesaler has a preferential position between the producer and the craftsman and operates as the interface between them. The wholesaler in the building industry has all products which are needed

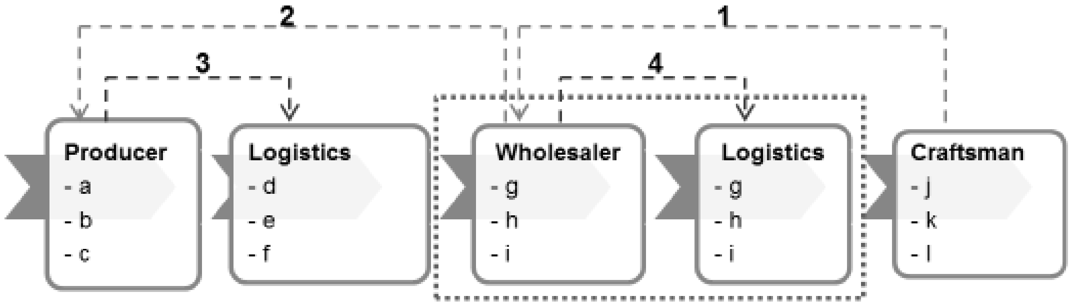


Figure 4.2: Logistics Experts
Source: Author's design based on (Corsten & Christoph, 2004, p. 60)

on the building site. So, architects and building planers can obtain all products which are needed from one wholesaler. Thus better conditions can be reached.

The producer has the advantage that he/she can produce and send articles to the wholesaler in a high volume. The task of the wholesaler is to store a broad spectrum of articles. He/she also distributes the articles and sends them to the craftsman. In most cases, he/she does not send them directly to the craftsman, but to the building site. The material flows from the producer to the craftsman and the information (order information) is transmitted from the wholesaler to the producer in four steps. From the craftsman, the information flows to the wholesaler and from the wholesaler to the producer (see Figure 4.2, lines (1) and (2)). The information flows (see Figure 4.2, line (3)) from the producer to the logistics and from the wholesaler to the logistics (see Figure 4.2, line (4)). This information flow is only handling delivery data, which means that the main information flow is opposed to the material flow; therefore, a pull system exists.

The logistics between the producer and the wholesaler is mostly an external one. The logistics between the wholesaler and the craftsman is mostly an internal one. That means that the logistics is mostly a part of the core competence of the wholesaler. Competences demonstrate knowledge of a special area (Brockhaus_d, 1970, p. 399). Core competences are competences which are *"skills that enable a firm to deliver a fundamental customer benefit"*

(Prahalad & Hamel, 1990). This is substantiated because customers get their goods quickly because wholesalers use their own resources and can control this by themselves.

To get a meaningful estimation of customers` requirements, it is necessary to look at all parts of the supply chain (Meuser & Nagel, 2009, pp. 466-470). Moreover, it is necessary to find the right extent of the survey. This means that because many different articles exist in the building, the interview partner should handle a lot of different long item articles.

The choice of the interview partner is shown in Table 4.1. The producer produces very different articles. For example, producer a produces metal and non-metal products for the building industry. Producer b produces water and waste water pipes; and producer c produces profiles and pipes for the building industry.

The interview partners in the logistics area are international businesses and transport all of their products for the building industry worldwide.

The wholesaler and the second logistics partner are closely linked together because the wholesalers usually have their own logistics. The wholesalers g, f, and i are sellers which deliver the building industry. The function of a wholesaler is to store and deliver directly to the building site. The demand of such articles is short-term; therefore, the wholesaler usually has its own logistics to transport the articles to the building site.

The last step in the supply chain is the craftsman. The craftsman uses the articles in the building industry. The chosen experts are two sanitary craftsmen, j and k. In the sanitary industry, often long items, for example water and waste water pipes, are used. The third interview partner is l, which installs metal profiles on the building site, such as tracks for garage doors or design metal profiles.

To evaluate if the chosen persons from the various steps of the supply chain are really experts, the characteristics which identify an expert are checked. If the given individual is really an expert, he or she must fulfil all points (see Table 4.1).

Table 4.1: Evaluation of the Expert Status

	Producer			Logistics			Wholesaler			Craftsman		
	a	b	c	d	e	f	g	h	i	j	k	l
A person who is accepted from other people that he/she is an expert	X	X	X	X	X	X	X	X	X	X	X	X
A person who could solve a problem in a special research area	X	X	X	X	X	X	X	X	X	X	X	X
A person who develops the research area by his own	X	X	X	X	X	X	X	X	X	X	X	X

4.1.2 Methodology of the Expert Interview

In an expert interview, complex correlations of knowledge are reconstructed to describe phenomena in the area of expertise. The researcher collects data in a communicative way. This means that it is necessary that the researcher and the expert relate to and communicate with each other. The researcher asks questions in an open manner, so the expert can answer freely, in his/her own words, and with as wide of a range of answers as he/she chooses (Meuser & Nagel, 2009, p. 472). An expert interview has no pure or strict form or structure, but it always has a clear thematic and structural orientation. The structure and the content of the interview is defined before the start of the interview. The focus and aim of the interview is to obtain the interviewee's specific knowledge step-by-step. The expert must not be influenced by the interviewer. The questionnaire of an expert interview only contains open questions, meaning that no answer possibilities are given. Flexibility and openness are key. The questions are a help or guide to find the way to the expert's specific knowledge on the given subject. During the interview, the interviewer must not influence the expert with his interpretations of things because only the opinion of the expert is of interest. The interviewer has the task to guide the interview. If he/she is not reserved enough, he/she could influence the expert's answers (Trinczek, 1995, pp. 59-67), causing the interview to be thrown out in later analysis. In order to evaluate the practicability of the interview, it is necessary to conduct a test interview at the beginning. Afterwards, the researcher must decide whether the open question structure is conducive to gaining the desired information, which, in the current study was about customer's requirements of the long-item logistics.

A disadvantage of the open questions is that the expert might think the interviewer only has amateur knowledge. Also, it can occur that conversation breaks slow down the flow of speech, thus inhibiting access to the expert's knowledge open (Liebold & Trinczek, 2009, p. 39). A further negative aspect is that the interviewer might react to the interviewee's answer and therefore influence the interview (Binder, 2006, p. 70).

If the expert loses the scope of the research area, it is useful to repeat the target of the interview, the problem that has to be solved, or in which way this specific area could be developed (Meuser & Nagel, 1991, pp. 441-471).

To consider the personal background of the expert is just as important as it is in other scientific areas. This means that the personal status of the person, their age, their gender, and their milieu affiliation are relevant. The conversation could be inhibited in case of e.g. different gender and age. For example, it can be difficult for a young female scientist if the area of expertise is dominated by males (Abels & Behrens, 1998, pp. 131-143). This is because the danger exists that experts could connect a slight body structure with a different interview style and link this with incompetence.

The duration of the interview should be maximum 20 to 30 minutes because in the industry, time is a precious good and managers do not like to “waste” time (Punch, 2003, p. 35).

4.2 Data Collection

4.2.1 The Interview Survey Questions

The survey objectives are derived from the research objectives (Punch, 2003, pp. 26-27). The target of the expert interview is to solve RQ one. Therefore, at first, the value types (quality, delivery date, packaging, storage, handling, and order (see Figure 4.3) have to be defined in order to derive the research questions from research objectives (Opielka, et al., 2010, pp. 47-51).

Figure 4.3 Derivation of the Interview Question

These value types are developed by taking a look at the customer. We have to look at the steps in which customers touch the long items physically or electronically. This has to be done upstream, which means against the material flow, just like the point of view we have in a value stream mapping (Rother &

Shook, 2006, p. 12). So, if we have the view upstream, customers first get in touch with the quality of the product. One step further, the customers handle the product, for example, at the installation. At the next step, the goods are stored. To store products, they have to be packed, for example, with steel straps. Again, one step further, the delivery date is fixed. In the building industry, the delivery date is an important key factor because a lot of different craftsmen have to work hand-in-hand at the building site. Therefore, the last step at the view upstream, against the material flow, is the order. For example, if the order is directly done at the building site, there are only a few possibilities, likely only one, which is to complete the order by phone.

The value types describe the area around which the interview questions are centred. To focus the interview on the topic of “long items,” the questions for the order, which is the first step at the value stream, are not asked. This is because the questions about the order do not tend directly to the long item product. The delivery time tends to be related to circumstances which are linked with the long item. But such questions are not useful when trying to get to the root of the matter. Therefore, it is better to ask the questions about the order at the end of the interview and to switch the value type “Quality” and “Order” like in Figure 4.3.

The aim of the expert interview is to generate inputs to contribute aspects to solve all three research questions. The main focus of the interview questions is to look for inputs for RQ one. Moreover, the expert interview is supposed to generate inputs for the third RQ.

1. Do customers have any special requirements for the logistics of long items?
2. What is the most sustainable method for designing a new cost-effective long item in-house logistics process?
3. What are the key factors for the implementation of a cost-effective sustainable in-house logistic system for long items?

At the start of the interview, small talk and general questions are necessary to get the conversation going. The general questions of the interview are useful to reach a harmonic interview atmosphere. Also, small talk could be used to verify whether the expert is really an expert. In case of the expert interview, many of the interviewed persons work for a company. Therefore, questions about the company and the individual's area of expertise are a good start. Starting the interview in this general manner demonstrates the researcher's respect for the company and the expert. A first set of questions deals with the following aspects:

1. Which sorts of long items do you handle?
2. At which segment of the supply chain does the company work?
3. In which area do you work in the company?

The following questions are questions help to identify the experts. Some examples are shown in the following.

1. Which characteristics can you identify that demonstrate your company's weaknesses in handling long items?
2. Which options exist to find a solution for these weaknesses in long item handling?
3. Do you improve the long item handling by yourself?

After evaluating the experts in such a manner, the questions from the survey start. The survey is divided into six blocks that each contain a set of questions. The first block of the survey deals with the quality questions. The quality questions are closely linked with the customers' requirements. At this stage, the questions apply to the quality of the product and the packaging. In detail, they are:

1. Is the quality of the delivered goods important for your company?
2. How important is the quality of the package for the long items?

The second part of the survey deals with the delivery time. There are different aspects, such as the duration of the delivery, the information flow at the delivery, and the actions to be taken if the delivery date changes.

3. What time do you want to get the products delivered?
4. How important is the information about the delivery date?
5. Which information do you need if the delivery date cannot be observed?

The third part in the interview deals with the packaging. This is the second part which deals with the packaging, as questions about the quality of packaging are asked in the first section as well. The difference in this stage is that the focus is on the technical aspects of the packaging and the handling. Also, ecological aspects are addressed.

6. Which package is needed to transport long items?
7. How many different types of packaging material could be used?
8. Normally, wood pallets are used for each long item. They are fixed e.g. with nails. Which material should be used for the packaging?
9. Do special requirements exist for the storage packaging?

In the next stage, the storage of long items is discussed. Long items are stored in very different ways. It could be that there are big differences in the storage of the same products in the same logistics chain. These questions help to identify whether the products are stored in a building or outside of a building. Another key factor is the identification of the products themselves.

10. How are the long items stored?
11. How is the labelling of products carried out?

The fifth stage examines the handling which can be done by hand or supported with technology or machines. This question is closely linked with the packaging. For example, special packaging is necessary if forklifts are to be used.

12. How are the long items handled in your company?

The last area of questions deals with the handling of the order. The customers preferences, such as in which way customers would like to place their orders, are in foreground. Every interview partner gets the same questions, regardless in which part of the supply chain the expert works. This is because it is possible that customers are persons from the same or the following stage in the supply chain. For example, if the sanitary craftsman orders products, he will order from the wholesaler. The wholesaler is the supplier and the sanitary craftsman, the customer.

13. How do you like to order?
14. Do you like the information about the order level?

4.2.2 Procedure of the Expert Interview

The expert interview usually has open questions (Liebold & Trinczek, 2009, p. 39). But special conditions regarding the technical area of expertise have to be considered because open questions are rarely used in such a technical field. So you run the risk the expert could connect open questions, to which there are (too) many possible answers, with inexperience on the part of the interviewer (Meuser & Nagel, 2009, pp. 470-472). This could result in limiting the interviewer's access to the expert's knowledge. Another important disadvantage of the open question form is that this form of interview requires a good deal of time. In the business world, time is valuable and experts do not want to lose too much time with the interview. These findings have been made evident during the test interviews.

Hence, as a result, I opted to conduct the interviews using closed questions. With the closed questions, the interview time can be planed precisely so that the interview can be kept in the predicted time schedule. Closed questions indicate that the interviewer has carefully arranged this interview with respect towards the expert and his/her field. Based on this structure, possible answers are formulated before the interview.

4.2.3 The Human Condition

The human condition of the expert in the interview has not been neglected. The human condition describes the emotional state of the person. It is important that a stress-free atmosphere exists during the interview (Liebold & Trinczek, 2009, p. 36). Furthermore, the impression of the physical condition of the expert is important. This means the interviewer has to check if the expert is feeling ill. This information is important to know because the personal conditions of the expert have an influence on his or her answers. Also, the interview time is scheduled towards the middle of regular working hours. This means not at the beginning or at the end of the work day. Paying attention to the human condition of the expert in the interview should guarantee that the expert is able to focus and concentrate on the interview.

4.2.4 Documentation of the Expert Interview

One of the important things about an interview is its documentation. Documentation is necessary for the analysis and the interpretation of the knowledge the interviewee presents during the interview. In an interview structured around open questions, it is necessary to precisely document the whole interview. Since it is nearly impossible to accurately note everything both parties say directly during the conversation, even with a specific style of writing, e.g. steno, it is helpful to use an electronic recorder (Liebold & Trinczek, 2009, p. 40). Similarly, protocols written directly after the interview are not reliable for the analysis because the meaning and affection of the interviewer are inevitably mixed with the answers provided by the experts. This leads only to a lower quality of data (Liebold & Trinczek, 2009, p. 41). However, with the closed question interview, the answers are formulated before the interview and the expert only has to choose one of the answers provided. With this interview style, the expert is less likely to demonstrate inhibition regarding the use of an electronic recorder because he or she is not expected to talk as freely. If an interview is recorded and saved electronically, the expert could be more reserved in his/her speech and/or the answers he/she provides and could block the access to his/her knowledge. Also, it is not possible to exactly interpret the individual answers because they have to be combined and evaluated as a whole. In this stage, there is a risk that the interviewer could answer dishonestly, possibly changing the overall effect of his/her presumed expertise.

However, answers which are formulated and can be chosen from the expert in the interview are exactly to evaluate, making the closed question interview structure the more precise method.

In the test interview, the electronic recorder is used to document the interview. If the expert has an aversion to documentation by electronic recorder, the interviewer can write the answers down directly during the interview.

4.2.5 Realisation of the Expert Interview

The expert interview is divided in two parts. The first part encompasses an assessment of the expert. This part should help to identify the interviewed person as an expert.

Two questions are used for this part. These questions are:

1. What is the most ineffective step in the process of handling long items in your company?
2. How do you improve your handling of the long item?

The expert interview is an interview which can be only considered in context. This means the human condition of the expert is important (Pöchtrager, 2011, p. 286). The interview should strive for objectivity, reality, and validity.

To gain experience with interviews, test interviews have to be done in which real interview conditions are observed. That means that the interview has to be conducted with real experts and the answers have to be in response to open questions. The open question form of the interview should help to gain knowledge which could not be gained in a structured (closed-question) interview. By using multiple choice questions, the evaluation of the results is important. An attentive reading of the evaluation can provide clues to identify new knowledge areas that should be included in the study(Binder, 2006, p. 73). If a clue is identified in the interview, it has to be evaluated and further research in this knowledge area has to be completed. Open questions interviews can only be done directly one-by-one, because the open question form needs a control by the interviewer. If using multiple choice interviews, they could be completed or conducted without the interviewer having to be present. However, in such a case, the interviewer would not gain a direct impression of the personal condition of the expert or know for sure if all questionnaires have been answered under the same conditions and if it was really the expert who answered the given questionnaire.

4.2.6 Experience Gained During the Test Interview

To test the interview, two experts were chosen. The experts to be included in the test interview were chosen by considering the variety of different products and processes each of the experts deals with on a regular basis. For the test interviews, these aspects are important because experts working in companies with a variety of products and processes can identify special requirements for long item handling in processes better than experts from companies which only handle long items. These experts are located in the supply chain steps “logistics” and “wholesaler.” So, considering these aspects, “K GmbH” was chosen from the logistics supply chain. From the wholesaler supply chain, “L KG“ was chosen for the test interview.

The test interviews were conducted to determine if the interview questions were comprehensible and easy for the expert to understand. The second target of the testing was to see if the evaluation of the answers given by the experts is accurate. Two questions were asked at the starting of the meeting, before the actual interview questions were asked. These two questions were aimed at evaluating the expert’s knowledge. If the evaluation works, the interview and the questions posed during it can be used for the actual study. The evaluation criteria are related to the research object and research subject. Furthermore, researchers can use these test interviews to determine whether the answer is substantiated by the existing knowledge in the research area.

The experience of the test interviews showed that the experts did not accept electronic documentation using a dictation machine. Neither of experts interviewed in the test interviews liked that the interview was saved electronically. Their reasoning for this is that the experts have constraints to answer when the answer is recorded. So, to protect the experts, the interviews were documented manually by writing down the answers at the end of each question. Another problem arose regarding the open questions. The length of the interview was about 2 hours and the feedback from the testers was that 2 hours was definitely too long. The interview took 2 hours because the experts used the open questions to answer in detail. Efforts on the part of the interviewer to bring the experts back to the detail level were partially successful. But with the interruption of the detailed answers, the flow of the conversation was interrupted or stopped all together at times. The result was that the expert was not able to pass on all of his knowledge to the interviewer.

Although the experts spent 2 hours in the interview, they did not like to spend so much time on one interview. The feedback from the expert was that the interview length of 2 hours has to be minimised. The maximum length of an interview in the business is 20 minutes. So, the test interview confirms the approach presented by Punch who also realised that 20 minutes is the maximum length of the interview (Punch, 2003, p. 35). To reach this time target, the experts suggested that the open question structure of the interview was very extensive and they would prefer to have a multiple choice questionnaire and no open questions.

According to the statements of the experts, it was not significant that the interview took place during regular working hours. But a good time for interviewing is at the main work time from 9 am to 5 pm. Early in the morning, most experts are busy with daily work and important meetings are often placed later in the day. Thus, the optimal time for the interview would be sometime in the middle of the day.

4.2.7 Modification of the Expert Interview

The interview was improved based on the experience and information gained in the test interviews. In order to reduce the interview time to a mere 20 minutes and to find a better way to document the interviews, the open question structure had to be reformulated to a multiple choice interview. With the closed question structure, more interview questions can be answered in the interview time of 20 minutes (Buber & Holzmüller, 2009, p. 249). A scale from 1 – 4 was created in which the answer 1 means that is not correct / not relevant and 4 means that it is very relevant / very important. Although the interviews are done one-by-one, the possible answers have to be limited to four possibilities. More than four answers are not necessary because of the Recency effect. Recency describes the phenomenon that when persons are asked in the interview they will choose mostly the last answer because they quickly forget the other answers (Jacob, et al., 2011, p. 107). The danger of changing from the open question form to the multiple choice form is that complex connections and contexts could be lost in the multiple choice interview because the answers have to be simplified into multiple choice answers. A further danger is that complex contexts could be generalised (Wolf, 2011, p. 169). By paying attention to these aspects and others, the interview was modified.

With the categorisation of the answers (1 to 4), it is possible to link the relevance with requirements. In the further stages, the requirements will be used for the planning of long items processes.

4.2.8 Realisation of the Formal Expert Interviews

The evaluation of the expert level and the personal conditions of the experts are documented in Table 4.2 (to keep the information of the companies confidential, the names have been changed). If a given candidate did not reach the expert level or if doubts arise at the personal condition, the expert interview could not be used (Creswell, 2009, pp. 178 - 181). All of the interviews took place during the main working hours, from 9:00 am to 3:30 pm.

Each potential expert had to be evaluated according to their expert level. Also, the personal conditions of every interview partner was evaluated and determined to be sufficient.

Therefore, all interviews could be included in the study.

Table 4.2: Conditions of the Interview

Conditions of the Interview									
	Question One		**Question Two**		**Personal Conditions of the Expert**				
Company	answer is on expert level	answer is not on expert level	answer is on expert level	answer is not on expert level	very good personal conditions - no sign of stress	good personal conditions - no sign of stress but a breeze of slightly tense	poor personal conditions - the interview cannot be done	**Interview Date**	**Time of Day, when the Interview takes Place**
a	X		X			X		08.08.2012	09:30 am
b	X		X		X			09.08.2012	09:00 am
c	X		X		X			07.08.2012	03:00 pm
d	X		X			X		10.08.2012	01:15 pm
e	X		X		X			10.08.2012	10:00 am
f	X		X		X			13.08.2012	10:30 am
g	X		X		X			14.08.2012	11:30 am
h	X		X		X			15.08.2012	02:45 pm
i	X		X			X		15.08.2012	10:30 am
j	X		X			X		17.08.2012	03:30 pm
k	X		X		X			17.08.2012	01:00 pm
l	X		X			X		20.08.2012	01:00 pm

4.3 Data Analysis and Evaluation

4.3.1 Evaluation of the Expert Interviews with Producers

The evaluation of an open question interview is divided into "transcription," "paraphrase," "coding," "thematic comparison," "sociological conceptionalisation," and "theoretical generalisation." The "transcription" contains the evaluation of the restructured interview (Valeva, 2012, p. 227). In the "paraphrase" phase, the interview is divided into sections according to content. In the "coding" step, the text passages with the same content are identified and connected to each other (Binder, 2006, pp. 78-81). In the "thematic comparison" phase, the similar text phrases from the different interviews are compared with each other (Liebold & Trinczek, 2009, pp. 41-45). In the "sociological conceptionalisation" stage, the text is completely separated from the content of the individual interview as well as from its initial chronological sequence. Knowledge is combined in the different categories. Then, in the last stage of the analysis, the "theoretical generalisation," the internal connections between the categories are sorted and linked (Meuser & Nagel, 2009, pp. 476-477).

In analogy to the evaluation from the open question interview, the multiple choice interview is evaluated in a systematic way. The major advantage of the multiple choice interview is that the knowledge is not enciphered in a restructured interview. The knowledge is structured to avoid mistakes made in transmission. Hence, the steps "transcription," "paraphrase," and the "coding" are not necessary because of the multiple choice structure. So, the evaluation starts with the "thematic comparison." Every step of the supply chain is evaluated on its own. That means that the results of the given step of the supply chain, e.g. all results of the step "wholesaler," have to be compared with each other. The target of this evaluation is to look for differences and to find an explanation why the differences exist (Liebold & Trinczek, 2009, p. 44).

The results of the expert interviews with the producers are shown in Figure 4.4.

The producers agree that the package quality, product quality, information order level, information in case of disarrangement of the delivery date, and the place of storage are very important. The product, package quality, and the information of the order level are points in which the producers have direct contact with the customers. The place of storage is only important for the producers and wholesaler products have to be packed in a specific way for storage purposes. The biggest differences in the answers are evident in the way to order. This gap arises because Producer 1 is a steel manufacturer and the way to order in this sector is only via a system like SAP or Oracle. Producer 2 and Producer 3 have their history in the building industry, as they produce steel goods for the building industry. Therefore, orders from Producer 2 and/or Producer 3 can be placed in a very simple way, by phone. Producer 1’s business partners are often big companies preferring to have an order process by a system such as SAP. It has emerged that the order differences depended on the company size. Larger companies use a structured order process with the help of an IT-system. Smaller companies use a phone to order products. Another big difference between the companies is in the delivery time. At the scale, one means that the products have two days time to reach the customer. In the sanitary industry, two days delivery time is fine. In other industries, products have to be at the customer just in time respectively just in sequence. Therefore, producers who supply the automotive industry have to deliver at the same day in sequence. The last big difference is in the use of different packaging material. If producers only work for the sanitary industry, they know that only a few different possibilities to recycle packaging material exists at the building site; therefore they only use a few different packaging materials. Producers who deliver to other industries as well are not sensitive to recycling.

In general, the producers are at the beginning of the supply chain. Therefore, they have to consider a good deal of requirements. The chart in Figure 4.4 shows that 9 of the 14 analysed points are important for producers.

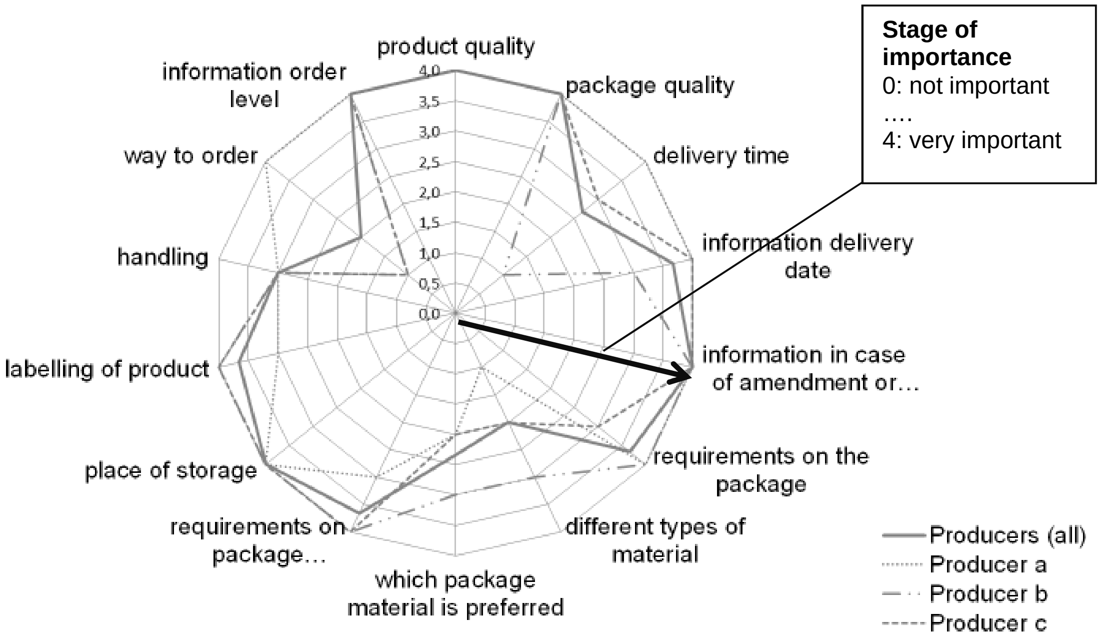


Figure 4.4: Result of the Producer Interviews

4.3.2 Evaluation of the Expert Interviews with Logistics Specialists

The answers in the logistics sector are centred on one area (see Figure 4.5). The answers to the questions connected to the topic “transport” are quite similar. The important requirements for the logistics sector are all points that deal with the scheduling, such as information about the delivery date, information in case the delivery date has to be amended or adjusted, and information about the status of the order. These requirements are necessary for planning how to transport the goods. The logistics sector is responsible for transporting the goods from the producer to the wholesalers. Long items are not usually redistributed to other transports because of the complexity in handling them. Big differences in the experts’ answers were evident regarding the topics “labelling of products” and “quality of packaging.” The differeces exists because of the size of the given logistics division in the respective companies and the different logistics stages.

Larger logistics companies use standardised equipement, such as convoyers, for instance, and they need excellent packaging for these goods. Also, the packaging has to be of good quality because the goods often have to change the transport vehicle if the logistics has multiple stages. For example, a good may arrive by ship and be transported to a truck, which then brings the goods to the customer. Because of these handling steps, the packaging has to be robust and durable.

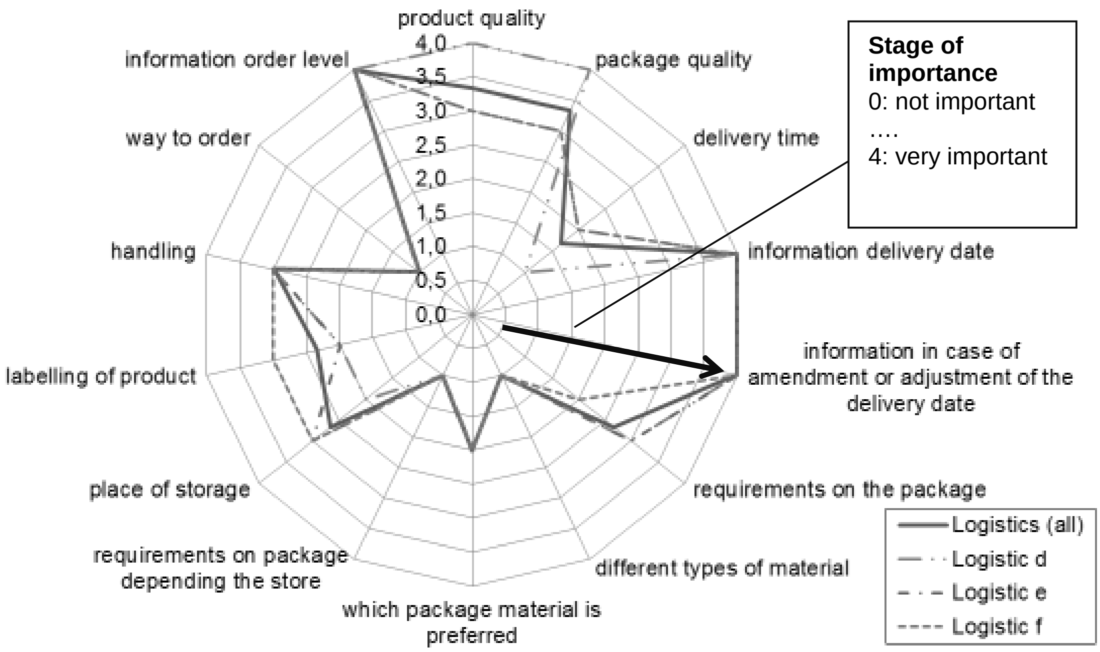


Figure 4.5: Results of the Logistics Interviews

4.3.3 Evaluation of the Expert Interviews with Wholesalers

One of the biggest differences in the interviews with wholesalers is related to the place of storage. This key factor depends on the size of the wholesaler. Larger wholesalers have their products stored in-house and smaller wholesalers store long items outside of a building. Therefore, the requirements for the storage are very different. If the goods are stored in a building, the packaging of the goods has to be more complex because they are handled by forklifts and stored in a storage hall.

Goods which are stored outside of a building often require little to no special packaging because they are stored directly on the ground beside the wholesaler’s shop. At best, they are stored in racks which have a roof. If long items are only seen as a niche goods for the wholesaler, their handling and the storage are often not of special interest to the wholesaler.

A further difference is the way in which orders are placed. Similar differences between larger and smaller wholesalers emerge here as in the place of storage. Smaller wholesalers prefer to order in a simple way like by phone, or E-Mail. To order via a system like SAP or Oracle is not possible for small wholesalers because they do not use such elaborate systems. Thus, differences arise in how orders are placed.

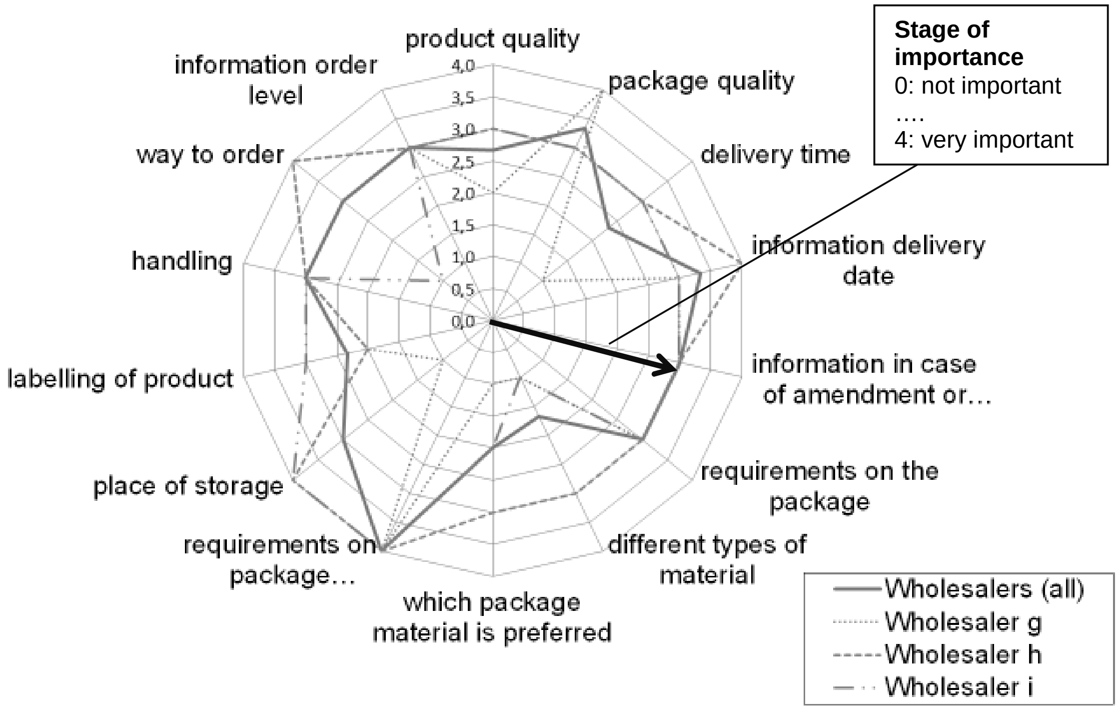


Figure 4.6: Results of the Wholesaler Interviews

The “packaging” is important for all wholesalers because they need functional packaging that is suited to their needs. Wholesalers have to pick products up directly in the storage facility; therefore, they need to open the packaging. After picking their products, it is important that the package can be closed again with minimal effort.

4.3.4 Evaluation of the Expert Interviews with Craftsmen

For the craftsmen, the “packaging” and the “handling” are important as well because they have to handle the goods at the building site. The handling possibilities at the building site are very rare. In best case, a crane or a forklift can be used. In worst case, they can only handle the long items manually. So, in this case the package has to be divided into smaller packages, which can be handled manually.

Craftsmen have different requirements on the way they prefer to place orders. Craftsmen in larger companies use electronic systems to place their orders. Traditional craftsmen like to order by phone directly at the building site.

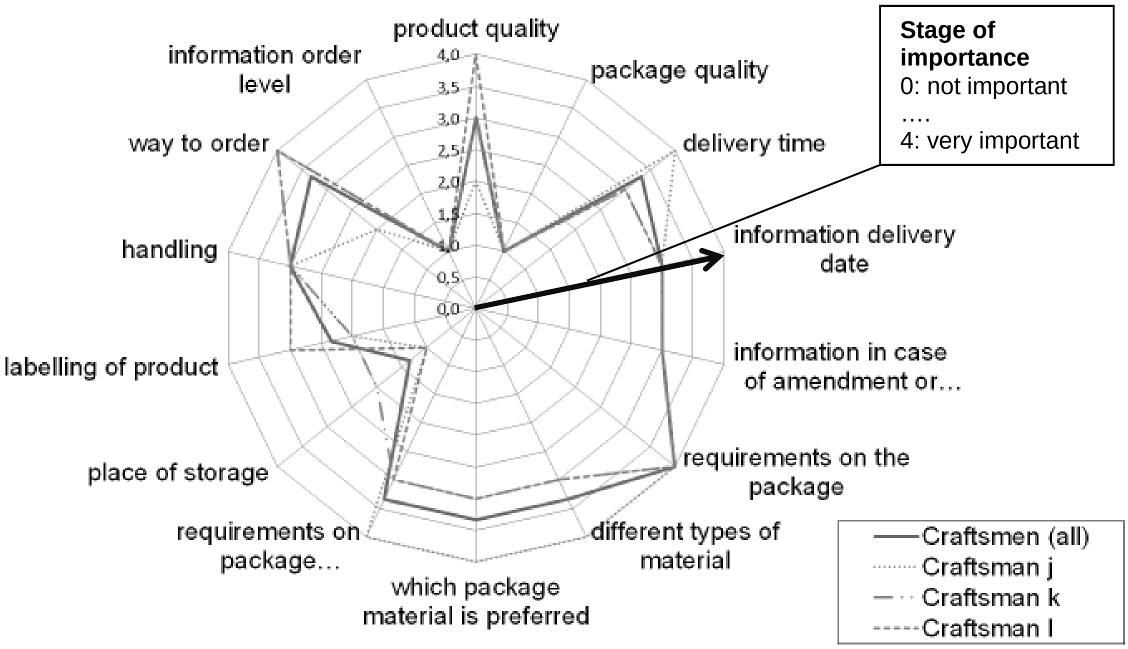


Figure 4.7: Results for the Craftsman Interview

There are also differences in the quality of the products. If craftsmen pre-fabricate products, they need to be of perfect quality. If they install the product directly at the building site, they can cut each product individually. Thus, if products are damaged, the damaged part can be cut off.

4.3.5 Comprehensive Evaluation of the Expert Interviews

Figure 4.8 shows all requirements from the expert interviews, noting details from each step in the supply chain. The red line shows the final summary, which is the combination of the results from all of the interviews. The other lines are the results line from the expert interviews within each step in the supply chain. So, this chart shows that the information about the delivery date and the information of the event that the delivery date has to be modified are the most important requirements across the whole supply chain. Also, the packaging requirements and the product quality are important.

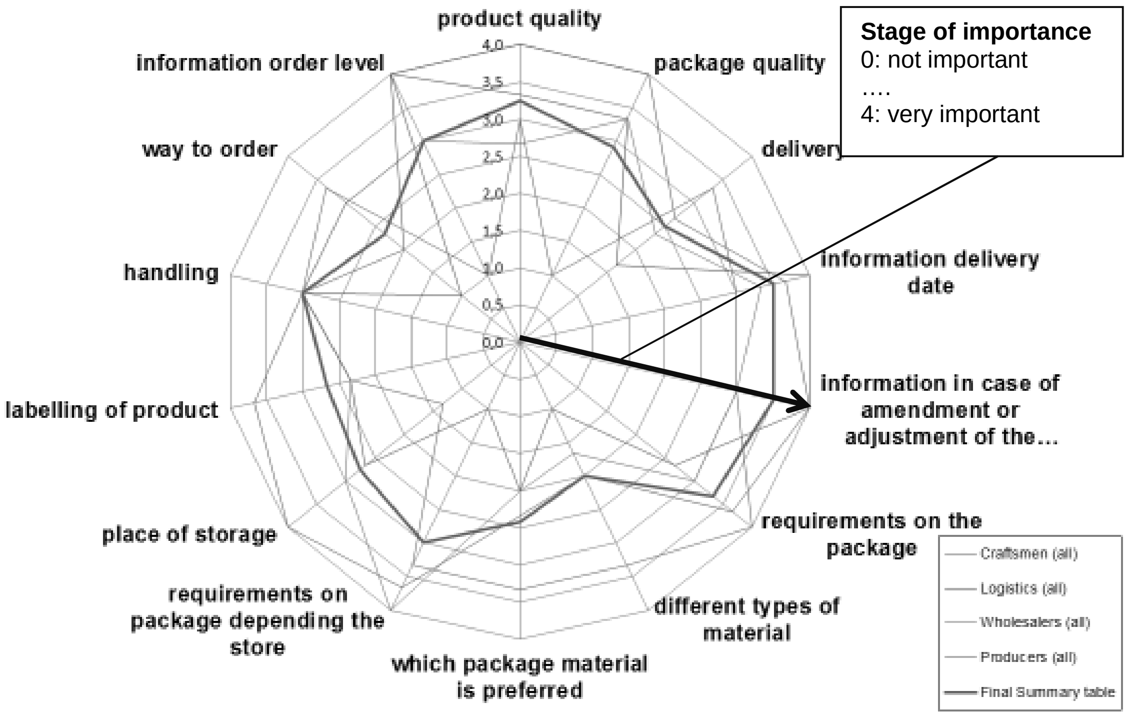


Figure 4.8: Final Summary of Expert Interview

Beyond that, the requirements can be divided into groups. In regard to the aim of this thesis, which is to develop a new framework for designing and developing cost-effective logistics chains for long items, it is useful to divide the requirements into three categories:

1. Must have criteria
2. Could have criteria
3. Nice to have criteria

In order to focus on “must have” criteria, we must be able to differentiate between the three criteria. So, the range for “must have” criteria is set from >3.0 to 3.5 and there are four additional criteria for distinguishing the “must have” items from the others. Four criteria seem to be a manageable number in the further process planning.

The “could have” criteria (see Figure 4.9) are from >2.5 to 3.0. In this range, there are six additional criteria. “Could have” criteria refers to the fact that these criteria may or may not be fulfilled at the planning of long items logistics chains.

The last clustering of requirements are called “nice to have” criteria. The range of this step is all criteria, which have an importance of 2.5 or less.

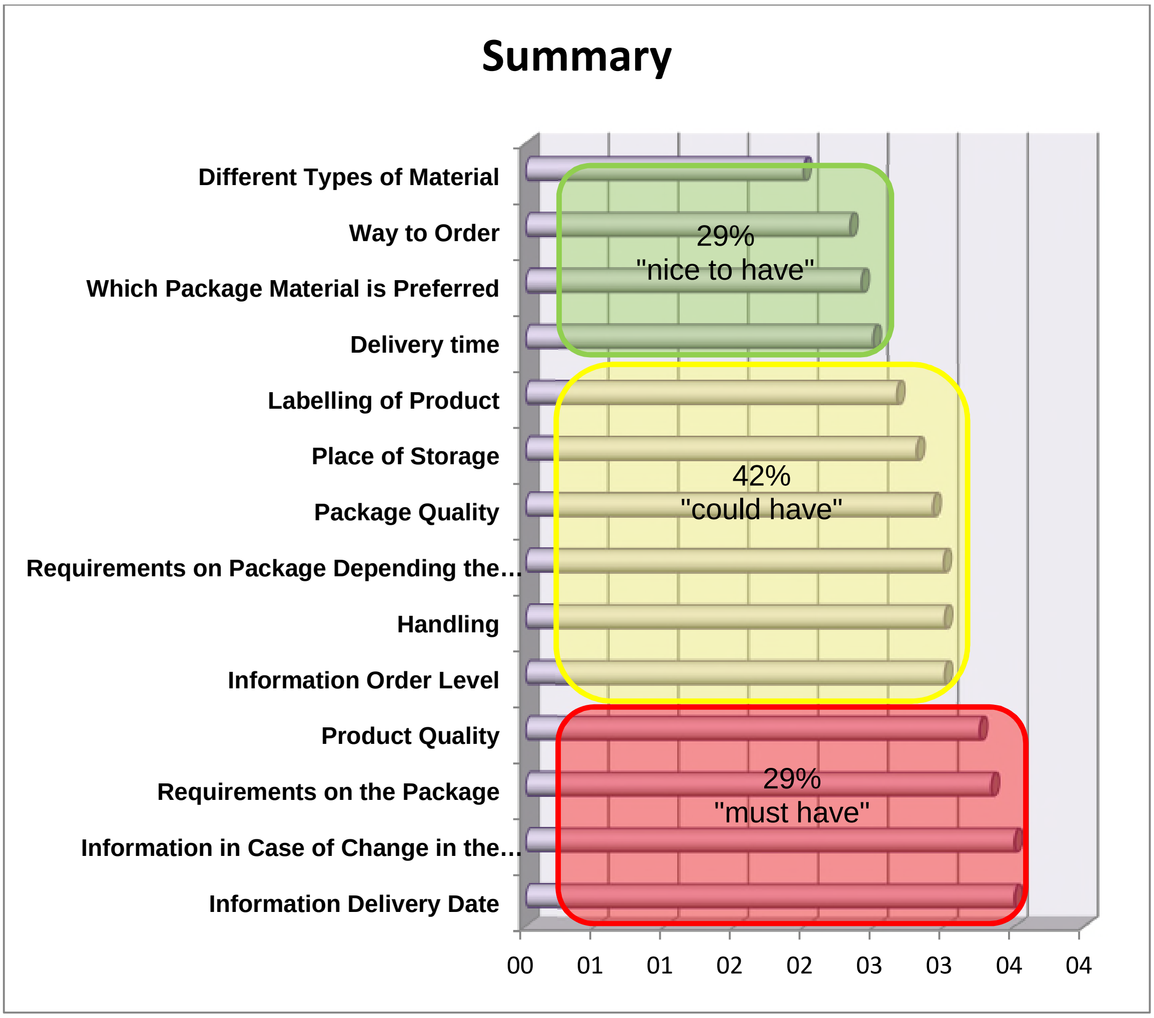


Figure 4.9: Requirements Sorted by Importance

4.3.6 Evaluation of the Results

The “must have” items are in the red area, the “could have” are in the yellow, and the “nice to have” are in the green area. So, all criteria we could find in Table 4.3 are recorded. The numbers on the left side of correspond to the numbers of the questions as they were posed in the expert interviews. The aim of this matrix is to check if the requirements are in the right area of green, yellow, and red. So, the first classification is implemented with the help of the right column, which is called “Summary.” The column “Summary” is the average of the column from before (average of “Producer” / “Logistics” / “Wholesaler” / “Craftsman”). If we look at these columns as they were presented before, we can see how the “Summary” is considered. In the best case, the range of the numbers before was fairly equal. In the case of the column “Craftsman,” however, there is a big difference. All “nice to have” criteria from the “Craftsman” have an importance of 3.3. According to the classification, requirements with an importance of 3.0 to 3.5 are “must have” criteria. Thus, these results identify significant differences in this area. It is impossible to ignore this difference because the “Craftsman” represents the end customers. But that does not mean that the complete classification has to be reworked. The better way is to look which steps of the supply chain are touched with these requirements. Only in these steps the requirements from the craftsmen should be considered specially.

Table 4.3: Requirements Evaluation Matrix

		Producers	Logistics	Wholesalers	Craftsmen	Summary
4	Information Delivery Date	3.7	4.0	3.[illegible]	3.0	3.5
5	Information in Case Change in the Delivery Date	4.0	4.0	3.0	3.0	3.5
6	Requirements on the Package	3.7	2.7	3.0	4.0	3.3
1	Product Quality	4.0	3.3	2.[illegible]	3.0	3.3
14	Information Order Level	4.0	4.0	3.0	1.0	3.0
12	Handling	3.0	3.0	3.0	3.0	3.0
9	Requirements on Package Depending the Store	3.7	1.0	4.0	3.3	3.0
2	Package Quality	4.0	3.3	3.3	1.0	2.9
10	Place of Storage	4.0	2.7	3.0	1.3	2.8
11	Labelling of Product	3.7	2.3	2.3	2.3	2.7
3	Delivery time	2.7	1.7	2.3	3.3	2.5
8	Which Package Material is Preferred	2.3	2.0	2.0	3.3	2.4
13	Way to Order	2.0	1.0	3.0	3.3	2.3
7	Different Types of Material	2.0	1.0	1.7	3.3	2.0

4.3.7 Typology and Interactions

To examine the craftmen's requirements every step of the supply chain is shown, thus developing a matrix for the typology and the interactions. The word "typology" stands for the different steps of the supply chain. The word "interactions" stands for the requirements (Liebold & Trinczek, 2009, pp. 51-52). In the left column of Figure 4.3, the steps of the process are shown from the receipt goods to loading and transportation of the goods. These are the main steps of the process which are comprised in every step of the supply chain. So, this is the maximum range of processes. It is also possible that one step of the supply chain only uses one step of the process. For example, the supply chain step "logistics" usually only comprises the step "transportation," so the column of "logistics" is only filled with requirements in the line "transport." The red numbers in Table 4.3 represent the craftsmen's requirements. The red numbers can be found in two areas in Table 4.3: in the green area for "nice to have" and in the red area for "must have." The matrix defines which requirements have to be considered at which step of the supply chain.

To demonstrate how the matrix works, an example is shown in the following:
If the wholesaler would like to plan how the goods should be loaded, the first has to look at Table 4.3. Here, he has to pay particular attention to the requirements in this step of the supply chain and to the corresponding step in the process. These steps have three areas of requirements:

"must have" (red)	4,5,6,1	and 8,13,7
"could have" (yellow)	14,12,9,2,10,11	↑
"nice to have (green)	3	and 8,13,7

The requirements printed in red (craftsmen) are transmitted from the green area to the red area. They have to be considered like all other requirements.

Process Steps	Supply Chain Stages											
	Producers			Logistics			Wholesalers			Craftsmen		
Goods Receipt	6,1 8,7	12,2, 11	13 8,7				4,5,6, 7,1 3,8,	12,2, 11	13 3,8,7	4,5,1 3,8,7	14,12, 2, 11	3,8,7
Storage	6,1 8,7	12,9, 2,10, 11	8.7				6,1 8,7	12,9, 2,10	8.7	6,1,2 8,7	12,9,2, 10,11	8.7
Picking	4,5,6 ,1	12,9, 2,10, 11	3,8,7				4,5,6, 7	14,1 2,9,2 ,10,1 1	3,8,7			
Delivery Combination	4,5,6 ,1 7,8	12,9, 2,10, 11	3, 7,8				4,5,6, 1 7,8	14,1 2,9,2 ,10,1 1	3 8,7			
Loading	4,5,6 ,1 7,8	14,1 2,9,2 ,10,1 1	3 8,7				4,5,6, 1 8,13, 7	14,1 2,9,2 ,10,1 1	3 8,13, 7			
Transportation	4,5,6 ,1	14,1 2,9,2 ,10,1 1	3.8	4,5, 6,1	14,1 2,9, 2,10 ,11	3.8	4,5,6, 1	14,1 2,9,2 ,10,1 1	3.8	4,5,6,1 3	14,12, 9,2,10, 11	13 3

Figure 4.10: Typology and Interactions

4.3.8 Detailed Classification of the Requirements

At the interview, the experts were not only asked to rate their answers according to importance from 1 to 4. The importance from 1 to 4 was combined with possible answers. Thus, in the planning phase, you have the advantage of finding out exactly how important the requirements are and gaining a better understanding of the concrete characteristics associated with an important requirement. If we look at the example of the stage before, we see that the wholesaler has to pay attention to the “must have” requirements 4,5,6,1,8,13,7 (red) when he plans the loading (see Figure 4.9). The number 4 deals with the topic “Delivery date” (left column). The number 4 is a “must have” criteria, so we look to answer possibility 4 (red line at number 4). There, the following text can be found:

> 4 We need detailed information about the delivery date → Information about the conveyance, delivery- number, -date, -hour

With the explanation it becomes clear how the process has to be designed. According to the characteristics of the requirements (red line at number 4), the wholesaler needs all information about the articles and the delivery dates. With this, the transport of the goods can be designed transparently and the craftsman, who is waiting for the goods, knows what the status of his order is. With this information, the craftsman is able to plan his work even better.

Table 4.4: Interview Questions and Requirements

Quality	1	Is the quality of the delivered goods important for your company?	4	The goods have to be in high quality because the goods have to be in an ideal quality for use.
			3	The quality of the goods is important and the products have to be undamaged; only little dirt is not a problem
			2	The products can be used with little damages and with dirt
			1	The quality of goods is not in foreground
	2	How important is the quality of the package for the long items?	4	The package has to be of the same quality from sending to delivery
			3	The package could have some little traces of the transportation
			2	The package could be damaged but the products have to be in high quality
			1	The quality of package is not of interest to us
Delivery Date	3	What time do you want to get the products delivered?		It is fine to get the delivery in/on…
			4	The same day
			3	The next day
			2	Two days
			1	The delivery days that are defined
	4	How important is the information about the delivery date?	4	We need detailed information about the delivery date --> Information about the conveyance, delivery -number, -date, -hour
			3	We only need the delivery date
			2	We need the approximate delivery dates only
			1	We don´t need any delivery dates
	5	Which information do you need if the delivery date cannot be observed?	4	…it is important to contact the customer and inform about the new delivery date and the time slot
			3	...we inform the customer about the new delivery date
			2	… it is nice to inform the customer about new delivery date
			1	… it is not necessary to inform the customer about the new delivery date, it is only important that the products are delivered anytime

Packaging materials	6	Which package is needed to transport long items?	4	We need the packaging for the safe transport, storage at the building and storage outside of the building
			3	We need the packaging for the safety transport, store at the building site
			2	The package is only needed for the safety transport
			1	We don't need any packaging
	7	How many different types of packaging materials could be used?	4	1
			3	2
			2	3
			1	it doesn't matter
	8	Normally for each long item wood pallets are used. They are fixed e.g. with nails. Which material should be used for the packaging?	4	I would prefer a packaging which is only made of wood, because of the safety of the goods and the disposal of waste
			3	I would prefer a packaging made of wood but to fix the package nails or (none-) metallic strap can be used
			2	Any type of packaging can be used to package the goods
			1	Long items should have no special wood frame
	9	Are there any special requirements for packaging?	4	Packages will be stored for a long time and will need to be opened and closed
			3	The package of the goods must be able to be opened (not to close) in storage
			2	The package must not be able to be opened in storage
			1	No special needs for the storage
Storage	10	How are the long items stored?	4	They are stored in an automatic long item storage / They are stored in a manual long item storage
			3	They are stored in a normal pallet storage as good as possible
			2	They are stored outside a building in a weatherproof pallet storage
			1	They are stored outside a building
	11	How is the labelling of products carried out?	4	The long items label must be designed by my own including all numbers on it e.g. storage seat
			3	The long items labels must have my article number, and my storage seat
			2	The long items must be labelled with my article number and your article number can be on it
			1	No label is needed

Handling	12	How are the long items handled in your company?	4	Heavy products can be handled manually
			3	The package is created for handling with forklifts, crane,…
			2	Products need a package to handle then with forklift
			1	Light products are handled manually
Order	13	How do you like to order?	4	By electronic order system which is connected between the buyer and seller system
			3	By e-mail
			2	By fax
			1	By postcard / telephone
	14	Do you like the information about the status of the order?	4	I would like to see every order level
			3	I would like to have the information about the order and the delivery date
			2	I would like to have the information about the delivery time
			1	I would like to have the information about the delivery date

4.3.9 Evaluation of the Method of the Expert Interview

At the end of the expert interview, the quality of the interview itself has to be evaluated. The results have to be checked according to criteria for excellence (Binder, 2006, p. 89) (Kelle, 2007, p. 227). The traditional criteria of excellence in quantitative empirical science are the objectivity, reliability, and validity. In the literature, there are a lot of different excellence criteria (Flick, 2000, pp. 249-269). Therefore, for the purposes of this study, we rely on the general excellence criteria for qualitative research presented by Mayring (Mayring, 2003, pp. 111-154). These are:

1. documentation of procedures
2. validation of argumentative interpretation
3. conduction of rules
4. proximity to the subject
5. communicative validation
6. triangulation

The **process has to be documented** accurately (Schönwandt, 2004, p. 149). To reach these targets, it is necessary that the methods and the mode of documentation are defined precisely. During the test interview and the optimisation of the interview from an open question interview to a multiple choice interview, the documentation is handled in writing. The advantage of this documentation is that only little mistakes in the transmission of the answer can arise. This form of documentation helps in the further evaluation stage.

The clustering of the questions, such as those related to quality, delivery date, etc., is useful in the interpretation and evaluation. The interpretation and evaluation of the knowledge acquired is not a mathematical calculation.

Therefore, a **validation of argumentative interpretation** is used. On the one hand, you can do so using literature in the field and, on the other hand, different answers can be discussed with experts to find out what the reasoning behind a given answer was (Binder, 2006, p. 90). However, during the interview it is not possible to discuss answers with the experts because by asking for the reason for an answer, the expert could be influenced. An advantage of the multiple choice interview is that the comparison of the answers with the answer steps from 1-4 are reproducible. Also, any differences in the answers can be identified in systematic and reproducible way. Furthermore, the additional questions at the start of each interview which deal with the identification and evaluation of the expert provide additional empirical knowledge which is used to create a valid interpretation.

The **conduction of the rules** is one of the important points. This point can be answered in two ways. The first way to answer the questions is to ask if the general rules of the expert interview have been considered. The second way to answer the question is to ask if all interviews have been conducted or carried out in the same way, according to the same rules.

To the first part, the general rules of the expert interview. One general rule has not been considered. This is that the questions have not been asked in an open format. This is because of the input from the two test interviews. This idea to combine multiple choice and closed questions was crafted by the experts because answering the open questions requires a lot of time, much more time than an expert expects to spend on an interview (Ernst, 2010, pp. 113 -116). Both of them gave the feedback that if the existing business contacts to the interviewer did not exist, the interview would have been cancelled after 30 minutes at the latest. Furthermore, two experts cancelled the interview after the starting question because they fundamentally did not accept an open question interview because it would require too much time. Moreover, it was noted that it would be respectful to develop answers in advance like a multiple choice questionnaire. Indeed, one risk at the expert interview seemed to be that the expert could consider the open question format to be disrespectful since it could appear like the interviewer is “unprepared.” The expert could think that the whole thing is a waste of his/her time (Liebold & Trinczek, 2009, p. 39). Hence, it is necessary to deal intensively with the topic long items in advance and develop a multiple choice interview to be carried out with experts. As a result of the researcher’s experiences in the test interviews, the open question format has been discontinued. By reworking the interview, one basic characteristic of the expert interview got lost: the possibility to gain knowledge which is only expert knowledge. Multiple choice answers are advantageous because they are pre-structured and experts were instructed that they could provide an open answer to any of the questions if they felt like none of the prepared answers was suitable. However, during the interviews, the choice of answers were sufficient and every expert was able to choose an answer for every question.

The second way to answer the question is to ask if all interviews have been done in the same way, according to the same rules. The style of the multiple choice interview helps to observe the rules because the method is the same every time. At each interview, the same questionnaire with the same questions and answers was used. Also, the personal conditions of the expert were evaluated every time. If the personal condition of an expert were not acceptable, the interview was cancelled. Furthermore, the interviews were all tightly scheduled. All interviews had been done within a few weeks. During the interview period of a few weeks, no aspects could be realised, which had an influence on the answers, like new scientific approaches or other practical approaches which could have influence on the experts' knowledge.

The start of the interview is used to reach a **proximity to the subject,**. To generate a stress-free atmosphere, the basic questions which deal with data regarding the company or the institute at which the expert works were posed at the beginning of the interview to generate slight intersections to the research area. During this entry into the interview, the proximity to the subject is developed. The interviews were conducted directly at the research or the working place, so the local proximity to the long items was given. During the interview, the interviewer kept his own talking to a minimum. This is necessary because the answers of the expert were not to be influenced and commented upon.

The validation of the results is done in two ways. The first way, the **communicative validation,** is done after the interview. The answers which have been given at the interview are shown and evaluated by the expert. This ensures that he/she has the chance to say they are correct and to substantiate his/her answers. Or, they can use this second time to change their answers. In either case, mistakes in the transmission are debarred.

The second way to evaluate an interview is to evaluate the answers. Therefore, special questions are needed. That means that two questions have the same content or the same target. Therefore the answers of the expert have to be the same. In case of the expert interview questions with the same subject matter exist. Take, for example, the delivery date. Question four of the expert interview deals with the direct delivery date. Question five deals with the rescheduling of the delivery date. Thus, the experts in the interview indicated that both data are important. So the answers are estimated to be similar. If these answers are not similar, it could be an indicator that the experts have not been chosen accurately. Furthermore, it could indicate that the quality of the questionnaire needs to be improved.

The **triangulation** is a different view on the expert interview. In order to gain a better understanding of the different views involved, different experts from different stages of the whole logistic chain were interviewed. Usually, by interviewing different experts from each step of the supply chain, more than one general consensus of what is important emerges at the end of the interview process. It is a sign of good quality if only one or two factors emerge in the end, for it demonstrates that a lot of people had the same opinion, even at different points in the supply chain. By including the different steps of the supply chain, it is necessary to ask more than one expert. The quality of the interview is substantiated because different experts have been asked in each step of the supply chain who have a different research area. For example, experts were interviewed who research or work in the area of steel, plastic, and wood long items.

By dealing with the evaluation of the expert interview according to general characteristics of qualitative research and evaluation, the interview itself was reviewed as was the researcher who developed the interview. The review should help to reflect the method which was used. Also, the critical review on the part of the researcher about the work which is done is necessary in order to be able to use the results in future work.

5 Chapter 5 Analysis and Evaluation of Existing Planning Frameworks for Logistics and Company Planning

5.1 Introduction

In this chapter the different planning frameworks are analysed and evaluated. Furthermore, with the help of the SWOT Analysis requirements are identified for the creation of a new planning framework for the long items logistics system planning.

5.2 Data Collection and Classification of Existing Company and Logistics Planning Models

There are different types of planning methods. Using some of these methods, complete supply chains can be planned while only parts of supply chains can be planned using other methods. An example for planning supply chain parts is to plan a logistics system or to plan a factory. This research focuses on planning methods for planning logistics systems and methods that are used for company planning. The wall of the building physically limits the planning method and the processes because they are located in this building. The physical limitation exists because the process has to be installed in “one” building or processes must be linked in a building network in which the different locations are in close proximity to each other. The special problem of planning systems for a concern is that a concern generally has a large number of business units. The planning method is only adaptable for planning the systems of single business units. To consider the special requirements of long items in the logistic planning, the method is only applicable for business units dealing with these special goods because other goods have other requirements. Planning methods for company and logistic planning cannot solve problems related to the connection of different logistic companies or systems. To connect different logistic and company systems in a concern, a method to plan supply chains is necessary.

The intention of the planning method is to plan logistic systems for products that have to be handled together with the same planning method. For example, in practise, long items like pipes have to be handled together with small items like fittings. Therefore, it is necessary to plan processes that can handle these different types of goods.

In general, process planning models are not designed for one specific product. They are applicable for many different products. This is a handicap because the specific requirements of a given product get lost. Losing information has an especially detrimental effect if a product has a lot of special requirements like long items products do. Therefore, aiming to make the planning models applicable for many different planning requirements and products is not helpful for planning long item processes because they still do not focus enough on the individual requirements. This is why a new framework for planning long items processes has to be created in this thesis.

To describe a planning model, there are two main levels of characteristics. The first level of characteristics is the phase of a model. A basic planning model comprises five phases (Grundig, 2013, p. 38):

1. Preliminary planning (describe the idea, planning of framework)
2. Structure planning (describe different variants and evaluate these variants)
3. Detailed planning (plan the variants in detail and pick one variant for implementation)
4. Implementation planning (make an implementation plan)
5. Implementation (implement the plan)

In addition to the planning phases, a level describing all necessary activities is necessary. So, the second important characteristic involves planning activities at every planning phase (Schmigalla, 1995, p. 93). Conventional planning methods like those presented by Grundig or Schmigalla have the implied assumption that the target planning and the customers' requirements are significant for the planning period and for a sufficient time of operation to be economically efficient. If, however, the customers' requirements change faster than the scheduled planning, this type of planning is not useful for one of two reasons. The first possibility is that the customers' changed requirements are not noticed or taken seriously. The second possibility is that the changed requirements are identified but cannot be considered because the planning model is too complicated and therefore not useful.

The effect of the changing customers' requirements is called permanent adaptability in company planning. We have to differentiate between different types of adaptability, including space, technique, organisation, and especially the adaptability in time (Harms, et al., 2003, p. 227).

Grundig compares different types of organisation adaptability (see Figure 5.2). In this figure, the main planning methods are compared. All of these planning methods describe five (planning) phases. In detail, these are the preparation planning, the structure planning, the detailed planning, the implementation planning, and the actual implementation. The planning method describes company planning. But today, it is impossible for company planning to omit or ignore logistic planning. This is because of the aim to produce more and more products in an efficient lean way. Components that are used to create products have to be "in flow," which means that the components are provided just in time and just in sequence. The result of this is that the in-house logistic is a basic element of the company processes. In general, the planning phases are divided with regard to the contents. The contents of the planning phases are arranged in a logical way. Contents and results that are inputs for other planning phases have to be solved at the beginning. The planning phases are not described precisely, i.e. they are described without specific aspects, so that they can be adaptable for different types of company planning. The planning phases are also scheduled. In planning phases at the beginning, changes regarding the planning targets and even changes of the planning requirements are easy to handle. Changes in further planning phases are much more complicated to involve and to consider in the planning. The planning process is an iterative process in which changes have to be incorporated.

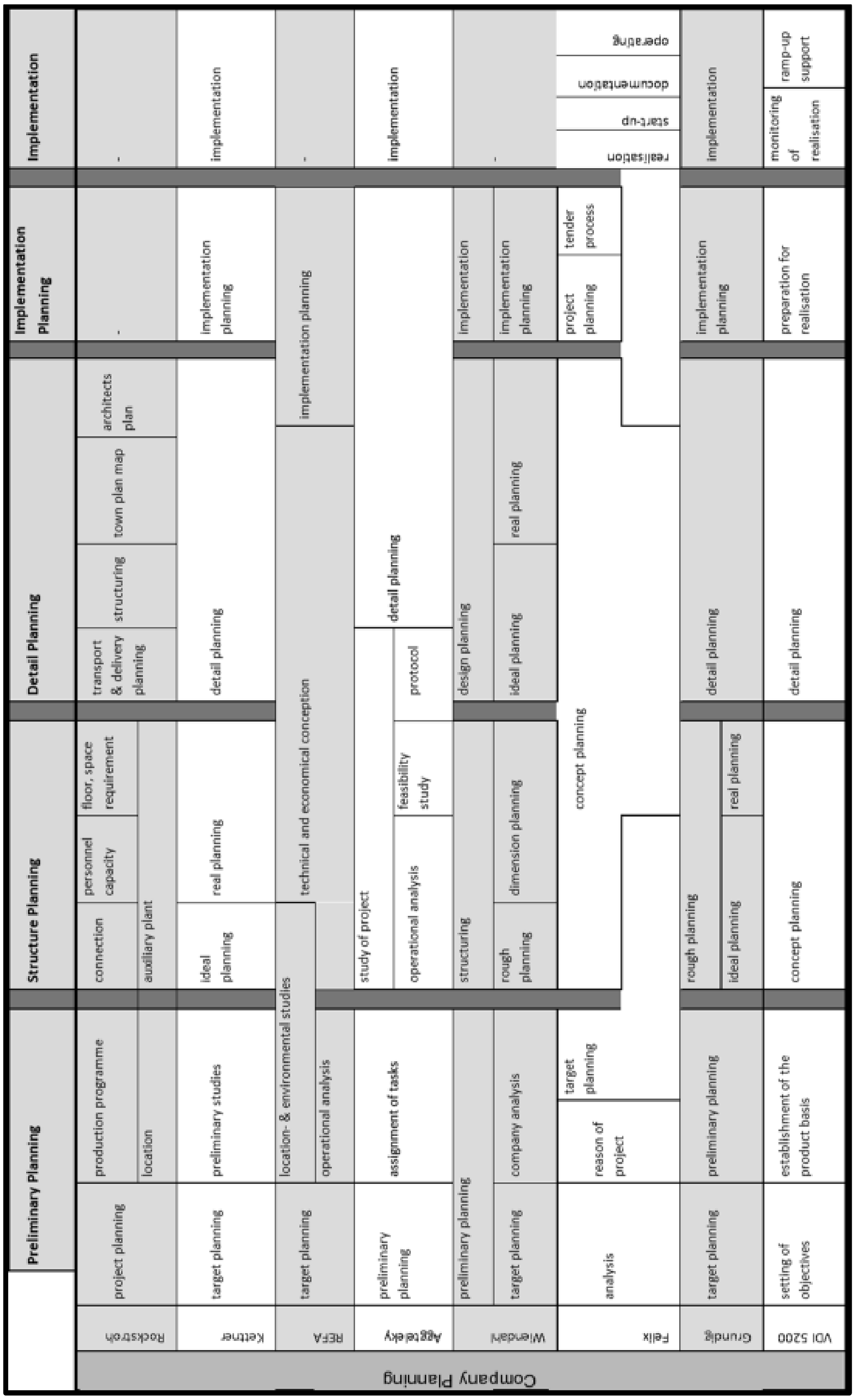


Figure 5.1: Types of Different Planning Phases (Part I/II)

Source: Author's design based on (Grundig, 2013, p. 38)(Rockstroh, 1980), (Kettner, et al., 2010), (REFA Verband für Arbeitsstudien und Betriebsorganisation e. V., 1985), (Aggteleky, 1987, 1990, 1990), (Gudehus, 2005), (Harms, et al., 2003), (Harder, 2008, p. 17), (Krampe & Lucke, 2006, p. 407), (Dittrich, 2002, pp. 13 - 21), (VDI, 2011, p. 9)

Logistics Planning	Preliminary Planning	Structure Planning	Detail Planning	Implementation Planning	Implementation
Gudehus	target planning	system planning	detail planning	tender process	implementation / operating
Harms	target and strategy planning / analysis of the current logistic system	structuring	control concept / parameterisation / real layout	-	-
Harder	target planning / analysis of the existing logistic system and evaluation / acceptance of the evaluated data	making variants / evaluation of the variants in correlation of the target planning / system planning	decision about the logistic system	making a realisation plan	realisation
Krampe	analysis phase / target planning / analysis of the conditions	definition of the target planning / concept planning / choice of one concept for detail planning	detailed planning	-	realisation
Dittrich	strategy planning	logistics planning		-	realisation

Figure 5.2: Types of Different Planning Phases (Part II/II)

Source: Author's design based on (Grundig, 2013, p. 38)(Rockstroh, 1980), (Kettner, et al., 2010), (REFA Verband für Arbeitsstudien und Betriebsorganisation e. V., 1985), (Aggteleky, 1987, 1990, 1990), (Gudehus, 2005), (Harms, et al., 2003), (Harder, 2008, p. 17), (Krampe & Lucke, 2006, p. 407), (Dittrich, 2002, pp. 13 - 21)

5.2.1 Preliminary Planning

Preliminary planning is the first step in the planning process. In this step, the fundamental planning requirements are clarified. In regard to the company planning models, the focus is on the target planning. In target planning, the basic structure, organisations, and economical and ecological aspects are fixed. At this step in the planning process, the persons who have the know-how and the ability to decide and fix the basic planning constitutions must be involved (Wiendahl, et al., 2005, pp. 34 - 35). Moreover, at this planning stage, inputs are handled that have not yet been evaluated sustainably. Because of the early planning stage, data collection is not very precise. For example, only the cumulated demand for one year and not the course of the demand for every day is considered. The disadvantage of this data collection method is that details under the surface are not noticed.

The basic data fixed in the target planning has a lot of influence on all following planning phases (Grundig, 2013, pp. 20 - 25). The target planning in the company and logistic planning phases is described like a little, individual planning project. In this planning project, a rough company plan is made. All of the main components are planned and evaluated in this planning stage (Schenk & Wirth, 2004, pp. 111 - 115). In addition, the methods that are to be used for the target planning are described, albeit insufficiently. However, the high value and influence of this planning step is recognised by every author. Also the time typically reserved for the target planning is short. In the current planning models, targets are supposed to be clear or easy to clarify if the planning shareholder attends a workshop or by analysing the company's logistics structure (Grundig, 2013, p. 25). The current planning methods (see Figure 3.6) start with the background that the target of the planning and the requirements are clear (Bracht, et al., 2011, pp. 122 - 124). The target planning considers targets that can be reviewed and targets that are to be reached in order to follow the vision of the company or the logistics system. Targets that will be reviewed are evaluated at every planning stage; thus, these targets have to be measurable (Krampe & Lucke, 2006, p. 62). The VDI guideline also divides the preliminary planning stage into two parts, the target planning and the establishment of the product basis. In the first part, the target of the planning project is defined. In the second part, all data that are necessary are collected. Furthermore, the data is evaluated after collection. But the disadvantage of the VDI guideline is that this guideline does not describe an explicit method for the data evaluation (VDI, 2011, pp. 11 - 12). A further basic element of the conventional planning process is the approach that requirements that exist from the beginning of the planning process are applicable in years in a stable market. If no target planning is included in the preliminary planning stage, a data analysis is conducted at this planning stage. This analysis is based on the current company or logistics system itself. That means the currently installed processes, equipment, and the layout are analysed. Product data from the past is analysed to use the experience from the past for further improvements. Beyond this, it is necessary to consider new products and the demand development of the products in the future. The developed product data for the future can be limited to five years because it is much too difficult and imprecise to look too far into the future. Therefore, longer data development is not helpful.

After the target planning or the collection of the data, the general planning approach is defined. Two planning approaches exist: he synthetic and the analytic planning approaches (Dittrich, 2002, p. 18). The analytic planning approach describes the planning from the “outside to the inside,” meaning that the way to plan starts at the ground, and moves on to the building, the processes, the equipment, and finally to the processes. The synthetic planning approach is from the “inside to the outside.” That means at first the processes, then the equipment, the building, and at last the ground is planned (Vollmer, 2003, pp. 245 - 246). The planning approach is defined in the preliminary planning. The advantage of the synthetic planning is that the focus is at first on the process. During this, the processes can be planned in an optimal way. The disadvantage of the analytic planning approach is that the processes are planned at the end of the planning process.

Depending on the long item process planning, commercial logistic planning approaches can be applied quite broadly. But because of this broad applicability, the focus on the special requirements gets lost. Therefore, processes for goods with special requirements have to be regarded precisely.

Furthermore, it is important that commercial and long item goods are planned with one planning approach because the special requirements can be considered consequently. This leads to effective and efficient processes. The target is that the planner obtains methodical help at the preliminary planning stage with the long item process planning. The wide definition of the planning process interferes with generating and transferring know-how of the long item planning. Therefore, the customers' requirements that are dependent on the long item planning have to be implemented in the first stage of target planning. The target planning is the initial point for further planning steps. If the right inputs are considered then, they can be useful in further planning stages.

The result of the evaluation of the first stage in the planning process, the preliminary planning, identifies strengths and weaknesses. The findings of the evaluation are presented in the following summary:

1. **Preliminary planning**

Strengths (internal)

a.) Clear focus and requirements are generated for further planning steps.
b.) A stable preliminary planning is the basis for further planning stages.
c.) The preliminary planning is the basis to structure the planning process and resources.

Weaknesses (internal)

a.) Too flexible and applicable, so no special requirements are considered.
b.) Short scheduled data analysis.
c.) Short or no evaluation of the data analysis.
d.) Requirements are only derived from the vision or strategy of the company or logistics system.
e.) Customers are less or not involved in the preliminary planning stage.
f.) It is not clear if the planning focus can be derived only from company and logistics strategies and visions.
g.) No clear statement regarding which planning methods are used.
h.) No extra consideration of the dimensions of the goods.

i.) No extra consideration of the consistency of the goods.
j.) Simplification of long items process planning.
k.) No methodical help at the long item planning.

Threats (external)

a.) Using the wrong planning method because of a false interpretation or because of a lack of information regarding the customers' requirements.
b.) No homogeneous customer opinion exists.
c.) Special requirements of products like long items are not considered and handled separately.
d.) The wrong processes are planned; customers would like processes with other output.
e.) Customers cannot identify themselves with the planned processes.
f.) The long items and the cargos of the long items cannot be used in further steps of the supply chain.

Opportunities (external)

a.) Involve customers in an early step.
b.) Involving the customers could help to transmit know-how from competitors.

New possibilities

a.) By involving customers early-on in the planning process, their inputs regarding the target planning can be considered.
b.) If the requirements are analysed and evaluated in a real and sustainable way, the planning stages "structure planning" and "detail planning" can be planned with clear focus.
c.) The preliminary planning is adapted to the long items planning.
d.) The target planning has to consider the customers' requirements for long items.

5.2.2 Structure Planning

The second planning stage involves structure planning. This is the second important planning stage because in this stage, the influence of the structure, processes, equipment, and personnel is significant. The purpose of the structure planning is to make decisions and note them in memos for the next planning stages. The content in this planning stage takes the form of a rough planning. In the rough plan, different variants of applicable company or logistic systems are created. The target of this planning stage is to create processes that are applicable, efficient, and effective. In derivation of the structure planning, the costs of the system, the necessary deployment of employees, the investment, and the return on investments are all calculated. Because of the high volume of work associated with describing one variant, the number of variants is limited by the project resources. If the planned structure is evaluated by lean criteria, parameters like lead-time, waste, etc. dominate (ten Hompel & Heidenblut, 2011, p. 49). The work that has to be done in the structure planning is nearly the same in all planning approaches. In the structure planning, the names of the steps differ and this planning step is divided into different subsections in different methods. Rockstroh has the finest subdivisions with the most explicit planning of the personnel capacity, floor, and space requirements. The advantage of dividing the planning phase consequently into subsections is that the results of the work are transparent at every subsection. In addition, the progress of the work in the preliminary planning is transparent (see Figure 5.2). Every subsection can be traced to determine if things are progressing smoothly. For example, if the planning schedule is not maintained at any stage, it becomes clear very quickly because the previous subsections would not provide any or suitable results.

Dittrich has the longest subsection in two planning stages. Here, the processes are planned in the structure phase. The depth of the development of each variant influences the quality of each variant and the schedule as a whole. The planning depth of all variants has to be on the same level. The right planning depth is reached when the main structure is deemed useful in practise. If the planning depth is too great, it could be difficult to maintain the schedule or timetable or other variants could be rarely or inadequately structured. For structure planning, the classic method of material flow planning is used. The German Foundation for Engineers (VDI) describes this traditional method in their guideline VDI 3300 because of the importance of the method. This guideline describes the "connection of all activities at the mining, production, mounting, and transportation of goods" (VEREIN DEUTSCHER INGENIEURE, 1973, pp. 2 - 4). In the structure planning, the material flow method shows how processes are linked to each other.

Moreover, the material flow method describes the exchange of materials and the way in which the materials flow (Pawellek, 2008, p. 183). Grundig and Kettner describe structure planning as the ideal and real planning (see Figure 5.2). The progression of the application from the ideal to the real planning is always the same. Ideal planning is always the first step and it has the task of describing the best connection of the different steps in the process. The focus in the process planning is only on the question of how the process can be arranged to work in an optimal way (VDI, 2011, pp. 12 - 14). Restrictions impeding the ideal planning are disregarded. The idea is to have an open view on the process, which enables the planner to create new ideas which would never be created if he paid much attention to predominant restrictions.

The second step is the real planning. In the real planning, all restrictions like building, grounding, etc. are considered. In these two steps, planners have the chance to reach completely new solutions because new approaches can be used without limits at the ideal planning stage. The real planning itself is divided in two different parts. In the first part, buildings and groundings are planned and in the second part processes, equipment, human resources, and investments (Pawellek, 2008, p. 228). Another component of the structure planning is the structuring of the processes. The structure of the processes can be a push and pull system. How to arrange the equipment is closely linked with the push and pull system. It is possible to employ workshop-orientated, line-orientated, or flow-orientated arrangements (Grundig, 2013, pp. 226 - 231).

The result of the structure planning is to have only a few different structures that serve as basis for the detailed planning. Handling more than a few planning structures in the stage of detailed planning would be waste of resources. The management decides which variants of the structure planning have to be planned in detail in the next stage. If the target of devising a few variants of the desired structures cannot be reached, an iteration loop has to be made to check the planning data and structure. The structure planning can have some iteration steps. It is also possible to repeat parts of the structure planning. In the structure planning, particularly basic material flows and basic processes are planned, so the requirements and the dimensions cannot be simplified because the dimensions of the goods have a high influence on the material and process flow.

Target planning is the initial point for the structure planning. Basic requirements from the target planning are used to plan the actual processes. The structure planning is the planning stage at which the processes are planned. Current planning models are imprecise at actually planning in a suitable fashion. They show only a planning frame and give inputs. But the target of this research is to describe in detail the advantages and disadvantages depending the long item logistic system. Furthermore, the focus is on the manual handling of the long items. This focus has been chosen because at an expert interview it was allocated that manual long items handling is preferred. In logistics companies, processes that use automatic storages or picking systems are rarely installed. This is because automatic systems are very cost intensive, require high maintenance, and are very inflexible. Therefore, they only prove to be economic when a logistics company has a high number of long items to handle.

The focus of research is clear on manual processes because the manual long item handling is more time intensive and complex for the employee than the handling with automatic equipment. Thus, the improvements are more necessary in the area of manual long item handling. The target of the research is to create a diagram to plan long items processes to help the planner develop accurate and efficient long item logistics systems.

2. Structure Planning

Strengths (internal)

a.) Creative process, in which new ideas have a chance to be regarded.

b.) Identify, test, and evaluate new equipment and processes.
c.) Creating new solutions is accepted and encouraged.

Weaknesses (internal)

a.) The planning process is complex because different variants are planned parallel.
b.) Different shareholders of the project may have different ideas and not act in accord with each other.
c.) Customers are not involved directly in this planning stage.
d.) Special requirements of processes, products, and customers are generalised.
a.) The same planning methods are used in the same way for the long items and the “normal” goods.
b.) The dimensions of the goods are not considered.
c.) The consistency of the goods is not considered.
d.) No specific methodical help for planning long item processes.
e.) For all main processes, like the in- and out-going area, calculation methods are needed, e.g. for the performance calculation.

Threats (external)

a.) Too many team players do not find an agreement about the structure of the variants.
b.) The depth at which the variants are developed is not correct.
c.) It may be difficult to find consequent agreement about one variant.
d.) The current structure seems easy for a planner to use, but in order for others to use it, certain know-how is needed.
e.) The long items cargos may not be able to be handled in other steps of the supply chain because of wrong packaging or wrong information flow.
f.) Long item processes are not transparent and are insufficient and perform slowly.

Opportunities (external)

a.) The structure planning can be used for different applications and products.

b.) The open form of the structure allows planners to find new approaches.
c.) The current structures are easy to understand and to transmit.
d.) Specific planning and calculation methods for the long items handling can be developed.
e.) Research of different planning approaches of long item handling and documentation of the results in figures that help further long item planning.

New Possibilities

a.) Involve users of the system in an early project stage to generate acceptance.
b.) Create connecting points to handle special requirements.
c.) Divide the structure process into smaller parts to reach transparency.
d.) Use new methods for the structure planning.
e.) Create a planning figure for the storage height and length planning.
f.) Create a method for determining how to plan that helps to plan different picking systems of long items and commercial goods.
g.) Create a calculation method for the planning of the main processes like the in- and out-going area.

5.2.3 Detail Planning

Most planning models situate detail planning or also called system planning as the last step of the planning process. For the most part, the planning processes do not divide this planning stage in subsections.

In the detail planning stage, the chosen variants from the structure planning are used as input. These few variants have to be planned in detail. The variants that are planned in the structure planning phase are mostly quite similar because as a result of the structure planning, all structures are evaluated by the same criteria. Only the variants fulfilling the criteria are used for the detail planning. In this phase, the processes of the operative level are planned. One of the first steps in the detail planning is the layout planning, which derives from the material flow method. Thus, a precise description of the processes in terms of equipment, space, and transportation is possible. One of the important targets in this planning stage is to create a system that is flexible to use. Because of the

minimisation of the product life cycle, the company and/or logistic system must be flexible. A complex planning system is required, not a simple one (Grundig, 2013, pp. 222 - 223). The lean approach is to implement the customer's demand directly in each production and logistics process.
In the detail planning stage, the requirements of long items have to be considered, such as, for example, the packaging. Furthermore, the material and information flow of the different process types have to be connected (for the long items and the "normal" goods).

In the detail planning phase, sub-processes like the transportation of the goods have to be planned in detail. Transportation is a good example that can be planned in the detail planning because the main process structure is fixed. Because of the long items have rather large dimensions, transporting them is extensive in terms of time, cost, and necessary space. Furthermore, the process of loading and unloading long items takes a lot of time using a forklift.

Moreover, in the expert interview, one expert noted that the information flow is an elementary part of the process for the customers. The information flow has to be transparent to be effective. Further research is necessary to determine if the long items processes prefer specific information flows.

The VDI guideline focuses on the detail planning stage within the building and equipment planning stages. It deals with the approval applications and the specifications of the services.

3. Detail Planning

Strengths (internal)

a.) Clear focus and clear planning tasks.
b.) The variants can be performed in parallel because the ground data have already been evaluated.

Weaknesses (internal)

a.) System users can be overloaded with new information.
b.) Users are prejudiced against the new system.
c.) Problems at the first contact at a late planning stage could produce a big iteration loop.
d.) Planning of the information flow is missing for long items and commercial goods.
e.) Complex transportation of long item goods.

Threats (external)

a.) The variant that is chosen in the structure planning is not applicable.
b.) Too many iteration loops discourage the process planning group.
c.) Information arrives at the customers too late in the process.
d.) Long items processes need a special type of information flow.

Opportunities (external)

a.) Consider the special requirements of products, customers, and users.
b.) The planned system should be flexible and adaptable to other systems.
c.) The planned system should support currently installed systems.
d.) Gain knowledge at the planning of long item processes that can be transferred to commercial planning methods.

New possibilities

a.) By planning only one variant, the planning focus is clear and parallel work is possible.
b.) Active integration of users and customers.
c.) The planning system has to be flexible and adaptable to other planning system.
d.) Develop a new transportation system for long items that is applicable to commercial goods.
e.) Identify knowledge at the long items information flow that can be transferred to other processes.
f.) Synchronisation of the processes from long items processes and processes with commercial goods.

5.2.4 Implementation Planning

In the planning process, the implementation planning is the stage in which the system that will be installed is fixed. Some planning models do not see this planning stage as an individual stage for company or logistics planning. The tasks in the implementation planning are quite similar to the tasks of the project management. For instance, one element in the implementation planning is the scheduling (Felix, 1998, p. 49). Therefore, implementation planning is neglected in company and logistic planning (Rockstroh, 1980), (Harms, et al., 2003). In continuous planning stages, it is important to involve system users directly. Thus, at the implementation planning, an intensive involvement of all users is necessary and the following steps are planned:

a.) Make a project plan and the project organisation with planning schedule and budget planning.
b.) Plan an architect tender process.
c.) Plan energy and environment aspects.
d.) Make a bare brickwork plan.
e.) Plan the installation of the company and logistic system equipment.
(Schmigalla, 1995, p. 94)

For Gudehus, the tender process is the most important process. He implemented the tender process in the system planning at the structuring. The implementation ends with the conclusion of a contract (Gudehus, 2005, p. 72). Felix describes a smooth transition from the structure- to the detail- and to the implementation planning. He calls this big planning stage concept planning. This planning stage ends with the licence planning for the building and the tender planning for the equipment (Felix, 1998, p. 94). The disadvantage of this approach is that this rough calculation is not transparent and actions within this planning step take a lot of time and effort.

For the VDI guideline 5200, the implementation planning is a basic stage because the VDI guideline is created by engineers with work experience. Therefore, many working details are described within the implementation planning. The disadvantage is that the implementation planning is focused on the implementation of high-tech equipment. Thus, if processes only use simple equipment, the implementation planning is not useful because of its high specification.

At the implementation planning, the test phase of the system and the information flow should be extended because of the special characteristics of long items. Because of the dimensions and the consistency of the goods, more time is needed to get the processes up and running. Furthermore, the different information flows of “normal” goods and long items have to be connected.

Implementation planning is the planning step in which the installation of the synchronised processes (long item processes and commercial good processes) is planned. One important point is that the installation of processes is planned and the processes are synchronised from the beginning. Furthermore, the actions which have to be done in case the processes do not work synchronously have to be defined.

4. Implementation Planning

Strengths (internal)

a.) Create the implementation planning. A lot of tools exist for project management.
b.) The advanced planning of the previous stages supports a clear focus.
c.) Involve customers and users to reach a better customer loyalty.

Weaknesses (internal)

a.) If the planning stage is done superficially, the danger exists that it could have a bad influence on the implementation.
b.) If the implementation planning is not differentiated from the other planning steps, the implementation planning could be neglected.
c.) Long item processes and processes for commercial goods do not work synchronously.

Threats (external)

a.) The initiators of the project, users, or customers push the project without planning the implementation precisely.
b.) Unwanted know-how could be transferred to competitors by the supplier(s).

Opportunities (external)

a.) Define a clear method and set a clear start and end point for this planning phase.
b.) Involve the customers and achieve better customer loyalty.
c.) Create processes that work in the same tact or amount of time as the customer processes.

New possibilities

a.) The input and output data has to be defined clearly. Only then is it possible to evaluate the data.
b.) Handle improvements in the implementation planning in a standardised way.
c.) Involve suppliers with high knowledge and a sustainable loyalty.
d.) All processes (long items processes and commercial processes) are organised according to the customer demand from the beginning.

5.2.5 The Implementation

The implementation is the rarely described phase in a planning system. Rockstroh, REFA, Wiendahl, and Harms do not integrate the implementation phase into their respective models. Only Felix describes the implementation stage. He divides this stage into the realisation itself, start-up, documentation, and operation. Gudehus only divides the implementation into two parts, the implementation and operation, without making an additional implementation planning. The documentation in Felix' description is a helpful point in the following operation stage because changes within the system that occur in the implementation cannot be reproduced later. Nevertheless, in this planning stage, there is no way to handle improvements. The task of the implementation is to handle the improvements that are identified in this stage. It needs a clear method to evaluate the improvements and to find out if the improvements are helpful. If they are helpful, their implementation is necessary. The biggest challenge is the implementation of improvements at the implementation phase of a new system, for during the start-up phase of a new system, dysfunctions can arise and interfere with the regular operation.

When implementing improvements, it is important that all material and parts of the information flow are involved because a consistent solution for "normal" goods and long items is necessary. If different handling systems for "normal" goods and long items exist, the results have to be shared in a short time period. In the implementation stage, the logistics system can start to work. The previously planned processes have to control the working results and standards in short time slots directly on the shop floor. If the implementation processes do not work according to the planned standard, the employees and the customers may infer that the planned processes are not useful and effective. Therefore, this is the phase the planner has to be at the shop floor and he has to talk about misunderstandings. Teaching and training the employees extensively during the implementation planning ensures that things go well once the process is actually implemented.

Because of the broad work experience, in the VDI guideline 5200, the implementation stage is divided into four parts. These include the monitoring, final documentation, start-up support, and factory evaluation phases. The monitoring includes the documentation of the implementation and the final documentation focuses on the documentation of the equipment. The start-up support deals with the monitoring of the performance from the processes at the implementation. At the end of the implementation, the factory performance is evaluated. Furthermore, at this stage, the know-how that has been generated has to be transmitted to the next factory planning project (VDI, 2011, pp. 17 - 22).

5. Implementation

Strengths (internal)

a.) If the implementation stage is included in the planning model, a direct response exists if the implementation can be carried out as planned.
b.) The experience gained during the implementation helps to generate knowledge for the next planning project.
c.) Gain knowledge at the beginning of the implementation phase and transfer this knowledge to the operation stage.

Weaknesses (internal)

a.) Not all planners are involved in the project or process until the implementation phase, so the know-how of the structure and detail planning can be lost or cannot be submitted sustainably.
b.) The planners and the operative employees do not work together closely and the planned system does not work effectively and efficiently.
c.) The shop floor method is not implemented.

Threats (external)

a.) Know-how could be transferred to competitors by planning employees who change companies and by suppliers who sell the same system to competitors.
b.) Suppliers are not able to deliver according to the schedule.

Opportunities (external)

a.) Persuade customers by noting the company’s knowledge, quality, effectiveness, and efficiency.
b.) The users can respond directly to the planning team.

New possibilities

a.) Gain knowledge for planning the next system. This knowledge can be used in all stages of the planning.

b.) Earn trust from the system users and customers. It is necessary to be able to transmit the system knowledge from the planning to the operative level.
c.) Handle improvements in the implementation stage.
d.) Installation of a consequent shop floor management.
e.) Installation of a training phase for employees.

5.3 Evaluation of the Existing Planning Models and Solution Development

Figure 5.4 to Figure 5.6 show the results of the SWOT Analysis, which is divided into two parts: the internal (see Figure 5.4) and external parts (see Figure 5.6). In the internal part, the internal strengths and weaknesses are described, while the external part indicates the threats and the opportunities.

In general, the planning stages do not all have the same importance. The importance of the stages shrinks from stage to stage because the influence that larger changes can have shrinks in further planning stages. If large changes are identified in later planning stages, the iteration stage is complex and needs a lot of effort to correct it.

Moreover, the planning stages at the beginning have to be done with care to create sustainable results. In the planning stages at the end, the created ideas and processes should only be improved but not changed completely. If a big change is necessary at the end of the planning, the planning results of the planning steps before are not as good as they should be. Furthermore, if the management cannot make the decisions regarding the implementation at the detail planning stage, the planning results will also not be as good as needed.

STRENGHTS (INTERN)

Preliminary planning	a.) Clear focus and requirements are generated for further planning stages. b.) A stable preliminary planning is the basis for further planning stages. c.) The preliminary planning is the basis to structure the planning process and resources.
Structure Planning	a.) Creative process, in which new ideas have a chance to be regarded. b.) Identify, test, and evaluate new equipment and processes. c.) Creating new solutions is accepted and encouraged.
Detail Planning	a.) Clear focus and clear planning tasks. b.) The variants can be performed in parallel because the ground data have already been evaluated.
Implementation planning	a.) Create the implementation planning. A lot of tools exist for project management. b.) The advanced planning of the previous stages supports a clear focus. c.) Involve customers and users to reach a better customer loyalty.
Implementation	a.) If the implementation stage is included in the planning model, a direct response exists if the implementation can be carried out as planned. b.) The experience gained during the implementation helps to generate knowledge for the next planning project. c.) Gain knowledge at the beginning of the implementation phase and transfer this knowledge to the operation stage.

Figure 5.3:The Findings of the Internal SWOT-Analysis, Part I

WEAKNESSES (INTERN)

Preliminary Planning

a.) Too flexible and applicable, so no special requirements are considered.
b.) Short scheduled data analysis.
c.) Short or no evaluation of the data analysis.
d.) Requirements are only derived from the vision or strategy of the company or logistics system.
e.) Customers are less or not involved in the preliminary planning stage.
f.) It is not clear if the planning focus can be derived only from company and logistics strategies and visions.
g.) No clear statement regarding which planning methods are used.
h.) No extra consideration of the dimensions of the goods.
i.) No extra consideration of the consistency of the goods.
j.) Simplification of long items process planning.
k.) No methodical help at the long item planning.

Structure Planning

a.) The planning process is complex because different variants are planned parallel.
b.) Different shareholders of the project may have different ideas and not act in accord with each other.
c.) Customers are not involved directly in this planning stage.
d.) Special requirements of processes, products, and customers are generalised.
e.) The same planning methods are used in the same way for the long items and the "normal" goods.
f.) The dimensions of the goods are not considered.
g.) The consistency of the goods is not considered.
h.) No specific methodical help for planning long item processes.
i.) For all main processes, like the in- and out-going area, calculation methods are needed, e.g. for the performance calculation

Detail Planning

a.) System users can be overloaded with new information.
b.) Users are prejudiced against the new system.
c.) Problems at the first contact at a late planning stage could produce a big iteration loop.
d.) Planning of the information flow is missing for long items and commercial goods.
e.) Complex transportation of long item goods.

Implementation planning

a.) If the planning stage is done superficially, the danger exists that it could have a bad influence on the implementation.
b.) If the implementation planning is not differentiated from the other planning stages, the implementation planning could be neglected.
c.) Long item processes and processes for commercial goods do not work synchronously.

Implementation

a.) Not all planners are involved in the project or process until the implementation phase, so the know-how of the structure and detail planning can be lost or cannot be submitted sustainably.
b.) The planners and the operative employees do not work together closely and the planned system does not work effectively and efficiently.

Figure 5.4:The Findings of the Internal SWOT-Analysis, Part II

THREATS (EXTERNAL)

Preliminary Planning

a.) Using the wrong planning method because of a false interpretation or because of a lack of information regarding the customers' requirements.

b.) No homogeneous customer opinion exists.

c.) Special requirements of products like long items are not considered and handled separately.

d.) The wrong processes are planned; customers would like processes with other output.

e.) Customers cannot identify themselves with the planned processes.

f.) The long items and the cargos of the long items cannot be used in further steps of the supply chain.

Structure Planning

a.) Too many team players do not find an agreement about the structure of the variants.

b.) The depth at which the variants are developed is not correct.

c.) It may be difficult to find consequent agreement about one variant.

d.) The current structure seems easy for a planner to use, but in order for others to use it, certain know-how is needed.

e.) The long items cargos may not be able to be handled in other stage of the supply chain because of wrong packaging or wrong information flow.

f.) Long item processes are not transparent and are insufficient and perform slowly.

Detail Planning

a.) The variant that is chosen in the structure planning is not applicable.

b.) Too many iteration loops discourage the process planning group.

c.) Information arrives at the customers too late in the process.

d.) Long items processes need a special type of information flow.

Implementation Planning

a.) The initiators of the project, users, or customers push the project without planning the implementation precisely.

b.) Unwanted know-how could be transferred to competitors by the supplier(s).

Implementation

a.) Know-how could be transferred to competitors by planning employees who change companies and by suppliers who sell the same system to competitors.

b.) Suppliers are not able to deliver according to the schedule.

Figure 5.5: The findings of the External SWOT-Analysis, Part I

	OPPORTUNITIES (EXTERNAL)
Preliminary Planning	a.) Involve customers in an early stage. b.) Involving the customers could help to transmit know-how from competitors.
Structure Planning	a.) The structure planning can be used for different applications and products. b.) The open form of the structure allows planners to find new approaches. c.) The current structures are easy to understand and to transmit. d.) Specific planning and calculation methods for the long items handling can be developed. e.) Research of different planning approaches of long item handling and documentation of the results in figures that help further long item planning.
Detail Planning	a.) Consider the special requirements of products, customers, and users. b.) The planned system should be flexible and adaptable to other systems. c.) The planned system should support currently installed systems. d.) Gain knowledge at the planning of long item processes that can be transferred to commercial planning methods.
Implementation planning	a.) Define a clear method and set a clear start and end point for this planning phase. b.) Involve the customers and achieve better customer loyalty. c.) Create processes that work in the same tact or amount of time as the customer processes.
Implementation	a.) Persuade customers by noting the company's knowledge, quality, effectiveness, and efficiency. b.) The users can respond directly to the planning team.

Figure 5.6: The findings of the External SWOT-Analysis, Part II

Derive New Possibilities from the Existing Planning Models Using the SWOT Analysis

Basically, there are four different strategies for gaining new opportunities (see Table 5.1). These strategies are created by matching different sections from the SWOT Analysis.

The s – o strategy describes looking for opportunities transmitted to strengths. The s – t strategy deals with finding new ways to save one's own position and strengths against other competitors. The w – o strategy describes ways to eliminate or transform the weaknesses into opportunities. And, the w – t strategy defends plans against external threats and protects against the development of internal weaknesses.

Table 5.1: SWOT Strategies

	strengths	weaknesses
opportunities	s – o strategy	w – o strategy
threats	s – t strategy	w – t strategy

The first applicable strategy in the preliminary stage is the w – t strategy. Figure 5.7 demonstrates the results in the preliminary planning. In point a.), the w – t strategy findings are noted. One result is that the customers have to be involved in the first step of planning. The second finding of the w – t strategy is that the data analysis and evaluation has to be done more intensively to gain an excellent basis for the further planning stages. In the structure planning, the w – o strategy is applicable. The structure planning is a creative planning stage so the idea is to transmit the weaknesses into opportunities. Because the customer requirements are defined at the first stage, it is necessary to involve users in the planning stage.

To consider the users' requirements and the customers' requirements, they have to already be integrated in the structure planning. The second important point is that the users must operate with this system directly after the implementation. Therefore, it is very important to involve the users at an early stage of the planning so that they can bring their inputs like how to handle long goods and how to handle and store the packaging. Furthermore, they can provide input about the special requirements for the transport of goods. This is helpful for the planning and the acceptance in the operation phase. The requirements evaluated in the first stage are the inputs in the second stage.

To integrate the inputs in the second stage, the plan needs a connecting point that describes how and when the requirements are to be integrated. Furthermore, the question arises of how the requirements are traced and how a measurement has to be designed to know the extent to which the requirement is fulfilled. To control the entire structure planning, it is necessary to divide the structure planning in little parts, so that every small part is easier to control. A further possibility at this stage is to create a method that helps to handle this process stage.

In the detail planning stage, the strengths-opportunity strategy is used. The key factor for a successful start in the detail planning is that the results of the structure planning are minimised to only one variant. Because by having only one variant the planning focus is clear and the way is open for parallel planning. In the detail planning phase, customers and users have to be involved to check if the requirements they implemented at the preliminary planning have been considered. If the requirements have not been considered, the preplanning has to be done once again. So, in the worst case, parts of the preliminary planning and the whole structure planning have to be reworked.

A further important aspect is the flexibility and adaptability of the system. In the logistic sector, market movement is very high, meaning, for example, that customers' requirements might change in a few months. Because of the dimensions of long items, long item processes are not easily changeable. The dimensions impede the fast changes.

At the implementation planning, the strengths and threats strategy is used. The findings are that in this stage it is necessary to work together with suppliers with a sustainable loyalty. Through contact with suppliers, a lot of new detailed ideas and little improvements are generated. To handle these improvements, it is necessary to create a method to check the improvements to determine if they support the whole system or if they only optimise one part of the process. At the implementation stage, it is also necessary to describe the input data and the output data to be able to evaluate whether or not the targets have been reached. A threat in this stage is that the system is described very clearly, but the management level does not have the patience to wait for a sustainable implementation planning. So, the consequence for the long item processes is that the implementation is not sustainable. At this stage, a lot of different problems are identified that are bad for the efficiency of the processes. In the case of complex long item processes, these problems will be raised again: thus, more time and more methods are needed to improve these processes. At the implementation, the strengths-opportunity strategy is used.

When the implementation stage is implemented in the planning process, the knowledge gained at this stage can be used to improve the planned system directly. It can also be used for further planning processes. Another challenge is to earn the necessary acceptance and trust on the part of the employees towards the new system. Employees are often conservative against new systems. Therefore, it is necessary to motivate them and to transmit the ideas behind the system to the employees. One further advantage of the integration is that customers can be persuaded by the effectiveness and efficiency of the system and its flexible adaptability to their own system. If people are involved and their inputs are used, they can see the improvements at the implementation and in the daily work. For example, equipment can be developed that protects goods from damages. Like in the implementation planning, the detected improvements have to be handled. The target is to use the same process for handling the improvement in the stage implementation planning and in the implementation stage.

As a brief summary one can say: In general, the existing planning models are flexible for different types of companies that handle a large number of different products. However, the wide range of adaptability in existing planning models neglects any special requirements the customers may have. So, if the special requirements cannot be integrated in the planning process, the planning process does not lead to the right results for the customers. This is why existing planning models often cannot be used. Current planning models can be divided into five different planning stages. In the existing planning models, the first planning stage (preliminary planning) is very brief.

Furthermore, the customers with special requirements need to be better involved at this planning stage because these requirements are a big part of the target planning. If the target planning is diffuse, the following planning steps in the planning model are not effective. Therefore, it is essential to know the customers' requirements very precisely. The second planning stage is the structure planning. The preliminary planning is the input for the structure planning. When the preliminary planning is conducted consequently, the results can be used directly for the structure planning. Otherwise, it becomes necessary to repeat the preliminary planning or parts of it. At the end of the structure planning, one main variant for the implementation has to be chosen.

The detail planning deals only with this one main variant. Because of the clear focus at the beginning, the planning steps are used efficiently. In the last two stages (the implementation planning and the actual implementation), the customers and users have to be involved and the improvements have to be handled.

New possibilities

Preliminary Planning — w – t strategy

a.) By involving customers early-on in the planning process, their inputs regarding the target planning can be considered.
b.) If the requirements are analysed and evaluated in a real and sustainable way, the planning stages “structure planning” and “detail planning” can be planned with clear focus.
c.) The preliminary planning is adapted to the long items planning.
d.) The target planning has to consider the customers’ requirements for long items.

Structure Planning — w – o strategy

a.) Involve users of the system in an early project stage to generate acceptance.
b.) Create connecting points to handle special requirements.
c.) Divide the structure process into smaller parts to reach transparency.
d.) Use new methods for the structure planning.
e.) Create a planning figure for the storage height and length planning.
f.) Create a method for determining how to plan that helps to plan different picking systems of long items and commercial goods.
g.) Create a calculation method for the planning of the main processes like the in- and out-going area.

Detail Planning — s – o strategy

a.) By planning only one variant, the planning focus is clear and parallel work is possible.
b.) Active integration of users and customers.
c.) The planning system has to be flexible and adaptable to other planning system.
d.) Develop a new transportation system for long items that is applicable to commercial goods.
e.) Identify knowledge at the long items information flow that can be transferred to other processes.
f.) Synchronisation of the processes from long items processes and processes with commercial goods.

Implementa-tion Planning — s – t strategy

a.) The input and output data has to be defined clearly. Only then is it possible to evaluate the data.
b.) Handle improvements in the implementation planning in a standardised way.
c.) Involve suppliers with high knowledge and a sustainable loyalty.
d.) All processes (long items processes and commercial processes) are organised according to the customer demand from the beginning.

Implementat-ion — s – o strategy

a.) Gain knowledge for planning the next system. This knowledge can be used in all stages of the planning.
b.) Earn trust from the system users and customers. It is necessary to be able to transmit the system knowledge from the planning to the operative level.
c.) Handle improvements in the implementation stage.
d.) Installation of a consequent shop floor management.
e.) Installation of a training phase for employees.

Figure 5.7: New Possibilities in Derivation from the SWOT-Analysis

5.4 Chapter Summary

The new possibilities identified by the SWOT Analysis method are used to create a new planning process. The overall aim of the new planning model is to create data with high quality in the preliminary planning stage. This approach is a stress field because generating a lot of detailed data in a short time is difficult. But, the advantage of detailed data is that in further planning stages, no additional work has to be done to create detailed data. This advantage is not unique to the long item process planning and can also be used for other planning models. A possibility for the first planning stage is to implement customers.

In the structure planning stage, users and customers have to be involved consequently because their know-how is helpful to create a user-orientated system. Moreover, the planned system should generate broad acceptance among users and customers. A further aid in the planning process is to generate a “red line” indicating which methods can be used and in which way the methods are connected. The result of the structure planning is to have only a few variants from which to make a decision which variant is the best and could be planned in further stages. At this planning stage, it is important to select only one variant at the end of this stage. This result is only possible when the basic data has been analysed and evaluated consequently so that it does not have to be reworked. Therefore, the special requirements of long items have to be analysed and evaluated consequently from the beginning.

At the detail planning stage, the subsections like processes, equipment, and buildings are planned in detail. Here again, the special requirements of long items have to be considered because special equipment is needed to handle long items. The precise planning is necessary to be able to determine and announce the subsections. This phase ends with the award of contract and a supplier has to be chosen for every subsection.

The implementation planning describes the implementation of the subsections, transition period activities, and the on-the-job-training of the new processes and equipment. The result of this planning stage is that no open question exists regarding how the implementation will be done.

At the implementation, the processes, buildings, and equipment are installed. At this stage, personnel are trained on the processes and the equipment. An important point at the implementation is that ideas to improve processes, buildings, and the equipment are managed and documented.

With the help of the precise data, the basis of a precise structure planning is possible. Beyond this, the high quality of the planning process is also noticeable in the detail planning because all subsections are evaluated In the last two stages, the aim of the implementation planning and implementation is to realise the planning results.

Chapter 6 Development and Implementation of a New Framework

6.1 Introduction

In this chapter, the new framework for planning long item logistics processes is created. The aim of this chapter is to describe the progress, the framework brings for the long items process planning.

6.2 Description of the Framework

The new planning process for planning long item logistics processes is shown in Figure 6.1.

The planning process is a new framework though it considers planning methods that have been used previously in commercial logistics planning processes. The elements of the planning process that deal with laws or economic rules are comparable to other planning, but planning stages that deal directly with the products are completely new. Furthermore, in this framework, methods are implemented to help establish a better planning procedure. So, it is expected get an effective and efficient system if this framework will be used to plan a logistics system with long items. The new proposed and developed framework uses the findings from the interview surveys with customers and the analysis of present existing planning procedures. By evaluating the present planning procedures, the author recognised that the long items processes are planned and used in an ineffective way. This is because the parameters of the existing planning procedures are not considered, however they are necessary to create an effective and efficient planning procedure. This gap in the present planning procedures is so big that a new planning procedure has to be created for long item logistics. In this new framework, methods from other research areas are implemented, as far as they are adaptable. Furthermore, the findings of research in the area of long items logistics are considered. The aim is to get sustainable findings so that planning stages do not have to be repeated because of incorrect results. With the new framework, incorrect findings can be detected directly and only the last planning stage has to be repeated.

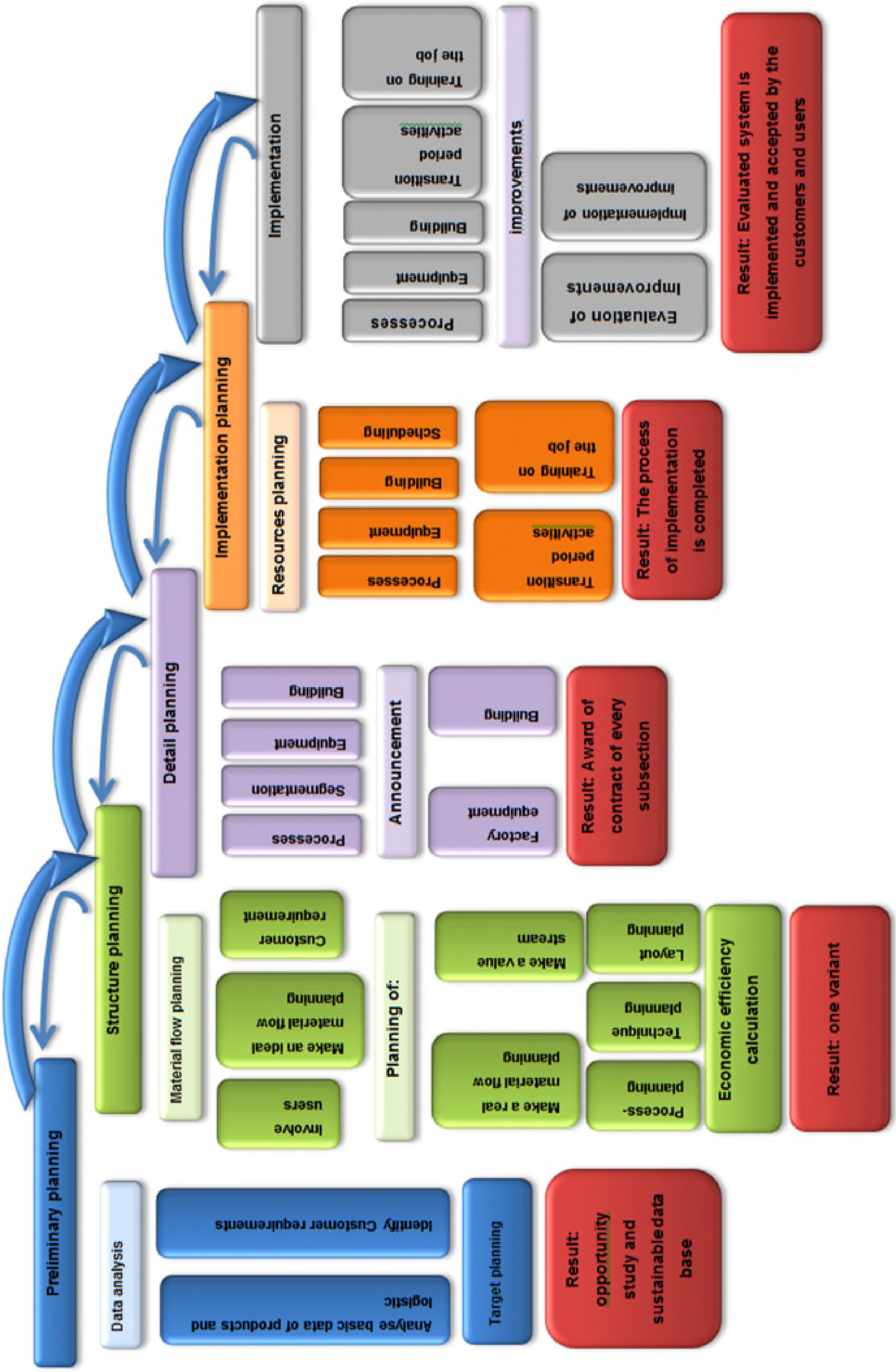


Figure 6.1: The New Framework to Plan Long Item Processes

6.3 Description of the Conceptual Framework

Before the concrete planning process of the framework starts, questions related to the system parameters like the planning horizon have to be defined (see Table 6.1). The advantage of a framework is that it provides an overview of the logistics system without requirement of further information. Thus, the framework is a guideline (Gudehus, 2012, pp. 597 - 600).

For this overview, all logistics processes are separated in parts. The intra-logistics comprises all logistics aspects within one business unit/company. The external-logistics contains logistics processes outside the own business unit/company. However, these logistics processes are important since they influence the own processes. An example for external-logistics is a freight forwarding company. The last logistics part is the internal-logistics. The internal-logistics comprises the corporate logistics with other companies. Thus, for example outsourced departments like the outgoing goods area are internal logistics (Gudehus, 2012).

Table 6.1: Example of a Framework at the Preplanning Stage, Part (I / III)
(based on (Gudehus, 2012, p. 599))

General Requirements of the Logistics System		Intra-Logistics	External-Logistics	Internal-Logistics
	Products	which products are handled	which products are handled	which products are handled
	Planning Time Horizon	medium term	medium term	short term
	Description	logistics for a production area	supplier logistics	distribution logistics, supplier logistics
	Location	one location	different locations	different locations
	Network	linked to the distribution logistics in the external logistics	closely linked with the suppliers logistics	many connections to other logistics
	Source	goods from suppliers and goods from two production areas	goods from suppliers	many different suppliers and two internal productions areas
	Sink	the distribution logistics	production area within the company	the production area within the company and the distribution of another business unit, e.g. another company of a group of companies
	Operating System	material provision logistics, storage logistics, picking logistics, dispatch logistics	storage logistics, picking logistics, delivery logistics	intra - logistics, external logistics, transfer logistics
	Material Flow	pull material flow	a combined push and pull system	different push and pull material flows, as well as a combination of different material flows
	Information Flow	in the opposite direction of the material flow	in the pull processes, in the opposite direction of the material flow; in case of push, material flow in the same direction	in the pull processes, in the opposite direction to the material flow; in case of push, material flow in the same direction
	IT-System	the whole logistics is supported by the IT system	the suppliers' IT is not linked to the company's IT system because the companies are completely independent and do not use the same IT-system	many different connections to IT systems of the allied companies
	Improvement Process	no continuous improvement systems installed	no improvement systems installed	different types of improvement processes
	Products	long items, euro - pallet material, packages	long items, liquids, pallets, special pallets	internal products, external products

Table 6.1: Example of a Framework at the Preplanning Stage, Part (II / III)

(based on (Gudehus, 2012, p. 599))

Requirements on the Organisation of the Logistics		Intra-Logistics	External-Logistics	Internal-Logistics
	Logistics operator	own logistics	external service provider	own logistics and external service provider
	Owner of the Operating Equipment	own equipment	equipment of the supplier	own equipment and supplier equipment
	Transport Service	external transports by external logistics services	transport by supplier	transport by supplier
	Owner of the Transport Equipment	external logistics service	transport equipment belongs to the supplier	transport equipment belongs to the supplier
	Owner of the Stock	own stock	stock of the supplier	own stock
	Familiarity to other Logistics Processes	other processes can be used for such products	new processes have to be developed	other processes can be used for such products
	Flexibility of the Logistics System	the logistics system could handle +/- 35% capacity and is adaptable to other products	the logistics system could handle +/- 15% capacity and is not adaptable to other products	the logistics system could handle +/- 35% capacity and is adaptable to other products

Table 6.1: Example of a Framework at the Preplanning Stage, Part (III / III)
(based on (Gudehus, 2012, p. 599))

		Intra-Logistics	External-Logistics	Internal-Logistics
Basic Requirements from Producers, Logistics, Wholesalers, Craftsmen	Information Delivery Date	electronically documented by IT system	electronically documented and transmitted by IT system	electronically documented and transmitted by IT system
	Information in Case of a Change in Delivery Date	electronically documented by IT system	electronically documented and transmitted by IT system	electronically documented and transmitted by IT system
	Requirements to the Package	package only for indoor transportation and storage	package for indoor and external transportation and storage	package for indoor and external transportation and storage
	Product Quality	inline measurements, quality gates	inline measurements, quality gates	inline measurements, quality gates
Additional Requirements for the Planning of Producers and Wholesaler Logistics	Delivery Time	door to door time shorter than one day	door to door time shorter than one day	door to door time shorter than one day
	Which Package Material is Preferred	only use wood, nails, and steel straps	only use wood, nails, and steel straps	only use wood, nails, and steel straps
	Way to Order	ordering via phone, fax, and IT system	ordering via IT system	ordering via IT system
	different types of material	only use 2 different package materials	only use 2 different package materials	only use 2 different package materials

The framework described in Table 6.1 is divided into four parts: the "general requirements of the logistics system," "requirements on the organisation of the logistics," "basic requirements from producers, logistics, wholesalers, and craftsmen," and "additional requirements at the planning of producers and wholesaler logistics." In the first section of the table, the 13 logistics requirements are presented (see Table 6.1 blue / white marked). It starts with the definition of the goods that are handled in the logistics system. The following requirements consider the planning time horizon.

The third requirement deals with the supply chain level for which the logistics is planned. At this point, the numbers of locations are defined (how many locations will exist after the planning process). The next requirement deals with the network of the logistics and the suppliers. The requirement source describes if the products handled in the logistics system are produced by their own or by a supplier. The requirement sink describes who the receiver or customer is and by whom the products are needed. The operating system requirement describes the different operating systems of the business units in the company and the systems of the suppliers and customers, e.g. SAP or Oracle. In addition, it has to be mentioned at this point when one business unit uses more than one system.

There are three different possibilities when it comes to the material flow requirement: pull, push, and/or mixed material flow. Mixed material flow is a mixture of a push and a pull flow of material. The requirement information flow is connected to the material flow. In push-orientated material flows, the information flows in the same direction as the material flow. In pull-orientated material flows, the information flows in the opposite direction of the material flows.

Almost all working processes are supported by IT-systems. Therefore, it is imperative to have an integrated information system that is matched to all processes. If suppliers and customers use the same information system, a minimum of connection problems will occur. If they do not use the same information system, the information transmission becomes more complicated and is not as fast and effective as it would be with the same information system.

At the requirement of improving the processes, it is important to involve the employees using the processes in the daily work. Planners and engineers often plan complicated systems and equipment. For example, since the Toyota Motor

Company rose to be the biggest motor company of the world, their production system has been deemed an effective instrument of success. Toyota involved the employees in the process optimisation and they added ideas for improvements. This shows that the users' ideas are very important and have to be considered in the planning stages. The users are not supposed to plan complex systems or equipment. They should only provide their own inputs for optimisations. However, a number of little improvements has important effects all together. Finally, the last requirement deals with the products to be handled.

Part II of Table 5.1 deals with the second part of the framework that presents the description of how the logistics is organised and it starts with the choice of logistics elements. The first requirement deals with the logistics operator. This contains the question of whether the company has its own logistics employees. Logistics systems are often completely outsourced because they are often not a core competence for a company. For example, if a freight company handles all of the transportation aspects from the company to the customer and delivers the company with goods, this part of the logistics process does not have to be planned. The planning can then be limited to the in-house logistics. Hence, it is necessary to define which logistics activities are done by the given company's own employees. The second requirement deals with the equipment that is needed for the work and the processes that the company owns or if other possibilities exist, such like renting or leasing. The requirement transportation of the goods out of the logistics company is one of the classic processes that is managed by freight companies in whole or in parts. The same is true regarding the requirement equipment that is necessary for the transportation. In general, the transportation company owns the equipment. Another important requirement is that in the logistics, the stockowner is often the supplier. Usually, a supplier is the owner of the goods until the goods are taken out of the storage. After that, the company becomes the owner of the products. All of these examples demonstrate possible limitations for the extent of the planning. If external companies are involved, these process stages often do not have to be planned because the external companies are responsible for these planning stages.

The next requirement deals with the familiarity to other logistics processes. To be able to estimate if new goods can be handled in the existing logistics system within a short time, it is necessary to describe the logistics processes in a precise way. All processes have to be transparent. To achieve this aim, it is also important to recognise the familiarity of long item processes to other “commercial good” processes.

The last requirement, the flexibility of the logistics is taken into account. The first requirement considered is the flexibility of the capacity, meaning determining if the system is adaptable to the customers’ demands and determining the limitations or boundaries to the system’s capacity. The second requirement of the system’s flexibility is to evaluate if the system could work with new and other products. To evaluate this in a short schedule, it needs a profile of each process. In this profile, all important key parameters of a process are described.

In the third part of the framework, the basic requirements from producers, logistics, wholesalers, and craftsmen are considered (see Table 6.1, marked red / white). These are findings from the expert interview. The process planning method is only a method for the intra logistics planning. For this purpose, the requirements of external customers have to be considered as well as requirements of customers from the internal logistics. These requirements have to be transmitted to the appropriate parts of the process. The most important requirement is to handle the information regarding the delivery date. In order to be able to make a precise statement about the expected delivery date, the whole process has to be scheduled precisely. The second requirement deals with the information in case a delivery cannot be delivered or completed on schedule. The challenge is to identify the delay, collect information regarding the delay, and transmit it to the customer within short time. A further requirement is the package quality. The package has to be usable for handling and storing. Beyond this, the requirement product quality has to be ensured. To check the quality, inline quality gates are in place.

In part III of the Table 6.1, the additional requirements regarding the planning of producers and wholesaler logistics are considered (see Table 6.1, marked green/white). These requirements are identified in the expert interview. The first requirement deals with the delivery time. Customers typically request quick delivery of the products, so this has to be considered at the planning. An additional requirement is the material of the packaging. There are different types of packaging materials; thus, a familiar requirement is the number of different packaging materials. This is important to consider because only a few possibilities to recycle packaging materials exist on a building site. The next requirement is the way to order. Craftsmen like to order directly on the building site by phone only. Thus, in this case, it is necessary to be able to handle the ordering and to transmit it to the wholesaler or to the producer.

6.4 Preliminary Planning

The aim of the preliminary planning is to gain a sustainable data base for the further planning stages. There are two approaches to the preliminary planning: the analytic and the systematic approaches. The first one progresses from the outside to the inside. This means the planning starts at the building planning and ends at the machine planning. The problem of this approach is that it is not possible to ideally plan processes because the processes are arranged to fit the specifications of the building. The systematic approach is the inside to the outside approach. This approach supports the planner in finding the ideal solutions. This is because the processes are planned first and then the buildings are constructed accordingly (Grundig, 2013, p. 24).

Basically, the systematic planning approach is used for the entire planning process. The result of the preliminary planning is to have a sustainable data base of the basic product and logistics data. Sustainable means that data are analysed and evaluated and only data, that is needed for the next processes is considered. Estimations cannot be used as basis for the planning, because all calculations are constructed on the data from the preliminary planning (basic data). If the basic data are not reliable, all further calculations would be not very meaningful for further processing for the late applications. The basic data is gained by analysing the product and logistics data. An example for basic data is presented in Table 6.2.

In the second stage of preliminary planning, the data from the history data from the company has to be analysed. Data from the past 5 years has to be considered This is necessary in order to find a trend, e.g. a seasonal trend or the effects of sales campaigns. The expectations for the future have to be defined based on previous experiences.

However, future planning is much more complicated because future data cannot be well-defined. Data for the future are based only on uncertain estimations. One possible way to define the basic data in the future is through derivation of the basic data from the previous period of 5 years. However, in this case the experiences about the flexible demand of the history have to be evaluated to determine if the flexibility of demand will be the same in the future and if the influences on the demand are the same as in the history. The important influences on the demand and the order-behaviour of the customers include determining whether new products will be placed on the market or whether the products are being delivered to new market segments of the logistics chains and to countries that have not been delivered yet. These new markets can lead to a completely changing demand.

Table 6.2: Basic Data

Material Number	Material Name	Dimensions of the Product	Dimensions of the Package	Number of Products per Package Unit	Door to Door Time	Picking Time	Information Flow	Labelling	Delivery Time	Location	Delivery Package
1											
2											
…											
n											

The data analysis identifies the basic data in detail, which enables us to compare effects like seasonal demand, peak demand and the variation of the data to the average demand. Therefore, the basic data have to be analysed at least on a daily basis. If this is possible, the basic data have to be defined in more detail, e.g. by analysing the demand on an hourly basis. Evaluating the demand is necessary because a logistics system cannot be calculated on the basis of average basic data. The performance data of the logistics system have to be calculated as precisely as possible to find the true demand because the system has to be able to handle peaks on the demand. There are three steps of a process of creating a sustainable database, as shown in Figure 6.2.

Figure 6.2: Process of Creation of the Basic Data

The second part of the preliminary planning is to identify the planning type. There are basically four different planning types. Specifically, these are new planning, modification planning, deconstruction planning, and revitalisation planning (Grundig, 2013, pp. 18 - 20). Without such processes, it is not possible to evaluate existing processes. This kind of new planning is normally called green field planning. If processes already exist, these are evaluated according to the customers' requirements as listed in Table 6.3 (this table is created by the author). The customers' requirements are different in each stage of the supply chain (see Chapter 5). Thus, it is very important to define exactly for which supply chain stage the logistics system is planned in order to be able to consider the right customers' requirements. Craftsmen, producers, and wholesalers have different requirements for the logistics system. These special and additional requirements have to be considered at the planning stages of the logistics system (see Table 6.3). With the help of Table 6.3, the planner can analyse and determine if the existing processes fulfil the logistical requirements.

Table 6.3 Evaluation of Existing Processes

		Incoming Goods Area				Storage				Picking				Outgoing Goods			
		process 1	process 2	process …	process n	process 1	process 2	process …	process n	process 1	process 2	process …	process n	process 1	process 2	process …	process n
Producers, Logistics, Wholesalers, Craftsmen (requirements that have to be considered at every stage of the logistics chain)	Information about the Delivery Date																
	Information in Case of Change in Delivery Date																
	Packaging Requirements																
	Product Quality																
Producers, Wholesalers (additional requirements that have to be considered at the intra logistics of planning of producers and wholesalers)	Delivery Time																
	Which Package Material is Preferred																
	Way to Order																
	Different Types of Material																

The last step of preliminary planning is the target planning. At this phase of the planning, the previously analysed data (basic data, company and strategy targets, process evaluation, and the framework) is combined and used to targets for further planning steps (see Figure 6.3). It is very important to have a sustainable database at this point because the following planning is based upon this data. If the database is not sustainable, the following planning could be incorrect and have to be repeated, which is time-consuming and cost-intensive.

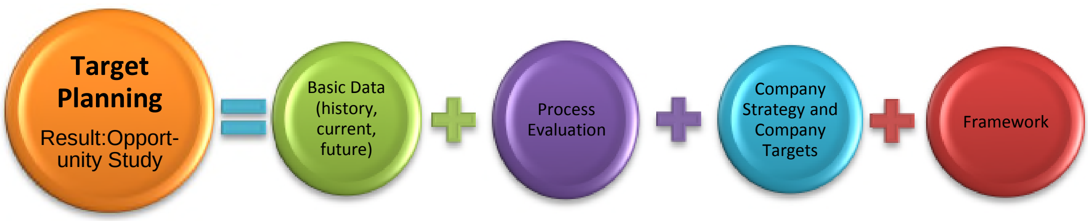


Figure 6.3: Elements of the Target Planning

The target planning is influenced by a company's strategic future plan. In the company strategic planning, the further fields of action, products, and threats are considered in an integrated way to determine the projected activities of a company in the future (Grundig, 2013, pp. 55 - 56). The target planning ends with an opportunity study. At the end of the opportunity study, the decision is made whether or not to continue with the planning process. The opportunity study considers the following points (Grundig, 2013, p. 56):

- Project definition
- Problem description
- Clear project target planning
- Show the rough direction in which the solution should be developed
- Definition of the level of performance
- Definition of the investment
- Development of a rough schedule
- Description of the project borders
- Description of the project structure

6.5 Structure Planning

In the structure planning, the logistics structure first has to be described. A logistics structure has two main parameters: the logistics process and the logistics products that are developed at each logistics stage (Stadtler, et al., 2010, pp. 254 - 260).

Figure 6.4 demonstrates the logistics structure. On the right side, the logistics processes like the storage, picking, etc. are included and on the left side, the names of the logistics products are shown (see Figure 6.4). The logistics structure is like an object list in the field of engineering, which enables planners to develop a material flow chart in analogy to the logistics structure.

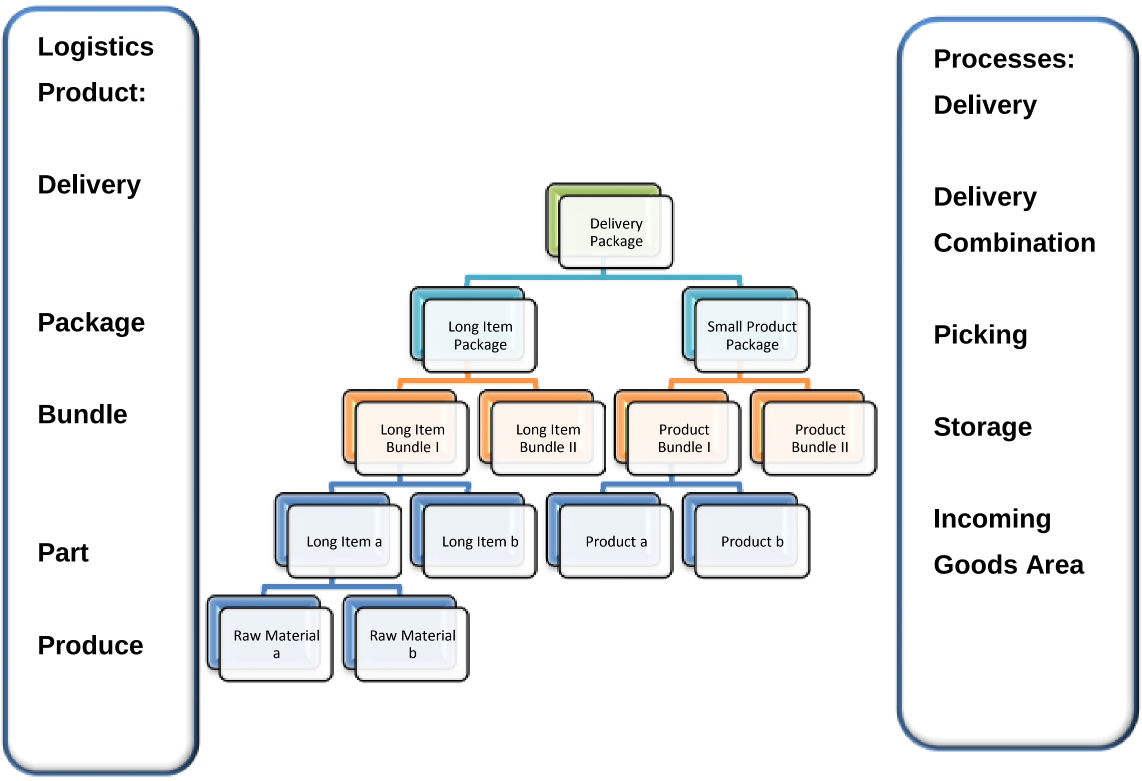


Figure 6.4 Example of a typical Logistics Structure
(based on (Grundig, 2013, p. 82), (Alicke, 2005, p. 14))

With the help of the logistics structure, the ideal material flow can be defined first. For every logistics product, a logistics structure has to be described.

To use the logistics structure in Enterprise-Resource-Planning (ERP), it is necessary to create a structure that is manageable by ERP. Thus, the logistics structure has to be organised by a matrix (see Table 6.4, created by the author). This matrix describes all logistics processes. Furthermore, it shows that many logistics products use the same logistics processes and equipment. Therefore, the layout and performance plan of the equipment has to be developed. On the basis of the logistics structure matrix, the ideal material flow can be created. In addition, the intensity of the material flow between processes should be shown clearly. With these findings, the equipment performance can be determined.

Table 6.4: Logistics Structure as a Matrix

Processes						
Product Number	Product Name	Incoming Goods Area	Storage	Picking	Delivery Combination	Delivery
1	bundle 1	X	X	X		X
2	package 1	X	X	X	X	X
…	…	…	…	…	…	…

6.5.1 Ideal Planning

The working plan and the material flow can be created based on the logistics structure. The material flow is very important for the logistics. Thus, the ideal material flow has to be created. Figure 6.5 describes the connection of the process stages in an ideal way. That means that in the ideal material flow, processes are connected regardless of any restrictions placed on them, such as regarding current buildings or current behaviours of processes. The aim is to generate a process chain in which the processes are directly connected and produced only according to the demand of the customers. If the customer demand varies, it is necessary to create a process chain that is flexible to meet the customers' demands. When creating an ideal material flow it is helpful to consider the seven types of wastes (see Chapter 3). The main purpose of an ideal planning is to create the ideal processes for the logistics system with a minimum amount of waste. With the help of the ideal planning, the dimensions of equipment can be calculated. Furthermore, the layout, employee allocation, and energy planning are included in this stage as well. In Figure 6.5, the circles comprise the names of the processes. The circles are connected by arrows, which have a different thickness. The thicker the arrow, the bigger the material flow is from one process to the other (see Figure 6.5).

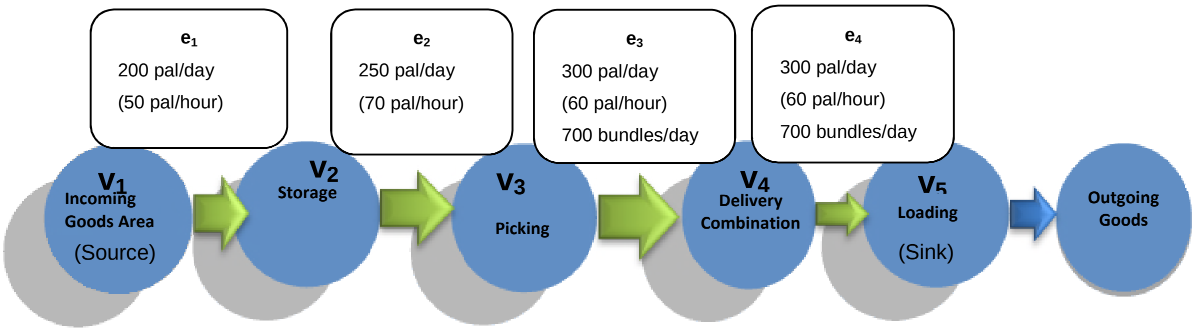


Figure 6.5: Ideal Material Flow Chart

The material flow chart is also called graph. A graph (G) is described by vertexes (V) and edges (E). Vertexes are the processes in the circle and the edges are the material flow arrows (Arnold & Furmans, 2009, pp. 50 - 55).

$$G(V, E) \qquad \textbf{(6-1)}$$

Where *G*: Graph

V : Vertex

E, e: Edge

and

$$V = \{1, 2, \ldots, n\} \qquad \textbf{(6-2)}$$

If the graph is directed, then the written form of the edges is not important *i,j* = *j,i*. If the graph is directed, then the elements of *E* are k_i (Arnold & Furmans, 2009, p. 51).

$$E = \{k_1, k_2 \; \ldots, k_n\} \qquad \textbf{(6-3)}$$

Edges that link two vertexes are written *k=[i,j]*. If all vertexes are connected by edges, then it is a complete graph. If all vertexes are connected, the number of edges can be calculated using the following equation (Arnold & Furmans, 2009, p. 51):

$$e = \frac{v(v-1)}{2} \qquad \textbf{(6-4)}$$

In the case that all vertexes are connected by edges k_{12} - k_{21}, then the number of the edges can be calculated using the following formula (Arnold & Furmans, 2009, p. 51):

$$e = v(v-1) \qquad \textbf{(6-5)}$$

From the ideal material flow, the adjacency matrix can be created. The adjacency matrix shows the relation of the vertexes to the edges of a graph. The matrix in Table 6.5 is developed by the author from the ideal material flow that is shown in Figure 6.5. At this matrix, the vertexes on the abscissa and the ordinate are sorted from vertex one (v_1) to vertex five (v_5). The number 1 describes that a connection between two vertexes exists. The number 0 describes that no connection between vertexes exists (Arnold & Furmans, 2009, p. 54).

Table 6.5 Material Flow Matrix

(based on (Arnold & Furmans, 2009))

	v_1	**v_2**	**v_3**	**v_4**	**v_5**
v_1	0	1	0	0	0
v_2	0	0	1	0	0
v_3	0	0	0	1	0
v_4	0	0	0	0	1
v_5	0	0	0	0	0

lower triangle

Some information can only be identified by analysing the elements in the matrix. Vertex 1 is only a sink because only edges go away from Vertex 1. Vertex 5 is only a source because no edges go away from vertex five. Only one edge goes to Vertex 5. In the graph, no loop exists because all diagonal elements are 0. A graph is topologically sorted when every vertex has a lower number than the following vertex and a bigger number than the previous vertex. The graph is topologically sorted because at the lower triangle of the matrix, all elements are 0. A graph like this has at least one exclusive source and one exclusive sink. The main material flow is arranged in one direction. In addition to the main material flow, there are also lateral material flows, which can be arranged in different directions. At the long item planning, it has to be considered that more than one main material flow exists. One material flow shows the “normal” goods and one material flow shows the long items.

The matrix helps to identify characteristics of a material flow. Beyond this, the material flow matrix helps to calculate the following parameters:

- Flow Performance
- Distances Between Vertexes
- Time Needed between the Vertexes

In the second level, an evaluation matrix is described. The rules for the evaluation matrix are that if no connection of vertexes exists, the edges = ∞. The diagonal elements of the matrix, $e_{ij} = 0$. If loops are necessary in the material flow matrix, $e_{ij} > 0$ (see Table 6.6). This is because one step of the process is repeated. The elements e_{ij} are a direct connection from the vertexes *(i) and (j)* (Arnold & Furmans, 2009, pp. 50 - 55).

Table 6.6: Evaluation Matrix

(based on (Arnold & Furmans, 2009))

	v_1	v_2	v_3	v_4	v_5
v_1	0	e_{12}	∞	∞	∞
v_2	∞	0	e_{23}	∞	∞
v_3	∞	∞	0	e_{34}	∞
v_4	∞	∞	∞	0	e_{45}
v_5	∞	∞	∞	∞	0

In the evaluation matrix, the elements like e_{12} have a physical meaning. In the practical application, the elements are either distances or times. The performances are shown in another matrix. The directly connected vertexes are shown in the adjacency matrix and the evaluation matrix, but in the graph, the ways for progressing from one vertex to another are not direct, but by passing by another vertex. The visual information is easy to view. But in a matrix, these ways have to be described because there are a lot of ways to find another vertex. With the knowledge of the different ways, the distances can be calculated and the shortest distance can be identified. The vertexes (1) and (5) are not directly connected. But by using other edges, it is possible to find a way from vertex (1) to vertex (5). In Figure 6.5, there is only one way from (1) to (5), as expressed in Equation (6.6) (Arnold & Furmans, 2009, p. 55).

$$\boldsymbol{e_{15} \coloneqq MIN\{e_{12} + e_{23} + e_{34} + e_{45}\}} \qquad \textbf{(6-6)}$$

If more than one way from one vertex to another exists, the shortest way has to be identified. By analysing the shortest way, the assumption is that the shortest way also requires the shortest amount of time for transportation. However, in reality, this approach has to be reviewed because some passage ways in a building could be smaller than others and the transportation equipment may not be able to drive through the shorter route. Another problem could be that too many vehicles are parked or operating on the factory roads which could lead to the longer required time. In the distances matrix, the distances are presented in metres. In case a loop exists, the distances from the same vertex, such as the vertex (1) to (1) can be > 0 because the goods could be stored on another place (Arnold & Furmans, 2009, pp. 51 - 58).

Table 6.7: The Distance Matrix [m] (indicated in metres)

(based on (Arnold & Furmans, 2009))

	v_1	v_2	v_3	v_4	v_5
v_1	0	400	∞	∞	∞
v_2	∞	0	500	∞	∞
v_3	∞	∞	0	600	∞
v_4	∞	∞	∞	0	700
v_5	∞	∞	∞	∞	0

To identify the demand of employees and equipment, it is necessary to make a time matrix. The time matrix considers the transfer time from one process to another. A transfer process contains three parts. Part 1 involves accelerating to the transfer speed. Normally, the transfer speed is maintained until the transporter nears the destination and applies the brakes. As soon as the transport vehicle stops, the process of unloading and loading starts. The loading and unloading procedure has to be documented. After the unloading and loading process is finished, the transfer process starts again by accelerating. The transfer time from one point to another is not the largest amount of time because the indoor speed of vehicles is limited to 14 km/h by law in Germany. The time that is needed from one vertex to the next vertex is calculated by the help of the matrixes in Table 6.7 and Table 6.8. The result of this calculation is shown in Table 6.8. It can easily be read by following the abscissas and the ordinate. As an example, the time that is needed from vertexes (4) to vertex (5) in comparison to the time that is needed from the vertexes (1) to vertex (2) is almost the double time. Considering these results at the planning supports the implementation of lean planning aspects by connecting processes in every possible case to eliminate transportation.

Table 6.8: The Time Matrix [s] (accelerating, applying the brakes, loading, unloading, and the documentation are considered)(time unit: seconds) (based on (Arnold & Furmans, 2009))

	v_1	v_2	v_3	v_4	v_5
v_1	0	103	∞	∞	∞
v_2	∞	0	128	∞	∞
v_3	∞	∞	0	154	∞
v_4	∞	∞	∞	0	180
v_5	∞	∞	∞	∞	0

6.5.2 Value Stream Mapping

The value stream mapping summarises all value-added activities from the beginning of the order to the end (Lindner & Becker, 2010, p. 9). The target of the value stream mapping method is to get a clear and transparent view on main material and information flows within a company. Furthermore, the mapping provides a way to analyse the connection of the material and information flow. In analysing the value stream, three different categories of activities emerge. The first type of activity includes process elements that are necessary to create a product. The second type of process elements includes waste that is necessary for the production. That means that the production in the existing form is not possible without this type of waste. This type of waste should be minimised systematically because it slows down the processes. This leads to further waste of human resources and to higher production costs. Furthermore, the transportation equipment is not used efficient so that the earnings are reduced. The third type of process elements are waste that are not necessary for the process and hence this type of waste has to be eliminated as quickly as possible (Womack & Jones, 2003, p. 38).

The border of the applicability of the value stream mapping method is the number of variants. If a large number of different products use many different processes, the processes cannot be concentrated to one value stream (Dickmann, 2009, pp. 274 - 275). Transmitted to the value stream of logistics processes, the value stream method can be used to analyse and evaluate different logistics processes. Especially for the analysis, this method is chosen for the comparison of long items processes and processes for “normal” goods. By using simple symbols, the similarities, differences, and points of contact are easy to identify. Figure 6.6 shows a value stream of a pipe logistics. At the top of the value stream (in Figure 6.6) is the ERP-system from which the processes get their information. Beyond this, processes send information to the ERP-system, e.g. that the process is finished.

Furthermore, the ERP-system is linked to the supplier and customers. The customer sends a forecast to the ERP-system and the ERP-system gives a forecast to the own supplier. All main characteristics of a process are described in the box. Important characteristics include the process name, the number of employees, and the cycle time. Between the process boxes, the inventory is marked with a triangle. Numbers are placed below the triangle, e.g. 4600A. Letter A stands for the product name and Number 4600 for the number of pieces. The information below the chart is called the “saw tooth curve.” The cycle time is placed at the deep line of this curve and the days of inventory is placed at the high line of this curve. At the right side of the saw tooth curve, the cumulated cycle time and the cumulated day of inventory are calculated (Rother & Shook, 2006, pp. 28 - 31).

The surprise is that the cycle time is much faster than the door to door time. Thus, the product spends most of its time in a value stream simply in the storage. With the help of the relation of the cycle time to the door to door time, a comparison of different value streams is possible. Beyond this, the saw tooth curve can be used to analyse a value stream. The value stream helps gain a complete overview of the whole supply chain and shows that there is not really much optimisation in the cycle time of the processes. The best optimisations are possible at the inventory phase between the processes. If the inventory sinks, the door to door time is sustainably shorter.

A value stream with fewer inventories is more flexible. If the customers change the order, the supply chain can produce or handle goods flexibly. With the help of the value stream, long items processes and processes for “normal” goods are easily to illustrate. Every supply chain gets its own value stream, as shown in Figure 6.6. The value stream for the long items is presented at the bottom and the value stream for the other goods is shown above this. If processes are done in parallel, the process with the larger amount of time is shown in the saw tooth curve. The value stream mapping supports a transparent information flow, which is a premise for some customers.

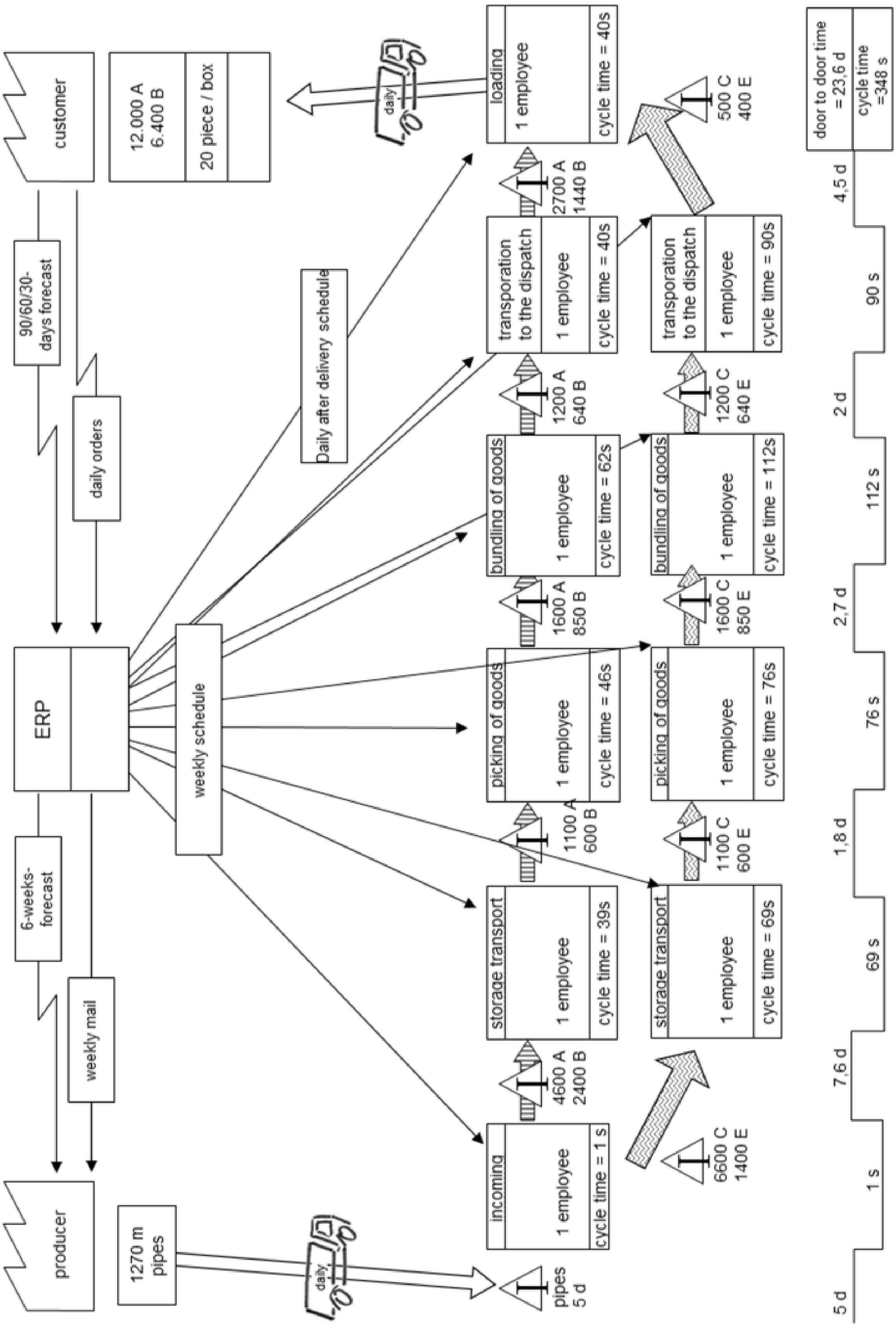


Figure 6.6 Value Stream of a Pipe Logistics

6.5.2.1 Rules for Creating a New Value Stream

To create a new value stream with a minimum of waste, the following eight rules should be regarded (Rother & Shook, 2006, p. 52):

1. The processes have to work at the same speed as the customer purchases these products.
2. None of produced goods should be stored unless they are necessary.
3. Stages in the process that produce waste have to be eliminated, if possible.
4. If possible, a continuous material flow without storages and buffers has to be created and implemented in an effort to minimise the door to door time.
5. If it is not possible to implement a continuous material flow, a Kanban cycle has to be installed.
6. Define the pacemaker process.
7. Synchronise all processes on the pacemaker process.
8. Shrink the batch size by considering every part and every interval concept (EPEI concept).

The first rule describes that the right number of goods has to be produced. The number of produced goods must not be higher than the number of goods the customers purchase. If possible, goods should only be produced if they are required by a customer. The door–to-door time has to be so short that the customer accepts this time as delivery time (Rother & Shook, 2006, p. 53).

The second rule deals with the waste type "stock." It has to be critically reflected if the stock is necessary or if the stock can be limited and reduced. So, for every produced good, the question has to be posed, why or for which purpose the good has been produced? Is it for the stock or for the customer?

The elimination of the other types of waste in the value stream is considered by the third rule. This involves examining which parts of the process could be eliminated because they produce waste. For example, if the process contains too many transports or waiting times between the processes, these types of waste have to be eliminated (Dickmann, 2009, p. 278).

The fourth rule says that if possible, all processes should be connected directly. As a result, the door-to-door time can be reduced.

If it is not possible to create a continuous material flow without storage areas and buffers, Rule 5 says that Kanban cycles have to be installed. A Kanban cycle has a stock with a limited maximum. Thus, the maximum of the stock cannot be extended because the maximum stock is limited by the maximum number of Kanban cards. The result of implementing the Kanban system is that waste from overproduction is limited (Womack & Jones, 2003, p. 58).

The pacemaker process is identified by the help of rule number 6. The pacemaker process is the process with the longest process time. In the best case, this stage of the process is shorter than the time the customer needs to order the goods, for in this case, the goods can be produced and directly be delivered to the customers. Thus, a stock or a buffer is not needed. For example, if the customer orders one good every two minutes, the pacemaker process should have a cycle time ≤ 2 minutes. If not, the process has to be optimised or the working time has to be extended.

The seventh rule deals with the adjustment of the processes on the pacemaker process. To synchronise all processes, no stock should accumulate between the processes. This synchronisation is important to minimise the cycle time losses.

The last rule addresses the batch size. If processes can handle small batches, the goods can be produced according to the customer demand. The danger of reducing the batch size is that the providing time of the machines is neglected. If the batch size is halved, the providing time of the machine has also to be halved. If not, the working time will be extended and the production costs of the goods increase. This is because the number of goods that is required stays the same. But if the providing time is not halved, the same product mix and same amount of goods cannot be produced within the working time. So, as a result, the working time would have to be extended. This problem is described by the Every-Part-Every-Interval concept (see Figure 6.7) (Rother & Shook, 2006), (Straub & Schiepp, 2010, pp. 42 - 44).

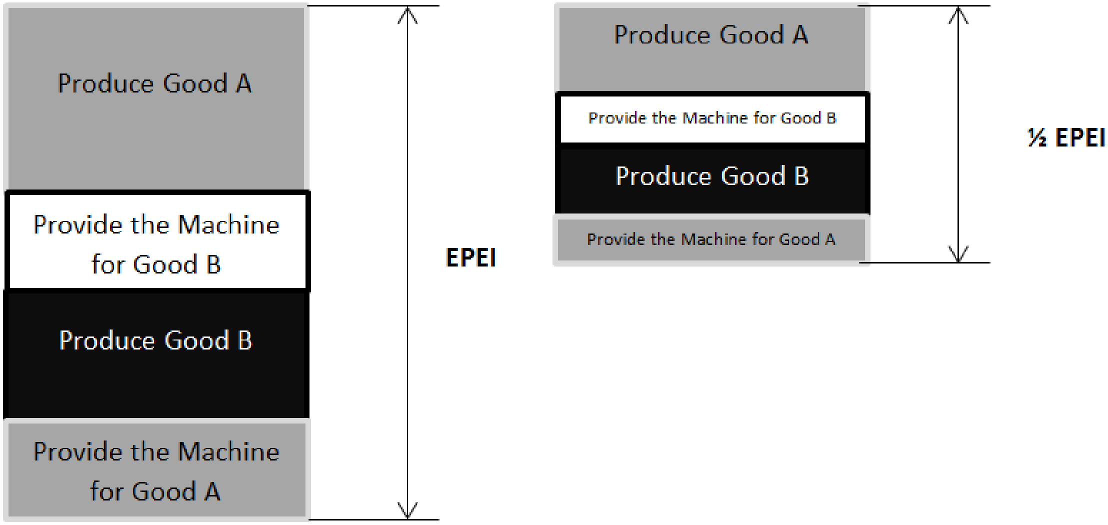


Figure 6.7: EPEI Interval of Two Goods

(Rother & Shook, 2006, p. 50), (Straub & Schiepp, 2010, pp. 42 - 44)

6.5.2.2 Example for Creating a New Framework

To demonstrate how the previously shown rules are applied, the framework in Figure 6.6 will be optimised as an example. Therefore, the customer cycle has to be calculated first (Rother & Shook, 2006, p. 40).

$$\boldsymbol{T_C = \frac{t_W}{K_B} = \frac{500^{min}/_{day}}{18400\,^{piece}/_{day}} = 1.63\,^{s}/_{piece}} \qquad \textbf{(6-7)}$$

Where: K_B: Customer demand

t_W: Working time per day

T_C: Customer cycle

Rule No. 1

A customer cycle with 1.63 s/piece means that the customer needs one good every 1.63 seconds. Therefore, in the best case scenario, all processes should have a cycle time of 1.63 seconds. But the real value stream shows (see Figure 6.6) that nearly all processes work at a much slower rate. This could be because more than one good has to be handled in every process. For example, let's say 20 goods are located in one box. If the transport time from the incoming goods area to the picking of goods area is 39 seconds and 20 pieces can be transported at one time, the transport time for one good is actually only 1.95 seconds, which is very close to the customer cycle (see Figure 6.8) (Rother & Shook, 2006, p. 40).

Rule No. 2

The production of goods is only started when the customer buys the goods. This is important to avoid overproduction and a large stock.

Rule No. 3

Eliminate processes that are waste and not necessary. In the case of the value stream from Figure 6.6, the storage transportation process can be deleted if the incoming goods area is placed directly beside the storage (see Figure 6.8).

Rule No. 4

In order to implement a continuous flow of the material between each process, all storages between the processes should be eliminated. In the current material flow, a continuous material flow between the processes "picking of goods" and "bundling of goods" is possible. Furthermore, the processes "bundling of the goods" and "transportation to the dispatch" can be connected (see Figure 6.8) (Rother & Shook, 2006, p. 40).

Rule No. 5

In all other processes that cannot be connected to a continuous material flow, a Kanban cycle has to be installed. In the example, this is possible at the "incoming goods area" and "picking of goods" and between the "transportation to the dispatch" and "loading". A Kanban cycle is only an intermediate step to the continuous flow (see Figure 6.8) (Rother & Shook, 2006, pp. 41 - 42).

Rule No. 6

The pacemaker process is the process with the longest cycle time. In this example, this is the “bundling of goods,” which requires 112 seconds (see Figure 6.8).

Rule No. 7

To address the synchronisation of the processes to the pacemaker process, the cycle time of the peacemaker process can be minimised by reducing cycle time losses. This is because the cycle time of the pacemaker process can be influenced by the employees that are involved in the process. If one employee additionally supports the “bundling of the goods,” for instance, the cycle time is cut in half (Rother & Shook, 2006, pp. 45 - 46).

Beyond this, the processes “picking of goods,” “bundling of goods,” and “transportation to the dispatch” are connected. Therefore, the sum of cycle times of these processes divided by the number of employees results in the new cycle time of the connected processes. Furthermore, the employee who is no longer needed (see Rule 3) can be involved at the “storage transportation” and can support the connected processes. In sum, these processes have a cycle time of 278 seconds; divided by the 4 employees, it means that the new cycle time is approximately 70 seconds. With 20 pieces per box, this means that a customer cycle of 3.47 s/piece is possible. However, in the example, the customer cycle is 1.63 s/piece, which means that 2.1 shift works are necessary to fulfil the customer demand (see Figure 6.8).

Rule No. 8

This rule deals with the EPEI concept that is necessary if different goods use the same processes and if processes or the machine have to be provided for the production of different goods. This can be, for example, to change the moulding cutter at the milling machine. However, these logistic processes have no providing time. Therefore, in this case, it is not necessary to check the EPEI concept (see Figure 6.8) (Rother & Shook, 2006, p. 50).

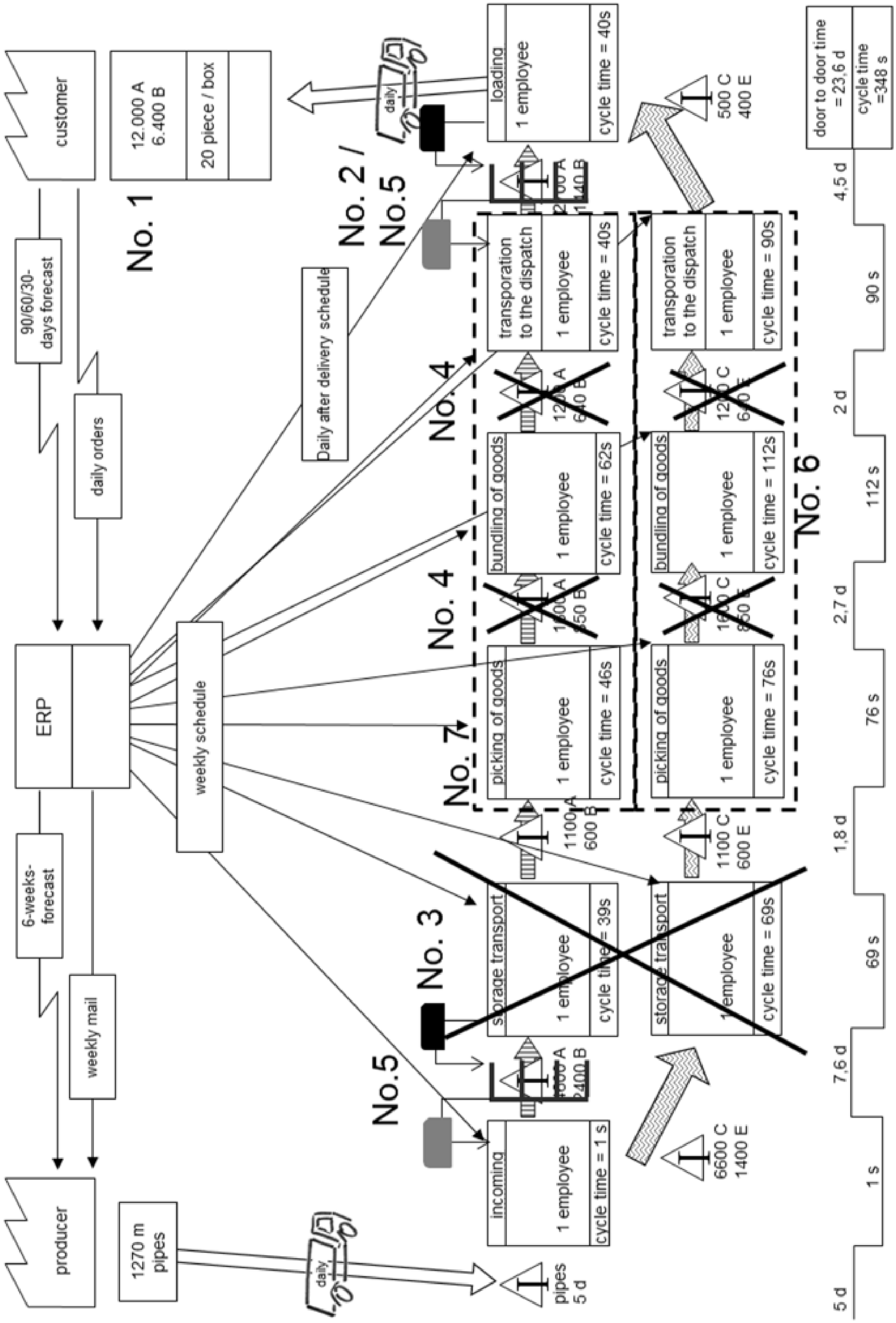


Figure 6.8: Optimisation of the Value Stream

6.5.2.3 The New Value Stream

In Figure 6.9, the new value stream is shown. The door-to-door time can only be reduced from 23,6 days to 18,9 days by connecting the processes. Furthermore, the cycle time can be reduced from 348 seconds to 140 seconds. The reduction of the cycle time is based on the reduction of the cycle time losses because of the different process times. In faster processes with shorter cycle times, more goods can be produced and the processes do not have to wait for slower processes. Because of the synchronisation of the processes “picking of goods,” “bundling of goods,” and “transportation to the dispatch,” these cycle time losses are eliminated.

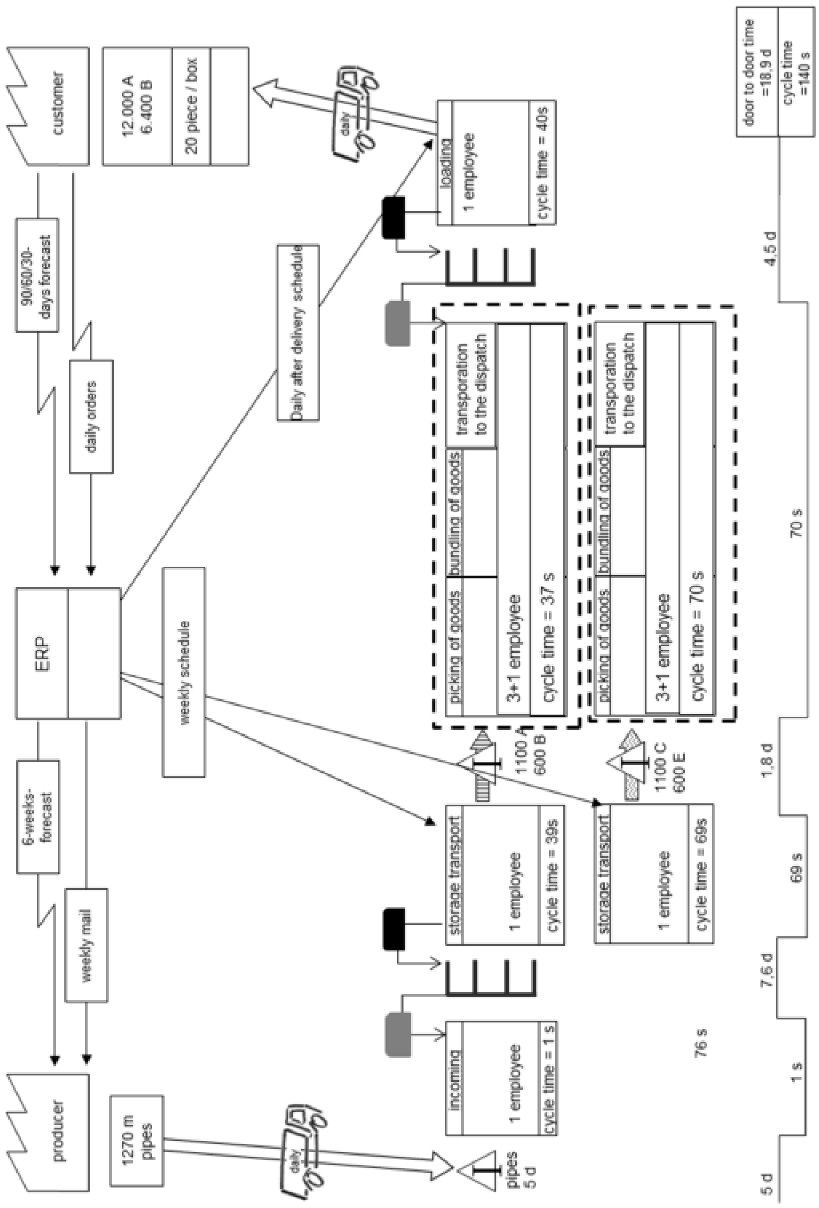


Figure 6.9: New Value Stream

6.5.3 Creation of Block Layout

The findings of the ideal planning help for the calculation of the various key performance indicators (KPI) of the logistics planning system. They are:

- Layout
- Employee
- Equipment
- Energy and other Media
- Investment

To create a block layout, the goods have to be categorised. An example for the goods' categorisation is listed by the author in Table 5.12. The core characteristic, whether or not the goods corrode, is put at the beginning. All further characteristics depend on this question. In Table 6.9, the whole number of goods can be calculated by summarising the “no corrosion” and “corrosion possible” cells.

Table 6.9: Categorisation of Goods (Example)

Characteristics / Length	**Small Parts**	**Normal Parts**	**2.5 metres - 4 metres**	**>4 metres - 6 metres**	**>6 metres**	
∑No Corrosion (no. c.)	261	987	117	61	0	
∑Corrosion Possible (c. possible)	76	259	56	25	0	
dimensionally stable	*12*	*50*	*6*	*11*	*0*	*no c.*
	6	*34*	*2*	*6*	*0*	*c. possible*
sensitive surface	*36*	*213*	*8*	*3*	*0*	*no c.*
	7	*38*	*17*	*11*	*0*	*c. possible*
sensitivity to dirt	*115*	*107*	*2*	*7*	*0*	*no c.*
	47	*31*	*1*	*4*	*0*	*c. possible*
no special characteristic	*98*	*617*	*101*	*40*	*0*	*no c.*
	16	*156*	*36*	*4*	*0*	*c. possible*

no c. = no corrosion, c. possible = corrosion possible

The next stage is to plan the layout. The processes are structured by the findings from the ideal planning stage. Thus, the design of the processes (vertexes) in the layout is similar to that in the ideal planning graph, but the layout also includes dimensions. Therefore, every process has an additional area element in square metre. The first layout is simplified to indicate the ways that building blocks are used for equipment and processes.

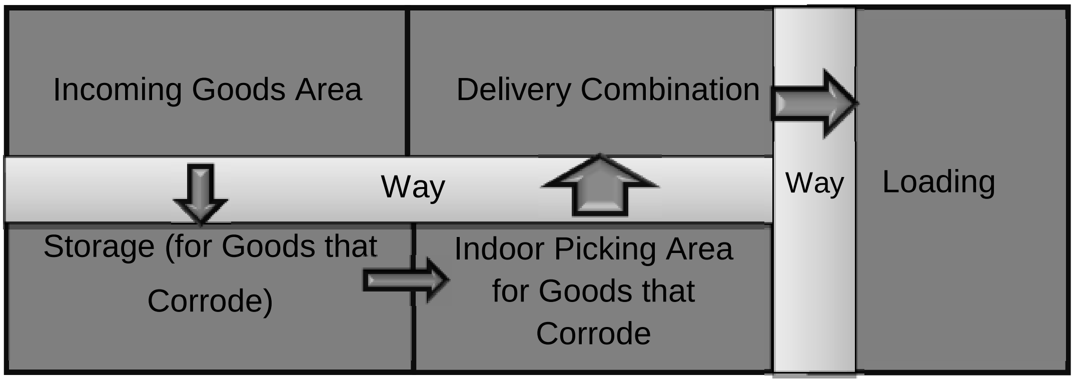


Figure 6.10: Building Blocks Layout

In addition to the block layout, the other areas such as roads, restrooms, offices, meeting rooms and the cafeteria are needed. Particularly, the roads for transporting long items must be big enough for the transportation vehicles. The street width is regulated by laws. Thus, the width of the streets can vary depending on the laws of the countries. In general, roads can be divided into roads that are only used by industrial trucks and roads that are also used by employees. Moreover, if the road is not used as one-way road, the width of the road has to be big enough for the both directions of transportations. These aspects have to be considered in this planning stage. In the end, one comprehensive version of the ideal layout plan can be developed.

6.5.4 Calculation of the Employee Demand

The next stage is to define the demands of employees and the demands of the equipment. Calculate the employee demand is important for every planning process because the performance of a logistics system is directly influenced by the number of employees. But in the case of long item planning, the employees are even more important because the dimensions and weight of the items are very different; thus the handling is more complicated. A consequence of this is that time differences arise between the processes. Long item processes are more time-intensive than other processes. For example, the picking of one long item like a pipe with a length of 4 metres needs more time than the picking of a fitting with a dimension of 4 cm x 4 cm x 4 cm even though only one piece is picked each time. Being aware of the time differences is important because a lot of working time could be lost if one employee has to wait for the others if the picking processes work synchronically and in parallel. In lean logistics systems, the target is to work synchronically to the customer demand. The calculation of the process time provides the basis for the calculation of the employee demand. For example, if one picking process requires 20 minutes and the working time each day comprises 420 minutes (7 hours) in all, one employee can only make 21 picks. If the working areas work synchronically and in parallel, each of these should take the same time in an effort to avoid wasting time.

In order to define the demand of employees, the process stages have to be calculated. If it is possible, the processes should be tested and the time should be measured. If processes already exist, this does not pose any problem. If no processes exist, the processes and the equipment can tentatively be built using wood and cardboard boxes to test the processes and observe the time necessary to complete them. If no identical processes already exist and if it is not possible to build a tentative model of equipment, the process time has to be ascertained using methods for time and motion studies. Some of these studies are Working Time Investigation Committee (REFA) or Methods-Time Measurement. (MTM) In the time and motion study, processes are divided into small parts. The processes are divided into motion parts such as opening your hand or taking one step forward. These little motions are evaluated by the REFA and MTM. Every motion has a time demand. The motions and the times can be cumulated so that the process times can be created. In addition to the pure process time, you can determine the changeover time and the personal allowance time. If the time necessary for the whole process is calculated, the demand of employees can be calculate as well. In addition to the employees working directly with the products (= services), “indirect” employees have to be calculated. “Indirect” employees are cooks, cleaners, members of the maintenance crew, mechanics, experts, businesspeople, and the management (see Table 6.10). The sum of “direct” and “indirect” employees is the number of the employees that are needed for the entire operation.

Table 6.10: Calculation Table for Employee Demand

	Main Process	Sub-process	Time for Process	Daily Working Time	Number of Employees
“Direct” Employees	Incoming Goods Area	sub-process 1			
		sub-process 2			
		sub-process n			
	Storage	sub-process 1			
		sub-process 2			
		sub-process n			
	Picking Area	sub-process 1			
		sub-process 2			
		sub-process n			
	Delivery Combination	sub-process 1			
		sub-process 2			
		sub-process n			
	Loading	sub-process 1			
		sub-process 2			
		sub-process n			
“Indirect” Employees	Type of Function				
	Mechanics				
	Experts				
	Business People				
	Management				
	Maintenance Workers				
	Cleaners				
	Cooks				
Employee Demand					

6.5.5 Calculation of the Equipment Demand

The next planning action considers the equipment. For this planning stage, the same basic table is used as in the calculation of the employee demand. The table is divided into 5 main processes and each main process also consists of a number of sub-processes as listed in Table 6.10. By having a look at Table 6.11 the planner can gain a detailed overview of the necessary equipment. The advantage of this table is that if parts of processes are transmitted to other processes, the equipment needed is shown directly. Table 6.11 is not explicitly for the planning of the long item logistics system. A table that is organised in that way also helps in many different logistics or production systems. This table is useful for the acquisition and the following inventory management that has to be done constantly at all process stages.

Table 6.11: Equipment of the Logistics System

	Equipment				
	Main Process	Sub - Process	Scanner	Forklift	…
Processes	Incoming Goods Area	sub-process 1	X	X	
		sub-process 2	X	X	
		sub-process n	X		
	Storage	sub-process 1	X	X	
		sub-process 2	X		
		sub-process n	X	X	
	Picking Area	sub-process 1	X	X	
		sub-process 2	X		
		sub-process n	X	X	
	Delivery Combination	sub-process 1	X	X	
		sub-process 2			
		sub-process n	X		
	Loading	sub-process 1	X	X	
		sub-process 2	X	X	
		sub-process n	X	X	
Equipment Demand					

6.5.6 Calculation of the Energy and Media Demand

The calculation of the energy and the media that processes demand is also a planning aspect that can be found in present process planning procedures. However, to be able to create a calculation of the return on investment, these costs have to be considered. Water and waste water planning is one of the most important planning points in the energy and media planning because water and waste water could not be available in every building or building site. Furthermore, the basic data about the energy demand, i.e. electricity, water, and pneumatics, have to be defined. Beyond this, it is important to evaluate the maximum demand because the energy demand must be planned according to the highest demand. The average demand is useful to determine the costs for each year. The accuracy of the average energy demand is sufficient for the structure planning. The typical energy for the building heating, "gas" is also listed in Table 6.12. If other possibilities or renewable energy source are used, the point "gas" has to be changed.

Table 6.12: Energy Demand

	Energy Demand for One Year					
	Main Process	Electricity [MW/year]	Pneumatic [m³/year]	Water [l/year]	Waste Water [l/year]	Gas [m³/year]
processes	Incoming Goods Area					
	Storage					
	Picking Area					
	Delivery Combination					
	Loading					
	Offices					
	Maintenance					
	Cafeteria					
Cumulated Energy Demand						

In the last stage of the ideal planning, it is time to calculate the overall investment required. The investment of the building has to be calculated by an architect.

There are two different types of assets. The investments are assets that are used to improve the output of a company. Such improvements can be made in two ways. The first way is to increase the amount of output. The second way is to increase the number of the variants of the output. Some costs are an asset if they are used for the activities that do not improve the output but, add the value to the equipment, e.g. to repair an equipment. These costs are called non-recurring costs.

Running costs are the day-to-day costs, such as employee salaries and energy costs. In this planning stage, these costs are calculated for each year.

At the end of the ideal planning, an economical study has to be conducted in order to determine if the investment and costs are profitable.

6.5.7 Creation of the Processes

In the in-house logistics planning, the following four basic processes exist:

1. Incoming goods
2. Storage of goods
3. Picking of goods
4. Outgoing goods

These processes are connected by transportation activities. Thus, to be able to use a subsequent process, goods have to be transported. This can be done manually using industrial trucks or using an automatic conveyer system. In these four basic logistics planning processes, goods are handled consecutively. Therefore, it is necessary to look at every process in detail and optimise every process in regard to the long item handling. In the planning stages, the customer requirements are considered. Furthermore, the necessary methods for planning effective and efficient long items processes are researched. The findings of the research should be clearly presented, so that planners can design further long items logistics systems using these findings.

To be able to start with the process planning, the package planning has to be done first. The packaging of each good has to be planned. At beginning, the packaging method for every good has to be defined. The package of a good can consist of more than only one package. For example, the first packaging level could be a carton. A number of cartons could then be packed in the second packaging level, a larger box. In the third packaging level, all of the boxes are placed on a pallet. So, this package has three different levels, the small carton (1^{st} level), the large box (2^{nd} level), and the pallet (3^{rd} level).

The planning procedure is limited by the stock planning. A number of different planning methods exist for planning stock. One traditional method is to plan the stock by demand (Alicke, 2005, pp. 37 - 38). In the stock planning by demand, new goods are ordered when a certain minimum stock of any given item is reached (Stadtler, et al., 2010, pp. 153 - 160). The stock management is part of the purchasing process and so it will not be discussed further in this thesis.

6.5.7.1 Creation of the Incoming Goods Area

In the incoming goods area, the long items enter the company for the first time. The tasks in the incoming goods area are to unload, buffer, unpack, sort, package, and pre-package goods (Martin, 2009, p. 337). In addition to these operations, the quality check is also integrated into the tasks in the incoming goods area. Employees conduct simple quality checks such as counting parts and checking the surface of the goods. More detailed quality checks are done directly by the quality employee. So, the processes and the areas of the incoming and quality control departments should be close to each other. Because of the different sub-processes of the incoming goods area, the long items are often moved and transported. Therefore, these processes have to be researched in detail in order to identify critical sub-processes and handling stages and gain planning support for further tasks related to the long item incoming goods area planning.

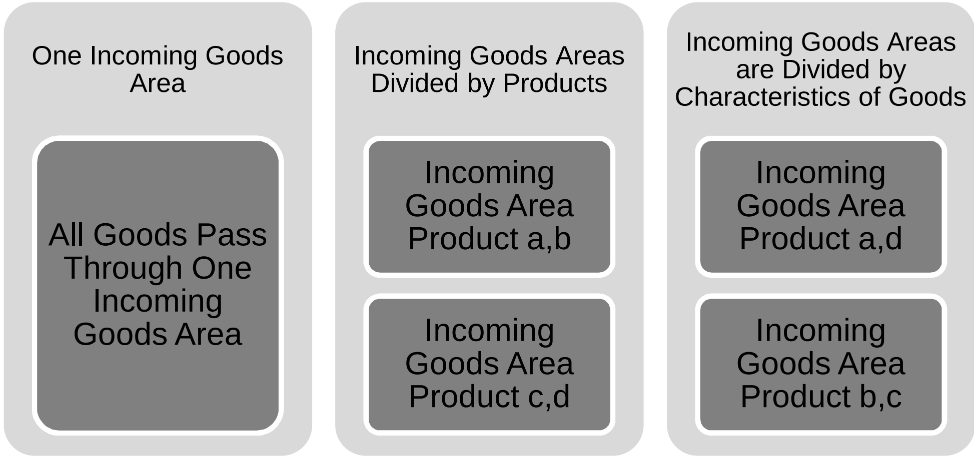


Figure 6.11: Different Types of Incoming Goods Areas
(based on (Martin, 2009))

There are normally three types of incoming process as shown in Figure 6.11. The first type only deals with one incoming goods area. In this area, all arriving goods are handled. This process type is only applicable if a limited number of products are handled or the products have the same characteristics, e.g. the same dimensions or the same aggregate state.

The second type of incoming processes is divided by products: Every incoming process has to handle selected products, e.g. long items are handled using Incoming Process I and commercial goods are handled using Incoming Process II. A criterion for the selection of products can also be applied. Thus, for example, steel products would be sent to the milling machine and synthetic granules that are needed for the production of long items are transported to an extruder machine.

The last type of incoming processes classifies the incoming goods according to their characteristics. That means goods with the same range of dimension are handled in one incoming goods area and goods with other dimensions in another incoming goods area. This process type has the advantage that the efficiency of the incoming goods area increases. That is because goods with the same requirements need the same special equipment and the same handling stages can be used. Therefore, the time required for the handling and the associated costs would be reduced.

Table 6.13: Material Flow Equations
(based on (Britzke, 2010, p. 217))

Incoming Goods Material Flow		$\lambda_i^{in}(t) = 0$					
		Yes		*No* $\lambda_i^{in}(t) \leq \mu_i(t)$			
Stock at the Beginning		*$B_i(t) = 0$*		*$B_i(t) = 0$*		*$B_i(t) = 0$*	
		Yes	*No*	*Yes*	*No*	*Yes*	*No*
Outgoing Goods Material Flow	**Start**	$\lambda_i^{out}(t) = 0$	$\lambda_i^{out}(t) = \mu_i(t)$	$\lambda_i^{out}(t) = \lambda_i^{in}(t)$	$\lambda_i^{out}(t) = \mu_i(t)$	$\lambda_i^{out}(t) = \mu_i(t)$	$\lambda_i^{out}(t) = \mu_i(t)$
	End		$\lambda_i^{out}(t) = 0$		$\lambda_i^{out}(t) = \lambda_i^{in}(t)$		

In Table 6.14 , the operation tasks from the incoming goods area are shown. Five of the six tasks have a direct influence on the performance of the incoming goods area. Only the buffering has no direct influence on the performance of the incoming goods area. The buffer has the task of storing products for a short time to smooth the handling in the incoming goods area. In case more goods are delivered than the incoming process can handle, the buffer is used to store products. If the incoming processes are quick enough to handle all incoming goods (input material flow = λ_i^{in}) directly, no buffer (buffer = inventory = B_i) is needed. Therefore, the buffer is not a direct indicator of performance. The key performance indicator of the incoming process is the limited performance (limited performance = μ_i). The limited performance (μ_i) describes how much workload per time can be handled (Britzke, 2010).

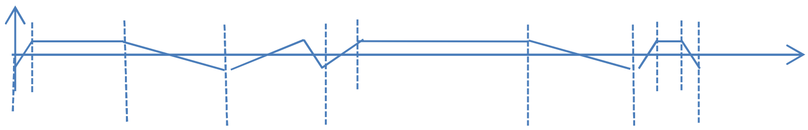
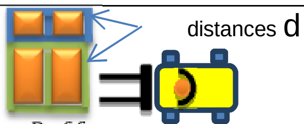
The outgoing material flow (outgoing material flow = λ_i^{out}) describes how many goods pass through the process. If the limited performance is smaller than the amount of incoming goods ($\mu_i < \lambda_i^{in}$), the buffer filling level rises ($B_i > 0$). If $\mu_i > \lambda_i^{in}$ the buffer is empty ($B_i = 0$) because the performance of the system is higher than the amount of incoming goods. The outgoing material flow (λ_i^{out}) can at most equal performance like the limited performance (μ_i) achieves ($\lambda_i^{out} \leq \mu_i$) (Britzke, 2010, pp. 215 - 216).

In connection to the incoming material flow, some different cases could be developed for determining how the outgoing material flow is conducted (Günthner, et al., 2010, p. 217). These cases are created by Prof. A. Günthner, a logistics researcher from the University of Munich. These can be used to establish general rules for all kind of material flows and are also applicable for material flows at the dispatch.

In general, the aim of planning is to make processes flexible to be able to manage a different amount of incoming goods. If the performance of the processes is smaller than the input in the incoming processes, the stock is built. If the performance is equal or higher than the input of the system, a stock would never be built. The characteristic of flexible adaptable processes is not a special requirement for the incoming goods area because all processes should be flexible and adaptable to the demand or workload.

Furthermore, the performance of the transport processes has to be determined. The transport process limits the performance of the transport and influences all processes that use transport equipment like for the unloading and sorting. In Table 6.14, the tasks of the incoming process and the influence factors of the performance of the incoming sub-processes are described. The pre-condition of the calculations is that experienced employees only execute working tasks. In the following subsections, methods for planning and calculating the incoming processes are presented.

Table 6.14: Tasks of the Incoming Processes

Tasks in the incoming goods	Key Performance Indicator (KPI)	Influence factor for the performance	Calculation of the performance
Unloading	X	equipment, employee	 time $t_i^{unl} = t_{drive\ to}^{unl} + t_{load}^{unl} + t_{pull\ out}^{unl} + t_{drive\ stor.}^{unl} + t_{unload}^{unl} + t_{drive/start}^{unl}$ under consideration $t_{drive\ to}^{unl} = t_{drive\ storage}^{unl} = t_{drive\ to\ start}^{unl} = t_{\sum accelerating}^{unl} + t_{drive}^{unl}$ $t = \sqrt{\frac{2s}{a}}$ $\mu_{unloading} = \frac{\tau_t}{t_i^{unl}}$
Buffering		space	 $A_{sum}^{Buffer} = \sum A_{cargo} + \sum A_{cargo,distance\ 1,2,3,4}$ $V_{sum}^{Buffer} = \sum A_{cargo} \cdot h_{cargo} + \sum A_{cargo,distance\ 1,2,3,4} \cdot h_{cargo}$
Unpacking	X	equipment, employee	$t_i^{pre} = t_{unpack}^{pre} + t_{sort}^{pre} + t_{pack}^{pre} + t_{prepack}^{pre}$ $\mu_{pre} = \frac{\tau_t}{t_i^{pre}}$
Sorting	X		
Packaging	X		
Pre-packagin	X		

Unloading

The first physical process at the incoming goods area is the unloading. The performance at the unloading is closely connected to the expenditure of time. To research the necessary working time, the unloading process has to be divided in smaller parts. By dividing the unloading process into smaller parts, the working time can be calculated. The unloading process starts with moving to the good area (see Table 6.14, subsection unloading). This movement includes the acceleration phase and the moving at maximum speed. Trained operators pick up the loading while they apply the brake. After picking up the loading, the forklift puts the loading out of a vehicle. This process stage is critical for the loading because the space around the goods is small and the good could hit with other goods and damage them. So, the unloading has to be done carefully and at a slow speed. In the next handling stage, the loading is brought to the storage which can be a buffer space or a pallet rack. The time of the transportation to the storage is called $\mathrm{t}_{\mathrm{drive\ stor.}}^{\mathrm{unl}}$ (see Table 6.14). The loading is also placed within the brake application. This brake application has a small negative acceleration because of the exact placing of the goods. Therefore, the time that is needed (t_{unload}^{unl}) is higher. The acceleration and the maximum speed of the forklift can vary depending on the performances of the forklifts.

Table 6.15: Calculation of Unloading Time

	$t^{unl}_{drive\ to}$		t^{unl}_{load}	$t^{unl}_{pull\ out}$		$t^{unl}_{drive\ stor.}$		t^{unl}_{unload}	$t^{unl}_{drive/start}$			
	acceleration time $t = \sqrt{2s/a}$ [s]	drive with max speed $t = s/v$ [s]	acceleration time $t = \sqrt{2s/a}$ [s]	acceleration time $t = \sqrt{2s/a}$ [s]	acceleration time $t = \sqrt{2s/a}$ [s]	acceleration time $t = \sqrt{2s/a}$ [s]	drive with max speed $t = s/v$ [s]	acceleration time $t = \sqrt{2s/a}$ [s]	acceleration time $t = \sqrt{2s/a}$ [s]	drive with max speed $t = s/v$ [s]	acceleration time $t = \sqrt{2s/a}$ [s]	$\sum$ [s]
Commercial Forklift, Commercial Cargo	4,1	112,5	8,2	8,20	4,1	4,1	112,5	8,2	4,1	0,45	4,1	270,55
Commercial Forklift	4,92	160,7	9,84	9,84	4,92	4,92	101,6	9,8	4,92	0,6	4,92	317,1
Four way forklift	5,5	160,7	11,04	11,04	5,52	5,5	160,7	11,0	5,52	0,6	5,52	382,8
									Δt commercial forklift/four way forklift			*65,7*

In Table 6.15, the time necessary for unloading one pallet is calculated. In this case, the pallet is unloaded sideways from the truck. The second condition is that the passages and roads used for the transportation are big enough that long items can pass through them diagonally on a forklift. For this research, two different types of forklifts have been used: one commercial ("normal") forklift and one four-way forklift truck. A four-way truck is special equipment used to transport long items. For this research, two forklifts have been used that are often used in practice. The commercial forklift was the type RX 20-15 from Still. The four-way forklift was ETV Q20 from Jungheinrich. Both forklifts are standard equipment and in the state of the art in regard to the performance (maximum speed and acceleration time).

If the passages and the space of the (un-)loading area are large enough to transport the goods diagonally and for loading and unloading a pallet, the standard forklift is quicker than the four-way forklift. Unloading one pallet takes round about 10 seconds if the distance from the storage to the area where the goods should be unloaded is only 100 metres. In Figure 6.12, the time one forklift needed to unload one pallet is presented. These results are demonstrated by curves. The time that one forklift needed is illustrated on the ordinate of the diagram. On the axis of abscissae, the distance from the point at which the truck was unloaded to the incoming goods area was presented. The grey curve shows the time differences between the commercial forklift and the four-way forklift in transporting long items. The Δt (commercial forklift / four-way forklift) is presented on the secondary ordinate on the right side of Figure 6.12. One example of how the results of the figure are extracted is presented in the following:

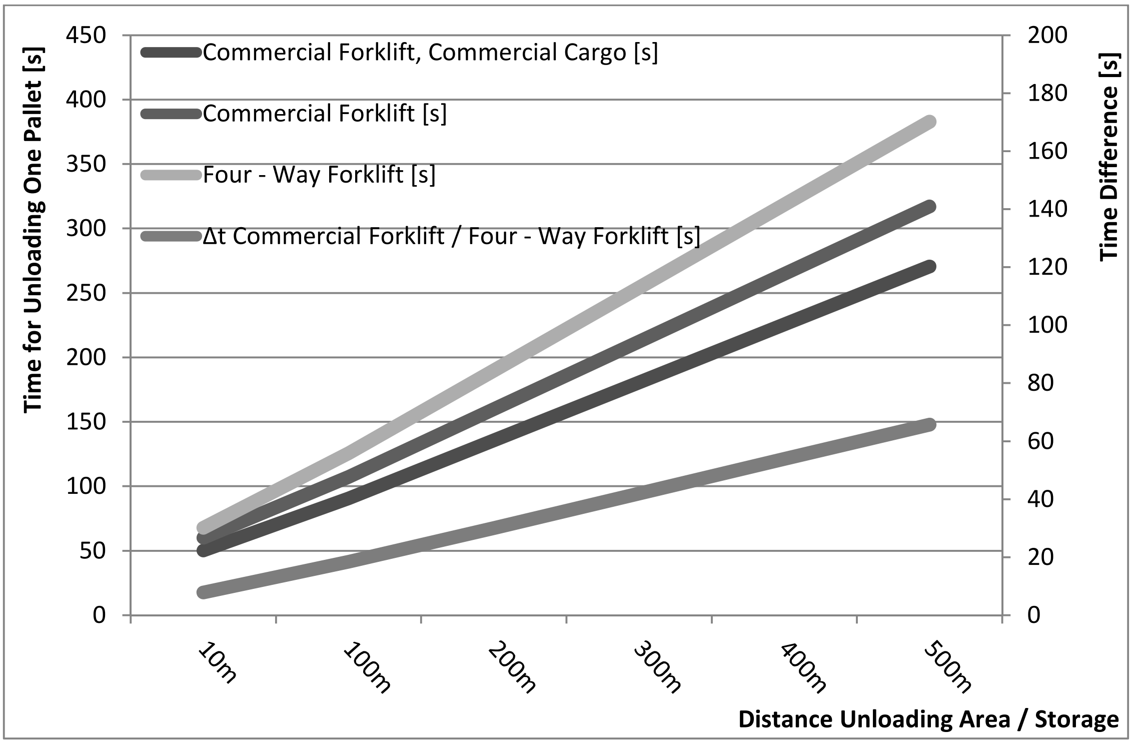


Figure 6.12: Time Differences at the Unloading by Using Different Forklifts

If the distance of the unloading area to the storage area is 500 metres, the commercial forklift needs 317 seconds to transport one pallet and to drive back to the starting point. The four-way forklift needs 382 seconds for the same procedure. So, the difference can be read directly at the *Δt*–curve at approximately 66 seconds (see Table 6.15). Therefore, for unloading only one pallet, the four-way forklift needs 30 seconds longer than the commercial forklift. The four-way forklift needs more time because the maximum speed is lower than the maximum speed of the commercial forklift.

Furthermore, the acceleration time of the four-way forklift is longer. So, if the distances between unloading and storage were to increase in a different setting, the time difference would increase proportionally as well. In this calculation, no barriers are considered. This means that stops due to busy passage ways or waiting for doors to open have not been considered. But these barriers are not to be considered because this sort of waste has to be eliminated in order to run efficient processes anyway.

Table 6.16: Comparison of the Different Types of Forklifts

Commercial Forklifts		Four-Way Forklift	
Advantages	Disadvantages	Advantages	Disadvantages
Fast Max Speed	Load is in front of the driver (limited view)	Goods can be transported lengthwise to the driving direction (smaller passage ways are needed)	It needs a lot of experience to drive with this type of forklift
Flexible Usable	Long items can only be transported diagonally to the forklift (larger passage ways needed)	The goods are placed beside the driver so the driver has a good view	

The advantages of using commercial forklifts are that they are faster and that they can be used for a large number of different tasks (see Table 6.16). The disadvantages are that the goods are loaded onto the forklift diagonally in front of the employees, therefore obstructing their view. So, the forklift has to drive backwards. The driver has no ergonomic body posture. Driving backwards can lead to accidents, which is a risk for other employees and for the goods. Moreover, a disadvantage of diagonally loading the items onto the forklift is that a larger road for the transportation and a larger road at the buffer zone (e.g. between the racks) are needed.

An advantage of using the four-way forklifts is that the goods are loaded lengthwise on the side of the four-way forklift. Thus, the goods are placed beside the driver. This has the advantage that the view of the road and the surrounding environment is not obstructed. Furthermore, the roads can be smaller because of the loading direction. Besides, the four-way forklift does not need so much space because of the arrangement of the loading. Therefore, the roads and space can be much smaller, which can be cost-saving. Moreover, it has to be considered that the driver must not drive backwards, which is very ergonomic and altogether safer.

Figure 6.12 helps with planning the incoming goods area, especially planning the unloading. A typical unloading process is described by speed ramps in Table 6.14. If the unloading process is different from this commercial one or if the forklifts have different performance data, the calculation has to be updated. But if commercial processes and commercial forklifts are used, the whole unloading time can be calculated with this figure. Moreover, if mixed loadings (long items as well as other sorts of items) are unloaded from one truck, two curves are needed for the calculation. The green curve in Figure 6.12 shows a commercial truck unloading commercial cargos. This curve is used to calculate the commercial cargos and the orange curve can be used to calculate the long items that are transported by commercial forklifts.

For the daily planning of resources, the performance data are needed (see Figure 6.13). On the shopfloor, the performance data help on a daily basis to plan the employee demand. An example of how this figure helps to plan the employee demand is presented in the following: If the distance from the unloading area to the storing area or buffer is 10m, a four-way forklift can carry 53 long item cargos each hour (see Figure 6.13, orange arrow). A commercial forklift can carry 60 long items cargos each hour (red arrow) and 72 commercial cargos each hour (black arrow). The performance figure is well applicable to small logistics systems. Figure 6.13 can be used to manage the shopfloor. The time necessary to unload a truck can be calculated and scheduled accordingly. Moreover, in derivation of the unload time of a truck the employee demand is also calculated. So, all of the information necessary to check the performance is available. If the performance is not suitable, arrangements have to be made. This process is schematically characterised in Figure 6.14. This figure can be used to obtain the long item requirements and commercial requirements of cargos.

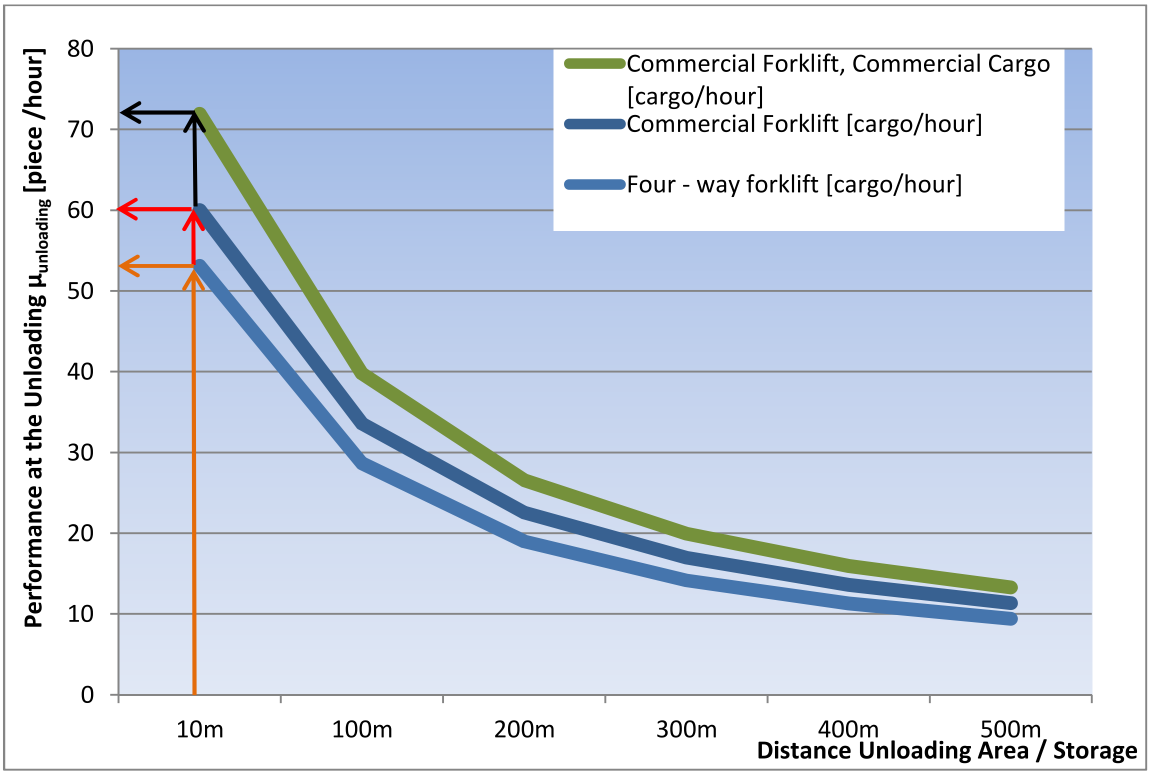


Figure 6.13: Performance Data of the Unloading Forklifts

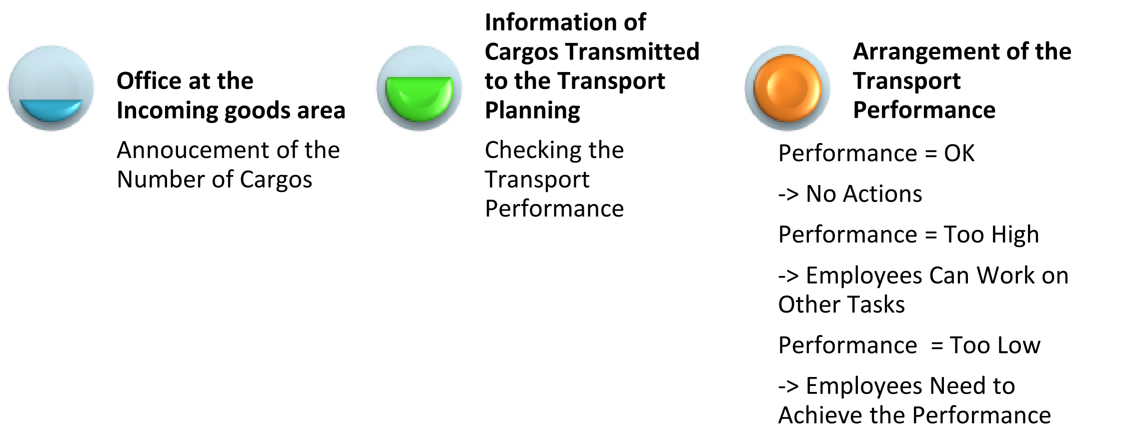


Figure 6.14: Performance Control and Adaption at the Shopfloor

<u>Buffering</u>

At the incoming goods area, a buffer is needed if more goods come in than the processes can handle. For example, if goods have to be brought to the storage with special forklifts which cannot work as quickly as required, the goods have to be stored temporarily in the buffer between the unloading and storage areas.

It is important that the buffer space is large enough to accommodate the maximum unloaded stock. This means the buffer space has to be bigger than the goods that are required to be stored in the buffer ($V_{\text{Buffer,space}} < V_{sum}^{Buffer}$). In derivation of the material flow, it stops when $\lambda_i^{out}(t) < \lambda_i^{in}(t)$ and $B_i(t)$ = max. In this case, no cargo can be unloaded.

The buffer volume can be determined using the number of goods and the volume of the goods that have to be stored in the buffer zone. Therefore, the number of goods and the volume of goods have to be figured out using an empirical value or calculated using forecast data. The buffer calculation has to be done in a way that the daily work and the work of maximum workload can be handled. But singular maximums that are higher than the usual maximums are not considered in such a calculation. These seldom maximums have to be managed with additional manpower. A sustainable buffer calculation at the handling of long items is very important because if the process performance is not sufficient, the oversized goods have to be stored chaotically in the logistics area, e.g. in the middle of traffic or walk ways or outside of the building.

It is important to mark the surface of the buffer in order to define the position in which the cargos should be stored. Furthermore, every bin location in the buffer has to be labelled in order to always ensure the transparency and traceability of every item. If space is not enough for a block storage, the goods can be stored in racks. Advantages of racks are that the goods can be stored at height and the floor space can therefore be used more efficiently. In block storage, goods can also be stored at height if products are stackable. But to have a good traceability, only the same goods should be stacked in one block. If a lot of different goods have to be stored in block storage, a lot of space is lost in the height.

Regardless if block or rack storage is used, handling distances have to be considered. Handling distances are necessary to be able to place the goods at the appropriate spots for storage. At minimum 5 cm on every side of the cargo is needed. The bigger the products are the more handlings space has to be considered. Long items with a length of 5 m need 10 cm to 20 cm of space on each side of the cargo item for handling. Therefore, every cargo must have this handling space on each side. An exception exists only if a cargo is placed directly on another cargo. In this case, the items may contact each other.

The second part of handling spaces must be considered in planning the roads. The roads in the buffer zone have to be marked according to the required width. The purpose is to get a visual transparency for everyone to know which part of the buffer belongs to the road and which part belongs to the storage area. For a smooth production flow, it is important that the markings are respected by the employees because if goods are stored on the road, the whole process might be constrained and goods could be damaged.

Unpacking / Sorting / Packaging / Pre-packaging

For transportation, goods are fixed with packaging material. But if the goods are used, they have to be unpacked. If the goods are transported internally, the package has to be opened in the incoming goods area. The Toyota approach is that waste should upstream. Packaging is necessary waste. If it is possible, the goods have to be unpacked as early as possible. The idea is to transmit the waste out of the own area of responsibility to the supplier. In the case of long items, the packaging (usually a wood frame) cannot be opened because doing so would destabilize the item. Therefore, such cargo can only be transported with packaging on a limited basis.

Closely linked with the unpacking is the sorting. In practice, these processes are often combined. Sorting is necessary if a mixed cargo is delivered and the goods on this cargo have to be separated.

Moreover, the packaging and pre-packaging are closely linked to the unpacking and sorting. If goods are separated, they have to be packaged again so that they can be handled further, e.g. transported by forklift. Furthermore, these separated goods and the cargos need new labels with the correct identification data. The pre-packaging is a mixed form of the packaging and sorting. So, goods are sorted to be packed into new bundles. The calculation of the time and effort is complex because all of these activities (unpacking, sorting, packaging, and pre-packaging) are activities with very different expenditures of time. Two characteristics have an influence on these activities. The first one is the effort in general. By effort, we mean the effort that is necessary to complete one activity. This parameter has to be divided in sub-parameters. These are:

1. Minimum effort means the effort that is required to only complete one activity without any additional tasks
2. Slight effort means the activity itself without any additional tasks because the activity is more complex than the minimum effort
3. Moderate effort means one activity is difficult and one slight additional activity, e.g. to gluing on a label or booking in system, also has to be completed
4. High effort means the activities are very difficult and a lot of additional activities have to be completed, e.g. complex booking in system
5. Maximum effort means the activity is very difficult and complex additional work has to be completed, e.g. unpacking long items and packing it for safe and convenient transport

The second parameter influencing the activities is the number of items. In general, the finding of this thesis is that the time effort per good sinks the more pieces are involved in one activity. Table 6.17 shows how the activities are connected to the effort and the number of pieces. The effort increases with a common logarithm. The table was created with the help of a research of the author in practise. More than 500 activities have been researched. Many activities are done with a different number of pieces. At the end, the results are idealised. So, the finding of the author´s experiment was that a difference between the minimum effort and the slight effort of 20% exists. In the case of minimum to moderate effort, a difference of 80% could be identified. From minimum to high effort, there is a difference of 200% and from minimum to maximum effort there is a difference of 300%.

Hence, Table 6.17 can be used for the time planning of incoming activities. The detailed planning of the time and effort required is not a shopfloor instrument, because exact data about the order is needed. The time that is needed for the manual activities in the incoming goods area can be calculated using the Equation (6.7). In derivation from the time calculation, the employee demand can be calculated. The input data can be extracted from an ERP-system. Furthermore, the calculation has to be carried out using software application like EXCEL because the number of calculations is high.

$$\boldsymbol{\delta_i = n_i * \varepsilon_i} \qquad \textbf{(6-8)}$$

Where: $\boldsymbol{\delta_i}$= Time Effort

n_i= Number of Activities

ε_i= Effort per Activity

Table 6.17: Time Table for Manual Activities in the Incoming Goods Area

	n_i (number of pieces)	δ_u [s] (unpacking)	δ_s [s] (sorting)	δ_p [s] (packing)	δ_{pr} [s] (pre – packing)
ε_{min}	1	95	25	185	235
(minimum effort)	10	80	20	155	215
	100	65	18	120	180
	1,000	55	15	100	150
	10,000	45	13	70	130
	100,000	40	7	45	90
ε_s	1	114	30	222	282
(slight effort)	10	96	24	186	258
	100	78	22	144	216
	1,000	66	18	120	180
	10,000	54	16	84	156
	100,000	48	8	54	108
ε_{mid}	1	171	45	333	423
(moderate effort)	10	144	36	279	387
	100	117	32	216	324
	1,000	99	27	180	270
	10,000	81	23	126	234
	100,000	72	13	81	162
ε_{high}	1	190	50	370	470
(high effort)	10	160	40	310	430
	100	130	36	240	360
	1,000	110	30	200	300
	10,000	90	26	140	260
	100,000	80	14	90	180
ε_{max}	1	285	75	555	705
(maximum effort)	10	240	60	465	645
	100	195	54	360	540
	1,000	165	45	300	450
	10,000	135	39	210	390
	100,000	120	21	135	270

6.5.7.2 Storage of the Goods

The large variety of storage options can be categorised in different ways. The first type of categorisation is to divide the storage options according to their functions in the supply chain. Using this categorisation, three different types of storage exist.

The first type is the storage for purchases. Goods that are purchased from a supplier are placed in this storage. The second type of the storage is a storage warehouse. This type of the storage deals with products that are produced within the company's own factory. These goods are only stored temporarily, such as between two processes. In this case, the storage is only a buffer. The third type of the storage is the distribution storage, which handles goods that are produced in the company's own factory as well as goods that are purchased from the supplier. However, these goods are only for selling.

A further possibility for categorising storage is based on the type of activity. In this categorisation, there are also three different types of the storages. The first type is the single-line store, in which only goods with single logistics packages are stored. The goods that are transferred to the stock are released from the stock in the same package in which they have been stored. Thus, these goods are not packaged in the stock. In the single-line store, it is not possible to pick a good from a cargo; rather it is only possible to pick a single cargo. The goods in the single-line store are reserved for the picking storage. Because of the precisely specified cargos and because there is no picking of a good from a cargo, the packaging is perfect and can be handled automatically. A single-line store can be built using flexible high bay racking, flat storage, and compact store for pallets or bins.

The second type of storage in this category is the picking storage. Cargos are placed at the stock as a full cargo. From this cargo, goods are picked. However, the goods are released from the stock in subsets only. So, if an order has to be picked, only the number of goods that the order needs is picked from the cargo. Thus, many pickings can be carried out until this cargo is empty.

This storage technique is of interest for the logistics planning. In Figure 6.15, the types of storage are classified as the solid, liquid, and gas storages. The logistics of the building industry is focused on the solid storage. The block storage is one of the simplest types of storage and it is often used in the incoming goods or outgoing goods area. Pallet and bin storage are multi applicable in almost every process. These storage options are standardised and available in commercial stores. These racks can be purchased directly in a large number from different sellers. The same is true for the cantilever rack. The cantilever rack is a multi-functional rack. It was created to store long items with a length similar to that of the rack itself. The cantilever rack has flexible arms so that the distances of these arms can be individually adjusted depending on the length of the long items. But, commercial pallets (800mm * 1,200mm or 1,000mm * 1,200mm) can also be stored in a cantilever rack with the help of inlay iron sheets or inlay traverses. All of these techniques can be used with automatic systems that automatically implement and remove the cargos. The size and performance of the storage varies depending on the task of the storage. This means that if the storage is only used as stock reliability, the performance of the automatic system is not very high. However, if the storage supplies a picking area, the replenishment performance of the storage must be adequate. Otherwise, the storage would be the limitation for the logistics process. A high performance replenishment of goods is possible if the aisles are short.

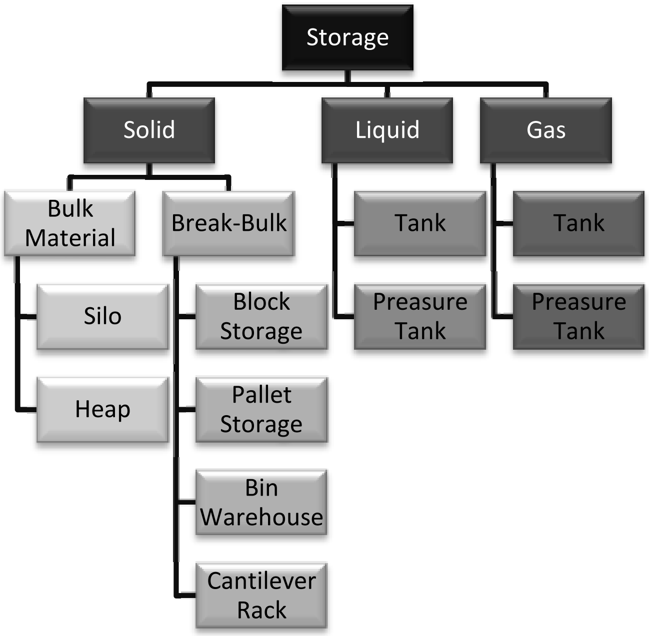


Figure 6.15: Different Commercial Types of Storages
(based on (Koether, 2007, p. 67))

In Table 6.18, the storage types that are directly constructed for long items are presented. The pictures of these special types are shown in Figure 6.16. Table 6.18 shows the meaningful application of storage options. As demonstrated, every storage type is equipped to handle different types of cargos. But, it is not economical to use e.g. a honey comb system to store small goods. Therefore, if new logistics are planned, a mixture of different storage types is often necessary. The most flexible storage system is the block storage. In a block storage, all types of goods can be stored and the only premise is that the volume of the block store has to be larger than the volume of the cargo. On the right side of the Table 6.18, the expanse consumption of every storage type is listed. The term expanse consumption refers to the volume of the room that can effectively be used for the storage. The block storage has the smallest expanse consumption. This is because the block storage only needs a small number of roads but a high storage expanse. If the storage expanse is significantly smaller than the volume of the room in which the rack is placed, the chosen rack is not the right type. This is because the available space is not used efficiently. Pallet storage for manual forklifts offers a minimum of expanse consumption. This is because the forklift has to have direct access to every location. Therefore, wide roads are necessary to reach every location.

Table 6.18: Types of Storages and Their Expanse Consumption

(based on (Martin, 2009, p. 344))

Type of storage	Small Goods e.g. Packets	Commercial Cargos e.g. (Euro Pallets)	Long Items			Expanse Consumption* [%]
			2,5 metres - 4 metres	>4 metres - 6 metres	>6 metres	
block storage	X	X	X	X	X	80
cantilever rack		X	X	X	X	40
pallet storage	X	X	X			45
drive-in-pallet racking	X	X	X			70
pallet storage for manual forklifts	X	X	X			40
pallet storage for automatic forklifts	X	X	X			60
gravity storage	X	X	X			65
mobile shelving system	X	X				75
Push-back racking	X	X	X			70
Honey comb storage system			X	X	X	60
stacking cradle storage system			X	X	X	70
automated block system			X	X	X	60
tower storage system			X	X		55

*Reference value, depending on the weight, dimensions, volume, depth of the storage, manual or automatic system, and the country laws of the road width.

In Figure 6.16, four different types of the special automatic long items systems are presented. These types are the systems from the storage producer Kasto (Kasto Maschinenbau GmbH & Co. KG, 2014).

The honey comb storage system is named accordingly because the storage system looks like a big honey comb with different compartments reserved for different goods. Goods are stored on big tablets within the honey comb and the automated stacker crane drives on rails between two honey combs and pulls the tables with the goods out of the honey combs. Afterwards, the automated stacker crane brings the tablets to a transfer station and employees can pick the goods from the tablets in a pick-up zone or they can replenish the goods. After the operations, the tablet is returned to the honey comb by the automated stacker crane.

Honey comb storage

Stacking cradle storage system

Automatic block system

Tower storage system

Source: All pictures from (Kasto Maschinenbau GmbH & Co. KG, 2014)

Figure 6.16. Different Types of Automatic Long Item Storages

The Stacking Cradle Storage System

This system is based on the block system. It is an optimised system that uses a controlled crane like an automated stacker crane and frames for the transport and storage of goods. In this system, the goods are stored in a frame. The width of the location is limited by the distance of the two frames. The crane limits the maximum distance of the frames (see Figure 6.16). The location dimension is limited by the dimension stability of the good. If goods are much longer than the frame but the stability is sufficient, then the good can also be stored.

Automatic Block System

In the automatic block system, the racks are connected with rails on which a controlled crane is placed. This crane is special because it can pick up the boxes because of its horizontal movements. The crane moves across the racks on a large traverse. In its vertical movements, this traverse is directed by the profile of the rack. The horizontal movement to pick up a box is due to a controlled and directed axis. The crane transports the box to a transfer station at which goods can be picked or be filled into the box. Because a box can include more than one location, goods that are not needed often can share one box. In practice, a box with a width of 500mm has one to three locations. More than three locations of a box are not ergonomic to handle at the picking and filling stages of the process because of the small width of the location itself.

Tower Storage System

The tower storage system is used only for a small number of long items. Basically, it has two main components. The first component is the rack in which the boxes are stored and the second component is the platform that transports the boxes. The platform is directed at the frame of the rack. The vertical movement is possible by a chain drive. The horizontal movement is along a directed axis. One box can also be divided into more than one location.

The key performance indicators (kpi) of an effective storage option can be calculated by Equations (6.8) to (6.11). This calculation is essential for planning long items logistics because the dimensions of the goods have large influence on the planning. Racks and passage ways cannot be varied as much as they can in the logistics of small goods. One important kpi is the expanse consumption that is shown in Table 6.18. Nevertheless, in this table, only average values are listed. To calculate the exact expanse consumption, the net expanse of the building without columns and other projecting edges is needed. Furthermore, the gross expanse is needed which includes only the rack expanse and the pick-up zone in front of a rack. In addition to the expanse consumption, the height consumption and the room consumption are other indicators (Martin, 2009).

$$\boldsymbol{e_c} = \frac{\boldsymbol{b_{nc}}}{\boldsymbol{st_{ge}}} \cdot \mathbf{100}[\%] \qquad \textbf{(6-9)}$$

Where: e_c = expanse consumption

b_{ne} = building net expanse

st_{ge} = storage gross expanse

One of the important logistics indicators is the turnover frequency of the stock. This indicator defines how often the stock changes in a defined timeslot (Weber, 2009, p. 56). It is possible to calculate this indicator by quantity or by monetary cost. The turnover frequency is created by the quotient of turnover and stock (Martin, 2009, p. 345).

$$\boldsymbol{tu_f} = \frac{\boldsymbol{tu_{st}}}{\boldsymbol{\phi\ st}} \qquad \textbf{(6-10)}$$

Where: tu_f : turnover frequency

tu_{st}: turnover storage

st: ϕstock

A further important logistics indicator that is closely related to the turnover frequency is the time for turnover. This indicator describes how long the goods are stored in the storage area. It is calculated by the quotient of time period (usually 1 year = 365 days) and turnover frequency.

$$\boldsymbol{t_{tu}} = \frac{\boldsymbol{t_p}}{\boldsymbol{tu_f}} \qquad \textbf{(6-11)}$$

Where: t_{tu} time for turnover

t_p Time period

tu_f Turnover frequency

Furthermore, the stock turnover is an indicator for efficient processes. The higher the stock turnover is, the higher the efficiency. This indicator is calculated with the help of the average stock and the turnover storage. The stock turnover is the reciprocal of the turnover frequency (Martin, 2009, p. 345).

$$\boldsymbol{st_{tu}} = \frac{\boldsymbol{\phi\ st}}{\boldsymbol{tu_{st}}} \qquad \textbf{(6-12)}$$

Where: $\phi\ st$: ϕstock

tu_{st}: Turnover storage

st_{tu}: Stock turnover

Stock Strategies at Warehouses

There are evaluation criteria for determining which warehouse type is necessary to store goods for given logistics. At the beginning, it can be said that usually a mixture of different types of racks is necessary to store a product portfolio. The storage strategies are the fundamental of the logistics and they have to be defined within the long item logistics. It has to be pointed out that in practise, long items are stored outside of a building; thus, the stock strategies can vary depending on the weather or the season. Moreover, if steel goods are stored outside of a building, problems associated with oxidation and rust can have an influence on the stock strategies.

FIFO (First in – First out)

In the FIFO strategy, which ever good arrives at the warehouse first will go out first as well. By using flow racks, this strategy can be implemented automatically. At all other storage types, regulation is required for managing the FIFO strategy. For goods that have a use-by date (like an o-ring), it is compulsory to use this strategy. The material of an o-ring can be destroyed if it is too old.

LIFO (Last in – First out)

In the LIFO strategy, the last good that is stored will go out first. This strategy is inevitable at block storage facilities or at the drive-in rack. The strategy is not necessary for the goods or the process, but it is simply generated by the equipment. To smooth the LIFO strategy, little blocks can be made. This has the advantage that if only a few articles are stored at a block, the turnover frequency is much higher than at a larger block. So, a FIFO is created with compromises.

Lateral Distribution

In a lateral distribution, all cargos are stored equally in the rack aisle. In this strategy, all goods are available as well. If one rack aisle cannot be driven through manually or automatically using a forklift, products from other racks can still be picked. Thus, this strategy helps in case of a breakdown. In the lateral distribution, the FIFO or LIFO strategies can also be used. In case a rack aisle is not usable because of a breakdown, the FIFO can still be used on a limited basis.

Double Cycle

The double cycle strategy is always possible and can be combined with other strategies. The double cycle strategy is designed for the scenario that when a good is stored in the rack, the forklift should choose and remove a cargo which is placed nearby to avoid making empty trips.

Route Optimised Storage

The background of the route optimised storage is to cluster and store goods according to the ABC types of goods. The clustering of the goods according to the ABC types is made using the turnover. A-goods are goods that make approximately 80% of the turnover but only constitute 20% of the company's goods. The B-articles have approximately 15% of the turnover but constitute 30% of the goods. The C-goods have only 5% of the turnover but constitute 50% of the goods. In the ABC-structure, all A-goods are stored close together so that the routes shrink to a minimum (Harder, 2008, pp. 69 - 74). Moreover, the ABC analysis can also be adapted for analysing the relationships between the amount of goods and the number of goods (Erlach, 2010, pp. 131 - 134). The structure of the goods in the rack is like an onion (see Figure 6.17). In the middle of the onion is the core, the A-articles. All A-articles are located directly in bottom. This is because the routes from one location to the next should be as short as possible. The second reason is that picking cargos that are stored in bottom is very easy. No vertical forklift is needed to reach the cargo. In the bottom, the goods can be picked directly without the help of any expedient. Then, in the depths of the “core” aisle, the B goods are stored. Besides, The bottom location can also be reached manually. These goods are also placed on bottom and can be picked manually. Furthermore, B goods are placed in the height of the core. To reach these goods for picking, equipment is needed. In the third range, the C goods are stored. These goods are placed at the end of an aisle or at the highest locations. But, the goods are quite far away from the ones that are located in Section A, so a lot of time is needed for picking. C-goods stored at the height can also only be reached with equipment. In this picking structure, a conflict can arise if long items and commercial goods are stored in one rack and the commercial goods are A-goods and long items are predominantly B-goods. This is because the effort to pick long items stored at a height is much higher than on the bottom of a rack. So, a compromise has to be reached regarding which goods have to be placed in the A- zone of the rack. This strategy is shown in Figure 6.17.

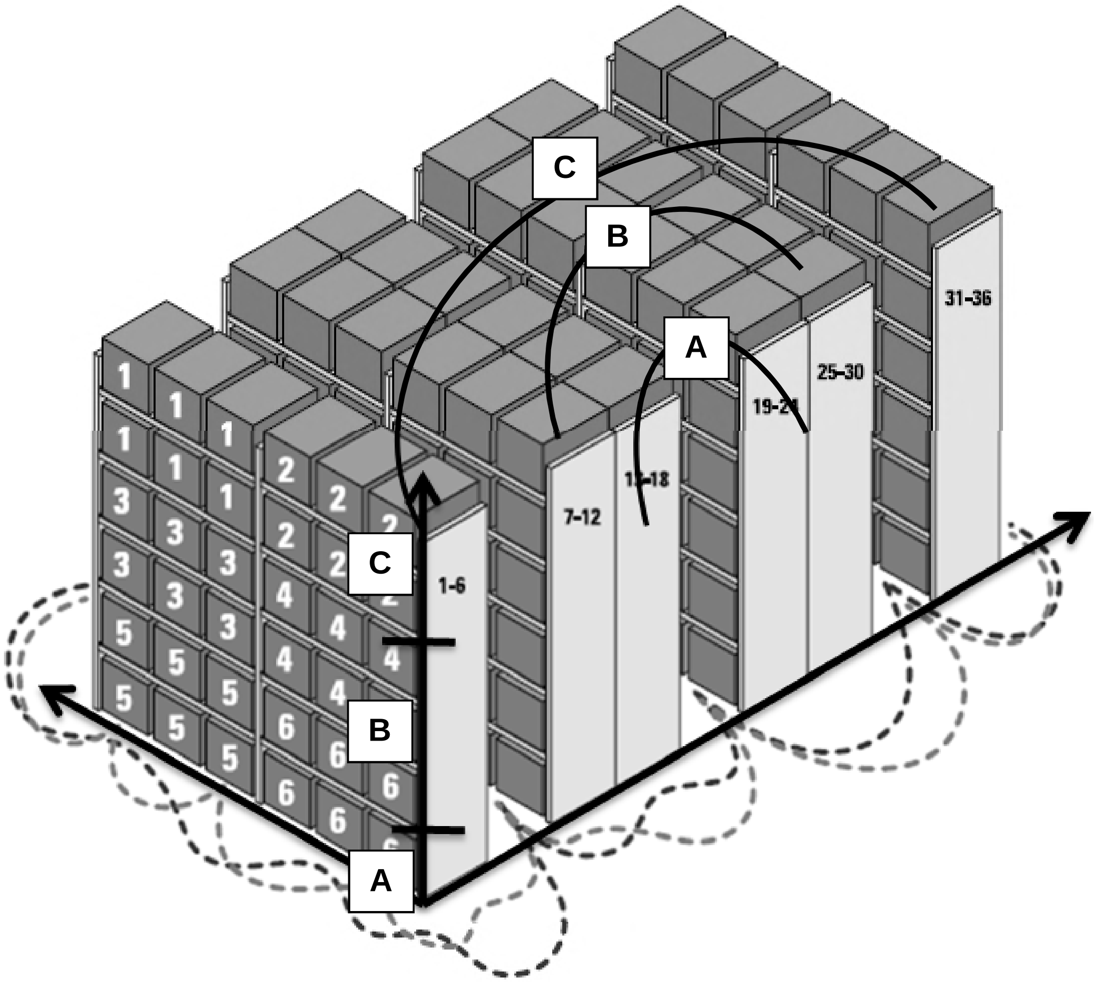


Figure 6.17. Commercial Pallet Rack with ABC-Structure
Source: In analogy to (BITO-Lagertechnik Bittmann GmbH, 2013, p. 8)

Branch Aisle Strategy

In the branch aisle strategy, the main aisle (main road) is placed in the middle of the warehouse and branch aisles branch off of it. This structure is used for small and moderately size storage facilities. This structure has the advantage that distances from one location to the next location are minimised.

Figure 6.18 shows a schematic layout of a warehouse that has one main road and the branch aisles.

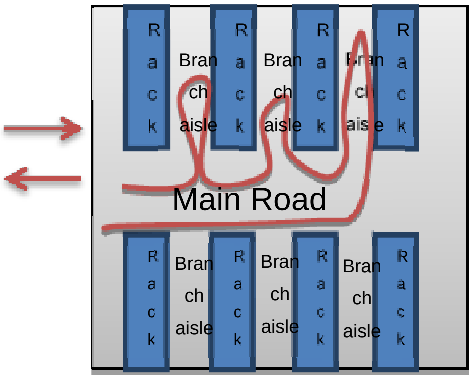


Figure 6.18: Branch Aisle Strategy of a Warehouse

Stripe Strategy

The stripe strategy can only be used by warehouses storing goods at a height. The stripe strategy describes that the forklift drives successively from location to location in a sort of stripe pattern. This strategy is only applicable in vertical storing and when using equipment that can drive vertically and horizontally. In Figure 6.19, the stripe strategy is presented. The red line is an example of the road the forklift uses. In this case, the forklift brings one cargo to the ground level and stores this one at Location 33. Afterwards, the forklift picks up the cargo at Location 12 from a higher rack, and brings it out of the warehouse. So, the forklift drives through the warehouse in a stripe pattern.

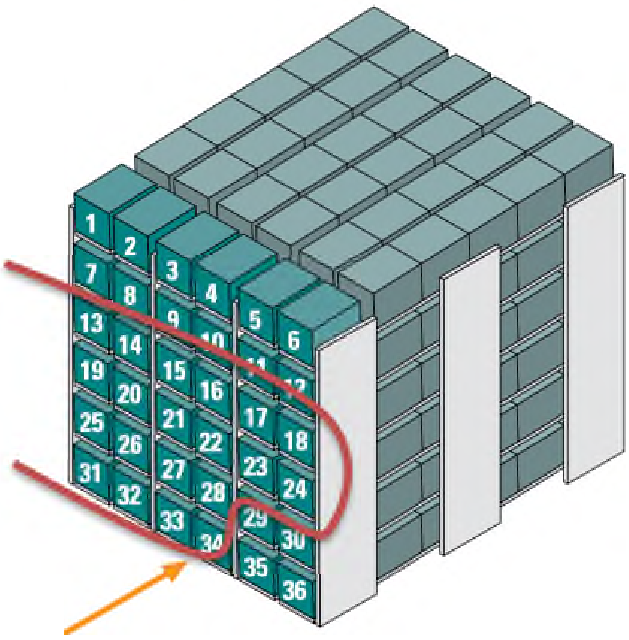


Figure 6.19: Stripe Strategy Warehouse

Source: In analogy to (BITO-Lagertechnik Bittmann GmbH, 2013, p. 9)

Packaging of Goods

Storing goods is an important requirement of the long item logistics. Figure 6.21 shows a long item cargo at the building side. In this cargo, it can be observed that if a cargo is open, the stability of the cargo is damaged. Therefore, the wood frame shifts to the left side. Furthermore, the wood frame is closed, although only half of the cargo is filled. The plastic wire divides the frame into different levels. This plastic wire has only the task of improving the stability of the wood frame. If goods are picked from a cargo, the plastic wire loses the tension. So, when opening a cargo, the plastic wire cannot be used to fix the open frames.

Figure 6.20: Long Item Cargo at a Building Site

Full cargos of long items can be stored directly on a rack, e.g. in a cantilever rack. To store long item cargos with picked goods, a special pallet or a platform is needed (see Figure 6.21). The open cargo has to be packed on a platform or on other special pallets like in Figure 6.21. On each edge of this pallet, stable uprights are fixed so that long items can be placed there. These cargos have also one additional advantage: They are stackable. So, this cargo can be used for block storage. The disadvantage of these long item pallets is that the goods are longer than the cargos. It is recommended that the pallet is longer than the goods so that damages can be avoided in the transport and the handling of the goods. If cargos are transported to other companies, pallets should be foldable so that the necessary space for the transport back can be minimised. This has the advantage that capacity and money is saved on the transport back.

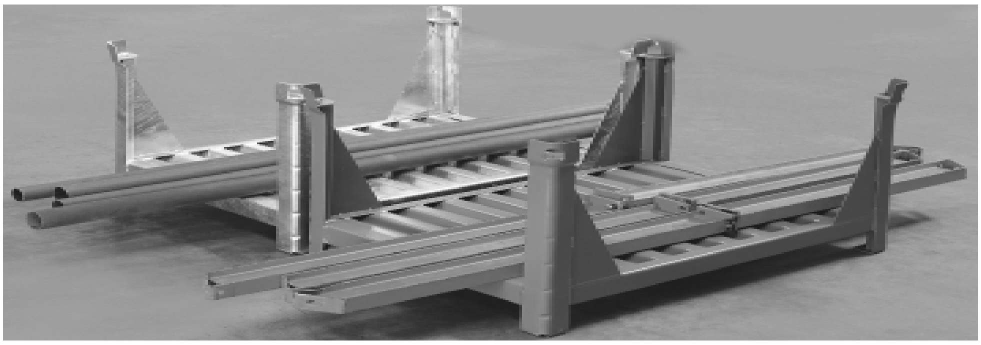


Figure 6.21: Long Item Cargo

Source: (KAISER+KRAFT GmbH, 2014)

Comparison of the Different Warehouse Types

Table 6.19: Performance of the Different Warehouse Types

Source: * (Kasto Maschinenbau GmbH & Co. KG, 2014), ** (Dambach Lagersysteme GmbH & Co. KG, 2013, p. 5), *** (Hauptkatalog SSI Schäfer Noell GmbH, 2012, p. 10), **** (Jungheinrich Vertrieb Deutschland AG & Co. KG, 2013, p. 3), (HUBTEX Maschinenbau GmbH & Co. KG, 2014, p. 4)

Type of Storage	Max. Construction Height [m]		Effective Load at Each Cargo [t]	Max. Volume of Cargos [piece]	Max. Length of a Cargo [m]	Maximum Aisle Length [m]	Silo Architecture Possible	Double - Cross Performance [double cross/hour]	Max. Vertical Speed of the Lift [m/min]	
Block Storage	12.1	****	1	1,000	16	200	no	15	42	****
Cantilever Rack* **	12.1	****	1	20,000	16	75	yes	15	42	****
Drive-in-Pallet Racking* **	12.1	****	1	20,000	3.9	50	yes	15	42	****
Pallet Storage for Manual Forklifts* **	12.1	****	1	20,000	3.9	100	yes	15	42	****
**Pallet Storage for Automatic Forklifts ** **	40		1	50,000	3.9	200	yes	60	60	
Gravity Storage* **	12.1	****	1	2,000	3.9	50	yes	15	42	****
Mobile Shelving System* **	12.1	****	1	500	6	16	no	15	42	****
Push-Back Racking* **	12.1	****	1	2,000	3.9	50	yes	15	42	****
**Honey Comb Storage System* **	26		5	4,000	8	28	yes	60	60	
**Stacking Cradle Storage System* **	14		3	1,000	24	30	yes	20	20	
**Automated Block System* **	20		5	1,500	12	25	yes	32	34	
**Tower Storage System* **	25		5	150	14.6	25	yes	30	32	

The different warehouses types are presented in Table 6.19. In the vertical axis, the types of warehouses are listed and in the horizontal axis, the characteristics of warehouses. For this comparison, current (January 2014) and real commercial data from the global logistics market are evaluated.

The table shows data and characteristics that are state of the art. This table presents the information of an overview of different types of warehouses and for planning a warehouse, so the data can be used for the structure planning of the warehouse. In the detail planning, the data have to be verified on the market with the actual performance data. If there are individual constructions or individual equipment, the commercial data can differ. For example, the maximum height of block storage is at 12.1 metres due to the limitations set by the equipment that is used to store the products. However, it is possible to create individual equipment, e.g. a forklift that can handle goods at a height of more than 12.1 metres. So, the data in this table are not limited by fundamental laws of physics. The data are limited for the state of the art equipment. The characteristic maximum volume of the cargos is the maximum soft border because these data are bench mark data from the equipment manufacturers. A higher volume is possible, but will result in a lower performance. Moreover, the maximum length of a cargo and the maximum length of an aisle are standard values for effective and efficient logistics. The silo architecture is an established term in the logistics. This term describes that in a silo architecture, the external racks are used as walls. Sandwich elements are installed at the outer racks that dam and protect against environmental conditions like rain and so on. Furthermore, the top side of each of the racks forms one part of the roof construction. So the racks are the main components of a building. The advantage is that a lot of money can be saved using this architecture. The disadvantage is that the racks are fixed in their given position for lifetime. It is impossible to replace the racks in another orientation. An example of a warehouse in silo architecture is shown in Figure 6.22. At the middle of the rack, the roof is marked with a red arrow. On the sides of the rack, sandwich elements are also installed.

The characteristic double cross performance describes the time that is needed to store one pallet in the rack and drive to another location, pick up another cargo, and bring this cargo to the pre-storage area. Thus, one cargo has to be stored in and another cargo has to be removed from the warehouse. This is called double cross in the logistics. An automatic forklift, e.g. an aisle bound racking crane, accomplishes 60 double crosses each hour. A manual forklift accomplishes only 15 double crosses in one hour.

The last characteristic is the vertical lift speed. This is an important characteristic because the vertical speed of a lift is lower than the horizontal speed. So, the vertical lift speed limits the performance of a lift. The honey comp storage system has the highest lift speed with 60 m/min.

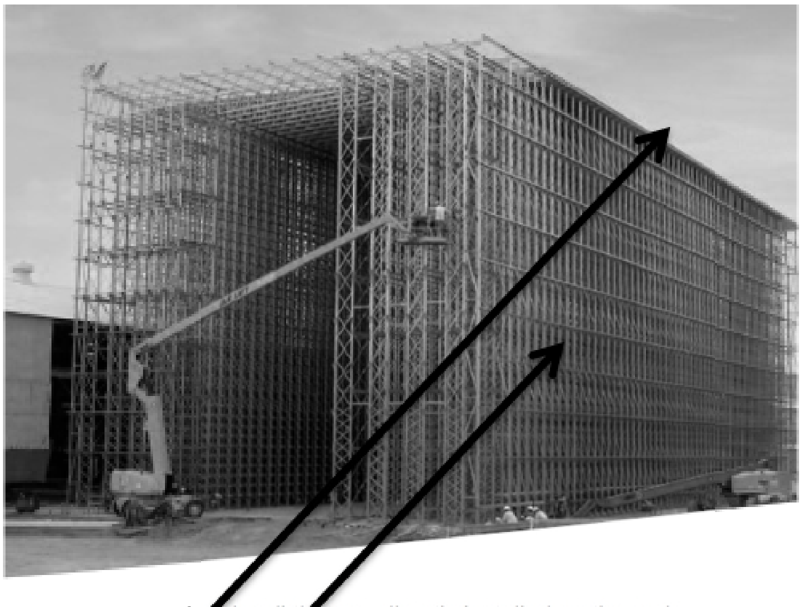


Figure 6.22: Honey Comb Storage System at the Installation

Source: (Kasto Maschinenbau GmbH & Co. KG, 2014, p. 15)

The maximum construction height in relation to the volume of cargos is shown in Figure 6.23. The information shown in the figure can be used in the planning process. Based on the previous planning stages, the planner has the necessary information about the number of locations sorted by cargo types. For example, there may be 1,000 locations for long item cargos and 2,000 locations for commercial euro pallet cargos. The red broken line is the planning line that varies at every use. In this example, the long items can be stored in the following automated warehouse systems: the honey comb storage, stacking cradle storage, or the automated block system. Moreover, all manual warehouse systems can be used with the exception of the mobile shelving system and the tower storage system (see Figure 6.23), as these systems do not have enough locations. One of the other warehouse systems can be chosen instead. In relation to the chosen warehouse system, the maximum construction height can be shown directly in this figure. The maximum construction height in the logistics is important because it is more affordable to build a high building with a small floor area than a low height with a large floor area.

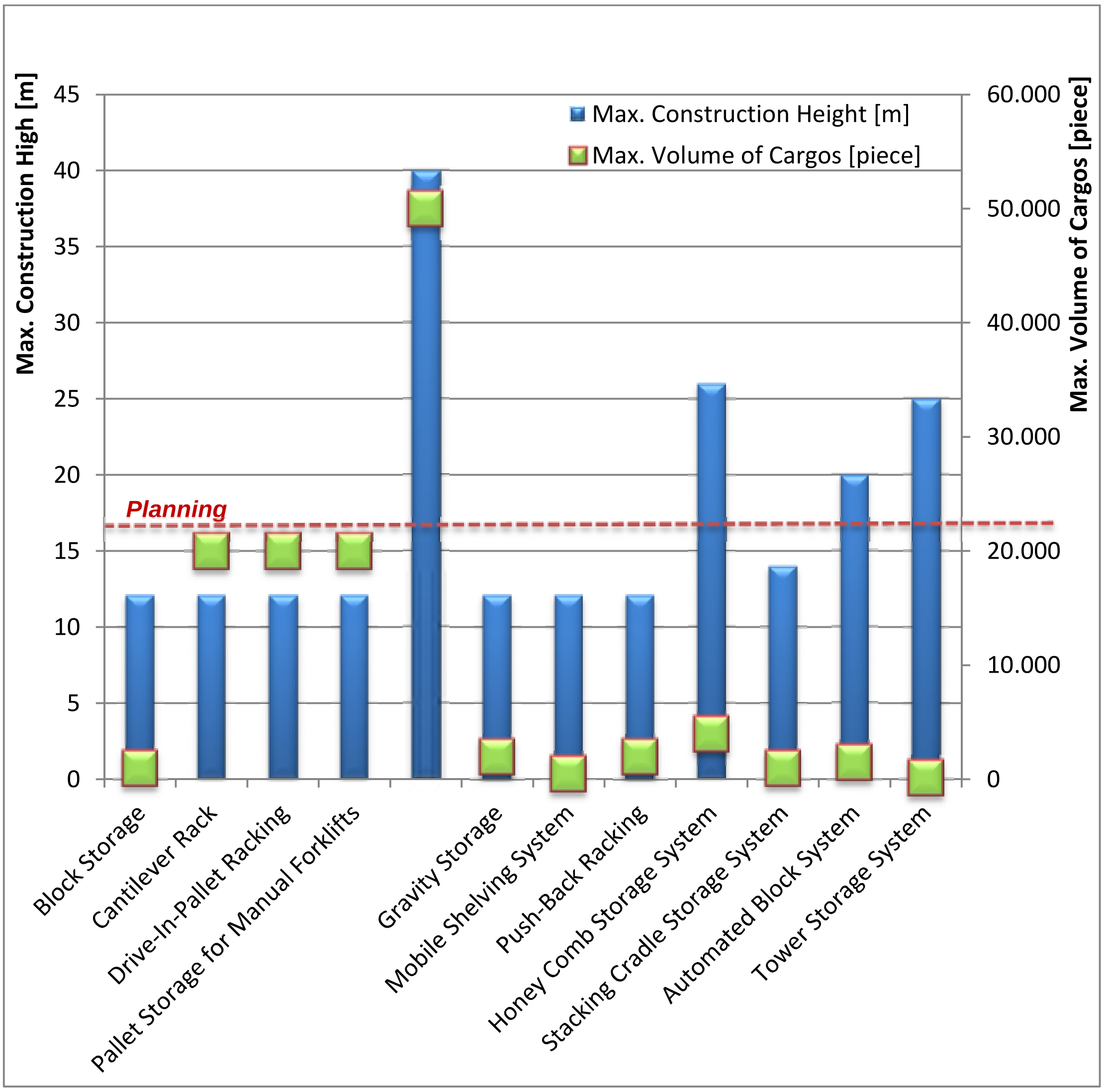


Figure 6.23: Maximum Construction Height in Relation to the Maximum Volume of Cargos

Figure 6.24 can also be used in the planning. In this figure, the maximum length of a cargo in relation to the maximum length of the aisle is shown. These two parameters are necessary for the dimension planning. Moreover, the dimensions are the basis for the performance calculation of the picking processes. This chart also has a broken red line, the planning line. This line helps with the planning. So, for example, if long item cargos with the length of 5 metres shall be stored in the warehouse, the line is fixed at 5 metres (see the left axis at Figure 6.24). All warehouse systems that pass or exceed the red line can be used. For example, the block storage clearly exceeded the red line. Furthermore, the length of aisle is at 200 metres in the block storage. According to these two data, the calculation can be made to determine how many goods can be stored in one aisle. With the additional data of the maximum height of a warehouse from Figure 6.23, the dimensions of the building can be calculated.

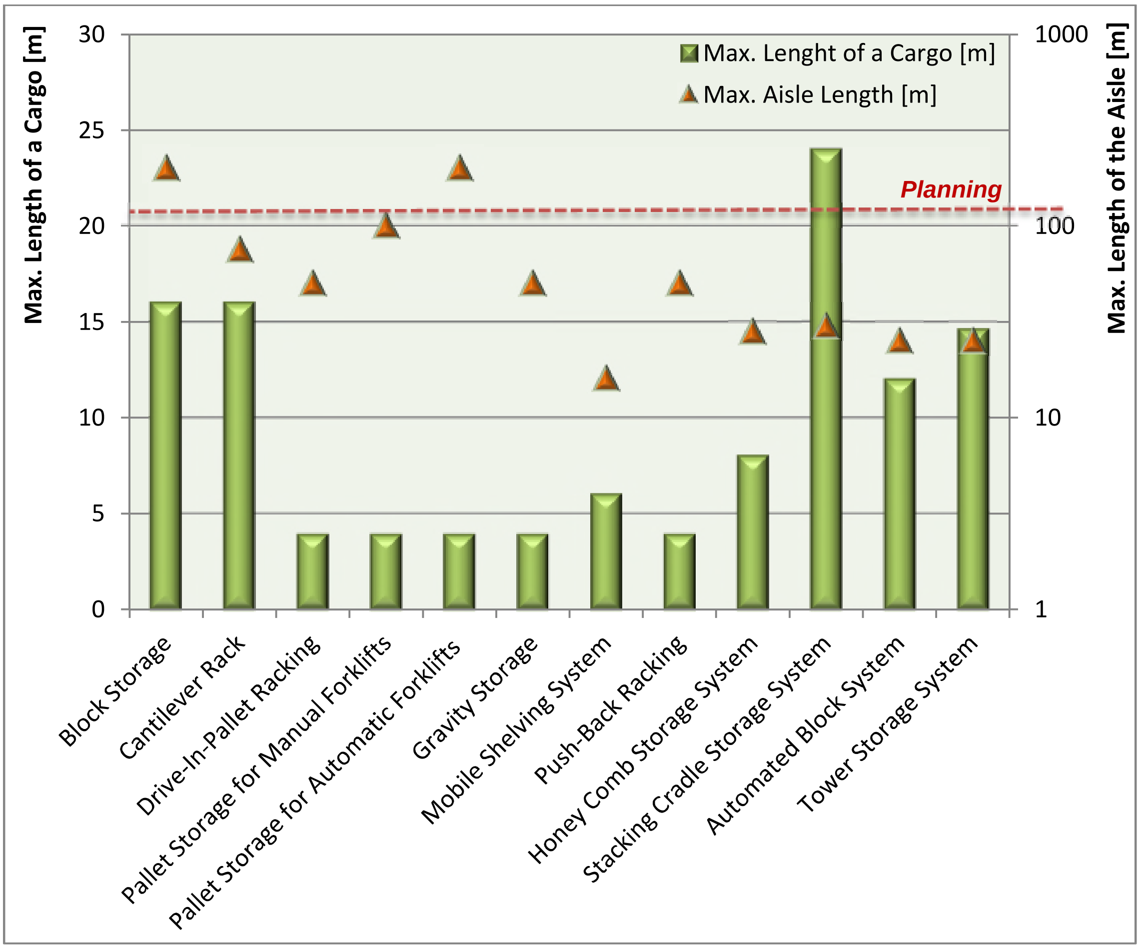


Figure 6.24: Maximum Length of a Cargo in Relation to the Maximum Length of an Aisle

Figure 6.25 deals with performance data and is the last figure that can be used to plan warehouse types. In Figure 6.25, many performance data are at the same level. This is because manual warehouse types use manual forklifts and these forklifts have roughly the same performance. Therefore, all manual warehouse types have the same performance. But. automatic warehouses have different performances. For example, a honey comb storage system has a maximum double-cross performance of 60 double crosses per hour. In comparison, a block storage only has a maximum double-cross performance of 15 double crosses per hour.

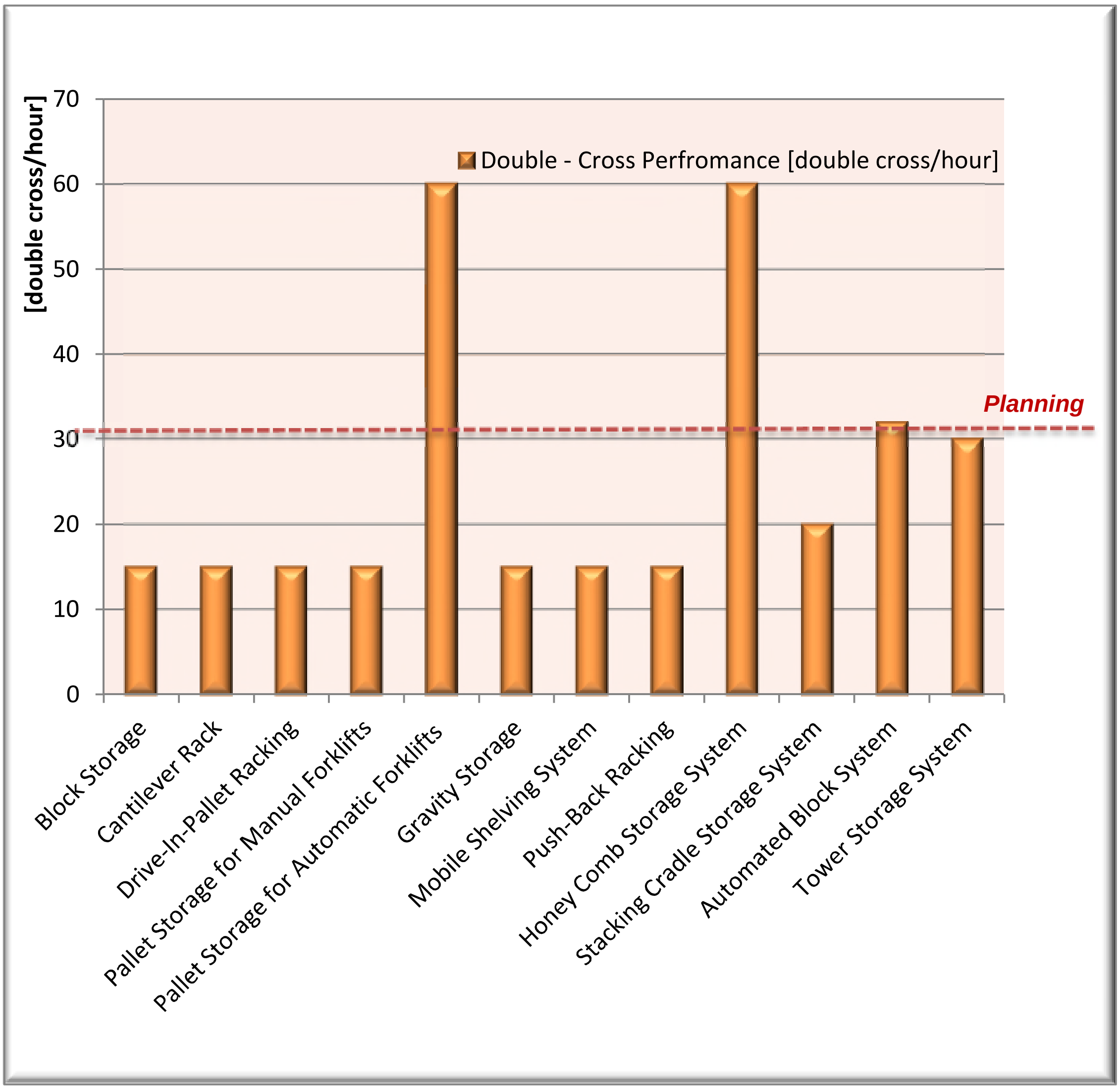


Figure 6.25: Double Cross Performance of Different Manual and Automatic Warehouse Types

6.5.7.3 *Creation of the Picking System*

The picking system consists of five stages (see Figure 6.26). It starts with planning the requirements of the picking system. In this stage, requirements such as the ergonomic, performance, quality, etc. are determined. In the second stage, scenarios of different picking systems are developed. The third stage deals with the flow planning. At this stage, the material flow is planned. The block planning describes the block layout for the picking area, which should not be confused with the block layout of the entire logistics system. At this stage, a specific block layout of the picking system is created. This block model is more precise and deals only with the picking system. In the last stage, the processes are planned (Günthner, et al., 2009).

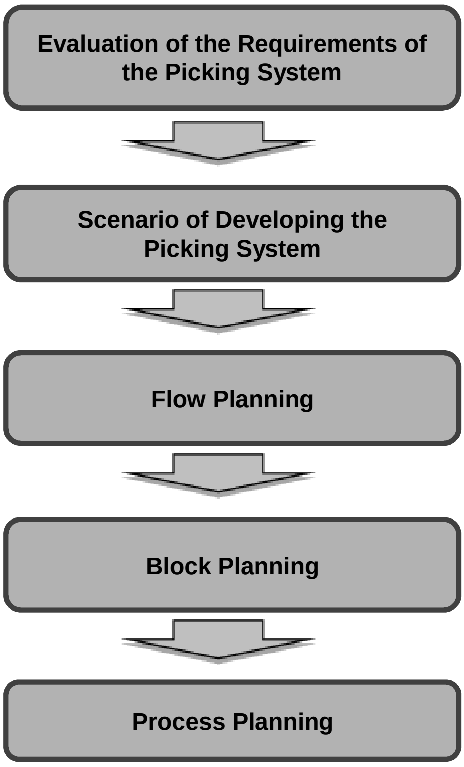


Figure 6.26: Picking System Planning Process
(based on (Günthner, et al., 2009))

Evaluation of the Requirements of the Picking System

Table 6.20 shows the requirements that are necessary for planning a picking system. The requirements are divided into seven different categories. These are performance, ergonomics, quality, costs, flexibility, lean, and replenishment. The requirement lean is important in case a lean production system exists. In this case, the created processes have to work with the same philosophy like the whole production system. The requirement replenishment deals with the transportation of goods if cargos are empty in the picking area. In this case, a new cargo has to be brought in and the empty cargo has to be brought away. For all requirements, subsections with special questions exist that have to be evaluated. The evaluation of the subsections is done according to the level of importance. The level 0 means that this requirement is relatively unimportant. The levels increase step-by-step to 5, which means that this requirement is most important. The data of Table 6.20 are presented in the radar chart in Figure 6.27. Thus, it is easy to see, which requirements are important and have to be considered (Günthner, et al., 2009).

Table 6.20: Important Requirements for the Picking System

(based on (Günthner, et al., 2009))

		1. Unimportant	2. Less Important	3. Important	4. More Important	5. Most Important
Performance	The performance of the picking system is flexible and adaptable to the demand					
	The performance of the picking system is described by the picks/hour					
	Minimisation of the distances from the goods that have to be picked					
	Minimisation of the cycle time of each order picking					
Ergonomics	Zero defect strategy at the picking					
	Ergonomically optimised goods at the picking area					
	Reducing the weight of the goods that have to be handled					
	Prevention of the rotary motion of the body with goods					
	Labels at the location of goods are clearly arranged					
Quality	Zero defect strategy					
	Identification of mistakes directly at the development					
	Closed loop of the quality control					
	Using methods to identify the reasons of problems					
Costs	Low operation costs					
	Low investment budget					
	Low maintenance costs					
Flexibility	Flexible for different products					
	Flexible working time model					
	Flexible organisation of employees					
	Flexible expandability of the picking system					
Lean	Flexible and adaptable to the customers' demand					
	Production depending the customers' cycle time					
	Synchronisation of the processes					
	Pull material flow					
Replenishment	Less crossing traffic of the picking vehicles and the replenishment vehicles					
	Easy change of empty carriers					
	As little repackaging as possible					

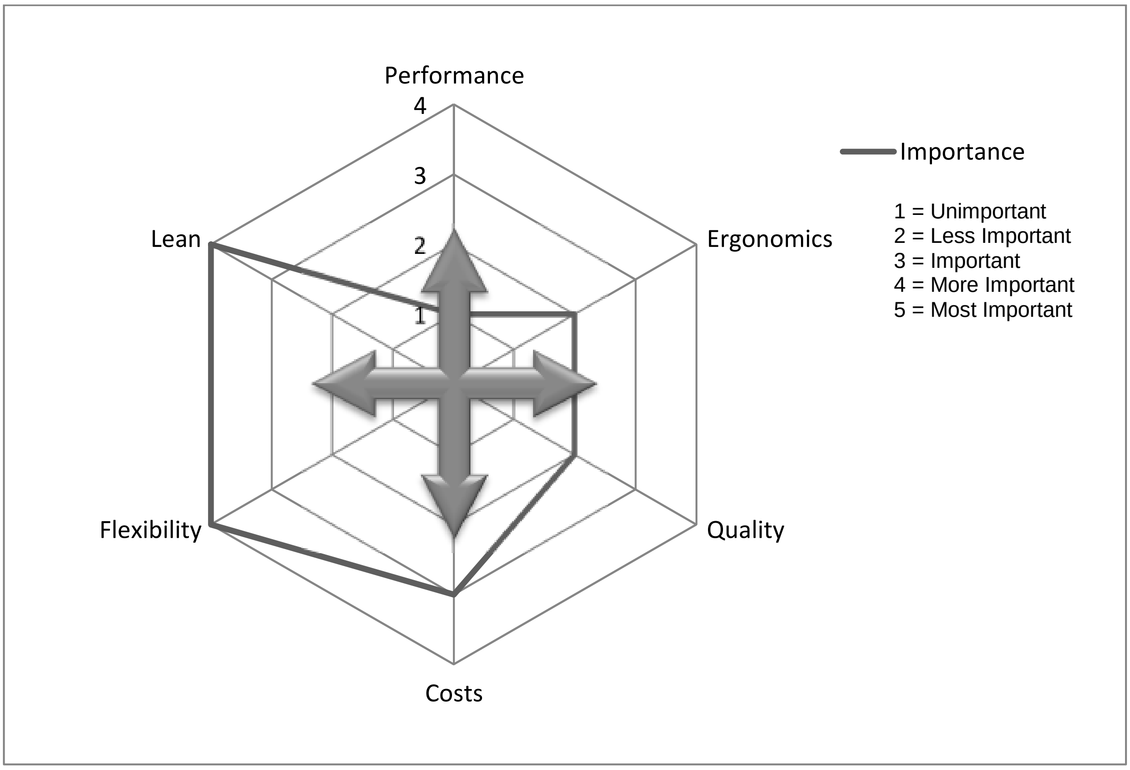


Figure 6.27: Requirements of a Picking System
(based on (Günthner, et al., 2009))

Structuring of the Picking System

The structure of the picking system is created using four different kinds of input data. The first kind of input data are the requirements of the picking system that are defined in the previous stages. In addition to these requirements, the customer requirements that have been evaluated by the expert interview are used. These are shown in Figure 6.28 (Günthner, et al., 2009).
Table 6.1, the red and white marked lines at the bottom of the table. Furthermore, data of typical customer orders are necessary. these data include the material number, the name of material, dimensions and weight. An order contains at minimum one position. A position is one type of article and one position can have at minimum one piece. Thus, orders can be very different in the dimensions and in the number of pieces. If no typical orders exist, a very large order and a very small order have to be used for the structure planning of the picking system. The fourth basic data are the structure of the process. The process structure itself describes the detailed handling stages in the picking process. One essential picking process is shown in Figure 6.28. The process

starts with the transmission of the order. In most industries, orders arrive daily. They are transferred to a picking order. The transformation from the customer order to the picking order is one of the main parts of the process because it influences the picking process. After the start of the picking process, the equipment and the sink cargo has to be prepared. The next stage is to go or drive to the first location to pick the goods (Günthner, et al., 2009).

At the location, the first task is to scan the location number and the product number. By doing this, the identification of the good is checked. If the location and the right good are deemed correct, the package can be opened. If the package is a wood frame, equipment like a pinch bar is needed. After the cargo has been opened, the goods can be picked and the cargo can be closed or fixed again. The closing or fixing of the cargo is necessary because the long item cargos lose their stability when they are open. After this stage, the picking ends and a new picking process can start. This means the employee has to go or to drive to the next location, identify, open, pick, and close the cargo. If all positions are picked from the order, the cargo has to be packed for a safe transport. At this stage, the cargo is closed. Because the customer orders are different in dimensions and in the amount of numbers, only limited variants of standardisations exist. Therefore, the U-wood frames have to be cut with a saw to the individual picking height, so that a stable frame protects the goods. For this closing process, further equipment like a hammer or a stapler is needed. At last, the cargo is labelled.

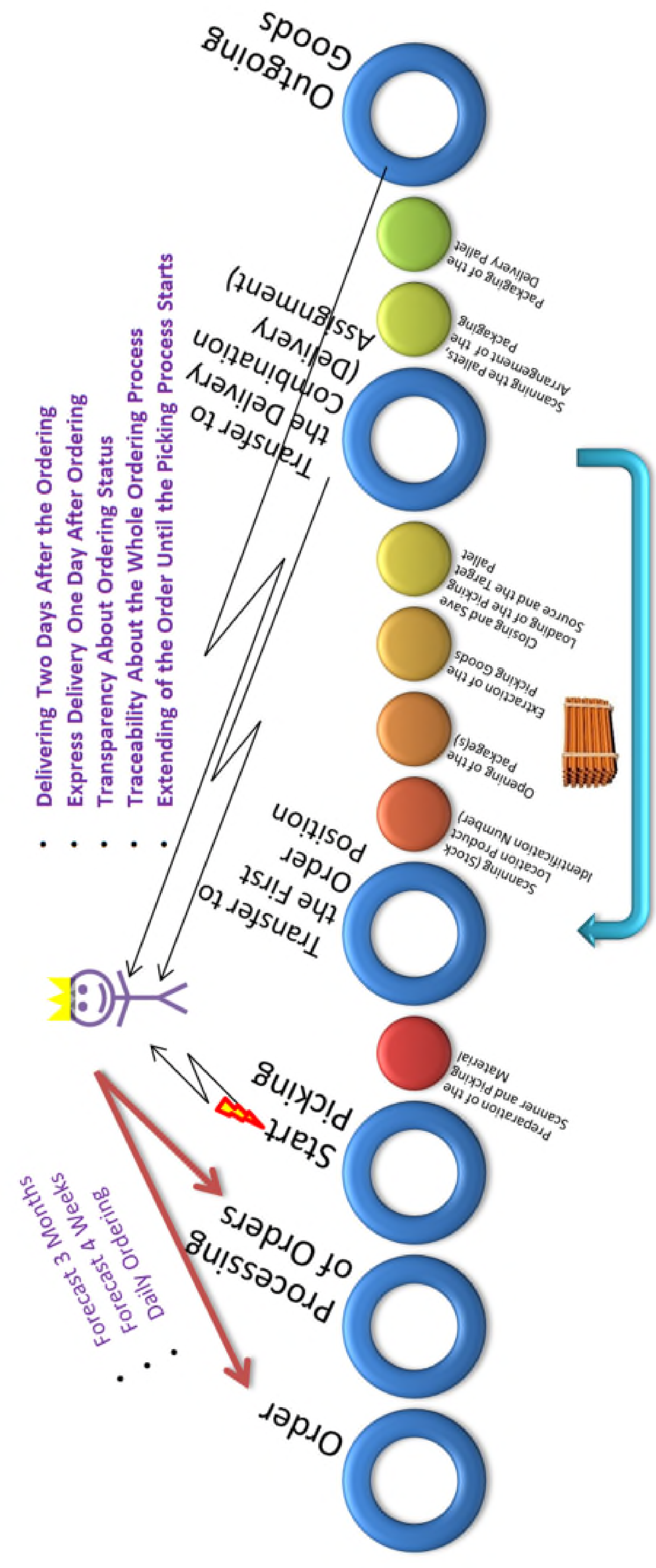
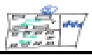
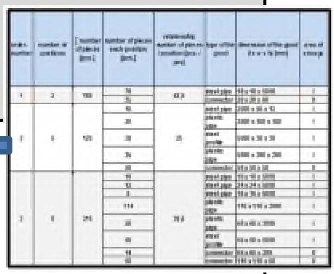
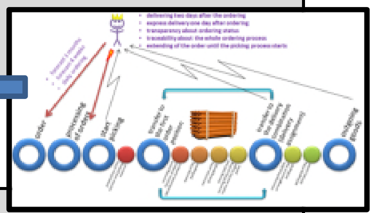


Figure 6.28: The Essential Picking Process from the Customer Order to the Outgoing Goods

Table 6.21: Structure Planning of the Picking System

			Sorted by Order, Parallel Picking	Sorted by Order, Serial Picking	Multi Order, Parallel Picking
					
Requirements at the Picking	**Performance**	*flexible and adaptable on the demand* *measurable performance* *the picking area is performance optimised* *minimisation of the cycle time*			
	Ergonomics	*ergonomically optimised picking area* *reducing the weight of a good that has to be handled* *prevention of the rotary motion of the body* *clearly visualised picking area*			
	Quality	*zero defect strategy* *identify mistakes directly* *closed quality loops* *methods to identify reasons of problems*			
	Costs	*low operation costs* *low investment budget* *low maintenance costs*			
	Flexibility	*new products can be handled* *flexible working model* *flexible organisation of employees* *flexible expandability of the picking system*			
	Lean	*adaptable to the customers' demand* *synchronic picking to the customers' needs* *pull material flow* *transparent information level*			
	Replenishment	*less crossing traffic* *easy change of empty carriers* *as little repacking as possible*			
customers' requirements	**Information flow**	*information about delivery date* *information in case of an amendment or adjustment of the delivery* *delivery time* *way to order*			
	Packaging	*different types of packaging* *requirements to the package* *which package material is preferred*			
	Product quality	*good product quality*			





Splitting an Order

In practise, customer orders may have to be split into different picking orders. The reasons for the splitting can vary. It can be necessary when the picking location is divided if more picking goods exist than can be stored in one building or room. Another reason could be that the orders are picked in parallel to reduce the door to door time or that goods have quite different dimensions like the constellation in the logistics of long items and commercial goods in the building industry. There are three basic ways to split picking orders:

1. Sorted by order, parallel picking
2. Multi order parallel picking
3. Sorted by order, serial picking

Sorted by Order, Parallel Picking

At this splitting, the customers' order is divided into parts depending on the dimensions of the goods. All long items are placed in one area and all commercial goods are placed in another area. This splitting can also be used for the same group of goods, if the room is too small to place all goods in one room. So, two picking orders are created, one for Picking Area I and another for Picking Area II. The third area is called “Delivery Combination Area” and is necessary to combine the picking goods from Picking Areas I and II. The advantage of this type of dividing the orders is that separating the picking areas reduces the cross traffic of forklifts. If the number of orders rises, more than one forklift can be used for the picking process because the ways have a width of 12.5 metres so the vehicles can pass each other. If the location of the cargos has a width of circa 1.5 metres, the driving passage way must have a width of 9.5 metres. This rather large distance is necessary because a four-way forklift has a length of circa 2.5 metres, excluding its load. So, if one forklift wants to turn around in the aisle, it needs the turn radius from the length of the cargo. This is because a forklift has a turn radius of 0 metres. It can turn directly like a carousel. One further advantage of having different picking areas is that each picking area is optimised according to the dimensions of its cargo, while a mixed picking area that includes long items and commercial cargos unavoidably has gaps between the cargos because of the different rack fields.

The disadvantage of the arrangement of the picking areas is that time differences at the process can arise. That is because the picking orders of the long items and the picking orders of commercial cargos are different. If the picking order of the long item cargo is extensive, the commercial picks are faster. Therefore, in the delivery combination area, the goods of the faster process have to be stored until the slower picking process is finished. The other possibility is that one picking process has to wait until the other picking process is finished. But this option is waste of working time. Thus, this arrangement of the picking area cannot be used if the whole company works in a lean management system.

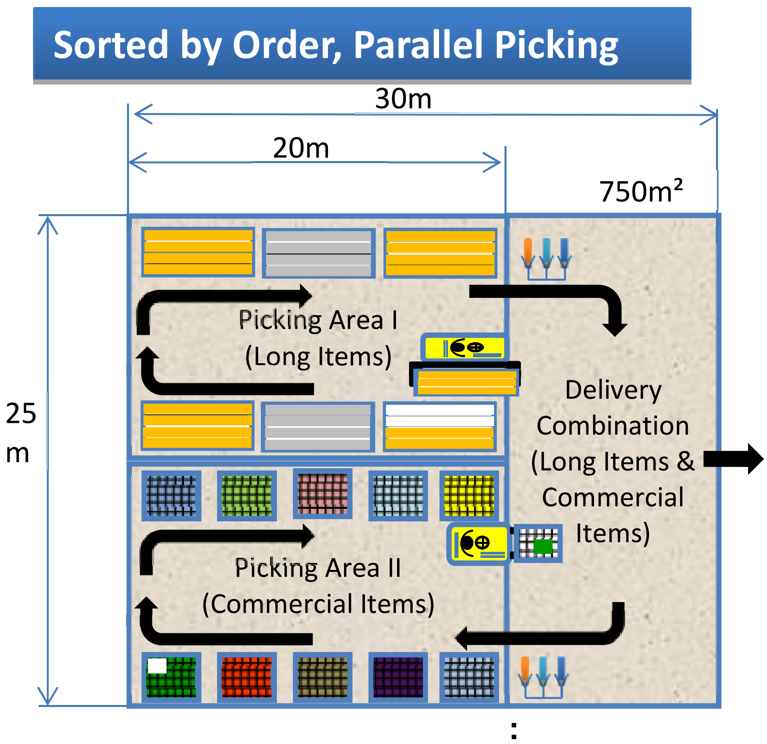


Figure 6.29: Sorted by Order, Parallel Picking

The multi order parallel picking

In this picking system, the customer orders are sorted by positions (see Figure 6.30). The picking areas are arranged in the same manner as in the sorted by order, parallel picking system. The only difference is that the picking orders are sorted. Another significant difference can be found in the delivery combination area. In this picking system, an additional process is added in this area. Before the goods can be combined, they have to be assigned to the customers' orders. Thus, the disadvantage of this picking system is the same as in the sorted by order, parallel picking. The advantage of this picking system is that the complicated and time-intensive opening and closing of long item cargos is minimised because more long items are picked together at one time. After the picking process the products are assigned to the customers' orders.

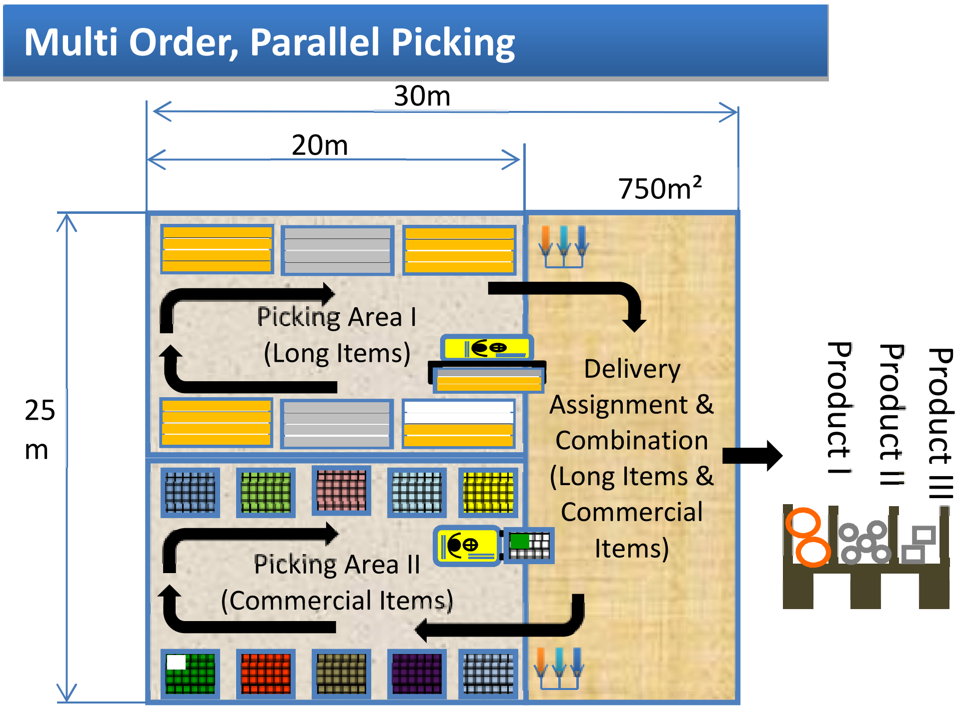


Figure 6.30: Multi Order, Parallel Picking

Sorted by Order, Serial Picking

The sorted by order, serial picking system is arranged differently. In this the picking system, areas are connected to one big picking area. In this area the goods (long items and commercial items) are mixed. The location of the goods is chosen in connection to the demand. Goods that are often purchased together are located close to each other. As a result, the necessary travel distances of picking orders are sinking. The delivery combination area still exists in this system, but the tasks, time, and effort shrink. The delivery combination area only has to pack goods for the transport. Because the goods are picked in one area only, all of the goods in the customer's order are picked and loaded on one cargo. This type of picking is called one stepped picking and it suits the lean philosophy because the disadvantage of different process times in picking areas is eliminated. A further advantage is that only one type of forklift is used. Thus, employees can concentrate on working with one piece of equipment. Just like the others, this picking system is scalable depending on how many employees and forklifts are involved. But the disadvantage is that the traffic in this picking layout is higher because all employees have to drive in one area. Therefore, it is necessary that the roads in the picking area are big enough for forklifts to pass each other and make turn. If the roads are too narrow, the employees are impeded and the picking performance goes down.

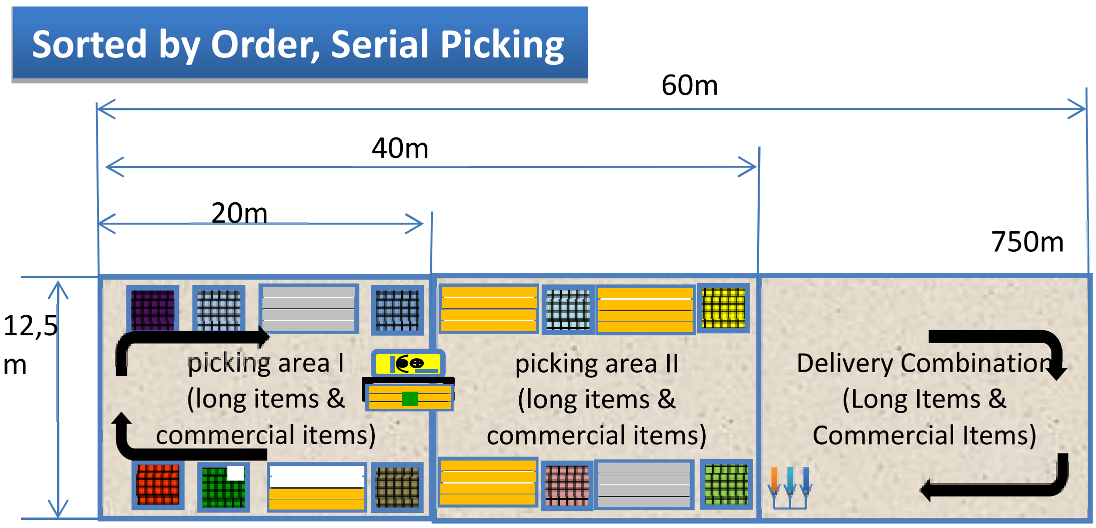


Figure 6.31: Sorted by Order, Serial Picking

Equipment

In this research, two types of forklifts have been used. For the long items, the four-way forklift from Jungheinrich, specifically the type ETV Q20 (see Figure 6.32) was used and in case a second picking area exists, a high lift pallet truck from STILL was used (Figure 6.33). Both of these forklifts are commercial equipment that can be purchased directly from a seller. However, the four-way forklift from Jungheinrich is made for the transport of long goods and cargos. It can drive in every direction: forwards, backwards, to the left and to the right because it has completely turntable wheels.

Figure 6.32: Four-Way Forklift from Jungheinrich Type ETV Q20

Source: (Jungheinrich AG, 2014)

Figure 6.33: High Lift Pallet Truck Still EXD-S 20

Source: (STILL Materials Handling Ltd, 2014)

Calculation of the Different Picking Systems

The picking systems are tested with three different picking orders. One small size, one medium size, and one large size picking order.

For the calculation of the picking time, the Equations (6.12 - 6.27) are used. These calculations are created in a research from ten Hompel, a logistics researcher focused on the research of calculation models for the in-house logistics (ten Hompel, et al., 2011, pp. 127 - 205). In the logistics, there are two different picking strategies. One is the "Man to Goods" strategy in which the employee goes or drives to the location and picks the goods directly from the location if the location can be reached by hand. If not, the cargos have to be brought to the reaching area of the hands, e.g. the cargo is transported by a forklift to the floor where a worker can reach it.

All Following Mathematical Models for the Calculations for the Pick Time [t_i] are Developed by the Researcher ten Hompel (ten Hompel, et al., 2011, pp. 129 - 130)

$$\boldsymbol{t_K} = \begin{cases} \boldsymbol{t_z + t_B} & \boldsymbol{for\ Man\ to\ Goods} \\ \mathbf{max}(\boldsymbol{t_z; t_B}) & \boldsymbol{for\ Goods\ to\ Man} \end{cases} \quad \textbf{(6-13)}$$

Where: t_K: picking time

t_Z: combination time

t_B: operation time

$$\boldsymbol{t_K} = \begin{cases} \boldsymbol{t_S + t_B} & \boldsymbol{for\ Man\ to\ Goods} \\ \mathbf{max}(\boldsymbol{t_{ZAZ-B}; t_{ZAZ-FT}}) & \boldsymbol{for\ Goods\ to\ Man} \end{cases} \quad \textbf{(6-14)}$$

Where: t_S: time for driving or going a distance

t_{ZAZ-B}: time between two arrival goods that are direct in sequence from the material provision e.g. storage

t_{ZAZ-FT}: time between two arrival goods that are direct in sequence from the replenishment e.g. forklift

$$t_Z = \begin{cases} t_S & \text{for Man to Goods} \\ \max(t_{ZAZ-B}; t_{ZAZ-FTB}) & \text{for Goods to Man} \end{cases} \quad \textbf{(6-15)}$$

Where: t_Z combination time

$$t_B = t_{basic} + t_{pick} + t_{waste} + t_n + t_{sort} \quad \textbf{(6-16)}$$

Where:

t_{pick} pick time (time form the picking by hand until to taking in the new cargo)

t_{waste} time that is used for waste e.g. counting, unpacking

t_{sort} time for sorting

t_n time that is needed for the driving or going of a distance between two locations

t_B : operation time

t_{basic} basic picking time e.g. starting an picking order on a computer

$$t_{basis} = \frac{t_{basic,n}}{n} \quad \textbf{(6-17)}$$

Where:

t_{basic} basic picking time e.g. starting an picking order on a computer

$t_{basic,n}$ basic picking time for n order positions

n number of order positions

$$t_{sort} = \frac{1}{P_{sort}} \quad \textbf{(6-18)}$$

Where: P_{sort} sorting performance e.g. from a sorting machine

Under Consideration of the Grab Time

The grab time is determined with the help of a points system. Every type of move is evaluated with points. These points are summed up and transmitted to a real time. In the MTM systematic, the unit for measurement is the TMU (Time Measurement Unit). For the grab, it is necessary to move 1.68 seconds. The grab movement consists of the following steps:

take - grab - bring - let loose (ten Hompel, et al., 2011, p. 137)
(18,4 + 7,3 + 19,0 + 2,0) *TMU* = 46,7 *TMU* = 1,68 s

Pick Performance per Pick [P_K] (ten Hompel, et al., 2011, p. 129)

$$P_K = \frac{1}{t_K} \quad \left[\frac{Pos}{h}\right] \qquad \textbf{(6-19)}$$

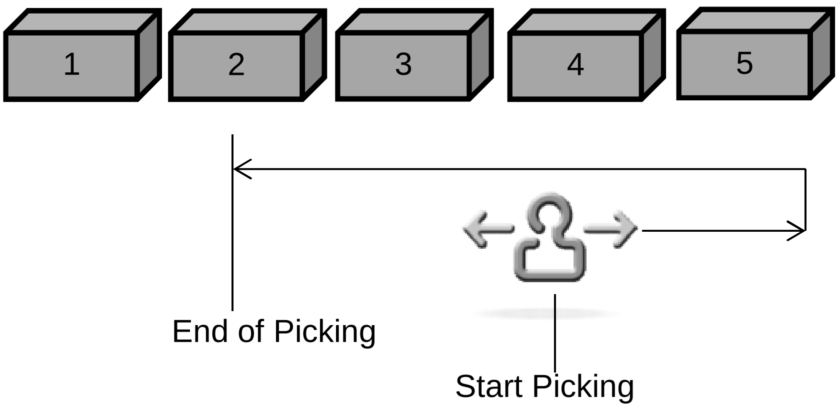
Where: P_K picking performance
t_K picking time

Pick Performance per Picking Order [P_P] (ten Hompel, et al., 2011, p. 129)

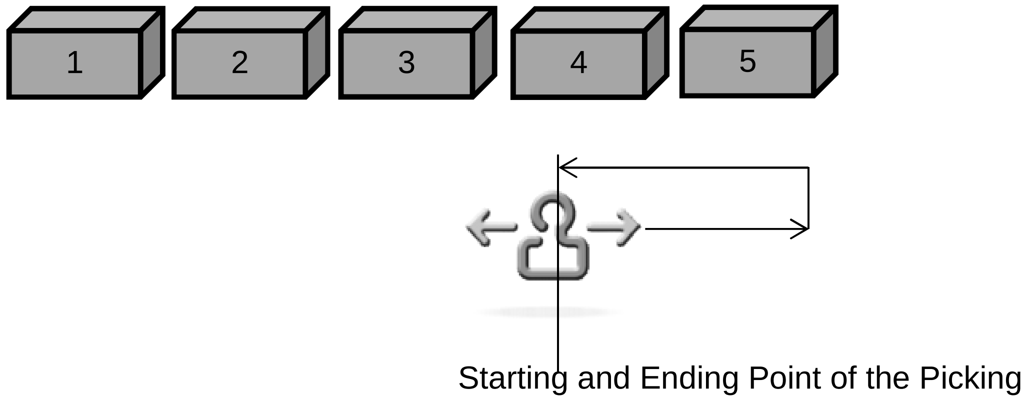
$$P_P = P_K \cdot n_P \quad \left[\frac{Pick}{h}\right] \qquad \textbf{(6-20)}$$

Where: P_P picking performance per picking order
n_p number of positions per order

Case 1: Calculation for one-dimensional, aisle-linked, unsorted picking area (ten Hompel, et al., 2011, p. 141)



(I.) Starting and Ending Points of the Picking Process is different (ten Hompel, et al., 2011, p. 141)



(II.) Starting and Ending Points of the Picking Process is the Same

Figure 6.34: Pick Systematic at a Level One Picking Area, Unsorted Picking Positions

Source: Based on (ten Hompel, et al., 2011, p. 141)

<u>Picking Distance [*sn*] and Picking Time in One-Dimensional, Aisle-Linked Picking Areas</u> (ten Hompel, et al., 2011, pp. 142 - 160)

$$s_n = n_P \cdot \frac{1}{3} L \qquad \textbf{(6-21)}$$

Where: L sum of length of the locations in one aisle

n_p number of positions per order

s_p picking distance

$$t_{waste} = t_{waste,n} \cdot n_P \qquad \textbf{(6-22)}$$

Where: t_{waste} time that is used for waste e.g. counting, unpacking

t_{pick} pick time (time form the picking by hand until to taking in the new cargo)

$$t_{pick} = t_{pick,n} \cdot n_P \qquad \textbf{(6-23)}$$

Where: t_{pick} pick time (time form the picking by hand until to taking in the new cargo)

$$t_{sort} = t_{sort,n} \cdot n_P \qquad \textbf{(6-24)}$$

Where: t_{sort} time for sorting

If:

The picking processes have a different start and end point, Equation (6.24) should be used:

$$n_a = n_p \qquad \textbf{(6-25)}$$

Where: n_p number of positions per order

n_a number of going to starting / ending points

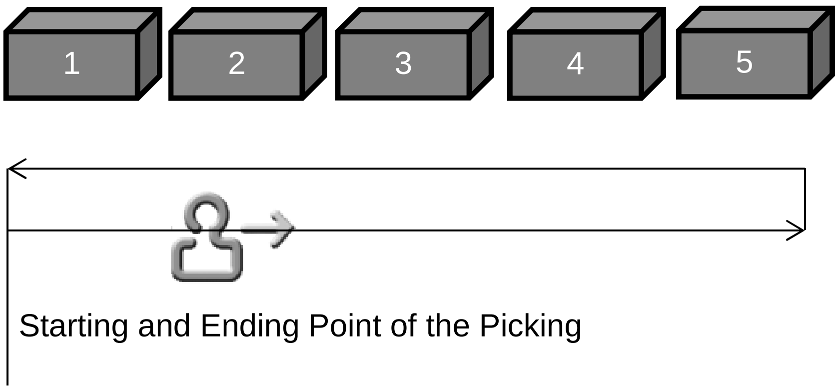
If picking processes with the same start and end point are added to the number of picking positions [n_p] + 1. This is because after the picking of the last position, the employee has to go back to the start point again as shown in Equation (6.25).

$$n_a = n_p + 1 \qquad \textbf{(6-26)}$$

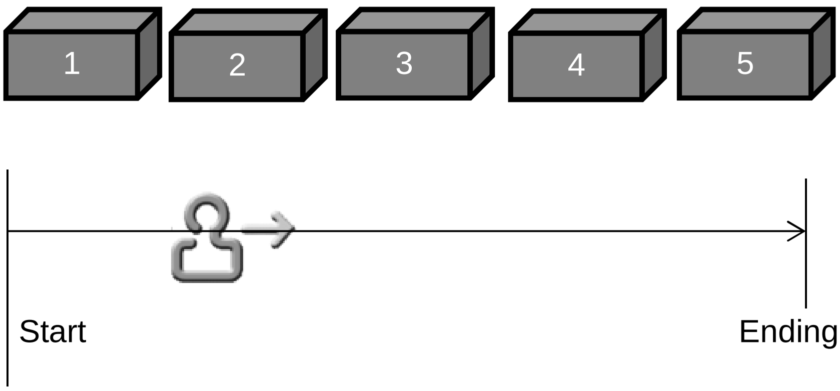
Equations (6.24) and (6.25) can be used to calculate distances and times for picking systems that have the same start and end point, but where the goods are not sorted. This means that the locations of the picking goods are not sequentially ordered to fit the customer demands. In a sequentially-order system, the goods that have the highest demand are placed at the beginning of the rack. Goods that are only needed rarely are located at the end of the rack. Thus, sorting the goods saves time and reduces the distances necessary for picking (ten Hompel, et al., 2011, p. 143):

Case 2: Calculation for One-Dimensional, Aisle-Linked, Sorted Picking Area (ten Hompel, et al., 2011, pp. 140-205)

In Figure 6.35, a sorted picking sequence is shown. In this figure, two different cases are shown. The first one is the case that the start and end point of the picking are not the same. The second one is the case that the start and the end point of the picking process are the same.



(I.) Starting and Ending Points of the Picking Process is the Same



(II.) Starting and Ending Points of the Picking Process is Different

Figure 6.35: Picking Systematic in a One-Dimensional Picking Area, Sorted
Source: Based on (ten Hompel, et al., 2011, p. 144)

Basic calculation of distance [s_n] and time [t_n] can be achieved using Equations (6.26) and (6.27), respectively:

$s_n = L$ **(6-27)**

Where:	s_n	picking distance for one order
	L	sum of length of the locations in one aisle

$$t_n = \frac{L}{v} + (n_P + 1) \cdot \frac{v}{a} \qquad \textbf{(6-28)}$$

Where:	v	speed
	a	acceleration

Results of the Calculation of the Picking Systems

To calculate the different picking systems, three picking orders with different positions are used because of the variable customer demands. One of these is a small order with only two positions. The second one is a medium sized order with four positions. The third one is a large order with eight positions. All orders contain both long items and commercial goods (see Table 6.22).

Table 6.22: Customer Order for Picking

Order-Number	Number of Positions	∑ Number of Pieces [pcs.]	Number of Pieces each Position [pcs.]	Type of the Good	Dimension of the Good (l x w x h) [mm]
1	2	105	70	steel pipe	18 x 18 x 5000
			35	connector	20 x 20 x 60
			10	steel pipe	2000 x 50 x 12
2	5	115	20	plastic pipe	3000 x 100 x 100
			20	steel profile	5000 x 30 x 30
			25	plastic pipe	5000 x 280 x 280
			50	connector	50 x 50 x 50
3	8	316	10	steel pipe	10 x 10 x 5000
			12	steel pipe	24 x 24 x 5000
			8	steel pipe	16 x 16 x 5000
			114	plastic pipe	110 x 110 x 3000
			58	plastic pipe	60 x 60 x 3000
			50	steel profile	50 x 50 x 5000
			14	connector	65 x 65 x 200
			50	connector	110 x 110 x 60

In Figure 6.36, the time for picking only long items is shown. It accentuates the fact that multi order parallel picking is the time-saving picking variant if only long items are picked. So, opening and closing the picking cargo saves more time than employees would need to select and arrange the picked goods according to the customer orders.

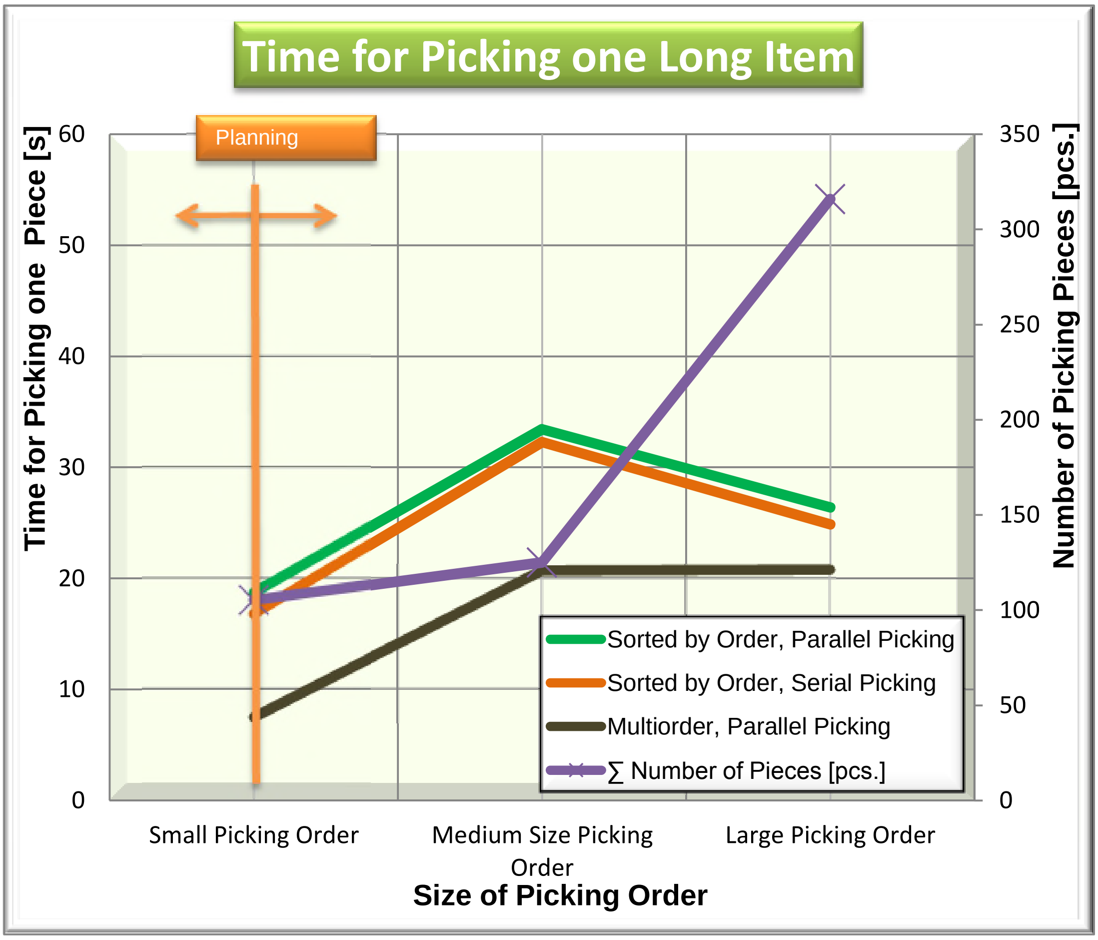


Figure 6.36: Picking Time per Long Item: Comparison of the Different Picking Systems

The little amount of time is necessary for picking the first order because only one long item position has been picked. So, according to the results, the picking systems sorted by order, parallel, and serial picking are close together. This is because the same systematic process is used at the beginning of the picking. Once the picking process starts, a cargo has to be prepared first. In the case of the multi order, parallel picking, there is a standard cargo for picking and collecting the goods. Therefore, a little of time is necessary for preparation. The picking time for the second order is the highest of the three calculations. This is because the second order contains many different positions of long items but only a low number of pieces. In the second picking order, only 75 long items had to be picked (see Table 6.22, sum up all pipes). Therefore, the time effort is the highest one because the number of picked goods is smaller than at the orders 1 and 3. In the third order, 252 long items were picked (see Table 6.22, sum up all pipes). Therefore, the picking time required for each long item sinks.

The third order has the highest number of long items at each picking position. Figure 6.36 shows that not only the number of pieces is important for the picking time but also the number of pieces per position. The number of pieces per position is decisive for the picking time and is directly related to the picking performance. The calculations are tested in a real picking system. Thus, every constellation is tested 10 times to gain significant results. By testing each constellation 10 times, the employees could get used to the process sequence. Thus, the difficulties at executing the process the first time are eliminated. The biggest difference in the testing was 6% discrepancy from the calculations. The orange planning line on Figure 6.36 can be used to make a rough planning for the amount of employees needed. Furthermore, this figure can be used for the shopfloor planning.

Figure 6.37: Picking Time per Piece; Comparison of the Different Picking Systems

Figure 6.37 presents the different picking systems. This figure shows that the traditional picking time increases for a high volume of goods. In the first picking order, all picking times are close together. So, it is difficult to determine which picking system is better suited for small orders. But with the additional number of goods that have to be picked, the picking time increases proportional at approximately 10% to 15% of the second and third picking orders. The performance of the picking system is based on the motivation and the performance of the employee working at these processes. Each of these three picking orders has been repeated 10 times and in the same sequential order. By maintaining the same sequential order, the experience of the employees does not influence the measured time in the test. The differences of about <6% are shown in comparison to the calculation, meaning that all measured times or calculated picking times have a standard deviation of 6%. If this percentage of picking systems is closer or more than 6%, no explicit conclusion can be made as which system has the higher performance. This is demonstrated for the first picking order in Figure 6.37. In this figure, the orange line is the line for planning the picking systems. It can be moved to the left or to the right to plan picking processes in a very simple way. This tool can be used for a rough planning of the picking system and for the planning of the employee demand on the shopfloor (Straub & Manz, 2013, pp. 34 - 36).

The picking system is chosen based on the calculations and Figures created in this thesis. The calculation is most important at planning new logistics systems. Nevertheless, in daily logistics operation, the demand on employees has to be planned again every day based on the customer demands. Therefore, the picking time figures are created and they are simple to use. On the shopfloor, only one graph exists. The figure of the implemented picking system can be used for the shopfloor planning. The size of the picking orders is also divided into three different sections. On the left side, the picking time for one piece is shown. By multiplying the number of goods with the picking time necessary for one piece, the employee demand in the picking area can be calculated.

6.5.7.4 Creation of the Outgoing Goods Area

The outgoing goods area has the task of transporting, loading, labelling, buffering, and packing goods. To fulfil these tasks, some different basic resources such as space and equipment are needed. Equipment like stretchers, forklifts, packaging material, and ramps are particularly important. Furthermore, equipment to store goods is also necessary.

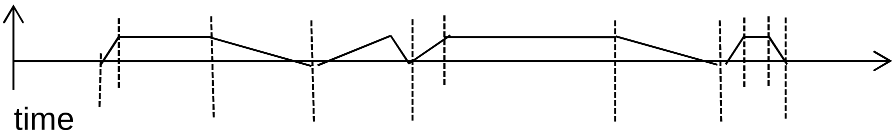
The outgoing goods and the incoming goods processes are processes that require areas within and outside of the building. The areas outside of the building are used for trucks, trains, or other vehicles. The outgoing goods processes have the task of making the cargos compact, which means that cargos have to be combined so that the number of cargos to transport and load is minimised. As a result of this process, the existing transportation capacity can be used more efficiently. The demand of space around the logistics building is very high because of the dimensions of the trucks. The trucks require a rather large turn and curve radius. Furthermore, places for parking the trucks before they can be loaded have to be considered in the planning in case they have to wait. The area outside of the building should be created with a minimum of cross traffic so that the trucks can drive without obstacles. The best way to avoid cross traffic is to let trucks only drive in one direction around the building and exit in a different direction. Furthermore, the number of ramps is an important key characteristic that affects the performance of the outgoing goods area.

Figure 6.38: Sorting of the Outgoing Goods Area
(based on (Martin, 2009))

There are three main possibilities for organising the outgoing goods area, just like for the incoming goods area. The first basic possibility is to have an outgoing goods area for all goods (see Figure 6.38). The second possibility is to have an outgoing goods area sorted by goods, e.g. the products “a” have one outgoing goods area and the products “b” have another outgoing goods area. This design of the outgoing goods area is applicable, for example, if one customer always needs the same goods and no other customer typically needs this product. The third possibility for sorting the outgoing goods area is related to the characteristics of the goods. In this case, for example, long items have their own outgoing goods area.

The calculation of the outgoing goods area is similar to the calculation for the incoming area. Table 6.23 shows the time calculation of the loading process. The driving cycle at the loading starts with driving to the loading station. When forklift arrives at the goods, the speed has to be slowed down. The braking process conduces to load the goods onto the bracket of the forklift in such a manner as to not waste any time. This takes place in the buffer of the outgoing goods area. The next stage is to turn the forklift and to drive to the truck. In front of the truck, the speed has to be reduced again because the cargo has to be placed carefully and precisely in the truck. Then, the forklift is ready to start the new loading cycle.

Table 6.23: Calculation of the Loading Performance

Tasks in the outgoing goods area	Influence factor for the performance	Calculation of the performance
Loading	equipment, employee	 $t_i^{load} = t_{drive\ to}^{load} + t_{loading}^{load} + t_{turn}^{load} + t_{drive\ truck}^{load} + t_{load}^{load} + t_{drive/start}^{load}$ Under consideration of $t_{drive\ to}^{load} = t_{drive\ truck}^{load} = t_{drive\ to\ start}^{load} = t_{\sum accelerating}^{load} + t_{drive}^{unload}$ $t = \sqrt{\frac{2s}{a}}$ $\mu_{load} = \frac{\tau_t}{t_i^{load}}$

The calculations for the outgoing goods area are shown in Table 6.24. For this calculation, the same forklifts are used as for the calculation of the incoming goods area. For this calculation, a distance of 10 metres is taken as an example. Because of the same basic calculation of the time effort of the unloading process at the incoming goods area and of the loading process at the outgoing goods area, the same figures can be used. In particular, this is for the loading time in Figure 6.12 and for the Performance in Figure 6.13.

Table 6.24: Calculation Time for the Outgoing Goods Area

	acceleration time	drive with max speed	acceleration time	acceleration time	acceleration time	acceleration time	drive with max speed	acceleration time	acceleration time	drive with max speed	acceleration time	Σ [s]
	t = √(2s/a) [s]	t = s/v [s]	t = √(2s/a) [s]	t = √(2s/a) [s]	t = √(2s/a) [s]	t = √(2s/a) [s]	t = s/v [s]	t = √(2s/a) [s]	t = √(2s/a) [s]	t = s/v [s]	t = √(2s/a) [s]	
Commercial Forklift, Commercial Cargo	4.1	2.25	8.2	8.20	4.1	4.1	2.25	8.2	4.1	0.45	4.1	**50.05**
Commercial Forklift	4.92	3.2	9.84	9.84	4.92	4.92	2.0	9.8	4.92	0.6	4.92	**60.0**
Four-way forklift	5.5	3.2	11.04	11.04	5.52	5.5	3.2	11.0	5.52	0.6	5.52	**67.8**
										Δt Commercial Forklift/Four-Way Forklift		***7.8***

6.5.8 Structuring of the Logistics Sections

In this section, the processes are structured, which can be done in different ways. One way of structuring is to design the processes by goods. In this case, processes dealing with the same products are placed in the same area. The advantage of this type of structuring is that products are only stored at one place. A further advantage is that the processes can be adapted to the exact requirements of the goods (Martin, 2009). For example, processes for long items need special equipment, which can be concentrated in this area. The disadvantage is that similar processes are often used at different parts of logistics systems. Therefore, a concentration is not always possible.

A further way for structuring processes is to combine similar processes (Martin, 2009). Therefore, every process only occurs one time. All goods are placed in one area and the processes have to be very flexible because they are used for many different products. It is difficult to consider special requirements associated with specific goods. The flexibility of processes competes against the efficiency, and in this structuring, the focus is on the flexibility.

The structuring according to the performance or the number of goods is a structuring in which the main focus is on efficiency (Martin, 2009). Goods with a high demand and similar processes are combined. In this type of structuring, different processes are used for similar goods. An example for improving the performance is to combine goods into one cargo. For instance, if customers always need the same number of products of one good, the appropriate number of these goods are packed in advance. Once the customers' orders come in, one of these pre-packed goods can be used. A further application is that goods that have a high demand are cumulated in a separate picking area. As a result, two picking areas evolve: one for fast-running products and the other for slow-running products. The disadvantage is that products are placed in more than one picking area, which leads to the high stock level.

For the structuring of long item processes, two types are suitable. The first one is to structure by goods. The second one is to structure by performance or number of goods.

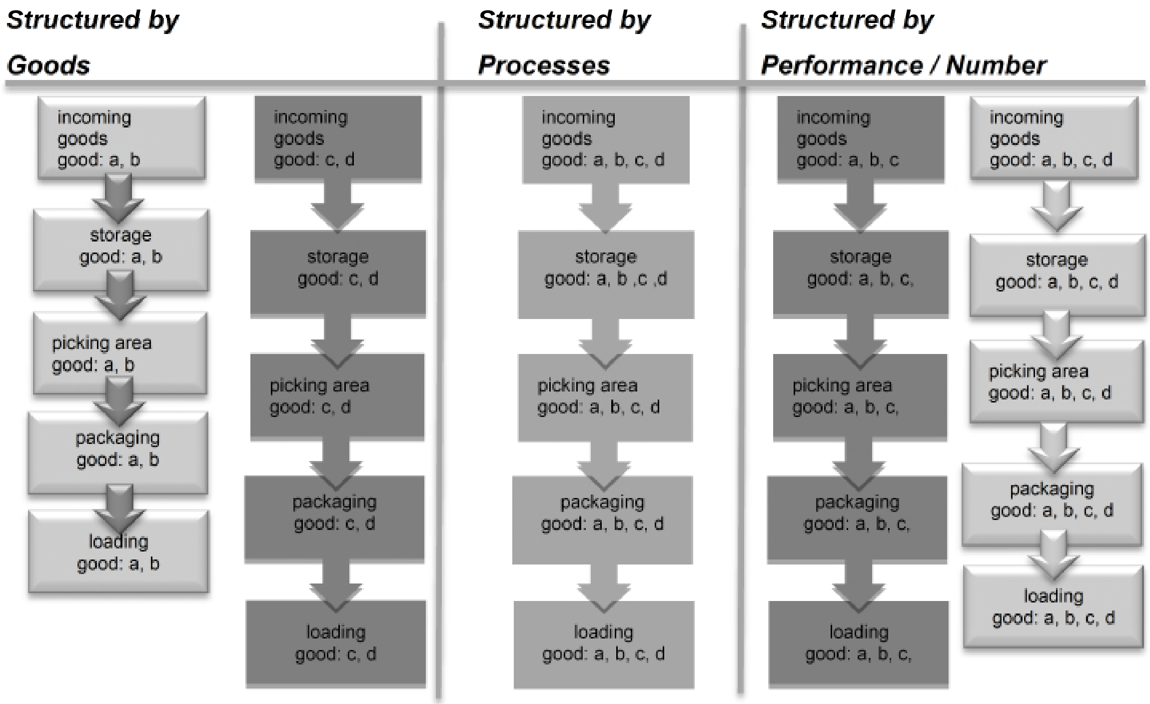


Figure 6.39: Structuring of the Logistics Processes
(based on (Martin, 2009))

6.5.9 The Real Planning

The real planning considers aspects and restrictions that were initially ignored or left unattended at the ideal planning stages. This is important, particularly for current processes in buildings, industrial processes and current country conditions. Moreover, the general visions and strategies of a given company have to be considered. At the ideal planning stage, only one strategy exists because there is only one way to achieve excellent processes . If the real restrictions were considered in the previous planning phases, no ideal processes could be planned and more than one variant would likely exist. However, at this stage, the variants developed in the real planning should be kept as similar as possible to the ideal planning. Thus, problems can occur, that have to be solved at this stage of the planning. For example, the design of the current building might have to be adapted to the requirements of the new logistics system, as far as this is possible. The planner has also to keep the costs in mind. Especially structural alterations can lead to high costs that have not always been considered at the first planning stages. Another problem can occur with currently installed logistics processes. These have to be adapted, too. But of course the planning at this stage has to consider, that the adaption has to be done while the currently installed processes move on. Otherwise, a high loss in profit can be the consequence.

6.5.10 The Comparative Cost Method

The comparative cost method is used to make a decision of which variant is the favourite or best-suited. This method is important for deciding which variant should be planned in detail. The purpose of this method is to choose only one variant. The detailed planning is complex and time intensive. Because of this, the previous planning phases (preliminary planning and structure planning) have to be efficient enough to create a decision model. The comparative cost analysis method contains three basic parts: the investment, costs, and capital analysis. These three parts are the capital disbursements, which stand in opposition to the earnings.

The analysis of the investment includes the capital investments for the property, building, infrastructure like the building site preparation, the fees for architects, and public authority fees (Warnecke, et al., 1996, pp. 14 - 19). The second part of the sensitivity analysis centres on the costs. The costs consider the costs associated with the processes, personal costs, machine costs (including the equipment costs), and energy costs like water, waste water, gas, petrol, and electricity (Warnecke, et al., 2003, pp. 32 - 40).

At the third point in the analysis, the capital costs are considered. In detail, these include the rate of return and the allowance of depreciation.

These costs and investments must be collected for every variant (see Table 6.25). By comparing the earnings, the decision can be made which type of variant is the most economic variant. The return on invest can also be calculated.

Table 6.25: Comparative Cost Method

(based on (Warnecke, et al., 2003))

			Variant I	Variant II
Service Life	- Service Life			
	- Operating hours			
Investment	- Property			
	- Building			
	- Infrastructure			
	- Equipment			
	- Architects and public authority fees			
Fixed Costs	- Allowance for depreciation			
	- Imputed interest			
Variable Costs	- Employee			
	- Machine			
	- Energy	> Water		
		> Waste Water		
		> Gas		
		> Petrol		
		> Electricity		
	- operating supply item			
Capital	Rate of return			

6.5.11 Evaluation of the Variants

The different variants that are considered in the real planning are compared in this evaluation using the specific criteria listed in Table 6.26. The red and the green criteria are the results from the expert interviews. These are important criteria for customers handling long items. The blue criteria are the internal criteria such as the handling of goods, door-to-door time and the investment etc. These criteria can vary from project to project. Moreover, soft facts like the ergonomics of systems should be considered. To get a quantifier, the criteria have to be weighed to analyse a priority setting. So, every criterion is compared individually with all other criteria. For example, the criterion “information delivery date” is compared with the criterion “information in the case of amendment or adjustment of the delivery date.” To achieve comparability, the criteria are rated. In this comparison, the criterion “information in the case of amendment or adjustment of the delivery date” is more important than for example the criterion “flexible expandable” and therefore this criterion is rated with the number “one” (see Table 6.26). If this system is adapted consequently at the end, a clear priority of criteria exists because a strict decision has to be made which criterion is more important at each comparison.

At the right side of Table 6.26, the summations of the weighting are listed. In proportion to the other criteria, the weighting in per cent is calculated. The result of the per cent summation of all criteria should be equal to 100%.

In the next stage, the planned variants are evaluated. Thus, every variant is evaluated by the same criteria. The scale of evaluation starts at one and ends at 100. If a variant fulfils a criterion to 100 per cent, this criterion is rated with 100. If the variant fulfils a criterion to 50 per cent, the variant is rated with 50. By doing this, every criterion can be evaluated accurately. In the further stage, the results of the weighting (from Table 6.26) are transmitted to Table 6.27. The weighting of the criteria is multiplied with the variant fulfilment. The results of these are shown at the right side of Table 6.27. The sum of the weighting of the variants shows the priority of the variants. In this case, the “Variant 1” has the highest priority. That means “Variant 1” best fulfils the criteria. Thus, “Variant 1” is the variant that should be realised. This method can be used to evaluate variants and to make a decision.

Table 6.26 Weighting of Criteria

	Information Delivery Date	Information in Case of Change in Delivery Date	Requirements on the Package	Product Quality	Delivery Time	Which Package Material is Preferred	Way to Order	Different Types of Material	Door-To-Door Time	Ergonomic Handling	Well-Known System	Low Incorporation and Job	Investment	Cost	Fit for Future	Variable Expandable	Absolut Summation of the Weighting	Relative Weighting Order
Information Delivery Date	X	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	11.03%
Information in Case of Change in Delivery Date	1	X	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16	11.76%
Requirements on the Package	0	0	X	1	1	1	1	1	1	1	1	1	1	1	1	1	14	10.29%
Product Quality	0	0	0	X	1	1	1	1	1	1	1	1	1	1	1	1	13	9.56%
Delivery Time	0	0	0	0	X	1	1	1	1	1	1	1	1	1	1	1	12	8.82%
Which Package Material is Preferred	0	0	0	0	0	X	1	1	1	1	1	1	1	1	1	1	11	8.09%
Way to Order	0	0	0	0	0	0	X	1	1	1	1	1	1	1	1	1	10	7.35%
Different Types of Material	0	0	0	0	0	0	0	X	1	1	1	1	1	1	1	1	9	6.62%
Door-to-Door Time	0	0	0	0	0	0	0	0	X	1	1	1	1	1	1	1	8	5.88%
Ergonomic Handling	0	0	0	0	0	0	0	0	0	X	1	1	1	1	1	1	7	5.15%
Well-Known System	0	0	0	0	0	0	0	0	0	0	X	1	1	1	1	1	6	4.41%
Low Incorporation and Job Training Time	0	0	0	0	0	0	0	0	0	0	0	X	1	1	1	1	5	3.68%
Investment	0	0	0	0	0	0	0	0	0	0	0	0	X	1	1	0	3	2.21%
Cost	0	0	0	0	0	0	0	0	0	0	0	0	0	X	1	1	3	2.21%
Fit for Future	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	0	1	0.74%
Variable Expandable	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	X	3	2.21%

1 more important

0 less important

Table 6.27: Evaluation of Variants

	Variant 1	Variant 2	Variant 3	Weighting Order	Weighted Results Variant 1	Weighted Results Variant 2	Weighted Results Variant 3
Information Delivery Date	80	70	50	11.03%	8.8	7.7	5.5
Information in Case of Change in Delivery Date	80	70	50	11.76%	9.4	8.2	5.9
Requirements on the Package	80	70	50	10.29%	8.2	7.2	5.1
Product Quality	80	70	50	9.56%	7.6	6.7	4.8
Delivery Time	80	70	50	8.82%	7.1	6.2	4.4
Which Package Material is Preferred	80	70	50	8.09%	6.5	5.7	4.0
Way to Order	80	70	50	7.35%	5.9	5.1	3.7
Different Types of Material	80	70	50	6.62%	5.3	4.6	3.3
Door-To-Door Time	80	70	50	5.88%	4.7	4.1	2.9
Ergonomic Handling	80	70	50	5.15%	4.1	3.6	2.6
Well-Known System	80	70	50	4.41%	3.5	3.1	2.2
Low Incorporation and Job Training Time	80	70	50	3.68%	2.9	2.6	1.8
Investment	80	70	50	2.21%	1.8	1.5	1.1
Cost	80	70	50	2.21%	1.8	1.5	1.1
Fit for Future	80	70	50	0.74%	0.6	0.5	0.4
Variable Expandable	80	70	50	2.21%	1.8	1.5	1.1
				Summation	**80.0**	**70.0**	**50.0**
				Priority	**1**	**2**	**3**

6.6 Detail Planning

In the detail planning stage, only one variant exists that has to be worked out in detail. Because of the sustainable planning done within the framework of the structure planning stage, the detail planning only has to focus on planning specific process parameters. The traditional parameters that have to be planned in detail include calculating the following (Schenk & Wirth, 2004, pp. 115 - 118):

1. Material flow
2. Describing the detailed value stream
3. Process duration
4. Employee demand
5. Number of locations
6. Performance
7. Costs
8. Equipment
9. Return on invest
10. Capital costs

Moreover, within the detailed calculation of the traditional process parameters, parameters that are identified to be important specifically for the long item process but that are planned inadequately by the traditional planning process methods have to be specified. The first parameter that is researched is the transfer of the information flow. The application of ERP-systems were started in many large enterprises in the 1990s and has been risen significantly since then. By installing an ERP-system, every logistics and production process can be made transparent and traceable. A trend is to create lean processes that are as simple and effective as possible for applications. Moreover, lean processes are claimed to be as transparent as possible. Therefore, it is necessary to research different information transportation systems that can be used for connecting processes.

A further task at the detail planning stage is to create a detailed block layout. Various software programs can be used for this task. One choice is the freeware OpenFactory3D, for example, which was developed by RWTH Aachen

(RWTH Aachen, 2014). Using this software, you can make precise block layouts. The dimensions of the building, equipment, etc. can automatically be transmitted into EXCEL and used for other stages in the planning process, such as in the architectural planning. Furthermore, the dimensions can be recorded in an EXCEL table and then exported back into the given software program for further applications.

There are other software that can be used to evaluate the static calculation of the material flow. for example, Materialfluss 2.0 is a freeware for this purpose (Magnin Simulation, 2014). This software can be used to evaluate the static planned material flow and the value stream. Material flow software is not specific for logistics of long items, but using such software in the long item planning is important because there are quite different materials that could use the same processes. Therefore, effects from the material flow have to be tested by a software program.

6.6.1 Transportation of the Material

In this section, non-commercial ways of transportation are researched. The Toyota production system considers a lean method for providing materials. This is called “Minomi.” As far as the author is aware, little literature exists about the Minomi method. This method can be used to provide materials in a simple way. The target of Minomi is to transport goods with a minimum effort and with a minimum of waste. For Toyota, the material provision is considered as waste. This waste is necessary because goods have to flow from one process to the next. But to create effective and efficient processes, it is important and necessary to minimise the waste caused by the transportation of the goods. This can be achieved by structuring the material provision without using boxes. An advantage of this is that there are no empty boxes that have to be handled, which thereby reduces the waste. Minomi is not a solid concept. It is philosophy for picking up, transporting, and unloading goods. The aim of this research is to identify which effects can be achieved by using Minomi in the plant area for the provision of long items. The focus will be on whether the Minomi method can be used for material provision of long items. Furthermore, this thesis researches which improvements can be achieved by using Minomi. For this research, different types of Minomi are compared to conventional methods of providing materials. Thus, the purpose of this study is to identify the effects of using different types of Minomi on the long item logistics system. Moreover, I evaluate for which types of long items the transportation using the Minomi method is possible and how these findings can be applied to other types of materials.

The transportation and the handling of long items is a challenge because of their dimensions. The dimensions are the reason why only a few possibilities are available for transporting the goods. Traditional equipment like cranes and forklifts are used for transport. Toyota’s idea was to reduce the use of this kind of equipment because they are bulky and expensive. Furthermore, many accidents occur by using this equipment and forklifts and cranes generally have high maintenance and repair costs.

Objectives

The first objective is to answer the question of whether Minomi can be applied to the transportation of commercial goods and long items. The second objective is to find out which requirements have to be fulfilled if Minomi is used for the provision of long items. The third objective is to identify the advantages of using Minomi for transportation.

6.6.1.1 Methodology of the Minomi Research

The first stage towards reaching the research objectives is to conduct a literature review. The aim of this is to learn about the industry’s best practices. Furthermore, it allows a comparative analysis and evaluation of my own research findings. The second stage is to identify and analyse the parameters of the case study. The “basic” material provision must be defined before different Minomi methods are tested. The “basic” material provision refers to the current material provision of long items. In addition, the execution of the case study is discussed and the required equipment is identified and defined. In the third stage, the research findings are compared with the “basic” material provision. Furthermore, they are compared with the other people's research results (Straub, et al., 2014, p. 257).

Execution of the Case Study

In each case study, two Minomi racks are used. One of these Minomi racks is mobile; the other rack is fixed in the manufacturing area. In this study, 30 pipes of the length of 2.5 metres are used. If boxes are used to move the pipes, 10 pipes are stored in each box. If no boxes are used, the pipes are stored unfixed. To obtain the reliable results, each case is repeated 10 times in order to achieve a sustainable evaluation (Straub, et al., 2014, p. 258).

Definition of the Basic Material Provision of Long Items

Two different basic material provisions of long items exist when it comes to long item pipes. The first way to provide the materials is to use a crane. This type of material provision is necessary in case the passage ways to the manufacturing area cannot be used for long item handling because they are too narrow. The second basic way to provide materials is by using a four-way forklift.

In this section, three case studies are discussed. In Table 6.28 and Table 6.29, the features of the two basic methods and of the three case studies have been listed.

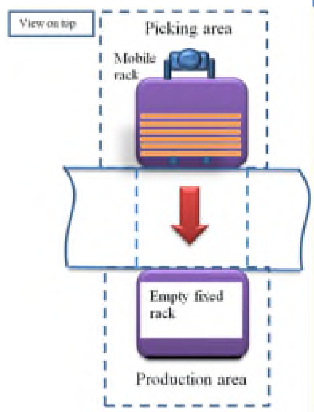
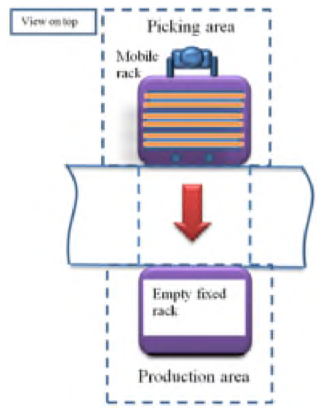
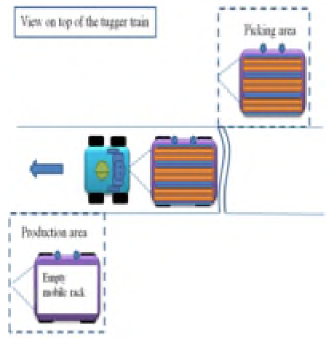
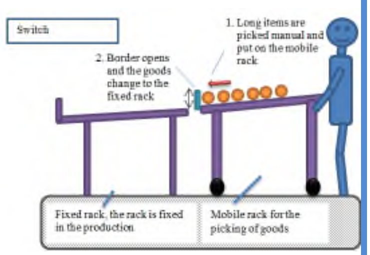
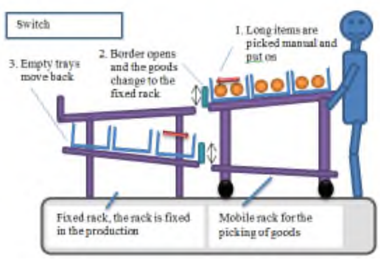
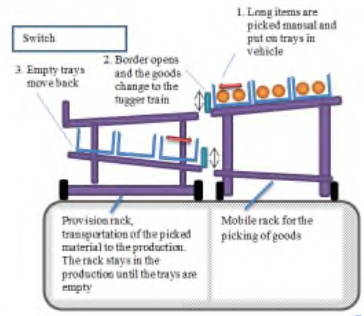
Table 6.28: Overview of the Minomi Cases

Source: (Straub, et al., 2014, p. 259)

	Basic Case I - Crane	Basic Case II - Forklift	Case I	Case II	Case III
Equipment	-one in-house crane, -long items are provided without boxes	-forklift, -long items are provided in boxes	-one mobile rack, -one fixed rack, -long items are provided without boxes	-one mobile rack, -one fixed rack, -long items are provided in boxes	-tugger train, -one trailer, -one fixed rack, -long items are provided in boxes
process steps	1. long items are fixed on the crane, 2. transfer to the provision area, 3. release of long items from the crane, 4. using long items	1. loading of the boxes, 2. transfer the boxes by forklift to the provision area, 4. placement of the box in the provision area, 5. grabbing the empty boxes, 6. unloading the boxes	1. loading of the mobile rack, 2. transfer the mobile rack to the fixed rack, 3. docking the racks, 4. change goods, 5. unloading fixed rack	1. loading boxes on the mobile rack, 2. transfer the mobile rack to the fixed rack, 3. docking racks, 4. change goods, 5. unloading boxes of the fixed rack	1. loading boxes on the trailer, 2. transfer the trailer to the fixed rack, 3. docking racks, 4. change goods, 5. unloading boxes of the fixed rack
number of repetitions	10	10	10	10	10

Table 6.29: Schematic Overview of the Minomi Cases

Source: (Straub, et al., 2014, p. 259)

Case I	Case II	Case III
		
		

Case I – Manual Minomi Rack, Goods are Transported without Boxes

The first type of Minomi considers the basic idea of Minomi, which is to use no boxes. One rack (the picking rack) is mobile. The other rack is fixed in the manufacturing area. The goods are reloaded from the mobile to the fixed rack at the docking of the racks. The goods (pipes) are placed beside each other on the Minomi rack. The surfaces of the pipes are directly in contact to each other (Straub, et al., 2014, p. 258).

Case II – Manual Minomi Rack, Goods are Transported in Boxes

In the second case study, the long items are stored in boxes. In this case study as well as in the first case study, two racks are needed. One fixed rack and one mobile rack are used. The mobile rack can be moved manually (see Figure

6.40, Figure 6.41, and Figure 6.42). The fixed rack is placed, for example, in the manufacturing area. So, if the mobile rack docks at the fixed rack, a shooting mechanism begins. The boxes containing the long items move from the mobile rack to the fixed rack. Each of the racks has two levels of roll conveyors. The upper roll conveyor transports the full boxes and the lower roll conveyor transports the empty boxes. Because of the different conveyor levels, the movement of the boxes are synchronic. The mechanism begins to function immediately once the racks are docked (Straub, et al., 2014, p. 258).

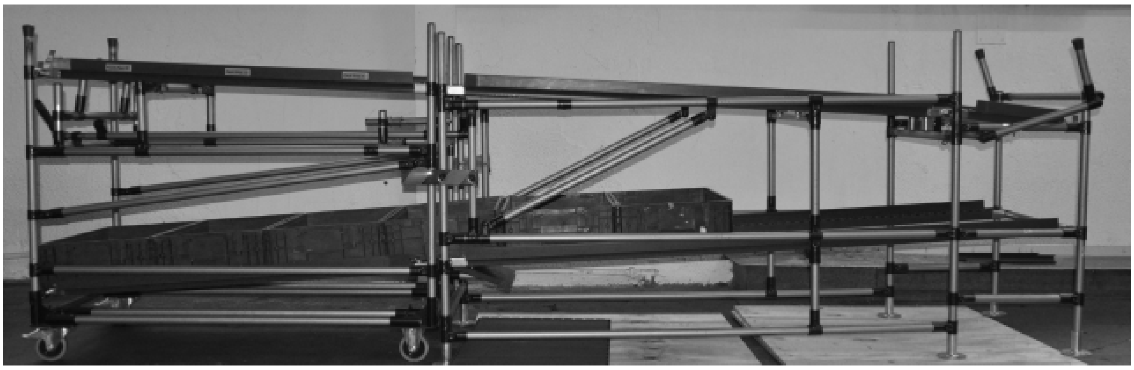


Figure 6.40: Case II of the Minomi Research

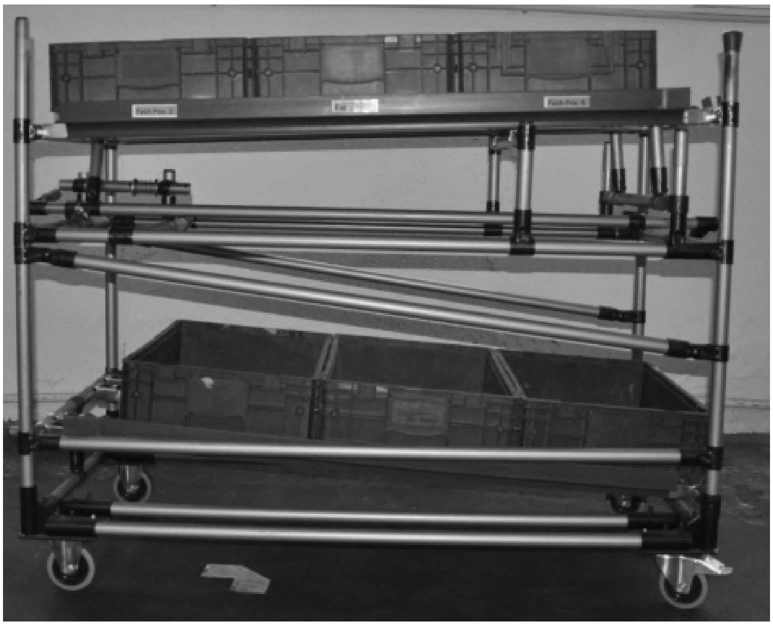


Figure 6.41: Mobile Rack (Picking Area)

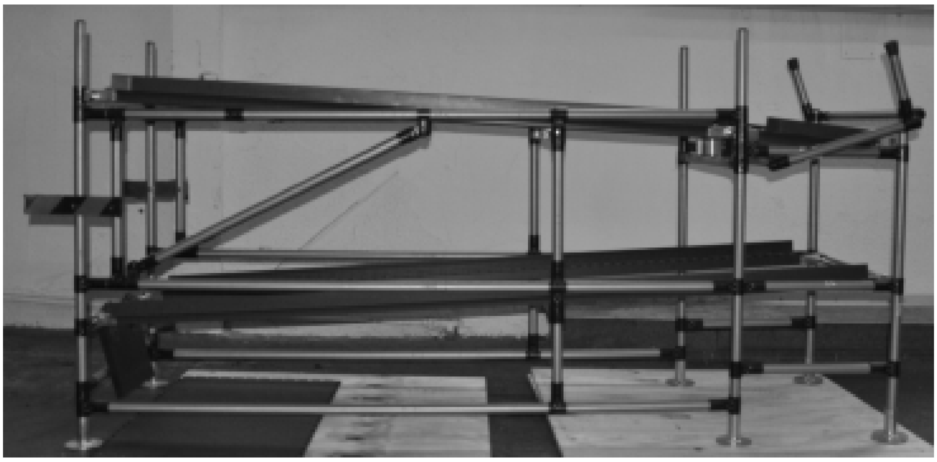


Figure 6.42: Fixed Rack (Production Area)

Case III – Manual Minomi, Goods are Transported by Tugger Train

The third case study requires complex equipment. On the manual mobile rack, the goods are picked in the boxes (see Figure 6.45). The transfer station (see Figure 6.44) is needed to transfer the goods from the manual mobile rack to the tugger train. This is necessary because moving the boxes directly from the manual mobile rack to the tugger train is not possible. The reason for this is that the forces that are necessary to start the moving mechanism on the cam track are so high that the mobile rack loses its position. Thus, the tugger train (see Figure 6.46). docks at the fixed transfer station. Here, all racks contain two levels (see Case II). The second mobile rack is transported by tugger trains, as the mobile rack is attached to the vehicle. The tugger train is needed to transport goods long distances. In front of the transfer station, a guide rail is installed to guarantee that the train and rack stop the right distance to start the mechanism. To do so, the tugger train must stand still. It has to wait until the changing process is finished. The changing mechanism is done completely by the forces of gravity; thus, no sensors, engines, or other electronic parts are installed (Straub, et al., 2014, p. 259).

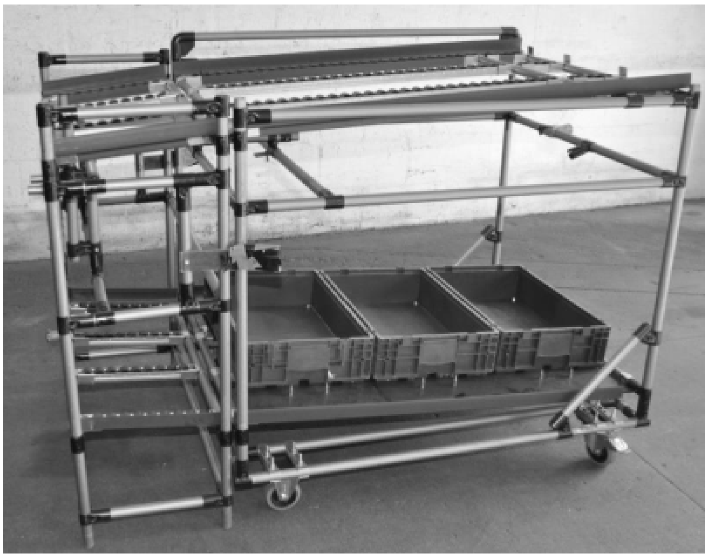


Figure 6.43: Minomi Case III, Picking Equipment

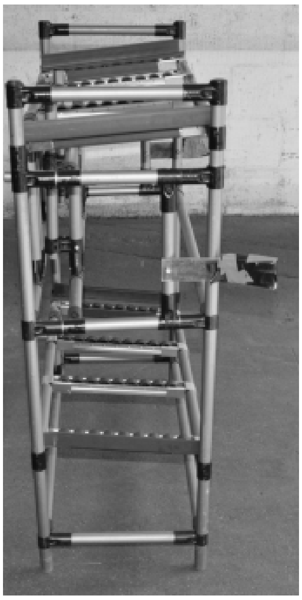


Figure 6.44: Transfer Station (Picking Area)

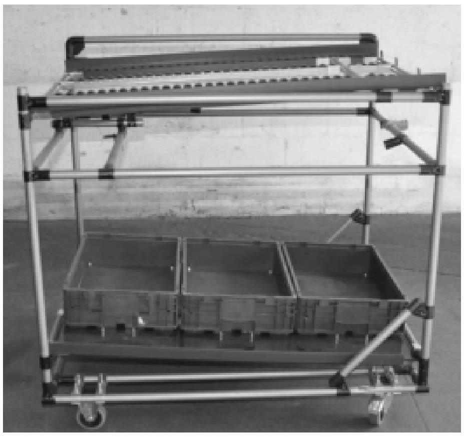


Figure 6.45: Picking Rack (picking area)

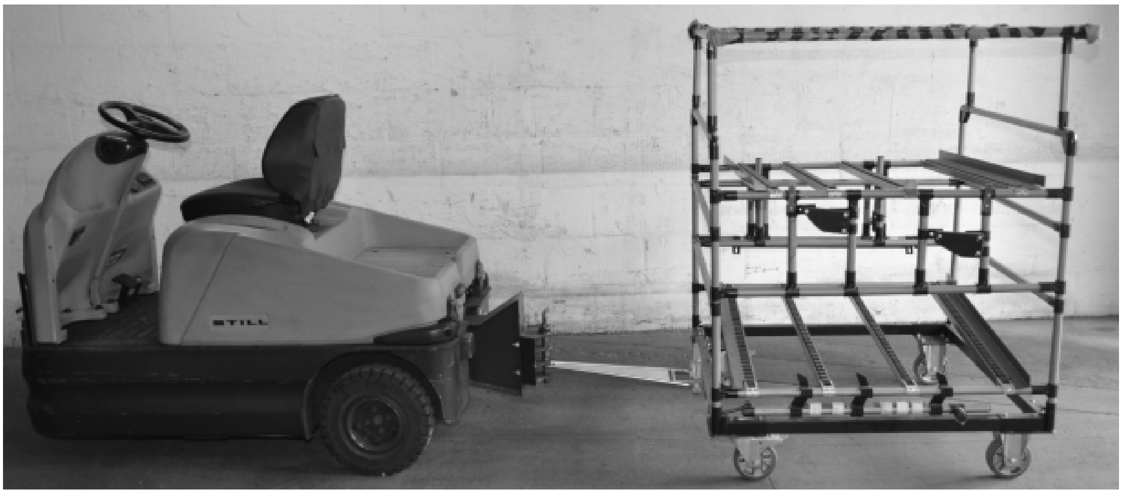


Figure 6.46: Tugger Train with the Second Mobile Rack

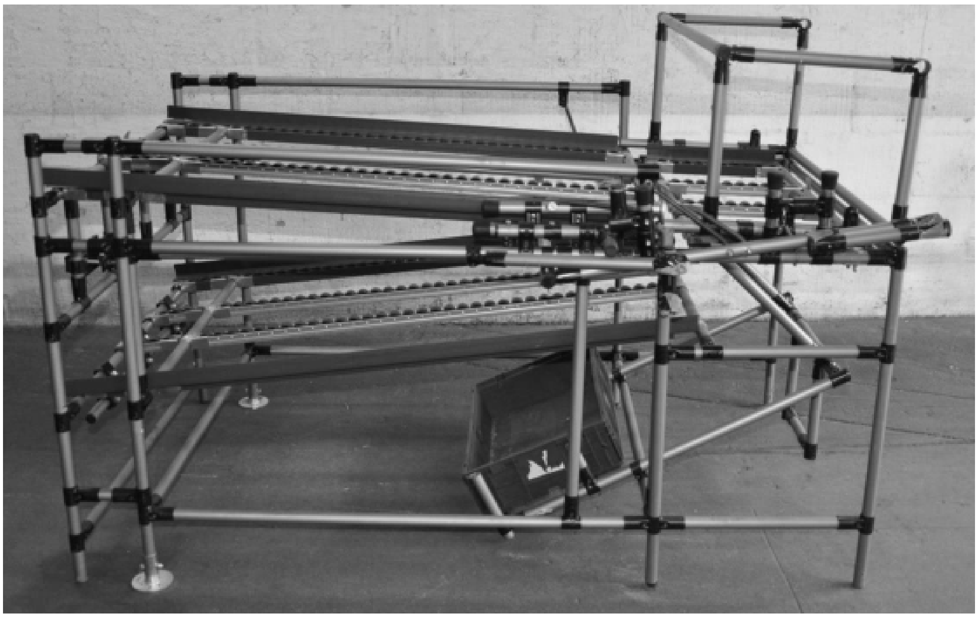


Figure 6.47: Fixed Rack in the Production Area

6.6.1.2 Findings

The amount of motion waste is one result of this case study. This study researched the wasted motion in relation to the changing of cargos. Material provision is a standard process in the logistics. The material provision describes the process of changing and moving goods. An empty cargo has to be exchanged with a full cargo in the production area or in the picking area. The standard commercial changing process considers picking up the empty cargo and unloading the full cargo. The time that is needed for changing one cargo is presented in Figure 6.48. In this chart, the different cases are shown in relation to the number of repetitions. Every case was repeated ten times. This figure shows that the time effort for each case is stable. The differences between each case are smaller than 10%. Because the time needed was fairly standard, the arithmetic average of each case can be calculated (Straub, et al., 2014, p. 260).

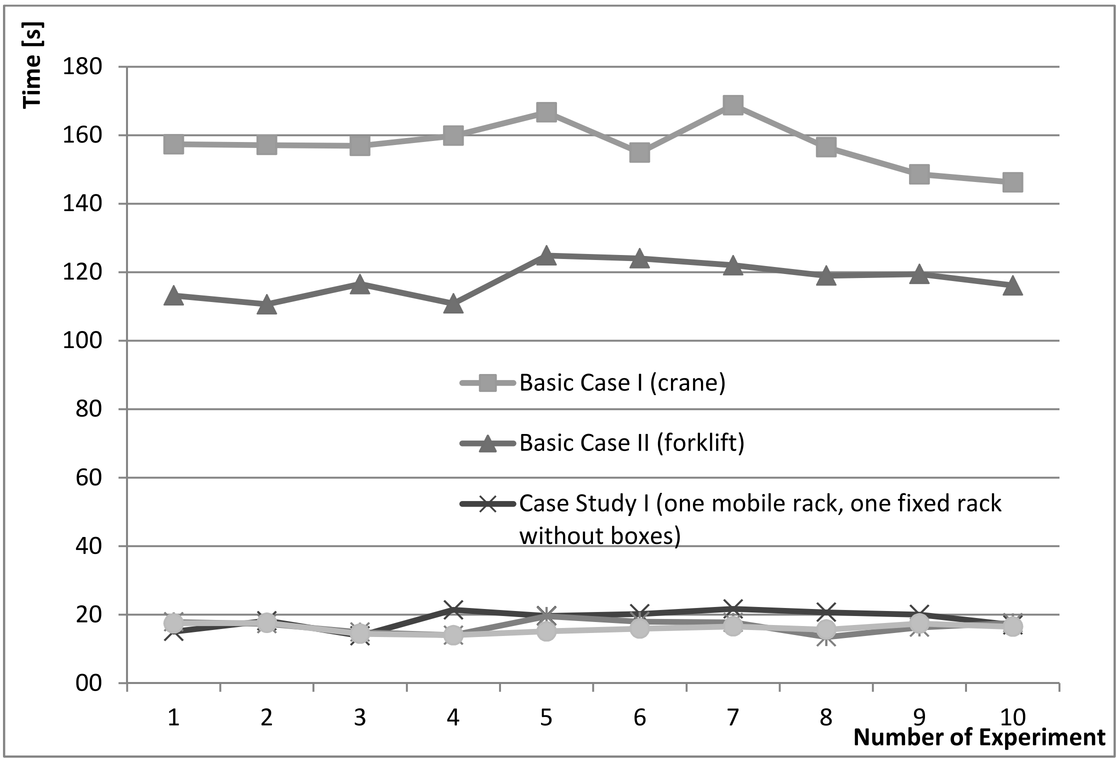


Figure 6.48: Motion Waste at the Changing of Cargos

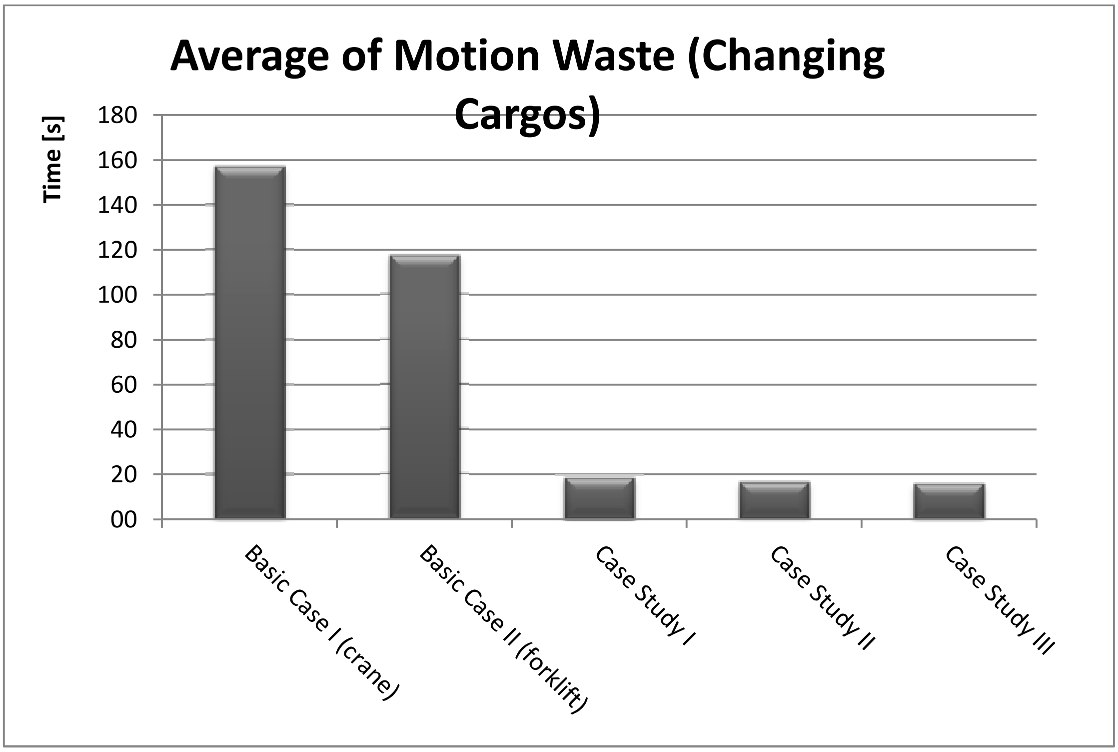


Figure 6.49: Comparison of the Average Motion Waste Resulting from Changing Goods

It has been found that the motion waste is significantly smaller when using Minomi than when using commercial methods of material provision (see Figure 6.49), which can be identified by analysing the time effort. The time effort in the case studies is smaller than at the first two basic cases. The most effective type of Minomi is the Minomi by tugger train. To provide one material, it needed round about 16 seconds. The other types of Minomi are not as effective as the Minomi by tugger train, but the differences in the time effort between the different types of Minomi are rather small. All types of Minomi save a large amount of time in comparison to the commercial types of material provision (i.e., by crane or by forklift).

The further findings are presented in Table 6.30. Some of the findings listed are qualitative ones. These findings indicate that a better ergonomic rack can be arranged and that the combination with other types of provisions is possible. Quantitative findings are findings that are measurable, such as the motion waste in time, the reduced circulation stock, or the number of transports (see Figure 6.50). This table shows the transported stock in comparison to the number of transportations. To transport one piece per cargo, it needs 270 seconds, which represents the basic time. The other curves are calculated in derivation to this basic time.

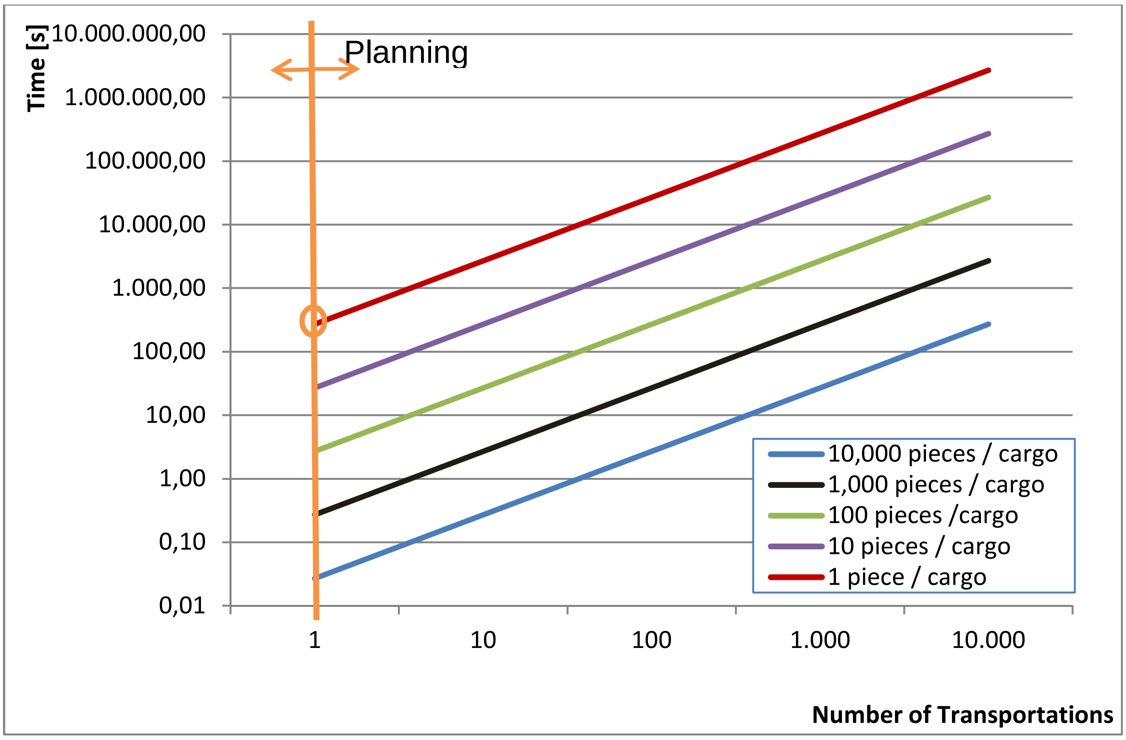


Figure 6.50: Transportation Time of Different Numbers of Pieces per Cargo and Different Numbers of Transports by a Basic Transport Time of 270s

An advantage of Minomi is that the goods are tangible in an ergonomic position because of the height of the racks, which reduces the ergonomic problems. A disadvantage of using Minomi can be identified in the first case. In this case, it can be identified that many products are damaged. The reason for this is that the goods are not placed in boxes, so the surface can be damaged due to the contact with other goods. Table 6.30 shows further interesting results.

In Case Study II and Case Study III, damages are prevented because the products are sorted in a tray. An important advantage of using boxes is that different types of long items can be placed in one box. A further advantage of boxes is that the sliding characteristic of the good is not influenced by the dimension of the good. Therefore, the box is necessary in the case of goods that do not slide and have to be transported by Minomi. The circulation stock can be significantly reduced. Because only the goods in the boxes are the circulation stock, no further inventory on pallets is needed. However, because of the small circulation stock, many additional transports have to be made. An additional disadvantage is that the goods have to be picked to the mobile rack if the production of the goods is not synchronic (Straub, et al., 2014, pp. 257 - 260).

The overall result is that Minomi supports the one-piece-flow. It is also applicable for long items up to a length of 4 metres. Because wide roads are needed, Minomi is not recommendable for goods with a length of more than 4 metres.

Table 6.30: Findings of the Case Studies

Source: (Straub, et al., 2014, p. 260)

	Reviewed Effects by Using Minomi	Case Study I		Case Study II		Case Study III	
		in comparison to basic case I	in comparison to basic case II	in comparison to basic case I	in comparison to basic case II	in comparison to basic case I	in comparison to basic case II
1	Reduction of Motion Waste	+++	++	++	++	++	++
2	Reduction of Damages to Parts	+	+	+++	+++	+++	+++
3	Reduction of Ergonomic Problems	-	+	+	+	++	++
4	Reduction of the Number of Process Steps for Material Handling	+++	+++	++	++	+++	+++
5	Reduction of the Circulation Stock	+++	+++	+++	+++	+++	+++
6	Reduction of the Number of Transports	-	-	-	-	-	-
7	Saved Time	+	+	+	+	++	++
8	Combinability with Other Types of Provisions	+	+	+	+	++	++

6.6.2 The Research of Different Information Flows Using the Kanban Method

In this section, the effects of using different types of Kanban in comparison to the conventional "Kanban cards" are presented. The research focus is on testing traditional, new, and simple ways of transporting information with the Kanban method. Thus, with this study, the effects of using different Kanban signals are identified and a guideline is created for the choice of the Kanban signal. Furthermore, the research identifies the characteristics that are important for choosing the Kanban signal depending on the application and the good characteristics. Six different types of Kanban signals are researched. Moreover, the focus will be on the question of whether the choice of the Kanban signal is significantly influenced by the geometrical shape of the goods.

The Kanban method was created by Taiichi Ohno. He was a leading production engineer and developer of the Toyota Production System (TPS). The Kanban method is one part of the TPS. The replenishment of the goods is traditionally derived from the sales plan. If the customer demand is stable, the goods are needed in the amount as they are replenished. But if the customer demand changes, the produced goods are not ordered anymore. In this case, a lot of effort is necessary to transport, store, and check the goods. Ohno had the idea to create a method that produces goods driven by demands. The material replenishment was coupled with the customer demands. Only goods should be produced that are ordered by customers. Furthermore, the amount of the material is fixed in every process stage because only the goods that are ordered are in the processes. By paying attention to this golden rule, the Kanban cycle is constituted (Ohno, 2009, pp. 59 - 71).

Objective

The research aims to compare different Kanban signals and evaluate their advantages and disadvantages. Furthermore, the application is categorised. The categorisation helps to choose the right Kanban signal considering the given key characteristics of the application of the Kanban method. However, the research must consider in advance, by which key parameters the definition of the Kanban signal is determined. The main research objective is to find out if the dimensions of the goods have an influence on the choice of the Kanban signal (Straub & Manz, 2014, p. 30).

Methodology

The research compares six different types of Kanban signals under consideration of the same criteria. To achieve a direct comparison of the Kanban methods, all of these systems are installed simultaneously. The different Kanban signals are researched at the replenishment of the picking area. The picking area is an area in which many different goods with different dimensions are handled. In the research, each Kanban signal is tested using long items and using small goods. In summary, twelve different Kanban cycles are researched (six different types of signals with long items and six different signal types with small goods). The frequency of replenishment is 3 hours. Every 3 hours, a Kanban signal has to start the Kanban cycle. The research cases are tested over a period of two weeks (every week contains 35 working hours) (Straub & Manz, 2014, p. 30).

Case Study

In the case study, the effects on different information flows are tested using different Kanbans (Kanbans with bins and Kanbans with cards). The Kanban with bins have all necessary information directly connected to the bin Figure 6.51. The Kanban by cards have all of the needed information on the cards. The Kanban card is not affixed permanently to the box. If the box is empty, the card can be sent to the filling process and connected to a filled box. If a box is not empty, the Kanban card cannot be changed because the information on the card is used to identify the goods in the box (Straub & Manz, 2014, p. 30).

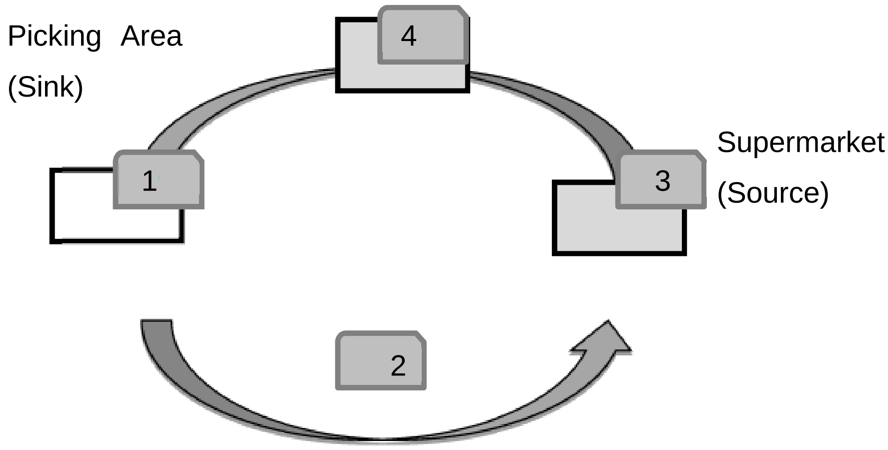


Figure 6.51: Principle of Kanban

Figure 6.52 shows the basic Kanban method with cards. There are two boxes at the picking area. Goods are only picked from one box. The second box is only used in case the first box is empty (Straub & Manz, 2014, pp. 28 - 30).

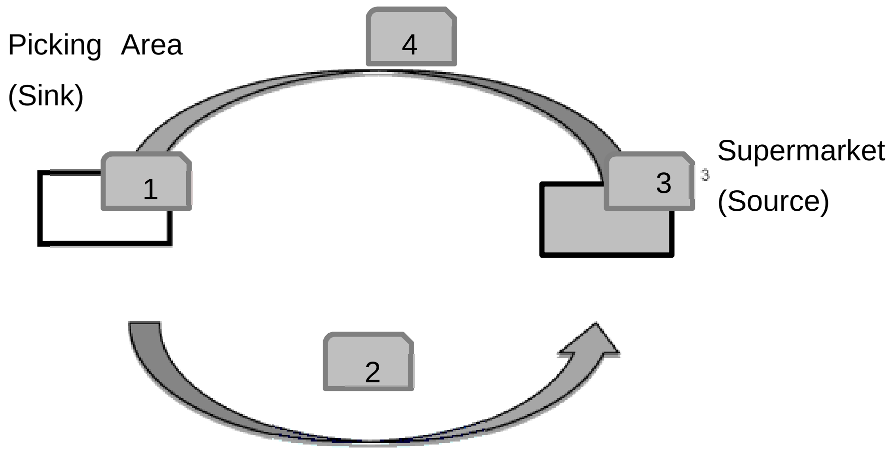


Figure 6.52: Principle of Kanban with Cards

When the box is empty, the card is separated from the box (1). Standardised boxes are used to carry the goods. These boxes can be used for many different goods. Furthermore, the empty boxes can be refilled with the same goods or other goods that fit in this box, which makes it easy to handle empty boxes. When the boxes are filled, a new Kanban card simply has to be affixed on the box. The tugger train brings new boxes filled with goods to the picking area and takes the empty boxes to the filling process. When the Kanban is separated from the box, it has to be handled carefully because it is the signal to pull goods from the previous process stage to the following process stage (2). Thus, when the Kanban signal is given, material is taken out of a machine or out of a rack. If products are purchased, they have to be stored in the supermarket. From there, the good or box that is needed at this moment is delivered: The Kanban can be affixed either on the good itself or on the box (3) and is transported to the picking area (4). The Kanban cards are handled with the help of a board, the Kanban board. At this board, the cards are collected before the card is affixed onto the next good or box. This is necessary because the Kanban card returns to the previous stage in the process. The Kanban card has to be handled with care because the Kanban card must not be lost (Straub & Manz, 2014, pp. 28 - 30).

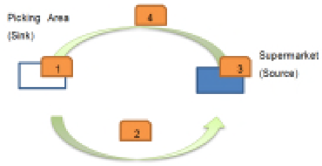
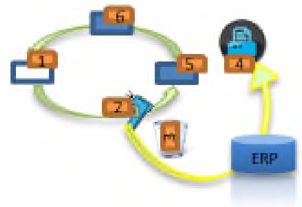
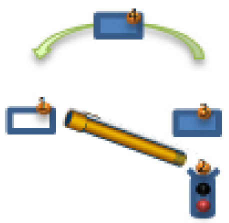
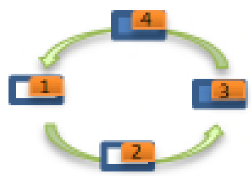
In addition to Kanban cards, other possibilities of submitting information exist. In many companies, ERP-systems are applied, which support the use of an electronic Kanban card. Furthermore, the ERP-system supports the monitoring and documenting of the Kanban process. When using an ERP-system, Kanban cards can often be used for one Kanban cycle. This is because on the Kanban card is a code that contains one certain product mix. Thus, if the card would be used another time, the included information would no longer be correct. The ERP-system counts only the cards. If one box is empty, a new card has to be printed for the ERP-system to start the next Kanban cycle. Thus, in this case, the Kanbans are recycled and reprinted for each material provision. Another alternative to using Kanban cards are balls. Golf or tennis balls are suitable because of their small size and because they can easily roll on pipes. However, when using Kanban balls, the information that can be submitted is limited. This is because the information can only be transmitted by the colour of the balls. But of course, using balls has advantages as well. For example, the Kanban balls can roll in a pipe to the picking area without the assistance of an employee. In the picking area, the employee then has to fetch the goods that are marked with the colour of the Kanban ball. Thus, this system only works when every box in the supermarket is marked with the appropriate colour. The advantage of using Kanban balls is that this system can be used for employees with dyslexia and dysgraphia. Of course it would certainly not work for colour-blind employees.

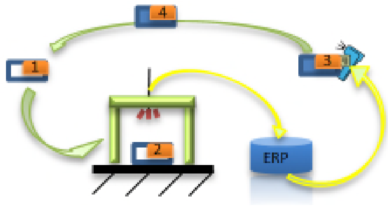
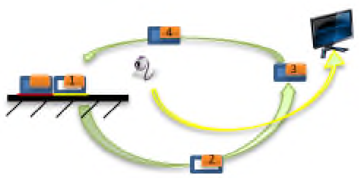
The second researched Kanban cycle is a bin Kanban connected with the ERP. Information is transported by the ERP. The bin Kanban cycle is used when the bins are adapted to the goods and other goods cannot be used for these bins. Empty bins are picked up and brought to the supermarket (see Figure 6.51, (1),(2)). All information that are needed are on this bin. At the supermarket (3), the bin is refilled. In the last stage of the Kanban cycle, the bin is brought back to the picking area (4). From this Kanban type, two other research cycles can be derived. In one Kanban cycle, an RFID tag is fixed on every box. On the RFID tag, information can be saved. If customers and suppliers are connected to the same ERP-system, they can use the information directly. A radio transmitter arranges the communication; therefore, it is necessary to place the bin directly under the transmitter. The supplier then knows that he has to deliver the refilled bins via the transmitted information.

Another Kanban cycle works with a simple monitoring. With the help of a commercial web camera and a commercial monitor, a live stream video feed is installed. The web camera and the monitor are connected without any interfaces to an ERP-system. The employee has to notice on the monitor that a bin is empty and that he/she has to bring a refilled bin. In order for the employee to better identify if the bin is empty or not, the empty bin has to be put aside. On the ground, a colour becomes visible once a bin is put aside and the employee can see that a refilled bin is needed. Every colour is marked with the material number so the employee can directly identify which good is needed. All different types of Kanban cycles are presented in Table 6.31.

Table 6.31: Types of Different Kanban Signals

Source: (Straub & Manz, 2014, p. 32)

	Kanban Type	Process	Process Information	Transportation of the Kanban Information
Kanban Using Cards	Kanban using a card		1. Remove the Kanban card 2. Transport the card to the supermarket 3. Affix the card to the bin 4. Transport the card and the bin to the picking area	All information needed is on the card
	Kanban by ERP		1. Remove the Kanban card 2. Scan the card, the information is sent to the ERP-system 3. Recycle the card 4. Print a new Kanban 5. Affix the card to the bin 6. Transport the card and the bin to the picking area	All information needed is in the ERP-system, only the transport information is on the Kanban
	Kanban using balls		1. Remove the Kanban (ball) 2. The ball rolls down the pipe to the previous process 3. Take the Kanban to the new bin 4. Transport the Kanban and the bin to the picking area	The information are transmitted according to the colour of the Kanban (ball)
Kanban With Bins	Kanban with bins		1. Remove all goods from the bin 2. Transport the bin to the supermarket 3. Fill the bin with goods or take a full bin of the same good 4. Transport the bin to the picking area	All information needed is marked on the bin

	Kanban by RFID		1. Remove all goods from the bin 2. Transport the bin to the RFID bridge, place the bin under the RFID scanner. The scanner starts automatically every 5 min. and sends the information to the ERP-system 3. Take the needed material from the supermarket. Close the order with manual scanning 4. Transport the bin to the picking area	All information needed is in the ERP-system and on the bin
	Kanban by webcam		1. Remove all goods from the bin. If the bin is removed, the surface of the floor becomes visible (yellow or red). Using a simple webcam, the floor is monitored. Thus, at the sink, the employee can see the colour of the surface and he knows that he/she has to bring a new bin 2. Transport the empty bin to the source 3. Fill the bin with goods 4. Transport the bin to the picking area	All information needed is transmitted to the webcam via the live stream

Findings

After researching the different Kanban cycle methods, 327 materials have been brought from the supermarket to the picking area. In Figure 6.35, the results of this research are summarized. In general, the installation and implementation of Kanban cycles without using the ERP and RFID is uncomplicated. To use ERP and RFID systems, the definition of the Kanban cycle in the computer system is necessary, which requires a good deal of effort. In a first stage, some basic data has to be implemented in the system. These are information about the supermarket, the picking area, vehicles and equipment, and the connection of the processes. However, if these requirements are fulfilled, such systems have the advantage of providing a clear overview about the information flows in this system. Problems could only be identified at the Kanban by RFID. These problems arose because the transmitter works like a cell phone, which means that radio reception must be available. In company buildings with thick cement walls, this was a problem because the radio reception was not sufficient. This leads to a limited applicability only at places with good radio reception.

In this regard, the Kanban via webcam was better. This is because of the location of the radio transmitter and the receiver in the same building. Thus, no problems arose in transmitting the information. The disadvantages arose in the monitoring of the screens. If an employee has to monitor a large number of screens, it is easy to lose track of which items need to be ordered. This problem arose also in the Kanban cycle using balls. This system is also only applicable when a relatively low number of goods have to be maintained. Another problem might be that the installation of the Kanban ball processes must be close to each other. Otherwise, installing the pipes would be very difficult because of the far distances. The installation is so difficult because the balls have to roll from one process to the next process on their own. Thus, differences in the height need to be considered as well as space to install the pipes.

The Kanban cycle using bins is suitable for products that need special boxes for transportation, such as boxes with special contours. The Kanban using cards is an effective method if many similar boxes are used. This is because the information flow is quick and the handling of the boxes is efficient by sharing the

Kanbans among the boxes. This research identified that the dimensions of the goods is not the dominant characteristic, but that characteristics like the transparency, the number of installed Kanban cycles, the traceability, the location of the processes, and the speed of the Kanban signal are important. Furthermore, it could be identified that it is important to know whether suppliers are involved. These are key characteristics that have to be considered when it comes to deciding which transmitting signal for the Kanban information should be chosen (Straub & Manz, 2014, pp. 30 - 32).

Table 6.32: Effects of Using Different Kanban Signals

Source: (Straub & Manz, 2014, p. 33)

	Kanban Using Cards			Kanban with Bins		
	Kanban using cards	Kanban by ERP	Kanban using balls	Kanban with bins	Kanban by RFID	Kanban by webcam
Installation of Kanban information signals	Little effort required for the installation. Supported by Microsoft Excel for printing cards.	For the installation of the Kanban cycles, user-level knowledge is necessary.	Little effort required for the installation if the source and the sink are not far away. The pipe has to be made and installed by a craftsman.	The information has to be affixed on a bin by iron sheet. The sheet has to be stamped with information.	On the RFID tag, information has to be electronically written by ERP. For this, user-level knowledge is necessary.	The ground has to be painted with colours. Also the webcam and the monitor have to be installed. For this, special operator level knowledge and a craftsman are necessary.
Change of Kanban information signals	New cards have to be printed.	The basic ERP data has to be changed.	By changing the ball or the meaning of the ball.	Changes are complicated because the information is directly stamped on the bin.	The basic ERP data have to be changed.	The colours on the floor have to be changed, therefore a craftsman is needed.
Kanban information signals	Good overview on the Kanban board.	Good overview on the ERP-system.	Good overview on the Kanban ball pipe	No general overview about the bins.	Good overview on the ERP-system.	Good overview on the monitor.
Security against loss of the Kanban signal	The employees have to handle the Kanbans with care.	The transparency of all Kanbans is available at the ERP-system at any time.	The employees have to handle the Kanbans with care.	The employees have to handle the Kanbans with care.	The transparency of all Kanbans is available at the ERP-system at any time.	Kanbans cannot be lost because no cards are in circulation.
Transparency of the signal handling	A Kanban board helps to gain transparency.	Full transparency via ERP-system.	Transparency only through on-the-spot checks.	Transparency only through on-the-spot checks.	Full transparency via ERP-system.	Full transparency via live stream.
associated with the transportation of Kanban signals of long items? If	None.	None.	None.	None.	Yes, because the RFID bridge has a limited space.	None.

Conclusion

Table 6.33: The Connection of Key Parameters to the Different Kanban Signals

Source: (Straub & Manz, 2014, p. 34)

	Kanban Using Cards			Kanban with Bins		
	Kanban using cards	**Kanban by ERP**	**Kanban using balls**	Kanban with bins	Kanban by RFID	Kanban by webcam
Transparency	X	X	X		X	X
Traceability		X			X	
Process locations close to each other	X	X	X	X	X	X
Process locations far away from each other		X		X	X	X
Suppliers are involved	X	X		X	X	X
High number of different Kanban cycles	X	X		X	X	
Quick transmission of the Kanban signal		X	X		X	X

The result of this research is that the dimensions are not a key parameter in choosing the Kanban signal. The dimensions had only a significant influence in the Kanban by RFID because the space at the RFID was limited. The key parameters are identified in Table 6.33. These parameters are used to choose the appropriate Kanban signal. In each case, the important parameters have to be considered. If, for example, the transparency and traceability are the most important factors, only a system with safe data transportation would be an option. If this cannot be realised, the Kanban by webcam might be an alternative, which is applicable for a limited amount of different goods. This research shows that the employees can handle this system easily. The same advantage holds for the Kanban cycle using balls. In this case, even employees with reading disabilities can work with this system.

6.7 Implementation Planning

The implementation planning considers two different tasks. The first task is to plan the test phase of particular elements of the planned system and the second task is to plan the implementation of the whole system (Schenk & Wirth, 2004, p. 118).

The implementation planning contains three different planning areas (see Figure 6.53). The first one is the resource planning. At this planning stage the processes, equipment, building, and schedule are planned. These planning tasks have to be divided in further subsection so that the planning can be made in detail. It is important that all planning activities are managed at one point. From this point, the planning task and planning schedule are controlled.

Figure 6.53: Implementation Planning

The transition planning is only necessary if existing processes have to be connected to new planned logistics system. The connection to other processes itself has to be planned in previous planning stages. The transition planning stage only deals with the question of by whom the implementation can be done.

The first new aspect in the implementation planning is the accentuation of the training needs of the employees. For this, the training on the job method is implemented. This method describes which employees are trained on the new processes. This method was created in the Second World War by the US military. The target of this method was to train women without a technical background to be able to work in the industry. The training on the job is a method that has four different stages for learning new processes. The first stage is to become familiar with how the new processes work. In the second stage, the trainer himself/herself starts to do the process while the trainee has to tell him/her what to do at the moment. At the third stage, the trainee executes the processes by himself/herself and the trainer stops only when he/she makes big mistakes. At the fourth stage, the trainee is only supervised and the mistakes are discussed at the end of the training.

Creating standards is a new element within the planning framework. To be able to efficiently implement a process, it is necessary to work according to specific standards. Usually these standards are fixed after a few weeks of work. So, if a planned system is installed, the new processes seem to be complex and non-transparent. If a standard exists, the knowledge that is transmitted from the trainer to the trainee can be structured in a logical and transparent way. Thus, standards support the training on the job method.

6.8 Implementation

This is the last stage at the planning stage. The purpose of the implementation is to implement at first the sub-systems and then the whole logistics system. Upon the implementation, the employees need to have know-how to be able to work at the logistics system. Furthermore, at this stage, a lot of improvements are created. The challenge is to find out which of these improvements really are improvements (Figure 6.54). Therefore, it is necessary to categorise these improvements. Thus, three categories are created. Low quality improvements are improvements that have no advantages in the economic, ergonomic, the door-to-door time, or the information flow. So, if at no level any improvement can be determine, this improvement will not be realised. If instead one or two advantages can be identified, these are considered medium quality improvements. These improvements could be realised, but not directly. The advantages have to be monitored for four weeks and if the opinion after four weeks is that the advantages are sustainable, then they can start to be implemented. The four week time period helps to identify if the advantages are sustainable in a lot of different constellations of the processes. Improvements that clearly have only advantages are high quality improvements and have to be realised immediately.

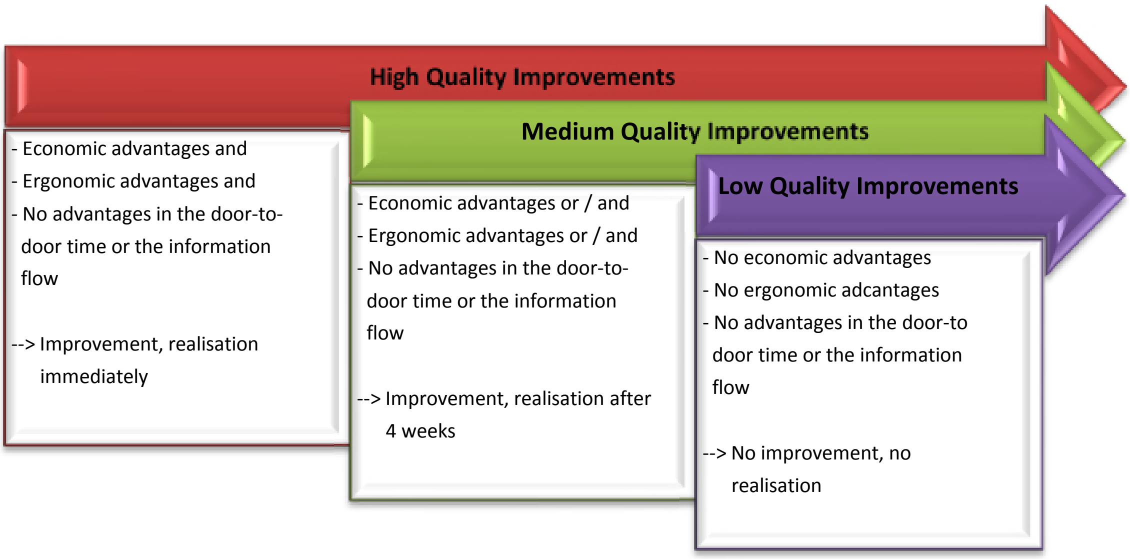


Figure 6.54: Identification and Categorisation of Improvements

6.9 Evaluation of the Planning Methods

At the end of the planning process, the evaluation can be made by comparing the results. Table 6.34 was created in this thesis. This table can be used to check if the implemented system works as planned. Every subsection can be evaluated by comparing the findings of the ideal planning to the implemented system. The evaluation of the criteria in Table 6.34 is a mixture of quantitative criteria that can be measured, such as performance, and qualitative criteria such as the question of whether ergonomic workplaces exist. If differences are identified, the reasons behind these differences must be researched.

Furthermore, it has to be determined whether activities should be created to correct the discrepancies between the planning and the implemented system or if the discrepancies can be tolerated.

A further key factor of the evaluation is to find out if the logistics system starts working as planned at the implementation planning. Beyond this, it is important that the maximum performance is reached. Therefore, adaptations might be necessary.

Table 6.34: Evaluation of the Variants

		Ideal Planning							Implemented System						
		material flow	value stream mapping	layout	employee	equipment	investment	cost	material flow	value stream	layout	employee	equipment	investment	cost
Attributes of the Logistic System	Products														
	Planning Horizon														
	Description														
	Location														
	Network														
	Source														
	Sink														
	Operating System														
	Material Flow														
	Information Flow														
	It - System														
	Improvement Process														
	Products														
Organisation of the Logistics	Logistic Operator														
	Owner of the Operating Equipment														
	Transport Service														
	Owner of the Transport Equipment														
	Owner of the Stock														
	Familiarity to Other Processes														
	Flexibility of the Logistic System														
Basic Requirements from Producers, Logistics, Wholesalers, Craftsmen	Information Delivery Date														
	Information in Case of Disarrangement of the Delivery Date														
	Requirements on the Package														
	Product Quality														
Additional Requirements at the Planning of Producers and Wholesaler	Delivery Time														
	Which Package Material is Preferred														
	Way to Order														
	Different Types of Material														

6.10 Chapter Summary

This chapter presents a new framework that supports to plan long items logistics systems. This framework can be used to plan a complete logistics system for long items and commercial goods. In this framework, new methods are created, implemented, and adapted to the requirements of long items and the customer requirements of the long items. Furthermore, the main work in this chapter of the thesis was to research the influences that long items have on logistics planning methods. Specifically, the task was to create planning methods from the research findings that can be used for further planning tasks. Therefore, the results are often presented in diagrams that are easy for planners to use. Thus, the research helps to plan the daily employee demand on the shopfloor. In the structure planning, methods are also applied that are used at present planning processes. However, these elements are also adaptable for planning long items logistics systems. The focus of the detail planning is on the transportation of goods and the transfer of information. The implementation planning describes the importance of standards and of the training for employees. The focus of the implementation is on how the improvements can be handled at the implementation stage.

Chapter 5 shows that at every planning stage of long item processes special requirements exist that have to be considered and that for these considerations, existing methods have to be adapted and new methods have to be created. Furthermore, this planning approach shows that if the planning standard has a high quality from the beginning, one variant for implementation can be chosen after the structure planning. This is advantageous because it saves planning resources and avoids repetition of planning stages because of imprecise or incorrect planning results.

6.11 Transmission Parts of the Framework

Parts of the framework developed can also be used in other planning frameworks. More specifically, parts can be used for logistics planning and for company planning frameworks.

Table 6.35 shows the transmission parts. The table is divided into the planning stages of preliminary planning, structure planning, detail planning, implementation planning, and implementation.

Table 6.35: Transmission Parts from the Framework

		Logistics Planning	Factory Planning
Preliminary Planning	Exact data analysis and evaluation	X	X
Structure Planning	Analysis of customer requirements	X	
	To have one planning variant at the end of the structure planning	X	X
	Create figures and tables for the process planning	X	
Detail Planning	Research of Minomi	X	X
	To research Kanban signals	X	X
Implementation Planning	Key parameters for a successful implementation	X	
Implementation	Handling of improvements at the implementation	X	X

In the preliminary planning stage, the data analysis and evaluation can be transmitted to each planning framework because this transmission part is used independently from the area of the planning framework.

In the structure planning phase, the customer requirements that are identified and evaluated at the logistics supply chain can be used at the logistics planning framework. Especially the requirements related to the quality, delivery time, and way to order are also important to other logistics planning frameworks.

Furthermore, to have only one variant at the end of the structure planning can be essential for other planning frameworks as well. Because of this decision, the planning effort at the detail planning stage is much lower because only one main variant has to be calculated. Therefore, many resources can be saved in employee hours, costs, and time. Beyond this, the planning gains a clear focus and the planning team is not confused by too many variants.

The figures and tables are only applicable on logistics planning frameworks. For example, the figure for the planning of the storage can also be used for the planning of euro pallets storage.

In the detail planning, the Minomi concept is researched. The researched Minomi concept is applicable at the planning of the material provision of commercial goods and at the material provision of long items at the company planning.

The planning support offered by choosing the Kanban signal can also be used in other logistics and company planning frameworks.

The key parameters that are useful in planning the implementation of the long items processes are logistics specific. The frameworks of the company planning deal with technical equipment in many regards. But other key parameters are necessary for the implementation. Thus, the key parameters cannot be transmitted.

At the implementation, handling the improvements in the implementation stage can also be used in other logistics planning frameworks and other company planning frameworks. The classification is not specific to the handling of long items. However, at the implementation of the long items processes, many improvements have to be made because of the complex planning of the goods due to their dimensions and instability. A lot of little optimisations of the equipment have to be made.

Chapter 7 Case Study

7.1 Introduction

The names of the companies that have been chosen for this case study have been changed to ABX, ABY, and ABZ to keep the data confidential.

ABX produces metal and plastic pipes for the water and waste water transport as well as connectors for the pipes. It is a company with round about 200 employees. Thirty of theses work in the logistics sector. ABX works together with ABY and ABZ. ABY transports the goods from ABX to the customers (wholesalers). ABX organises and realises the processes from the incoming goods area to the picking area on its own. ABZ, a temporary employment agency, manages the dispatch. ABX has many different storages types for long items outside of the building and inside the building. However, many of their processes do not work as effectively as the customers require. The customers are, for instance, dissatisfied about the long delivery time of normally four days and the non-transparent ordering process. Furthermore, 1100 parts per million (ppm) mistakes occur in the picking. This high number of mistakes is due to the fact that in 2013, a new assortment of pipes came on the market. Since ABX offers this new assortment of pipes, but still relies on their old procedures, the working processes do not work well. One complication is that the goods are stored outside of the building. To improve the customer relations, it is necessary to reduce the mistakes. One possibility is to improve the building in such a way that the material flow is simple and transparent. One idea proposed by Atec-Pipes' management board is to plan a new, more effective company for the production and logistics of long items. The production and the logistics are planned on a green field without considering the current building. In the further sections, only the logistics planning method for long items is used.

The logistics of ABX handles 82 different long items and 374 commercial goods. All of these commercial goods are ordered in connection to the long items products. The different logistics and storage types are shown in Figure 7.1. The aim of the case study is to test the developed framework for logistics planning. Furthermore, the planned system has to be implemented. Beyond this, it is tested if the logistics system works like planned. If so, it is evidence that the planning framework works well.

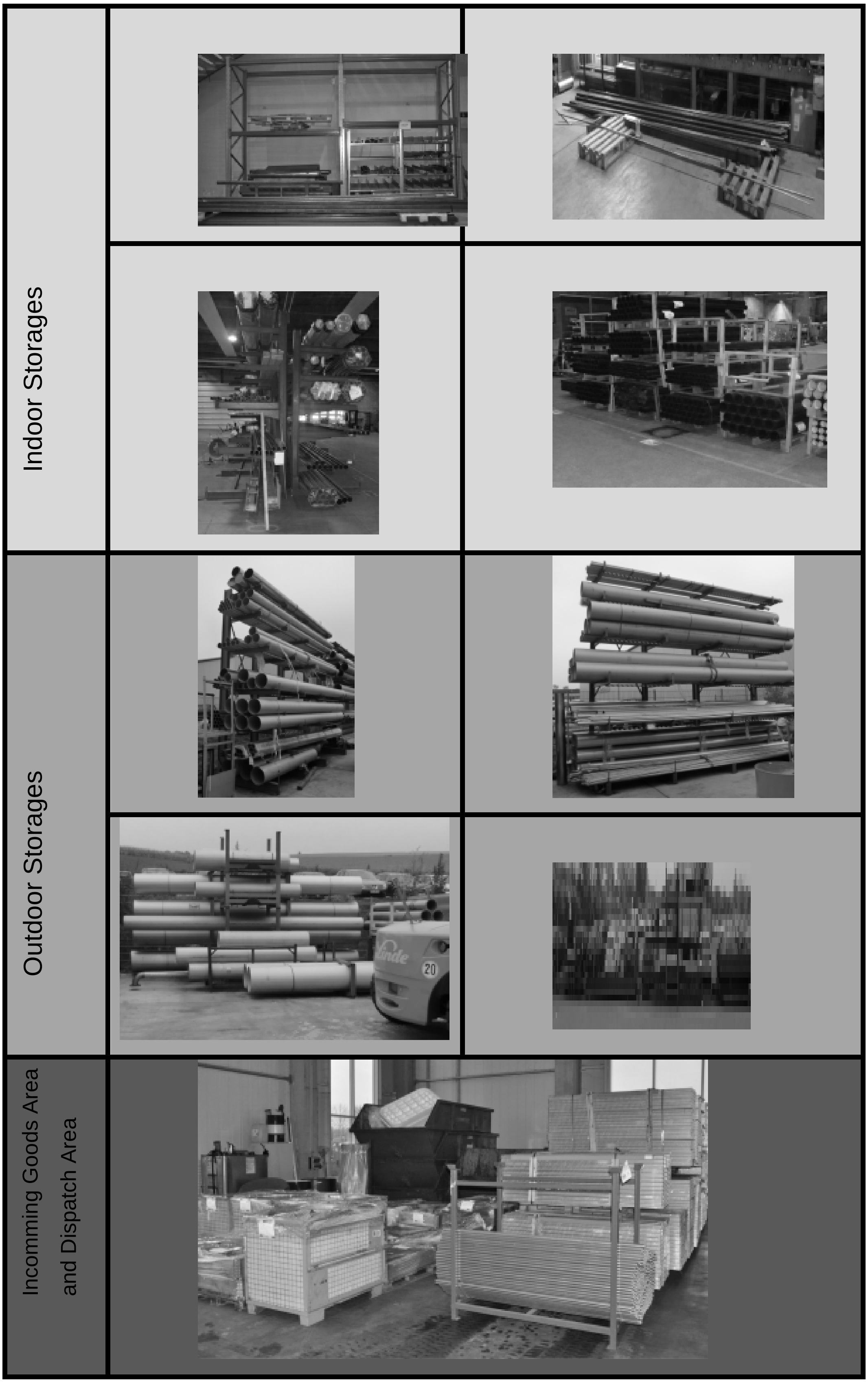


Figure 7.1: Different Types of Storages at ABX

7.2 Preliminary Planning

Table 7.1 describes the framework that ABX uses. They have been working together with ABY and ABZ in the past and will continue to in the future. ABY transports the goods from ABX to the customer. ABX does not deliver the goods directly to the end customer. The sales channel at the building industry goes to the wholesaler first and from the wholesaler to the customer. ABZ is an independent company that is located in the ABX building. ABZ' only task is to execute the dispatch processes. In the past, ABX decided to concentrate on the core competences and to produce only pipes and steel profiles. Thus, the dispatch processes were transferred to a logistics company. Goods are traditionally transported to the wholesalers by a forwarding company. ABY and ABX have a contract in place that is valid for three years; the current aim is to extend the currently existing contract.

Because of the logistics problems that have surfaced over the past two years, ABX decided to plan a new logistics system. The target of the new logistics is to fulfil the customer requirements and to implement cost-effective logistics processes. Thus, it is important that ABX and ABZ are located within one building. The idea is to have an excellent interface between these two companies. Interface does not only mean the electronic interface but also the fusing of the companies. The overall aim is that the processes of both companies will work smoothly together. Beyond this, the connection of the IT-network is an essential attribute of the logistics system. To be able to control the information flow, an ERP-system, for example, can be implemented. Using such a system, you can check at which process stage a given good is located at the moment. Furthermore, the suppliers and customers can connect their systems to an ERP-system and make changes to their data.

ABX handles only self-produced goods. Thus, only raw material which is needed for the own production is handled in the logistics.

ABX has a new production system. In this production system, the continuous improvement process is implemented. In derivation to the production system, the logistics system should also have a continuous improvement system.

The core requirement of ABX is to execute the processes from the incoming goods area to the picking area on its own. The dispatch is done by ABZ. Furthermore, ABZ has its own equipment and employees. ABY organises and executes the delivery to the customers using their own employees and equipment.

Because of the seasonal fluctuation of the demand, the completely in-house logistics system should be flexible +/- 35% of the performance.

As a basic requirement of the producers and the logistics (see Chapter 4 entitled "Data Analysis and Evaluation"), the information about the transport is an important aspect that has to be considered. The customers and the partners in the supply chain want to receive information about the status of the order process. Furthermore, in case the delivery date has to be changed, the information has to be transferred to the customer and to supply chain partners like ABZ or ABY, so that they can synchronise their processes with the changed delivery date.

The quality of the goods has to be checked at inline measurements and quality gates at ABX. Inline measurements monitor only a few important quality aspects directly during the production process. For example, with the installation of an inline measurement in the picking area, the picked goods can be weighed after each picking to determine if the right number of goods has been picked. At quality gates, many quality aspects are checked. If all aspects are fine, the product can pass the quality gate. For example, a quality gate can be installed before the goods arrive at the dispatch. Thus, this gate can monitor the delivery combination process by checking if all of the goods within one order are located in one delivery.

The additional requirements for the producers and wholesalers logistics that have to be considered are the delivery time, packaging material, different types of packaging materials, and the way in which orders are placed.

ABX is a producer. Therefore, it is necessary to consider these requirements.

Table 7.1: Framework for the Long Item Logistics Planning for ABX (Part I/III)

		Intra-Logistics (ABX)	External-Logistics (ABY)	Internal-Logistics (ABZ)
Attributes of the Logistics System	Products	plastic water pipes plastic waste water pipes metal water pipes	plastic water pipes plastic waste water pipes metal water pipes	plastic water pipes plastic waste water pipes metal water pipes
	Planning Horizon	5 years	3 years	5 years
	Description	incoming goods storing of goods material provision of the production area	transport logistics. ABY transports the goods to the customers	ABZ is responsible for the dispatch logistics
	Location	one location, in the same building as the production	no fixed location, only trucks come to load the goods	one location in the same building as the production
	Network	connected to ABY, ABZ, and to the customers	connected to ABX, ABZ, and to the customers	connected to ABX, ABY, and to the customers
	Source	only goods from the internal production are handled	only goods from ABX are handled	only goods from ABX are handled
	Sink	dispatch area ABZ	transport the goods to the customers logistics	load the goods on the truck of ABY
	Operating System	material provision logistics, storage logistics, picking logistics,	transfer logistics	dispatch logistics
	Material Flow	mixture of push and pull organised material flows. Goods are produced for anonymous customers, but the production processes are organised by pull material flows	the goods are pushed from ABZ to ABY	the goods are pulled from ABX to ABZ
	Information Flow	the information flow is a mixture of ERP based and manual visual material flow, e.g. go and see principle	the information flow is organised by ERP-system	the information flow is a mixture of ERP based flows and manual pull information flows
	IT-System	the whole logistics is supported by the ERP-system	ABY is not connected to the ERP-system of ABX and ABZ	ABZ is connected to the ERP-system of ABX
	Improvement Process	no continuous improvement systems	no improvement systems	no improvement systems
	Products	long items, commercial pallet material, packages	long items, liquids, pallets, special pallets	long items, commercial pallet material, packages

Table 7.2: Framework for the Long Item Logistics Planning for ABX (Part II/III)

Organisation of the Logistics	Logistics Operator	uses company employees for all processes	the external transport provider uses its own employees	the external service provider uses its own employees
	Owner of the Operating Equipment	company equipment	equipment from ABY	equipment from ABZ
	Transport Service	in-house transports by the company's employees for the processes: incoming goods storing of goods material provision of the production area picking for customers	transportation processes to the customers are done by ABY	the transport processes of the dispatch are done by ABZ
	Owner of the Transport Equipment	at the processes: incoming goods storing of goods material provision of the production area with own equipment	ABY has its own transport equipment	ABZ has its own equipment for the dispatch process
	Owner of the Stock	ABX is the owner of the goods in all process stages		
	Familiarity to other Logistics Processes	other processes can be used for such products	new processes have to be developed	other processes can be used for such products
	Flexibility of the Logistics System	the logistics system could handle +/- 35% capacity and is adaptable to other products	the logistics system could handle +/- 15% capacity and is not adaptable to other products	the logistics system could handle +/- 35% capacity and is adaptable to other products

Table 7.3: Framework for the Long Item Logistics Planning for ABX (Part III/III)

		Intra-Logistics	External-Logistics	Internal-Logistics
Basic Requirements from Producers, Logistics,	Information Delivery Date	the customer get the delivery date via E-Mail	no direct communication to the customer	no direct communication to the customer
	Information in Case of Disarrangement of the Delivery Date	the customer gets the new delivery date via E-Mail	no direct communication to the customer	no direct communication to the customer
	Requirements to the Package	package for the indoor and outdoor transportation and storage	no change of packaging is necessary	package for the indoor and outdoor transportation and storage
	Product Quality	inline measurements, quality gates	incoming quality check at the customer	quality check at the dispatch and at the loading
Wholesaler Additional Requirements to the Planning of Producers and Wholesaler	Delivery Time	normal delivery two days delivery time, express delivery one day		
	Which Package Material is Preferred	only use wood, nails and steel straps	at this step no packaging material will be used	only use wood, nails and steel straps
	Way to Order	ordering via phone, fax and IT-system	ordering via ERP-system	ordering via ERP-system
	Different Types of Material	only use 2 different package materials	at this step no packaging material is used	only use 2 different package materials

7.2.1 Basic Logistics Data Analysis

The basic data from the goods that are handled in the logistics processes have to be evaluated. An abridgement of the basic data is presented in Table 7.4. The basic data considers all data that pertains to handling the goods. The unity is a special measurement for long items. In the building industry, long items are often measured in metres and not in pieces. For example, a plumber on the building site prefers to order 60 metres of a 5-metre pipe and not to order 12 pieces of a 5-metre pipe.

Table 7.4: Excerpt of Basic Logistics Data from the Year 2013 from ABX

Name of the Good	Unity	Inventory	Minimum Inventory Level	Maximum Inventory Level	Piece / Metres per Package Level I	Piece / Metres per Package Level II	Piece / Metres per Package Level III	Location	Cargo Type	Volume of the Good [dm³]	Picks per Day	Positions per Day
Connector CST 90	piece	360	8.0	720	10	60	0		euro - pallet	0.209	15	3
Pipe CST 28	metre	28	38.0	48	6	24	120	LPS 01.02.03	long item - pallet 5m	0.177	37	24
Pipe CST d30	metre	45	44.0	55	4	20	40	LPS 01.04.01	long item - pallet 4m	0.616	50	2
Profile CST 40x40	metre	0	12.0	15	3	12	36	LPS 04.02.01	long item - pallet 3m	1.385	155	69
Profile CST 50x50	metre	0	80.0	100	6	24	48	LPS 03.02.03	long item - pallet 6m	2.29		

The package level (I, II, or III) describes how many products are placed in one package. Package level I is always used for one item or good. Package level II describes a bundle of goods or items. That means if a customer prefers to order 60 metres of a 5-metre pipe, the package level II is 60 metres. This is because the customer orders the same amount of products so often that it is useful to pack a bundle. Thus, the picker has only to pick one bundle. Package level III always describes the measurement or amount of full cargo. For example, 120 metres of long items can be placed in one cargo. The picks and positions per day describe the performance needed. One position considers at minimum one pick. For example, if 10 metres from the long item pipe CST 28 (see Table 7.4) are ordered, the employee in the picking area needs to pick two pipes for this one position. These basic data are evaluated for the whole assortment of articles that is handled in the current logistics system at ABX. The next stage is to evaluate the same data from the past. In the case of ABX, only the data from the last three years are available since that is when the ERP-system was changed and the previous data was lost. The data from the past has to be evaluated particularly to determine the effects that extremely high or low demand have had in the past. This is problematic because the ERP-system does not always book all picking activities on the same day. Thus, a high demand can be result of a delayed booking, e.g. due to server problems. Therefore, it is necessary to evaluate if the peaks really occurred in the past and if so, what the reason behind them was.

Furthermore, it is necessary to look at the future and to create basic data for the future. ABX needs basic data for the next five years because the planning horizon is five years. Future data can be created in derivation from the sales plan. At ABX, a few article groups have no sales plan. In this case, the average of the growth from the last three years of an article group is used for the extrapolation.

The long items are classified in Figure 7.2. The handling requirements increase from the left side of the chart to the right side of the chart. This means that goods that cannot corrode are easy to handle and store. If goods are sensitive to dirt, the handling and storage the requirements are very complicated. Each good is classified into one category. If a good can corrode and is sensitive to dirt, it receives a higher classification, i.e. the sensitive to dirt category would be chosen. This figure shows that only 17 out of 82 long items can corrode. Approximately 20% of the long items cannot corrode and can therefore be stored and handled outside of a building. 65 long items have to be handled and stored in-house.

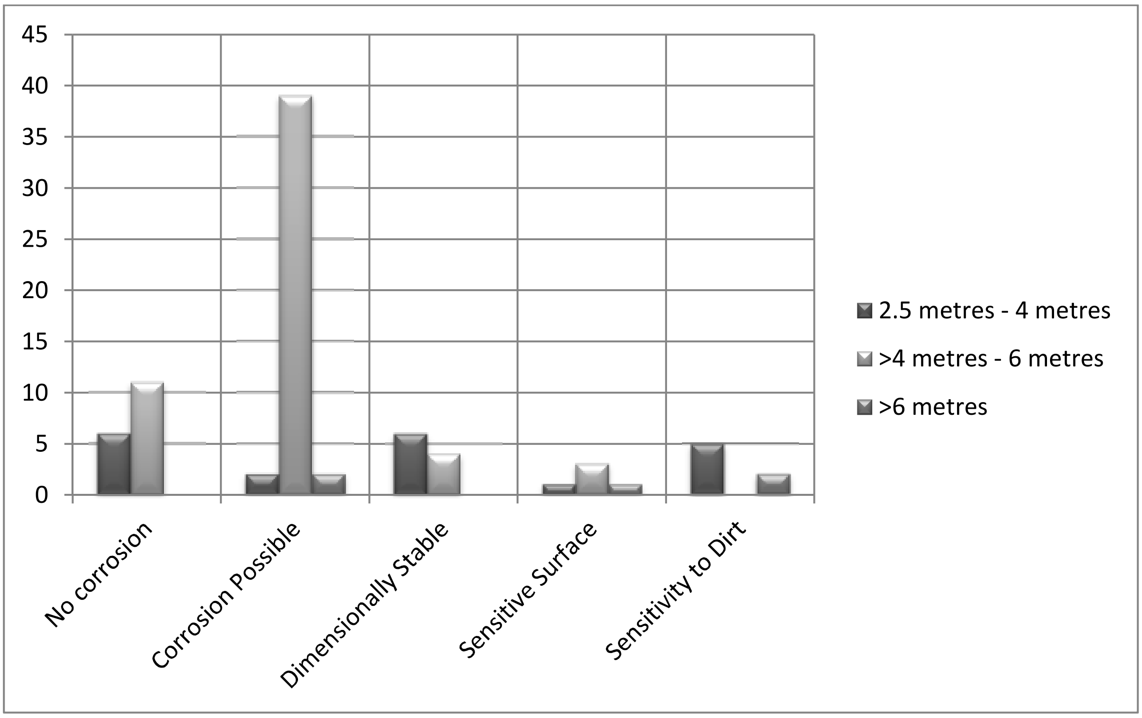


Figure 7.2: Classification of the Long Items from ABX

Further basic data are analysed with an ERP-system (see Figure 7.3). These data are real and current data. This figure shows always the maximum number of goods that are stored, picked, etc. on one day. In this case, the maximum can be chosen because the fluctuation from the maximum on any given day is less than 10%. Using the inventory curve, it can be evaluated that the storage capacities were filled much more in December than in the months before. Moreover, it is evident that this effect occurs every year. This is because wholesalers couple the end of the business year with the end of the calendar year; thus, they only want to have a small inventory level. This effect can be identified in the commercial goods and in the long items.

Table 7.5: Planning Data for the New Logistics System

	Today	5 Years
Number of long items	87	87
Number of commercial goods	1597	1917
Maximum inventory long items [long item pallets]	559	671
Maximum inventory commercial goods [commercial pallets]	1597	1917
Maximum position per day [positions / day]	147	176
Maximum picks per day [picks / day]	371	445

Furthermore, it can be identified that the number of positions has remained almost “constant” for years and that the picks vary in connection to the positions. The number of picks increases from March to April and shrinks the rest of the year. That is because in April and May the craftsmen need many goods to work on the building sites. Because of the high pick level and the “constant” positions, the number of goods per position increases in the months April and May.

The future data are created according to the specifications of the management of ABX. The basis for the calculation of the future data is the data from the year 2013. Using the data from the year 2013, the management of the ABX forecasts a moderate growth. The demand will increase in the following years. The growth is always based on the year 2013. That means that in 2017, the growth is expected to increase at a rate of +15% compared to the 2013 values. Furthermore, the management decided that the same growth is expected for the interpolation of the inventory, picks, and positions. Moreover, within the next years, no additional products are expected to come on the market. Since products over the next five years are only expected to be optimised and to substitute other products, the same growth factor can be used. The expected growth over the next five years is as follows:

- 2014 +2%
- 2015 +5%
- 2016 +10%
- 2017 +15%
- 2018 +20%

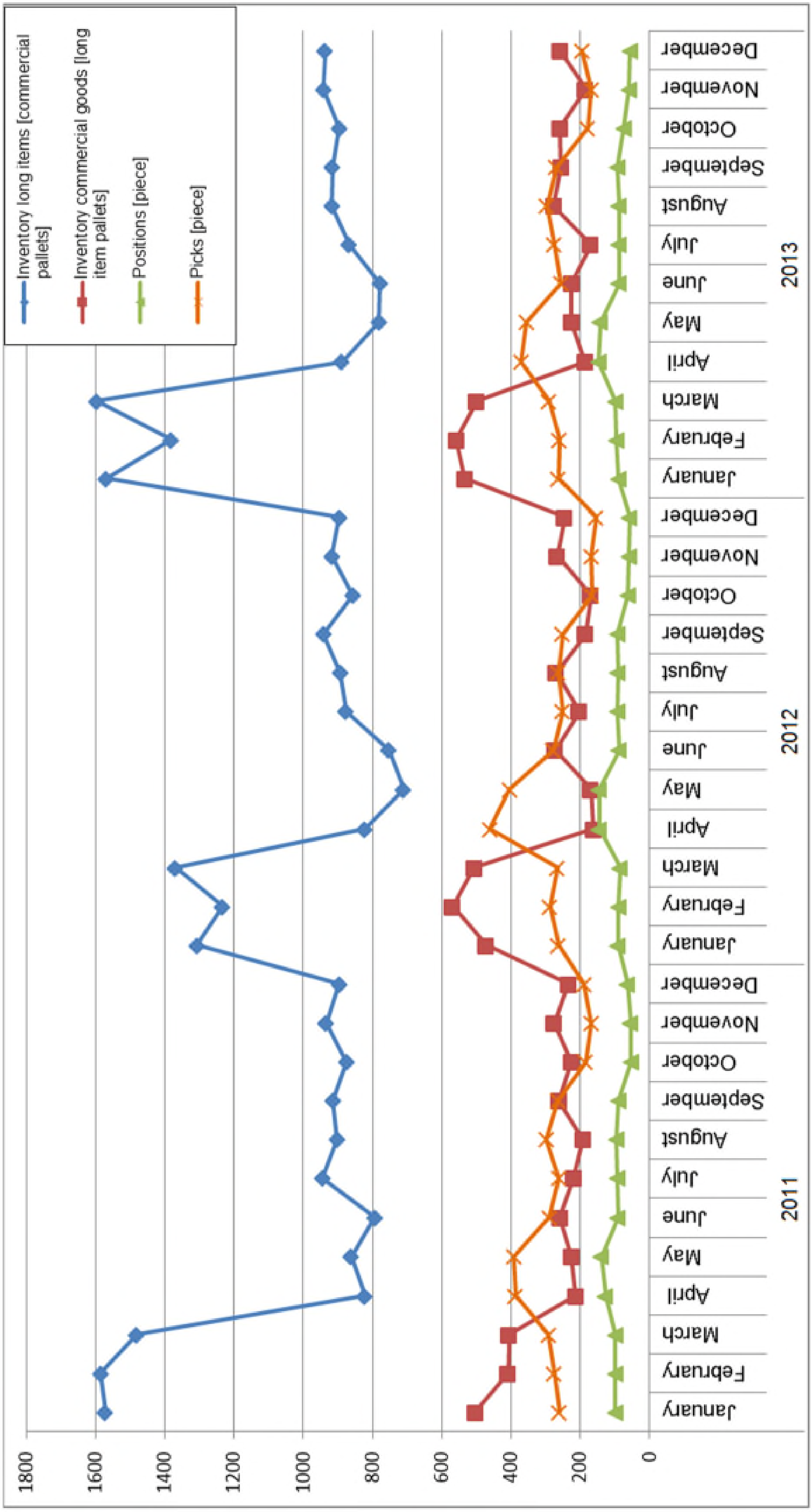


Figure 7.3: Basic Data from 2011 to 2013

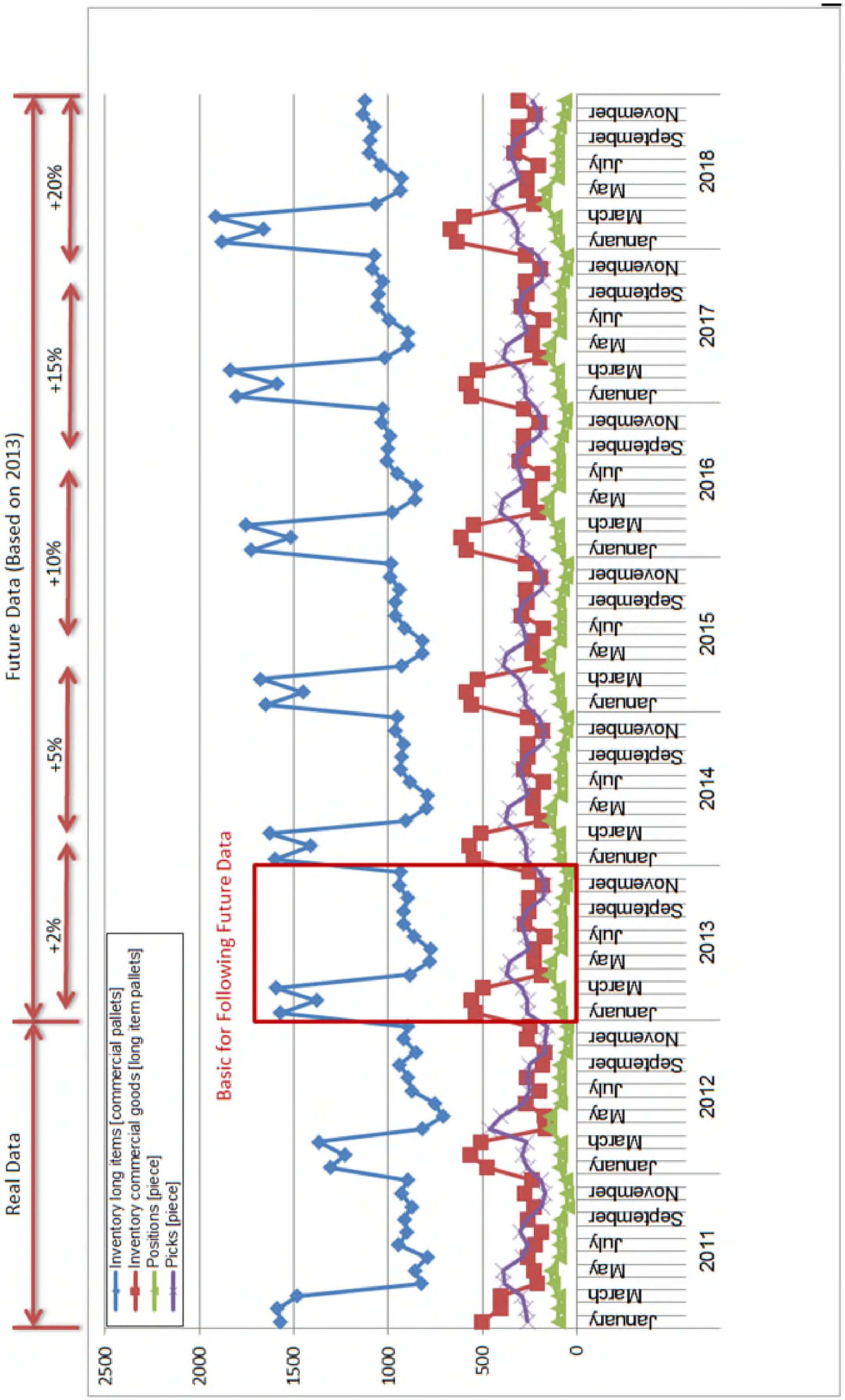


Figure 7.4: Basic Data for the Future

7.2.2 Process Evaluation of ABX and ABZ

In the next stage, the current processes have to be analysed. These are listed in Table 7.6. The processes are divided into the four basic logistics areas: the incoming goods area, storing, picking, and outgoing goods area. Overall, there are 16 processes. On the left side of the table, the customer requirements that were identified in the expert interview are listed. The 16 processes are analysed if the customer requirements are considered in each of these 16 processes. The method with which orders are placed is not considered in any of the logistics processes because the customers place their orders at the sales department of ABX and not at the logistics department. The process evaluation shows that the focus at ABX is on the product quality. This requirement is considered in all process stages while the requirements on the packaging material are only considered slightly.

However, not all requirements have to be considered at each stage in the process. For example, the information about the delivery date is only important at the outgoing goods area. Especially at processes in the outgoing goods area, the delivery times are considered. For the new logistics system the requirements pertaining to the delivery time and the packing have to be implemented.

Table 7.6: Current Process Evaluation of ABX

Area	Process	Producers, Wholesalers (additional requirements that have to be considered at the intra logistics of planning of producers and wholesalers): Way to Order	Which Package Material is Preferred	Delivery Time	Producers, Logistics, Wholesalers, Craftsmen (requirements that have to be considered at every stage of the logistics chain): Product Quality	Packaging Requirements	Information in Case of Change in Delivery Date	Information about the Delivery Date
Incoming Goods Area	Incoming Goods Registration	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Not Considered	Not Considered
	Unloading	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Not Considered	Not Considered
	Repacking	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Not Considered	Not Considered
	Separating	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Not Considered	Not Considered
	Put the Goods in Storage	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Not Considered	Not Considered
Storage	Relocate the Goods to the Picking Area	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Not Considered	Not Considered
	Relocate the Goods to the Dispatch	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Not Considered	Not Considered
Picking	Picking of the Goods	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Considered	Considered
	Package of the Picked Goods	Not Considered	Considered	Considered	Considered	Considered	Considered	Considered
	Transport the Picked Goods to the Outgoing Goods Area	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Considered	Considered
	Buffering of the Goods for the Outgoing Goods Area	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Considered	Considered
	Material Provision of the Production Area	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Not Considered	Not Considered
Outgoing Goods Area	Make a Transportation Packaging for the Goods	Not Considered	Considered	Considered	Considered	Considered	Considered	Considered
	Shipping Labelling for all Goods	Not Considered	Considered	Considered	Considered	Considered	Considered	Considered
	Loading of the Goods	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Considered	Considered
	Return Shipment	Not Considered	Not Considered	Not Considered	Considered	Not Considered	Not Considered	Not Considered

7.2.3 Company Strategy Planning

The company production systems have four main columns (see Figure 7.5). The first and most important column concerns the safety involved in the process. For ABX, it is important that all processes are implemented safely and that the customers' and employees are protected from hurting themselves or other persons. Thus, the products have to be handled and used in such a way as to eliminate any danger that can arise from handling the goods.

The second and the third column are the customers. For ABX, it is important that the customers are satisfied with their products. The customers are so important to the company that they have to be considered at two stages in the production system. Thus, the findings from the analysis process to optimise the delivery information and the packaging are supported at ABX' production system.

The last column is the quality. ABX views the quality of their products as the foundation of good customer satisfaction. Therefore, all processes focus on ensuring the quality of the products. This can also be identified in the process evaluation.

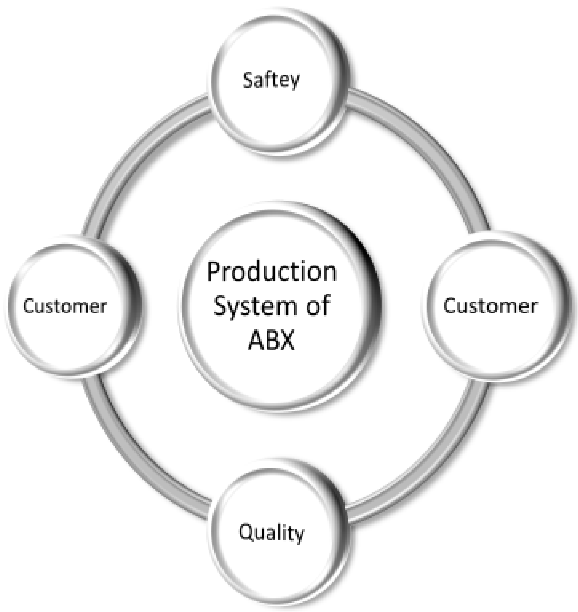


Figure 7.5: Production System of ABX

7.2.4 Target Planning

The preliminary planning phase ends with the target planning. In the target planning, the opportunity study connects the basic data, the information from the process evaluation, and the company strategy (see Table 7.7). By combining such elements, the target planning generates the new results, such as the rough direction that the planning should take. Furthermore, the performance and capacity data (findings from the basic data evaluation) help to make a first rough investment calculation. Hence, for this project, an investment of approximately 2.5 million euro will be needed for the logistics equipment, IT, and for the construction of a building.

Beyond this, a rough schedule of the planning and implementation can be developed and the project structure can be fixed. This target planning takes the form of a document for the management board an represents a first milestone in planning an efficient logistics process. Other milestones are reached at each end of the planning stages. At a milestone, the results of the planning stage have to be monitored. Moreover, milestones represent the starting point for the next planning stage. Using the target planning, the management board can decide if the project will move on to the next stage. Because of the exact evaluation of the basic data and process data, the quality of the planning in such stages is very high. Thus, planning stages seldom have to be repeated. The decision of the management board is to pass the milestone and proceed to the structure planning phase of the project, while keeping the limited investment of 2 million euro in mind.

Table 7.7: Opportunity Study for ABX' New Logistics System

Project Definition	Plan a new logistics system for ABX.
Problem Description	The current logistics system does not consider the customers' requirements. Too many process problems, e.g. long delivery time, missing information flow to customer.
Clear Project Target Planning	Customers receive their goods at latest in two days after ordering. Transparent information flow of the in-house processes. Create a long item storage for 700 pallets. Create a storage for 2000 commercial pallets.
Show the Rough Direction in Which the Solution Should Be Developed	One building that considers all in-house logistics processes from ABX and from ABZ. All processes should be directed to the customer demand and work synchronically.
Definition of the Level of Performance	The performance of the picking areas has to be improved to 450 picks/day. The performance of the logistics system has to be improved to 180 positions/day.
Definition of the Investment	Approximately 2.3 million euro.
Development of a Rough Schedule	Implementation of the logistics system in February 2014.
Description of the Project Borders	All processes that are not logistics processes are not considered. Furthermore, the limitations are only on the intra and internal logistics. External logistic processes like the transportation are not considered.
Description of the Project Structure	A core project team with 6 persons and the management board have to decide about the milestones. The milestones are set at the end of the preliminary planning, structure planning, detailed planning, implementation planning, and implementation stage.

7.3 Structure Planning

The first activity of the structure planning is to create a clear logistics structure. The logistics structure shows how the process and the goods are connected. This structure is divided into two tables. Table 7.8 considers only long items. All long items pass through the incoming goods, storage, picking, and the outgoing goods areas. 49 long items pass through the delivery combination. This is because 33 long items are sold only on full pallets that cannot be combined with other goods. Long items are not provided for the production process because they are not used in the production process; they are only produced by ABX.

Table 7.8: Logistics Structure of the Long Items

82 Different Long Items

Material Number	Incoming Goods Area	Storage	Picking	Delivery Combination	Material Provision	Outgoing Goods Area
510170035	1	1	1	1	0	1
510170045	1	1	1	1	0	1
510170055	1	1	1	1	0	1
510170065	1	1	1	0	0	1
510170075	1	1	1	1	0	1
510170085	1	1	1	1	0	1
510170095	1	1	1	1	0	1
510170105	1	1	1	0	0	1
510170115	1	1	1	0	0	1
…	…	…	…	…	…	…
Results	23	82	82	49	0	82

1… Goods are used in this process

0… Goods are not used in this process

Table 7.9: Logistics Structure of the 374 Commercial Goods

Material Number	Incoming Goods Area	Storage	Picking	Delivery Combination	Material Provision	Outgoing Goods Area
810170038	1	1	1	1	1	0
810170048	1	1	1	1	1	1
810170058	1	1	1	0	1	0
810170068	1	1	0	0	0	0
810170078	1	1	1	1	0	1
810170088	1	1	0	0	0	0
810170098	1	1	0	0	0	0
810170108	1	1	1	0	1	1
…	…	…	…	…	…	…
Results	374	374	185	179	189	198

1… Goods are used in this process

0… Goods are not used in this process

Table 7.9 shows the commercial goods. All commercial goods (374) pass the incoming goods and the storage areas. Only 179 pass the delivery combination. Further 189 goods are provided in the production. Almost half of the numbers of goods are used for the production of commercial goods or long items. These are, for example, rubbing seals that are used for every pipe, pipe connectors, or window profiles.

In all, 198 commercial goods pass through the outgoing goods area. The differences from the outgoing goods area to the delivery combination is due to the goods that are only delivered in full packages, such as sheets of drywall. If one of these pallets is opened, more effort is required to repackage it in a suitable shipping package than the value of the goods.

7.3.1 Ideal Planning of the Material Flow for ABX

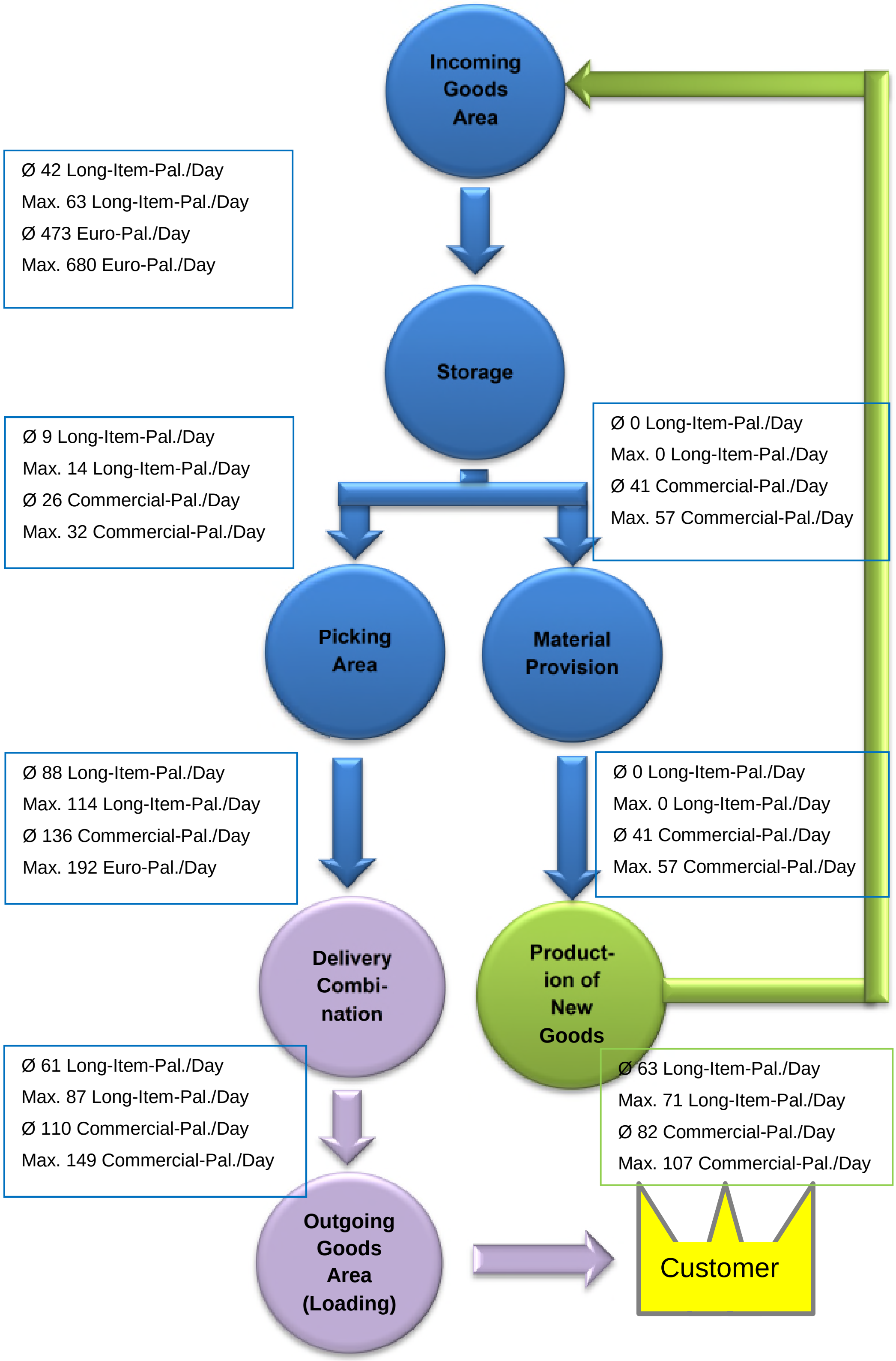


Figure 7.6: Ideal Material Flow Chart for ABX

ABX’ ideal material flow chart is presented in Figure 7.6. All of the blue circles represent processes at ABX. The arrows represent the materials transported from one process to another process. The purple circles represent processes implemented by ABZ and the green cycle and arrows depict ABX’ production. The green processes are beyond the planning scope of the logistics system. All goods (long items and commercial goods) use one incoming good area and are transported to one storage. From this storage, goods are transported to either the production area or to the picking area. However, the delivery of long items does not take place in the production area because long items are not used in the production. The ABX production transports the long item goods to the storage.

ABZ is responsible for the delivery combination and the loading. In Figure 7.6, each text box indicates the average number of pallets and the maximum number of pallets that have to be transported from one process to another and is separated into commercial goods and long items.

7.3.2 The Value Stream of ABX New Logistics System

The ideal value stream of the ABX logistics is presented in Figure 7.7. The first stage of the value stream is to calculate the customer cycle. This can be done using the below equation. The customer cycle is not fixed by only one calculation, as it changes with changes in the demand. For the structure planning, two customer cycles are necessary: the average and the maximum customer cycle.

The processes shown in blue represent ABX logistics processes. The processes shown in green are the production processes at ABX. The purple processes represent ABZ’ processes. The small number of stored goods is because the goods are transported directly to the rack and not located in the incoming goods area. The inventory (see Figure 7.7) of the incoming goods area is indicated in pallets for reasons related to quality control (10 CP, 5 LIP).

The door to door time from the incoming goods area to the customer is 17.8 days. The process time required for all processes are 1155 seconds (0.05 days). Every part of the process is connected with the ERP-system. This is necessary so that the customer receives a direct response about the status of their order. The order process is completely transparent. Furthermore, the customer can see directly if a change in the order is possible. Such amendments are possible until the picking process starts.

The longest time, goods are usually stored in the storage is 11.5 days. This is because ABX has to order certain quantities from its suppliers. Because of the small company size of ABX, it has little influence on delivery quantity from other manufacturers. The stock at the picking process is also rather large, as this area is forced to stock two pallets of each good. Under consideration of 82 long items, 164 long items pallets are necessary. Since there are 180 fixed long item locations, 16 additional locations are needed in order to have extra locations in case of a sales action. Moreover, 52 locations are reserved for commercial goods.

$$\boldsymbol{T_C = \frac{t_W}{K_B}} \qquad \textbf{(7-1)}$$

Where:	CP:	Commercial pallet
	K_B:	Customer demand
	LIP:	Long item pallet
	t_W:	Working time per day
	T_C:	Customer cycle

Average Customer Cycle

For long items $\quad T_C = 413\ {}^{s}/_{LIP}$

For commercial goods $\quad T_C = 229\ {}^{s}/_{CP}$

Maximum Customer Cycle

For long items $\quad T_C = 289\ {}^{s}/_{LIP}$

For commercial goods $\quad T_C = 169\ {}^{s}/_{CP}$

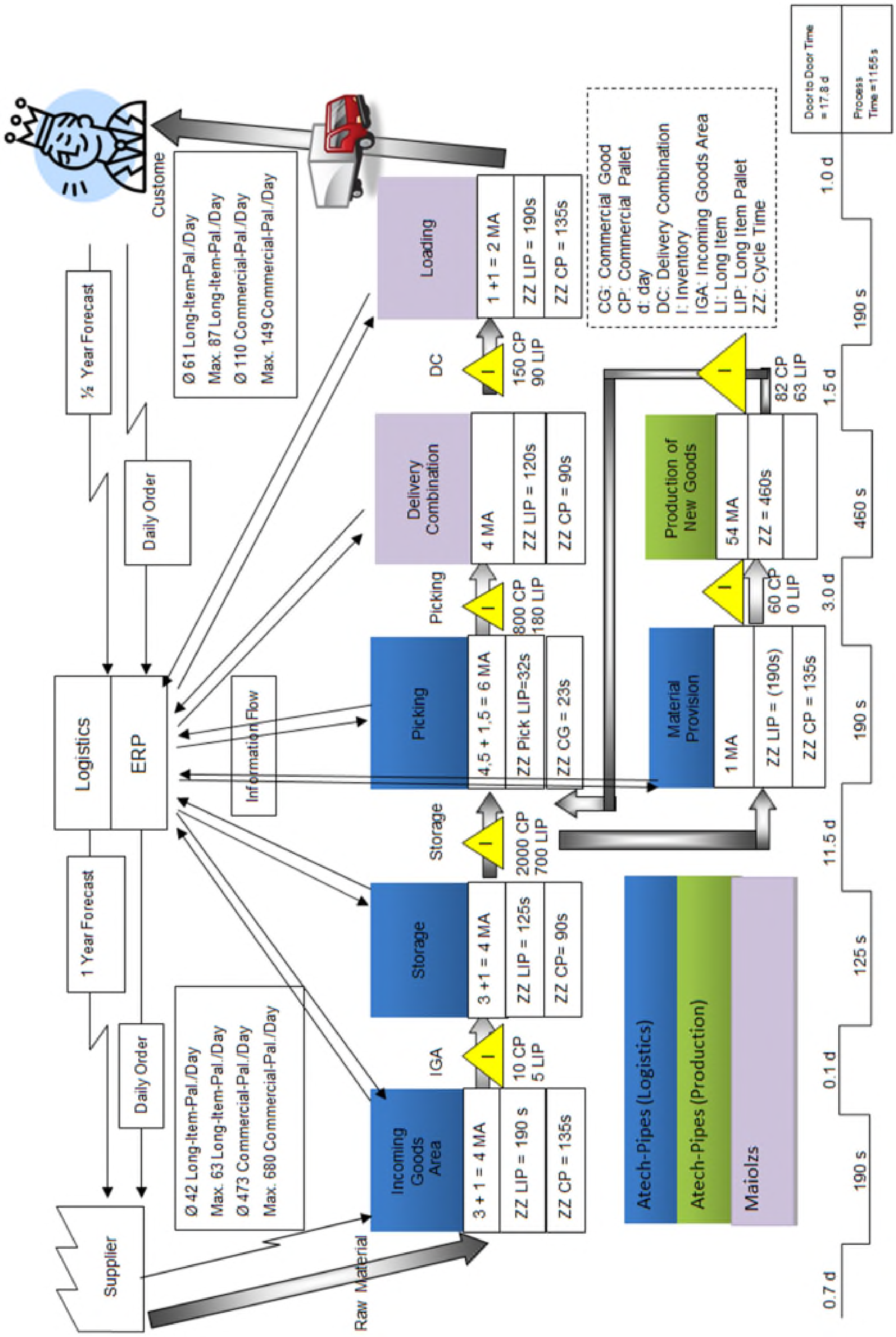


Figure 7.7: ABX’ Value Stream

7.3.3 Creation of the Block Layout for ABX' Logistics System

To create a block layout, the pallet expanse must first be calculated. This can be done by considering the number of goods and the data from the value stream.

In Table 7.10, all of the expanses for each process are noted. Figure 7.8 shows the block layout of the ABX logistics. The orange arrows represent the material flows. Arrow (1) shows the goods that are at the incoming goods area. They are transported directly from the incoming goods area to the storage areas. The long items are transported along arrow (2). The transportation of commercial goods in the storage is depicted by arrow (3). The provision of the picking area is done from the commercial goods storage and from the long item storage. This is shown by arrows (5) and (6). Arrow (4) marks the material provision of the production. Employees from the production facility transport the goods from the production. Therefore, arrow (7) is marked green. Arrow (8) represents the transport from the picking area to the delivery combination area and arrow (9) shows the transportation from the delivery combination to the outgoing goods area.

$$\boldsymbol{A_{LIP} = l_{LIP} * b_{LIP} = 6m^2} \quad \textbf{(7-2)}$$

$$\boldsymbol{A_{CP} = l_{CP} * b_{CP} = 1{,}2m^2} \quad \textbf{(7-3)}$$

$$\boldsymbol{A_{SELIP} = A_{LIP} * n_{LIP}} \quad \textbf{(7-4)}$$

$$\boldsymbol{A_{SECP} = A_{CP} * n_{CP}} \quad \textbf{(7-5)}$$

Where:

A_{LIP}: Expanse of long item pallet

A_{CP}: Expanse of commercial pallet

A_{SELIP}: Shelf expanse of long item pallet

A_{SECP}: Shelf expanse of commercial pallet

b_i: Width

l_i: Length

n_{LIP}: Number of long item pallets

n_{CP}: Number of commercial pallets

Table 7.10: Expanse of the Long Items and Commercial Pallets

	Number of Long Item Pallets [piece]	Number of Commercial Pallets [piece]	Expansion of Long Item Pallets [m²]	Expanse of Commercial Pallets [m²]
Incoming Goods Area	5	10	30	12
Storage	700	2,000	4,200	2,400
Picking	180	800	1,080	960
Production	4,000 m²			
Delivery Combination	90	150	540	180
Loading	90	150	540	180

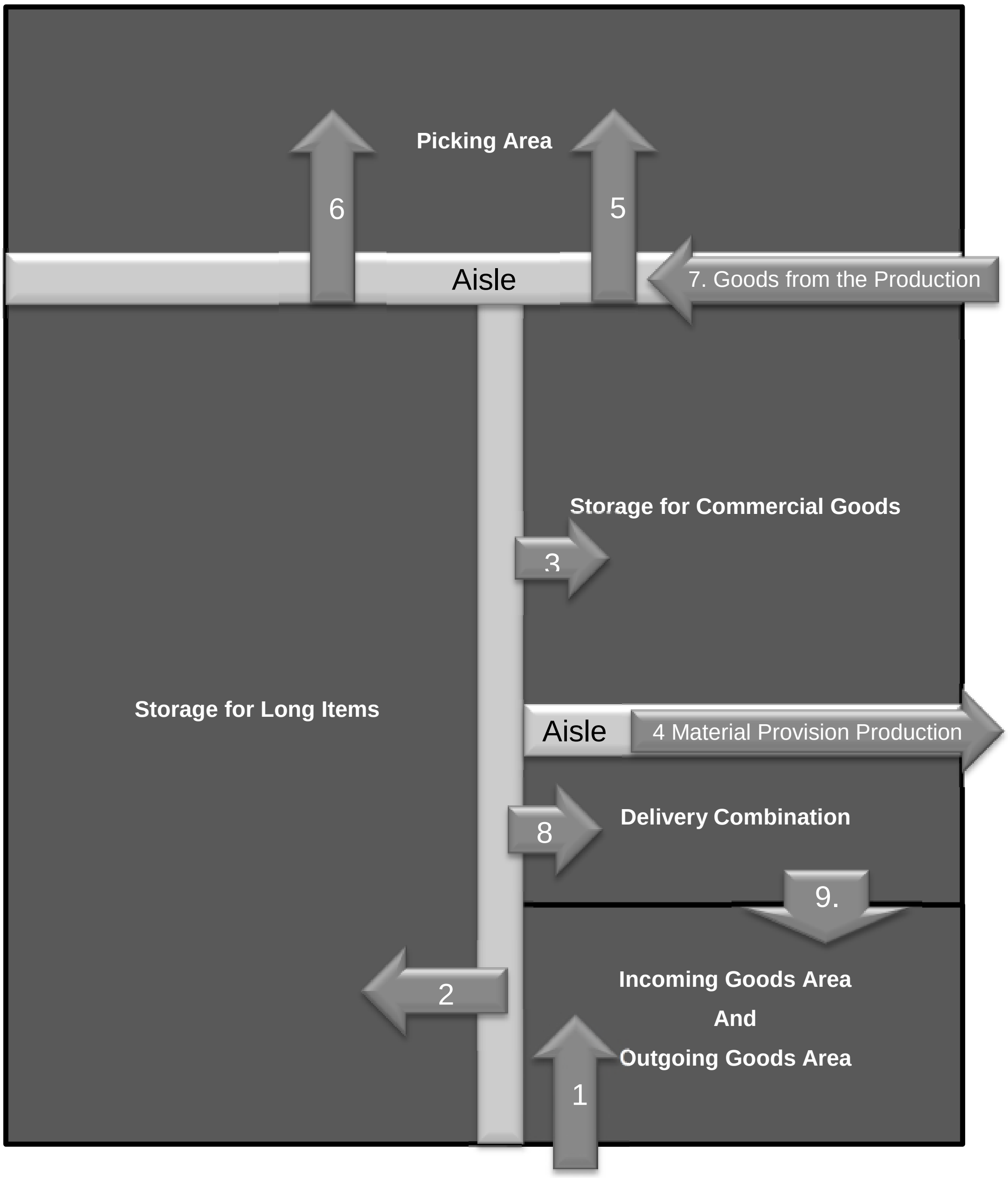


Figure 7.8: Block Layout of the ABX Logistics

7.3.4 Calculation of the Employee Demand

The bases for the calculation of the employee demand are the ideal material flow, value stream, and the block layout. In whole, the ABX needs 21 employees (see Table 7.11). All material provision processes are located under the subtitle “storage”. Especially the employees for the material provision of the production are also included in the storage processes. The ABZ (purple marked) needs 6 employees for the delivery combination and the loading. The ABX needs 15 employees for the own logistics processes. The administrative employees control the ERP-system and are the leader of the employees working in the processes.

Table 7.11: Calculation of the Employee Demand in the ABX Logistics

Main Process	Sub-Process	Time for Process [s]	Daily Working Time [min]	Number of Employees
Incoming Goods Area	Unloading LIP	190	420	1
	Unloading CP	135	420	1
	Unloading Truck	240	420	1
	Goods Check In	30	420	1
Storage	Material Provision of the Picking Area LIP	125	420	1
	Material Provision of the Picking Area CP	90	420	1
	Material Provision of the Production CP	135	420	1
	Administrative Work		420	1
	Manage Empty Boxes		420	1
Picking Area	Picking LIP	32	420	3
	Picking CP	23	420	1.5
	Administrative Work		420	1.5
Delivery Combination	Delivery Combination LIP	120	420	2
	Delivery Combination CP	90	420	1
	Administrative Work			1
Loading	Loading LIP	190	420	1
	Loading CP	135	420	0.5
	Administrative Work		420	0.5
			Number of Employees	21.0

7.3.5 Calculation of the Equipment Required by ABX

The calculation of ABX' equipment is listed in Table 7.12. The equipment needed for its IT contains a mobile computer like the Motorola MC67 (see Figure 7.9). Using a mobile computer, it is possible to monitor the starting and endpoint of every stage of the process. Thus, every stage is transparent. The customers can exactly see which order level their orders have. In addition to such technological equipment, ABX requires forklifts. The four-way forklift and the commercial forklift are forklifts like the ones described in the previous chapter. The packaging and unpacking equipment include nippers, hammer, nails, and bands to frap the loading. Almost every employee working in an operative process needs some sort of packaging or unpacking equipment.

Figure 7.9: Mobile Computer Motorola MC67
Source: (Motorola Solutions, Inc., 2014)

Table 7.12: Calculation of ABX' Equipment

Main Process	Sub-Process	IT-Equipment	Four-Way Forklift	Commercial Forklift	Unpacking Equipment	Packing Equipment
Incoming Goods Area	Unloading LIP	1	1		1	
	Unloading CP	1		1	1	
	Unloading Truck	1		1		
	Goods Check In	1				
Storage	Material Provision of the Picking Area LIP	1	1		1	1
	Material Provision of the Picking Area CP	1		1	1	1
	Material Provision of the Production CP	1		1	1	1
	Administrative Works	1				
	Manage Empty Boxes	1	1	1		1
Picking Area	Picking LIP	3	1		3	1
	Picking CP	1		1	1	1
	Administrative Work	2				
Delivery Combination	Delivery Combination LIP	2	1			2
	Delivery Combination CP	1		1		1
	Administrative Work	1				
Loading	Loading LIP	1	1			
	Loading CP	1		1		
	Administrative Work	1				

7.3.6 Calculation of ABX' Energy

The energy demand for one year can be calculated using the specification of the equipment or the building. If no specifications exist for the building, comparative specifications from existing buildings can be used. Table 7.13 shows ABX' energy consumption. The data about the electricity and pneumatic consumption is taken from the equipment specifications and from data from the old building. The calculation for the new building is done in analogy to the square metres from the old to the new building. It is possible to calculate the water, waste water, and the heating in analogy to the square metres from the old building.

Table 7.13: Energy Demand of the ABX Logistics for One Year

	Energy Demand for One Year					
	Main Process	Electricity [KW/year]	Pneumatic [m³/year]	Water [l/year]	Waste Water [l/year]	Heating [KW³/year]
Processes	Incoming Goods Area	12,000	1,000	20,000	20,000	200,000
	Storage	21,000	800	5,000	5,000	70,000
	Picking Area	39,000	5,000	5,000	5,000	70,000
	Delivery Combination	18,000	7,000	5,000	5,000	70,000
	Loading	13,000	200	20,000	20,000	200,000
	Offices	6,000	0	10,000	10,000	120,000
	Maintenance	8,000	1,000	9,000	9,000	80,000
	Cafeteria	4,000	0	11,000	11,000	70,000

7.3.7 Creation of the Processes of ABX' Logistics

7.3.7.1 Incoming Goods Area

Because of the limited number of different goods, the incoming good area is not divided into different parts. That means that all goods pass through one incoming good area. This organisation of the incoming goods area fits for small companies like ABX, so it is possible to use the existing equipment for all of the incoming goods.

At the incoming goods area, all goods are directly stored into the storage. Thus, no buffer exists in the incoming goods area. This is why the stock in the incoming goods area is zero (B_i=0). To guarantee this, it is necessary to establish rules. One rule can be to never to start unloading more than one truck at a time. That means that you have to finishing unloading one truck before moving to the next. Thus, the performance of the unloading process is limited by the performance of the forklift. The distance from the truck to the rack is 200 metres. Therefore, a commercial forklift that transports commercial pallets needs 135 s/CP (λ_i^{in} =135s/CP). A four-way forklifts needs 190 s/LIP (λ_i^{in}=190s/CP) for the same distance when transporting long items pallets.

The incoming goods area has the sole task of unloading the trucks and transporting the pallets to the rack. At ABX, no unpacking, sorting, packaging, or pre-packaging is necessary.

7.3.7.2 Storage in ABX Logistics

ABX handles long items with maximum length of 6 metres. To choose the storage type for the ABX logistics, some previously created tables and figures are quite useful. These are shown in Figure 7.10. First, Table 6.21 is used to evaluate which storage type is suitable for the long items.

The appropriate categories are marked in orange in Figure 7.10. ABX handles long items with a length between 2.5 metres and 6.0 metres. The logistics must be able to store 2,000 long item pallets. Figure 6.25 shows that the block storage can only be used for 1,000 long item pallets. Therefore, block storage is not suitable for ABX. The cantilever rack can, however, store 20,000 long item pallets and is thus suitable for ABX.

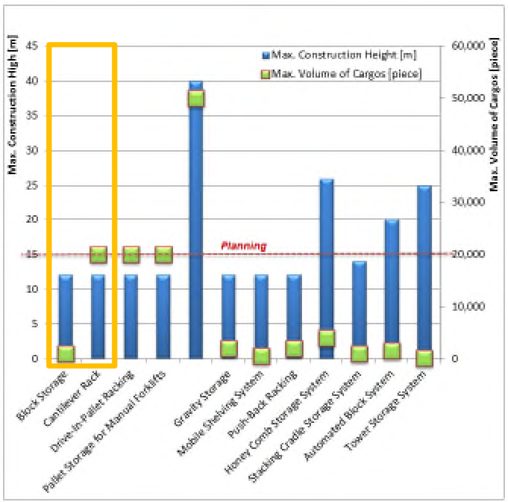
When storing only 2,000 long item pallets, an automatic rack is too expensive. When using the manual cantilever rack, the maximum height is at approximately 12 metres (see Figure 6.23). The maximum length of the cargo is 16 metres at a maximal length of the aisle of approximately 80 metres (see Figure 6.24). The double cross performance is 15. That means that 15 pallets can be placed in the storage while 15 other pallets can be removed from the storage on the way back. Thus, the forklift never has to make an empty run. Thus, because the cantilever rack fits to all requirements of ABX' logistics, it is chosen for the processes.

see Table 6.21

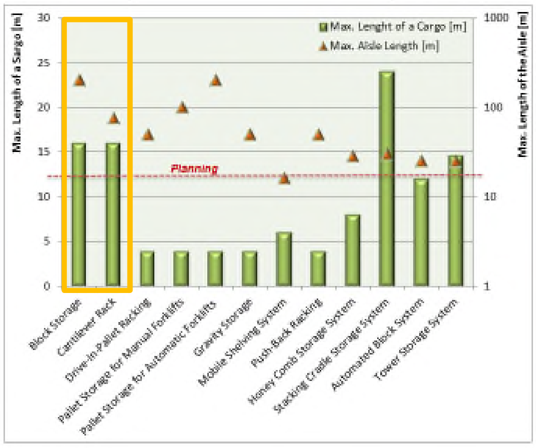
Type of storage	Small Goods e.g. Packets	Commercial Cargos e.g. (Euro Pallets)	Long Items			Expanse Consumption* [%]
			2,5 meters - 4 meters	>4 meters - 6 meters	>6 meters	
block storage	X	X	X	X	X	80
cantilever rack		X	X	X	X	40
pallet storage	X	X	X			45
drive-in-pallet racking	X	X	X			70
pallet storage for manual forklifts	X	X	X			40
pallet storage for automatic forklifts	X	X	X			60
gravity storage	X	X	X			65
mobile shelving system	X	X				75
Push-back racking	X	X	X			70
Honey comb storage system			X	X	X	60
stacking cradle storage system			X	X	X	70
automated block system			X	X	X	60
tower storage system			X	X		55

see Table 6.22

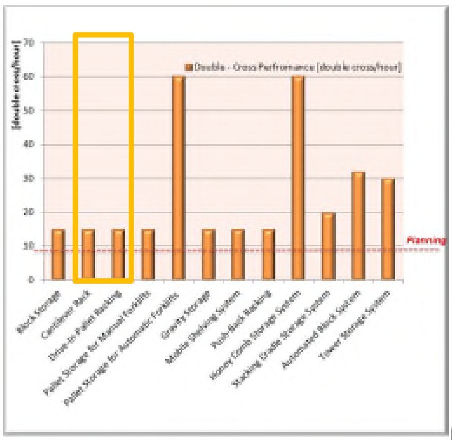
Type of Storage	Max. Construction Height [m]		Effective Load at Each Cargo [t]	Max. Volume of Cargos [piece]	Max. Length of a Cargo [m]	Maximum Aisle Length [m]	Silo Architecture Possible	Double - Cross Performance [double cross/hour]	Max. Vertical Speed of the Lift [m/min]	
Block Storage	12.1	****	1	1,000	16	200	no	15	42	****
Cantilever Rack***	12.1	****	1	20,000	16	75	yes	15	42	****
Drive-in-Pallet Racking***	12.1	[illegible]	1	20,000	3.9	50	yes	15	42	[illegible]
Pallet Storage for Manual Forklifts***	12.1	****	1	20,000	3.9	100	yes	15	42	****
Pallet Storage for Automatic Forklifts **	40		1	50,000	3.9	200	yes	60	60	
Gravity Storage***	12.1	****	1	2,000	3.9	50	yes	15	42	****
Mobile Shelving System***	12.1	****	1	500	6	16	no	15	42	****
Push-Back Racking***	12.1	****	1	2,000	3.9	50	yes	15	42	****
Honey Comb Storage System*	26		5	4,000	8	28	yes	60	60	
Stacking Cradle Storage System*	14		3	1,000	24	30	yes	20	20	
Automated Block System*	20		5	1,500	12	25	yes	32	34	
Tower Storage System*	25		5	150	14.6	25	yes	30	32	



see Figure 6.23



see Figure 6.24



see Figure 6.25

Figure 7.10: Storage Planning Tables and Figures for ABX' Logistics

7.3.7.3 *Picking System for the ABX Logistics*

In the first stage of the creation of the picking system, the requirements are described in Table 7.14.

Table 7.14: Requirements of the Picking System at ABX

			1. Unimportant	2. Less Important	3. Important	4. More Important	5. Most Important
Performance	a.)	The performance of the picking system is flexible and adaptable to the demand					X
	b.)	The performance of the picking system is described by the picks/hour			X		
	c.)	Minimisation of the distances from the goods that have to be picked				X	
	d.)	Minimisation of the cycle time of each order picking				X	
Ergonomics	a.)	Zero defect strategy at the picking					X
	b.)	Ergonomically placed goods at the picking area					X
	c.)	Reducing the weight of the goods that have to be handled				X	
	d.)	Prevention of the rotary motion of the body with goods			X		
	e.)	Labels at the location of goods are clearly arranged			X		
Quality	a.)	Zero defect strategy					X
	b.)	Identification of mistakes directly at the development					X
	c.)	Closed loop of the quality control				X	
	d.)	Using methods to identify the reasons for problems		X			
Costs	a.)	Low operation costs		X			
	b.)	Low investment budget		X			
	c.)	Low maintenance costs			X		
Flexibility	a.)	Flexible for different products				X	
	b.)	Flexible working time model				X	
	c.)	Flexible organisation of employees				X	
	d.)	Flexible expandability of the picking system				X	
Lean	a.)	Flexible and adaptable to the customers' demand					X
	b.)	Production depending the customers' cycle time					X
	c.)	Synchronisation of the processes					X
	d.)	Pull material flow					X
Replenishment	a.)	Less cross traffic of the picking vehicles and the replenishment vehicles				X	
	b.)	Easy change of empty carriers			X		
	c.)	As little repackaging as possible					X

Figure 7.11 helps to gain a better overview about the picking requirements. The focus on the picking system at ABX is on a lean system that works in the same direction as the customer's order the products. The performance of the picking system must be as flexible as the customer demand. Furthermore, it is necessary to have a high quality at the picking process. The quality in the logistics is, for example, the door-to-door time required to move the goods from the order to the delivery.

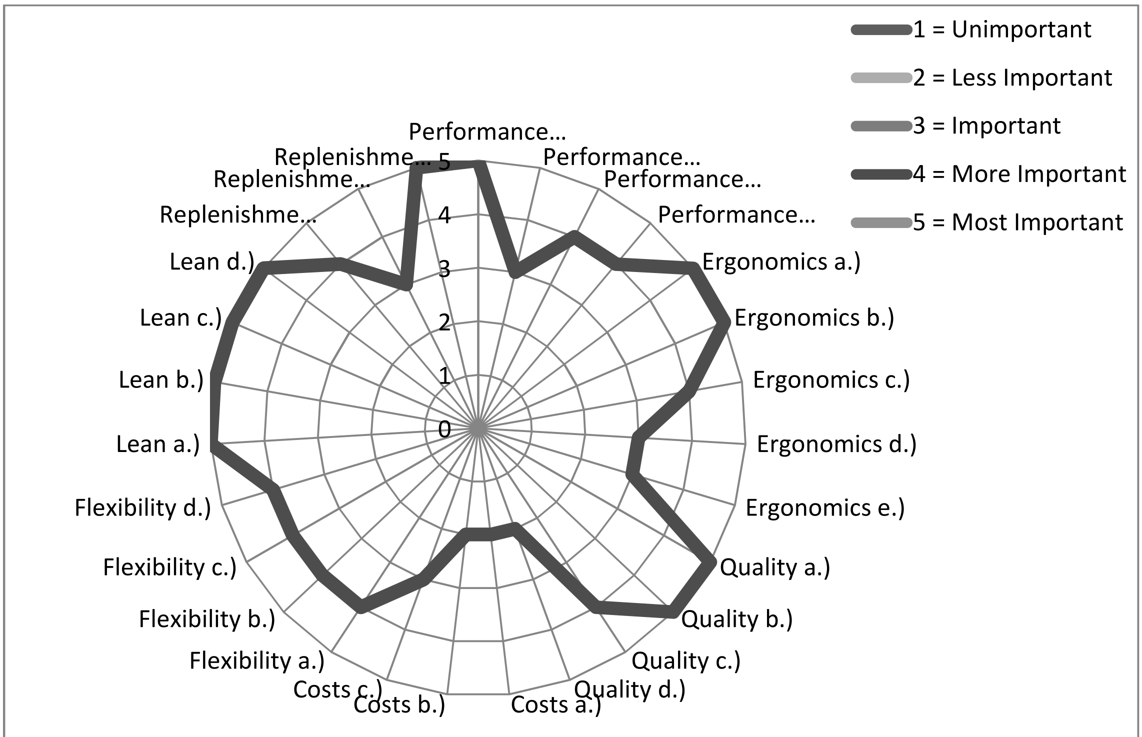


Figure 7.11: Overview to the Picking Requirements at ABX

Structuring of the Picking System

The picking system is shown in Figure 7.12. In the picking process, the focus is on a transparent system. Thus, every important stage of the process is monitored by the ERP-system. Beyond this, the customer can connect to the ERP-system, which is advantageous because the customer can directly check the status of an order. Thus, the customer is informed in case of changes in the delivery schedule.

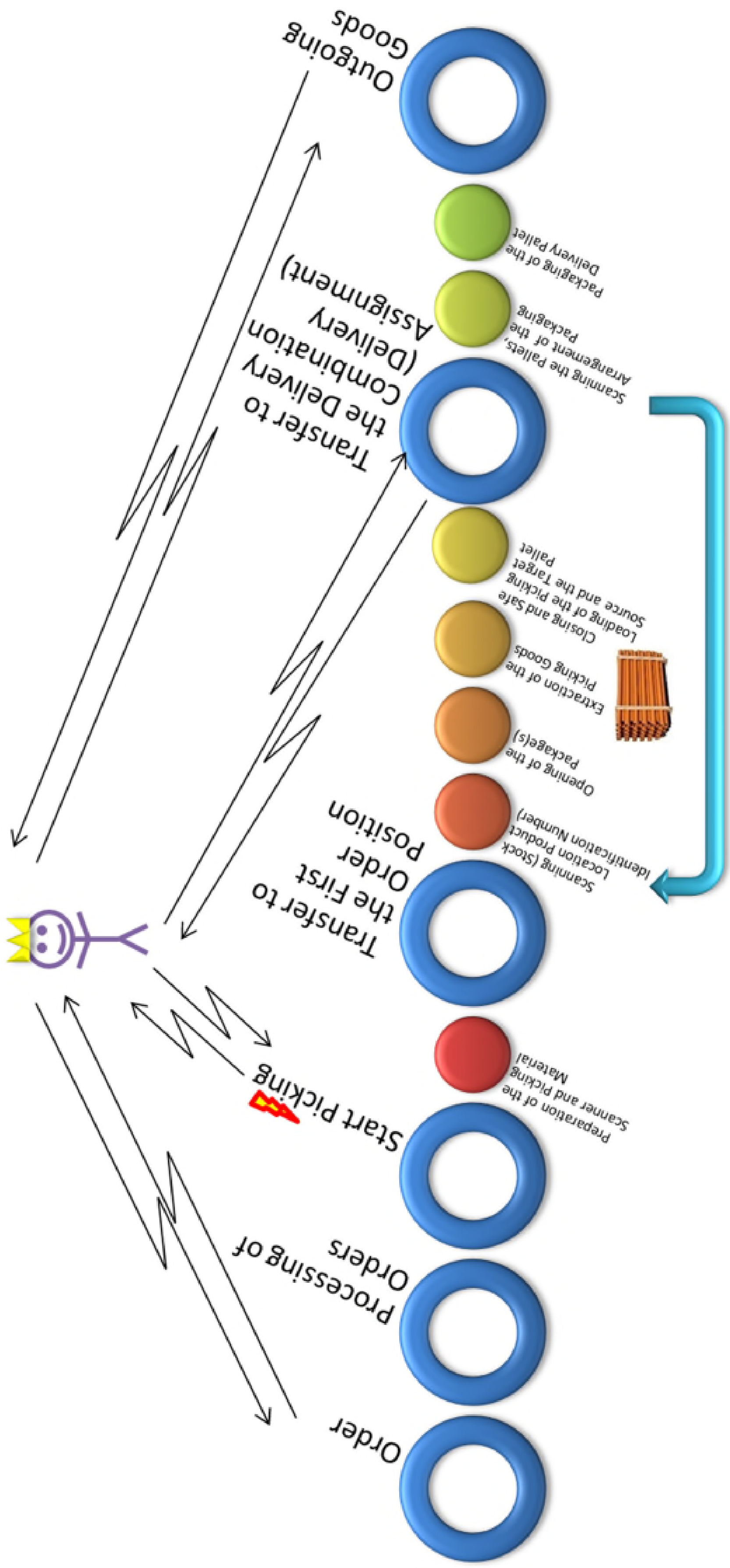
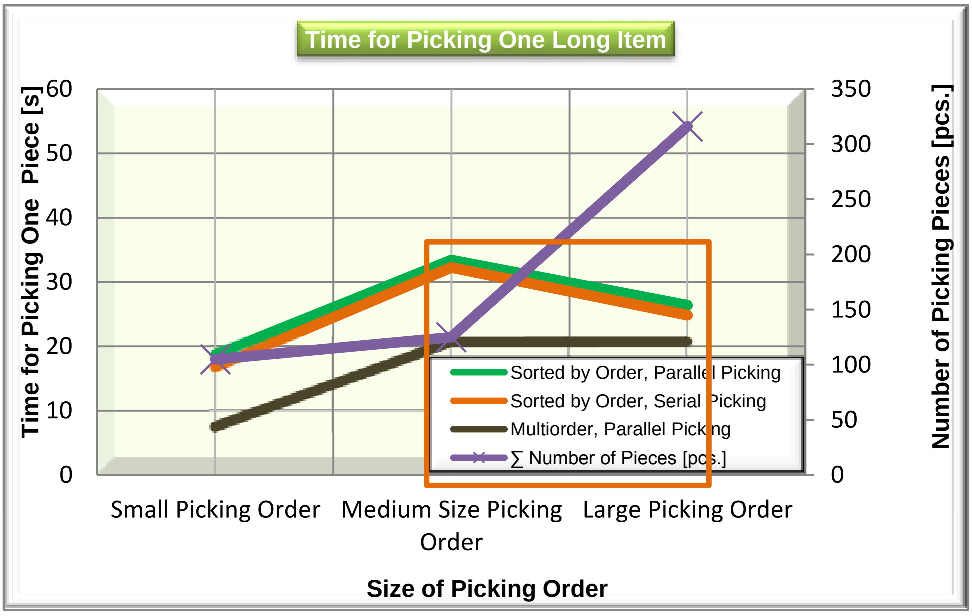
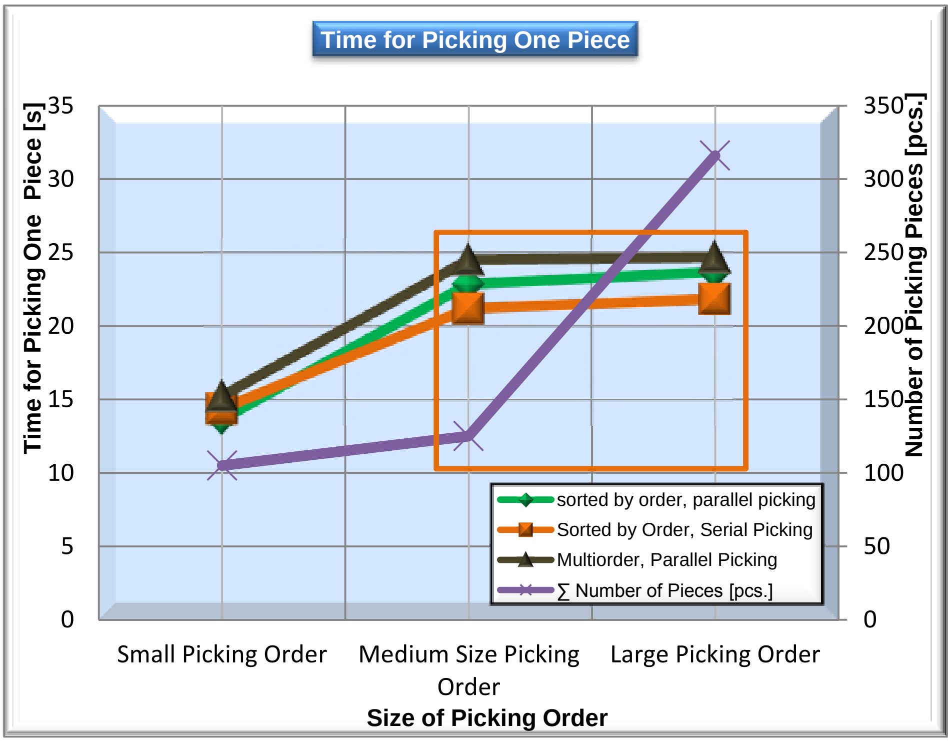


Figure 7.12: Structuring of the Picking System

Three different layouts exist for the block layout of the picking area. These are presented in detail in the chapter 6, entitled “Development and Implementation of a New Framework.” Because ABX supplies wholesalers with products, the delivery size ranges from medium or to large.



See Figure 6.36



See Figure 6.37

Figure 7.13: The Block Layout

In Figure 7.13, the medium and the large orders are marked in orange. If only long items are handled in the logistics system, the multiorder, parallel picking system is to be used (see Figure 6.36). However, ABX' logistics has to transport long items and commercial goods. Therefore, Figure 6.37 is to be used. In this chart the serial picking system that is sorted by order is the most effective. In this picking system, the picking time for a medium-sized picking order is 21 seconds and for a larger order 22 seconds.

7.3.7.4 Outgoing Goods Area

The outgoing goods area and the delivery combination processes are handled by ABZ. At the delivery combination, the pallets for the same customer and truck are combined and compacted in order to ensure a minimum of loading capacity. At the delivery combination area, a maximum of 114 long item pallets and 192 commercial pallets are placed. In order to ensure that the pallets can be combined, no goods are stored in the racks. Thus, the employee can combine the pallets directly. The outgoing material flow is at a distance of 200 metres from truck to rack and commercial forklifts and commercial pallets require 135 s/CP (λ_i^{in}=135s/CP). The limited performance of four-way forklifts in transporting long items pallets is 190 s/LIP (λ_i^{in}=190s/CP). In the outgoing goods area the area for long items has to be created for 87 goods. These 87 (B_{LIP}=87 long item pallets) goods are the maximum number of long items pallets that leave the logistics. Furthermore, at the outgoing goods area 149 commercial pallets (B_{CP}=149 commercial pallets) have to be handled.

7.3.8 Structuring ABX

The whole logistics of ABX is structured by processes. That means that all of the goods use the same incoming area, the same storage, the same picking area, the same delivery combination, and the same loading process. The advantage of this structuring is that no parallel processes exist. Parallel processes are not ideal because it is often difficult to synchronize parallel processes since the process times from different processes are always different and buffers are needed.

7.3.9 The Real Planning of the ABX Logistics

Only in this stage of the planning are the planning restrictions like the connection to the production area at ABX considered. The ideal planning can be realised in a green field planning as long as there are not any restrictions from the local government or legally binding land-use plans. In the case of ABX, no restriction of the legally binding land-use plan exists; however, there are restrictions regarding the production. The restrictions arose at the production planning. The production has to be attached at the logistics building. Therefore, a new variant close to the ideal planning has to be created. The production planning would like to use the area in front of the building for the moulding machines (see Figure 7.14, marked with black and white lines). The goods arrive in the incoming goods area (1) and are split into two long items storages (2) and the commercial goods storage (3). The goods will be transported to the production (4) on the same aisle or path as in the ideal layout. The picking area retrieves goods from the long item storage and from the commercial goods storage (5). Goods from the production area (6) are delivered to the commercial storage and long item storage (7). After the picking, the goods are brought to the delivery combination (8) and to the loading area (9). Afterwards, the transport (10) to the customer starts.

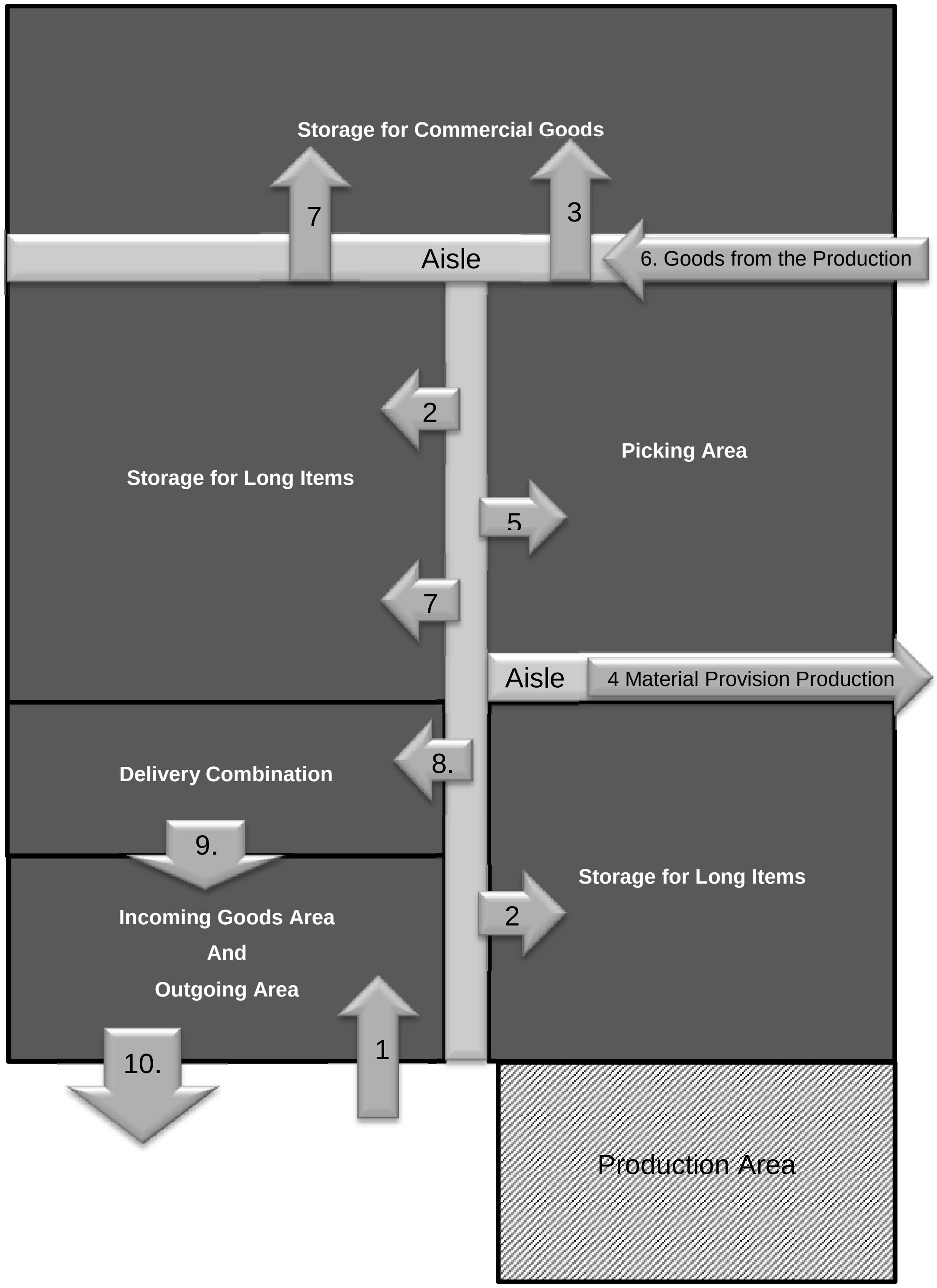


Figure 7.14: Variant II with Amended Production Area

7.3.10 Costs and Investment for the New Logistics at ABX

In Table 7.15, the costs and investments of the different variants are shown. The ideal variant requires an investment of 1,985,000 €. Variant II requires an investment of 2,055,000€. The investment of the Variant II is a little more expensive than the limit set by the management board, which was at 2 million euros.

Table 7.15: Investment and Costs of the New Logistic at ABX

			Ideal Variant	Variant II
Service Life	- Service Life		14,000 €/year	15,000 €/year
	- Operating Hours		2,700 €/h	3;050 €/hour
Investment	- Property		32 €/m²	32 €/m²
	- Building		1,2 million €	1,25 million €
	- Infrastructure		500,000 €	520,000€
	- Equipment		250,000€	250,000€
	- Architects and public authority fees		35,000€	35,000€
Fixed Costs	- Allowance for depreciation		150,000 €/year	150,000 €/year
	- Imputed interest		15%	15%
Variable Costs	- Employees		58 €/hour	58 €/hour
	- Machines		72 €/hour	72 €/hour
	- Energy	> Water	2,00 €/litre	2,00 €/litre
		> Waste Water	3,00 €/litre	3,00 €/litre
		> Gas	0,045€/kwh	0,045€/kwh
		> Petrol	1,4 €/litre	1,4 €/litre
		> Electricity	0,18 €/kwh	0,18 €/kwh
	- Operating Supply Item		18,000 €/year	18,000 €/year

7.3.11 Evaluation of the Criteria

The evaluation of the variants contains two stages. The first stage involves weighting out the evaluation criteria (see Table 7.16). The most important criterion is the "requirements on the packaging." Furthermore, the "information in case of change in delivery date" and the "product quality" are very important. The "costs" and "investments" are not important because ABX thinks that if they have good logistics processes with high quality, the customer will accept a higher price.

Table 7.16: Weighting Out the Evaluation Criteria

	Information on Delivery Date	formation in Case of Change in Delivery Date	Requirements on the Package	Product Quality	Delivery Time	Which Package Material is Preferred	Way to Place an Order	Different Types of Material	Door-To-Door Time	Ergonomic Handling	Well-Known System	Low Incorporation and Job Training Time	Investment	Cost	Fit for Future	Variable Expandable	**Absolut Summation of the Weighting**	**Relative Weighting Order**
Information on Delivery Date	**X**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**11**	**9,2%**
Information in Case of Change in Delivery Date	**1**	**X**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**12**	**10,0%**
Requirements on the Package	**0**	**0**	**X**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**13**	**10,8%**
Product Quality	**0**	**0**	**0**	**X**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**12**	**10,0%**
Delivery Time	**0**	**0**	**0**	**0**	**X**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**11**	**9,2%**
Which Package Material is Preferred	**0**	**0**	**0**	**0**	**0**	**X**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**10**	**8,3%**
Way to Place an Order	**0**	**0**	**0**	**0**	**0**	**0**	**X**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**7**	**5,8%**
Different Types of Material	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**X**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**6**	**5,0%**
Door-to-Door Time	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**X**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**9**	**7,5%**
Ergonomic Handling	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**X**	**1**	**1**	**1**	**1**	**1**	**1**	**6**	**5,0%**
Well-Known System	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**X**	**1**	**1**	**1**	**0**	**0**	**3**	**2,5%**
Low Incorporation and Job Training Time	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**X**	**1**	**1**	**0**	**1**	**3**	**2,5%**
Investment	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**X**	**1**	**1**	**0**	**2**	**1,7%**
Cost	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**X**	**1**	**1**	**2**	**1,7%**
Fit for Future	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**X**	**0**	**6**	**5,0%**
Variable Expandable	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**X**	**7**	**5,8%**

1 = Important

0 = Less Important

In Table 7.17 both variants are evaluated. The ideal planning variant achieves 95of 100 points. Variant II is awarded 89 of 100 points. The fact that the ideal variant achieved almost a perfect score is evidence that it fulfils the customer requirements quite well. Because of this evaluation, the management board of ABX decided to realise the ideal planning variant.

Table 7.17: Evaluation of the Variants at ABX

	Variant Ideal Planning	Variant II	Weighting Order	Weighted Results Variant Ideal Planning	Weighted Results Variant II
Information on Delivery Date	100	100	9.2%	9.2	9.2
Information in Case of Change in Delivery Date	100	100	10.0%	10.0	10.0
Requirements on the Package	90	80	10.8%	9.8	8.7
Product Quality	95	95	10.0%	9.5	9.5
Delivery Time	95	70	9.2%	8.7	6.4
Which Package Material is Preferred	90	90	8.3%	7.5	7.5
Way to Place an Order	100	100	5.8%	5.8	5.8
Different Types of Material	95	95	5.0%	4.8	4.8
Door-To-Door Time	95	75	7.5%	7.1	5.6
Ergonomic Handling	90	90	5.0%	4.5	4.5
Well-Known System	80	80	2.5%	2.0	2.0
Low Incorporation and Job Training Time	80	70	2.5%	2.0	1.8
Investment	100	90	1.7%	1.7	1.5
Cost	100	90	1.7%	1.7	1.5
Fit for Future	100	100	5.0%	5.0	5.0
Variable Expandable	100	85	5.8%	5.8	5.0
Sum				95	89

7.4 ABX' Detail Planning

At the detail planning stage of the ABX logistics, the architect plans are drafted (see Figure 7.15). The architect's plan contains three floors. The upper two floors are the connection to the office building. On the bottom, a large gate is considered for the incoming goods area and for the outgoing goods area. The long item racks are placed on the left side. The rack has the same length as the aisle and the shelving frames can be connected and are flexible to the rack length.

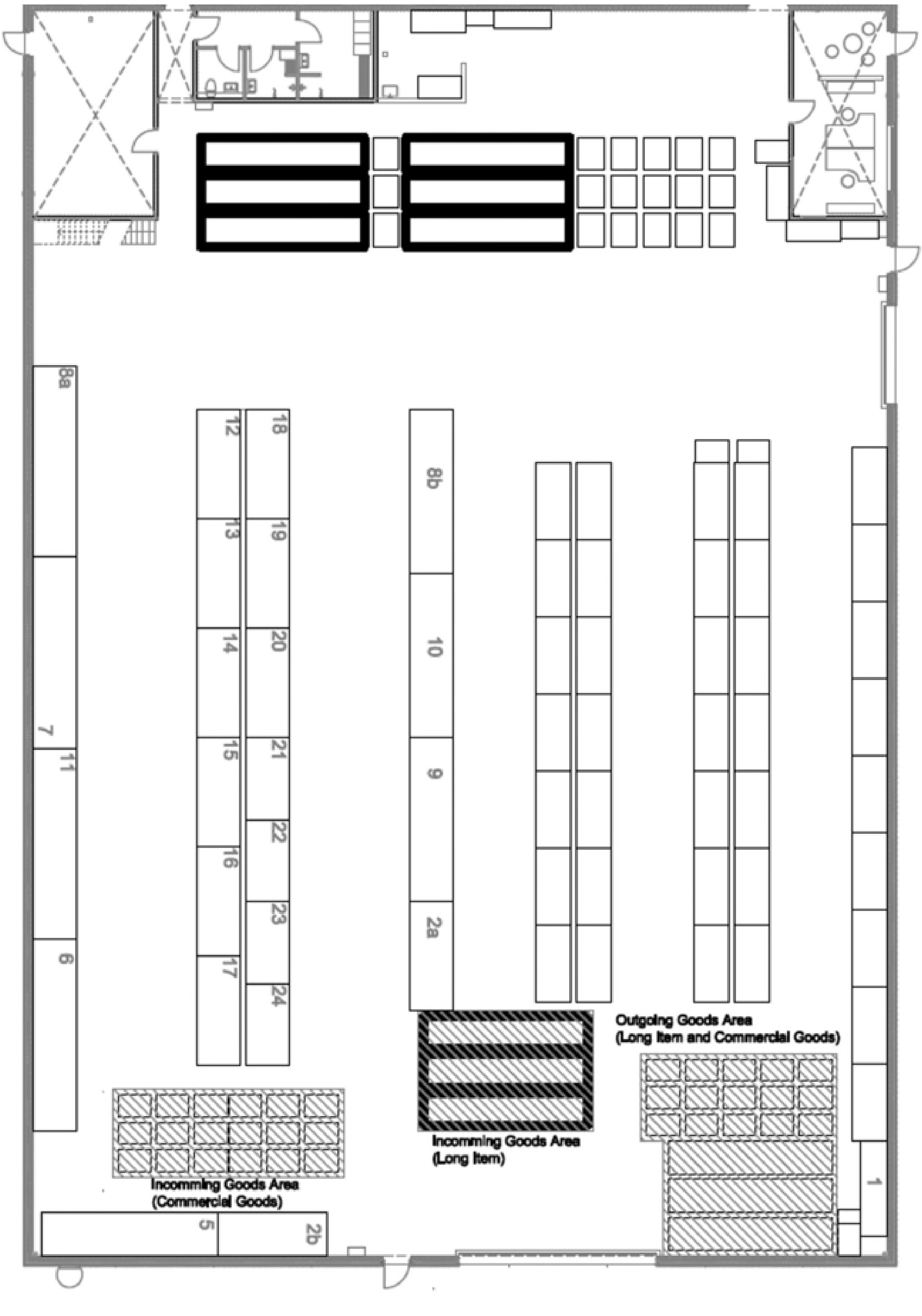


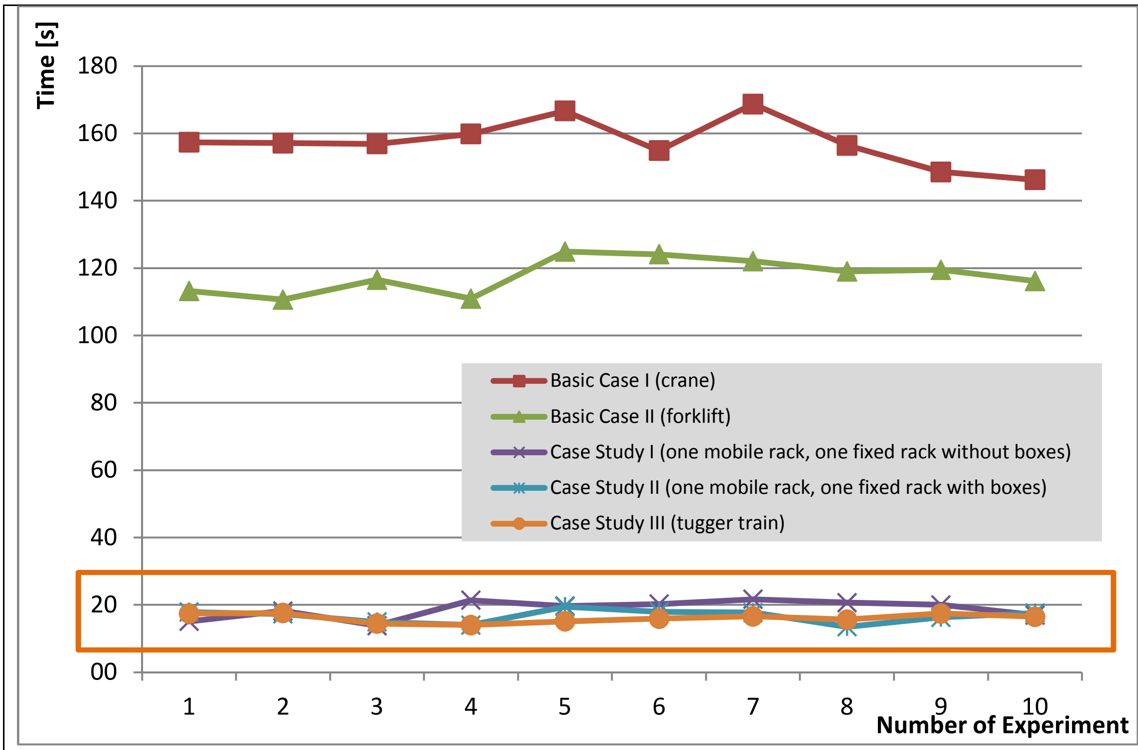
Figure 7.15: Architect Layout for ABX

7.4.1 Transportation of the Goods

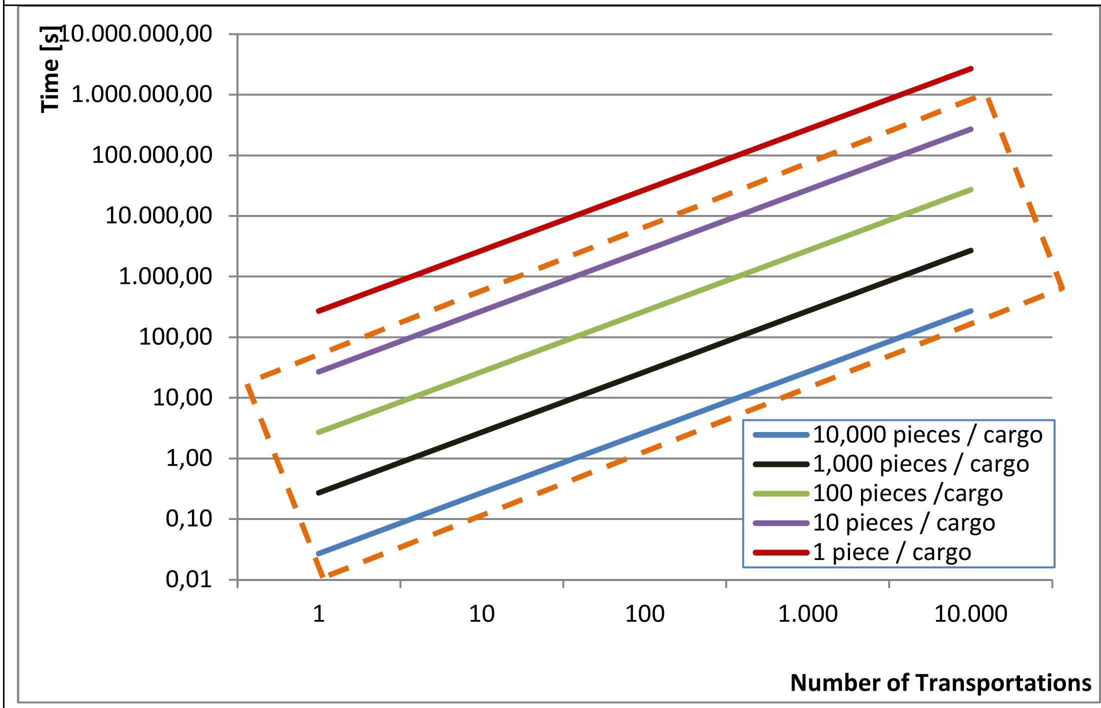
At ABX, all processes are connected using manual transports. At the incoming goods area, picking area, delivery combination area, and the outgoing goods area, forklifts are used to transport the goods. Depending on the processes, special forklifts have to be chosen. Thus, at the incoming goods area and the outgoing goods area, forklifts that can load and unload trucks are used. At the picking area, forklifts are used that are able to pick goods vertically from the shelving units and racks.

Three different types of Minomi have been researched for the provision of commercial and long items pallets, but only the Minomi by tugger train is applicable for these transportation tasks. In Figure 7.16, the findings from the research about the different Minomi types are presented (see Figure 6.48). In this figure, the orange box marks the Minomi types. Because using the Minomi saves a significant amount of time, the Minomi with tugger train is used for the provision of the production and the picking area.

The number of transports is connected with the number of goods that are placed on one cargo. The target of the Toyota production system is to have a one-piece flow. That means if the customer orders one piece, only one piece is produced. The result of a one-piece flow is a minimum stock but maximum of transports (see Chapter 6.4 “Detail Planning”). ABX’ aim is not to install a one-piece flow Instead, it aims to minimise the transports so that the number of goods per cargo is significantly higher. ABX wants to transport at minimum 10 pieces per cargo. This target is marked orange in Figure 7.16 (see Figure 6.50). This has to be considered at the calculation of the box filling.



See Figure 6.48



See Figure 6.50

Figure 7.16: Planning of the Transportation

7.4.2 Information Flow at ABX

The information flow is an important requirement for the customers of the building industry. The customers want to know the status of the order at all times. For this reason, it is necessary to create a completely transparent information flow. Furthermore, it is necessary that the customer have the possibility to check the information. The easiest way to make the information flow transparent for the customers is via ERP. Every process is connected with the ERP-system. Thus, the start and the ending of every process have to be monitored in the ERP-system. Allowing the customer to connect to the ERP-system, the order stage is completely transparent.

7.5 Implementation Planning of the New Logistics System at ABX

The implementation plan of the new logistics system is shown in Figure 7.17. The implementation starts in calendar week 30 in 2013 with the building licence and ends in calendar week 16 in 2014 with the description of the standards (see Figure 7.17). One of the important stages at the implementation planning is the planning of the stabilisation and improvements. It is important to handle the improvements in a standardised way.

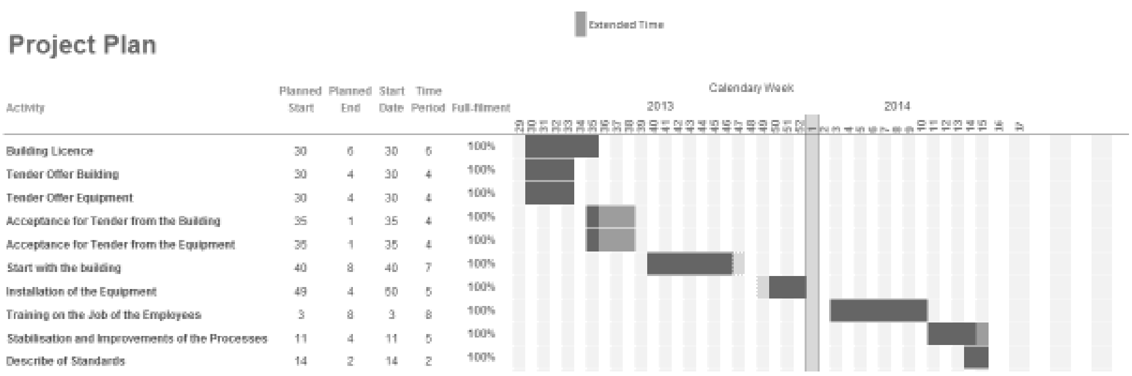


Figure 7.17: Project Plan of the Implantation of the Logistics at ABX

7.6 Implementation of the Logistics System at ABX

The implementation of a new logistics system is one of the critical milestones at the end of the planning process. The planned system has to be implemented in daily life. At the implementation, it becomes evident that three different types of employees exist. The first type of employees is open-minded to a new system and new processes.

These employees support the implementation actively with new ideas. The second type of employees is neutral to the implementation of new logistics system. They do not block the implementation, but they do not promote the implementation either. The third type of employees is very conservative. They are very resistant to the new system. These employees have a selective sense on things that do not work in an ideal way. Thus, they focus on these things and form the opinion that the new system as a whole is poor.

To generate a successful implantation, the idea arises to focus on the improvements that were evident in the case study. It is not be expected that complex planning tasks work perfectly from the beginning once they are implemented. Therefore, the idea is to generate an improvement handling. Thus, all improvements are handled like a little treasure. The message communicated is that improvements are not bad, but good because they help to optimise the logistics system.

In Chapter 6, the improvements are classified into three categories (high, medium and low quality improvements). Every employee is tasked with noticing things that do not work ideally every day for the duration of one month. The duration of one month has been chosen, because this time is needed to detect the aspects that do not work perfectly yet. Furthermore, in the first month after the implementation, every employee is allotted 1.5 hours every day to tend to his/her own improvements. The idea is that every employee has enough time to work on their own improvements and becomes even more familiar with the new logistics system. A given employee is only given additional help if he/she is not able to work on his/her own improvement, for example, in case the support of a craftsman is needed. In the first four weeks, 146 high quality improvements are made to the new system (see Table 7.18).

Table 7.18: Improvements at the Implementation Stage at ABX

	High Quality Improvements	Medium Quality Improvements	Low Quality Improvements
Incoming Goods Area	31	85	128
Storage	14	68	92
Picking	64	107	180
Delivery Combination	28	59	76
Outgoing Goods Area	9	84	30

7.6.1 The Process of Handling Improvement at ABX

All improvements use a standardised process (see Figure 7.18). If an improvement is identified, the head-workman categorises this improvement at high, medium, or low quality. If the quality is low, the improvement is not realised. If the improvement has a medium quality, the employee himself/herself will do the optimisation. If the employee cannot realise the improvement by himself/herself, a craftsman is called in to offer support. If the head-workman categorises the improvement as such of high quality, he/she discusses it with the planner of the logistics system. In this case, the planner has to categorise the improvement as well. If the planner also thinks that it is a high quality improvement, he/she has to check which steps are necessary to implement this improvement and which consequences exist for the whole logistics system by implementing the improvement. If the advantages from the improvement are higher than the disadvantages, the improvement can be realised. The realisation is done by the employee who identified the improvement, the craftsman, and the planner, who monitors its realisation.

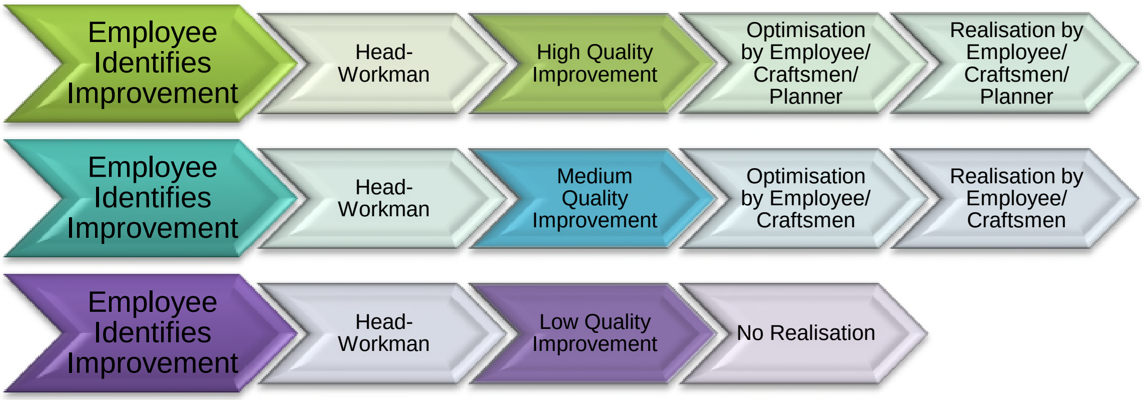


Figure 7.18: Process of the Handling Proposed Improvements

7.6.2 Implementation of Standards Supported by the PDCA-Cycle

With every improvement, it is necessary to monitor if the planned target(s) have been realised. For the succesful implementation and in order to monitor the realised tasks, the PDCA-cycle is helpful and can be used (see Figure 7.19).

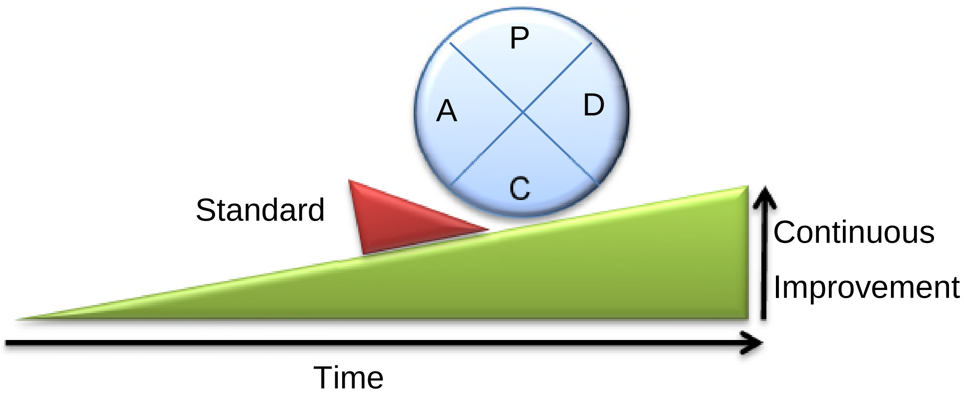


Figure 7.19: PDCA–Cycle (Kostka & Kostka, 2011, p. 34), (Schönsleben, 2007, pp. 911 - 913)

The first stage of the PDCA-cycle is the planning stage (P). At this stage, the improvements are identified, the quality of the head-workman is evaluated, and the realisation is discussed. At the do (D) stage, the improvement is realised. The check (C) stage monitors the realisation. If the realisation is successful, the act (A) stage begins. At this stage, the new standards are defined, which are necessary for a sustainable installation of the improvements.

Every employee has to work with this standard until the next improvement is identified and implemented. The improvement process is not successful if the results at the check stage are not satisfactory. In this case, the PDCA-cycle starts at the beginning at the planning stage (P). The PDCA-cycle is repeated as long as it is necessary to achieve satisfactory results.

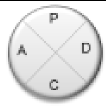
7.6.3 The Necessity of the Visualisation of the Improvements

It is very important to visualise every identified improvement. The visualisation has three tasks. The first task is to make the improvement visible and understandable using the help of a card (see Table 7.19). This need was identified at the implementation stage because it was difficult to handle the improvements only on the computer. Because not every employee has access to and the knowledge necessary to work with a computer, the second task is to write the improvements on large boards on the shop floor.

The problem on the shop floor boards was that the employees forgot to go to the board and to check the activities and work on the improvements. Thus, the third task was to create an improvement card. The employee has to write the improvement card. This card always stays with the employee. A copy is made at the start of the PDCA-cycle and this copy is put on a board on the shop floor. Every day, a team meeting takes place and the progress of the improvement is checked. Thus, the employee has all of the needed information on paper and in his/her possession.

The daily meetings are necessary in order for the improvements to progress quickly. Any given improvement card should be finished after at most four weeks. If the employee recognises that his/her improvement is implemented, he/she becomes more and more motivated to generate new ideas for improvements and implement them. This was the experience at the implementation of the logistics system at ABX.

Table 7.19: Improvement Card at ABX

<table>
<tr><td colspan="7">Improvement Handling Card</td></tr>
<tr><td colspan="2">Improvement Name:</td><td colspan="3"></td><td>Quality of the Improvement:</td><td>Mark the PDCA Stage:</td></tr>
<tr><td colspan="2">Description of the Improvement:</td><td colspan="3"></td><td>High Quality
Medium Quality
Low Quality</td><td></td></tr>
<tr><td colspan="2" rowspan="2"></td><td rowspan="2">Activity Description</td><td rowspan="2">Name of the Executive Employee</td><td rowspan="2">Date of Realisation</td><td colspan="2">Is the Activity Successful?</td></tr>
<tr><td>Yes</td><td>No</td></tr>
<tr><td rowspan="3">Activities at the Planning Stage:</td><td>1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Activities at the Do Stage:</td><td>1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Activities at the Check Stage:</td><td>1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Activities at the Act Stage:</td><td>1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

7.6.4 Monitoring the Progress of the Implementation

The progress of the implementation has to be monitored every day. At ABX, the investments, improvements, and the process implementation are monitored to check if all activities are in schedule. The everyday monitoring is chosen to make it possible to react quickly in case problems or deviations from the description of the planned system arise.

The monitoring of the implantation progress is also conducted on the shop floor. If a discrepancy from the planned logistics system is identified that cannot be solved with the improvement process, a Kaizen workshop is made. The Kaizen workshop is a method from the Toyota Production System. It is a method to improve processes and to eliminate waste. The Kaizen workshops from Toyota are scheduled for one week (five working days). On the first day, the problem or improvement is analysed. On the second and third days, solutions for the problems are generated. On the fourth and fifth days, the favourite solution is realised. At the end of Day 5, the realisation is presented to the management board. After the Kaizen workshop, the problem is solved and the improvement can be used in daily work.

For ABX, the Kaizen from Toyota is used as example. However, the Kaizen workshops at ABX that are made at the implementations are only scheduled for three days. Day One is used for the analysis of the problem or improvement and to generate different solution variants. To have a clear focus, ABX limited the number of solutions to three. On the second and the third day, the solutions are realised. On the third day, the solutions are also presented to the management board.

At the implementation, seven Kaizen workshops are conducted. Two of these are in the picking area, two in the incoming goods area, two in the delivery combination area, and one in the outgoing goods area. The team that is involved in the Kaizen workshop comprises one planner of the logistics system, two employees from the process, one craftsman for the realisation, and one neutral person that is not involved in the process. The neutral person is important for a neutral perspective to the tasks and to the solutions.

7.6.5 Key Factors for a Successful Implementation Process

At the implementation of the logistics system at ABX, six key parameters for a successful implementation are identified (see Figure 7.20). The first key parameter is the improvement of the processes with the employees. If the employees can work in a system they have developed by their own, the motivation for working with the new system increases. The second key parameter is monitoring the implementation progress. A daily monitoring of the schedule, investments, and improvements helps to identify problems at an early stage.

Thus, optimisations, improvements, and Kaizen workshops can be used to solve the problems. Another important point is the appreciation of the work at the implementation. The implementation of a new logistics system means additional work for the employees. Furthermore, at the implementation, they have to work with a system with problems and with standards that are defined the first time. The system is not fully developed. To estimate this work at the implementation, gifts for improvements or the participation of Kaizen workshops should be given to the employees. For high quality improvements or for additional work on the weekend, extra money has to be paid. Another basic factor is that during the Kaizen workshops, the focus is on simple improvements for days so that the results are always excellent. However, reaching these findings is very important for the team.

Another key factor is the motivation of the employees at the implementation. Thus, the planner and the head-workman must have an intuition regarding whether or not the employees are satisfied with the processes or if they have to coach the employees to make improvement cards or plan a Kaizen workshop.

The last key factor is to present the results of the implementation to everybody on a shop floor board. Beyond this, it is helpful to create some kind of traffic lights for the implantation schedule, implementation invest, the performance, and capacity of the day. Thus, every employee can see if the traffic lights are green, everything is fine.

If the lights are yellow, further actions have to be planned. If the lights are red, the criteria, e. g. the investment, is wrong and activities are started for the improvement. By considering these six parameters, ABX’ logistics system is installed in the planned schedule. At the implementation, no troubleshooting was necessary because the implementation and the planning were clear and transparent for the employees. Thus, the employees are motivated to work in a new logistics system.

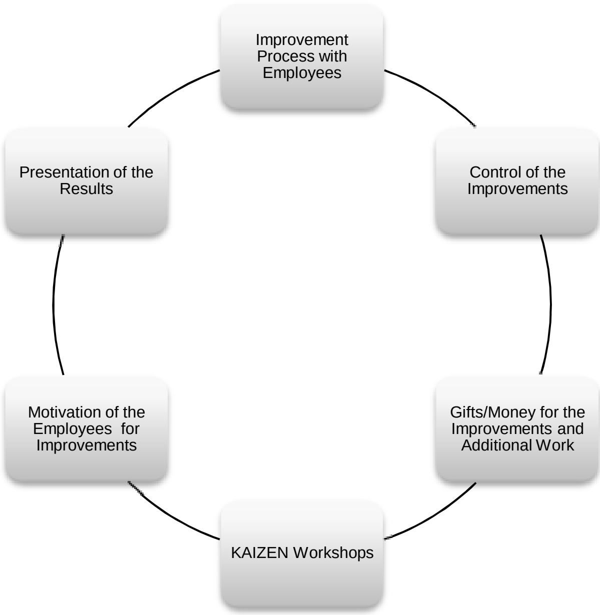


Figure 7.20: Key Parameters for a Successful Implementation of a Logistics System

7.7 Chapter Summary

At the planning of the ABX logistics, the planning framework for the long item logistics planning was used. The application of the planning framework has shown that precise data at the beginning of the planning process had a positive effect on the time schedule since previous process stages do not have to be repeated. The preliminary planning was much more precise and therefore needed more time in comparison to existing planning frameworks.

At the structure planning the big advantage arose, that the analysed data has already been evaluated and was usable for the structure planning. This planning stage focuses on the ideal planning. In derivation to the ideal planning, the value stream and further calculations were carried out. At the ideal planning only the ideal process was planned. Restrictions because of old processes or habits from old processes have not been considered. The calculations of the value stream and employee demand etc. based on the ideal planning confirmed that the ideal planning should be realised. Almost at the end of this planning stage, restriction was considered at the real planning as a part of the structure planning. Because the real planning is executed at the end of the structure planning, the thinking in an ideal way with a minimum of waste has become manifested in the minds of the planners. This lead to the result that the real planning was very close to the ideal planning. Furthermore, at the structure planning many useful figures from this thesis supported the planning process and the equipment planning in a positive way. Because of the precise basic data and the planning charts, a fast structure planning could be carried out. Only a small number of repetitions was necessary. The planning variants were quite similar because they are very close to the ideal planning. Therefore, the decision for one variant at the end of the structure planning was possible.

The detail planning at the ABX started with one variant. Besides, in this planning stage, the precise planning at the previous planning stages supported the transport planning and the information flow planning enormously. Since the customers require a transparent information flow, all information flows are controlled by an ERP-system. The ABX uses SAP. Every process and storage, where a long item is located, has been captured at SAP. Furthermore, the customers are connected to SAP. Because of this, all processes are completely transparent for the customer, if they have access to SAP themselves. Another advantage of using the ERP-system is the traceability. SAP also helps in case of mistakes to relocate the charge and support the quality processes.

At the implementation planning, the schedule, time and cost plans were developed and the training needs of the employees have been evaluated. This was the first time for the ABX to plan an implementation in detail.

At the implementation of the new logistics system of the ABX trainings have been carries out. The training time for the employee had to be extended because the new processes were quite different to the old processes and therefore more training was needed than it was planned. But the employees had a positive attitude towards the training of the new processes. The feedback of the employees was consistently positive. Furthermore, the continuous improvement process was new for the ABX in this form. By classifying the improvements, the high-quality improvements have been identified and implemented as far as possible. The ABX logistics already had an improvement system but the old improvement system has not been applied by the employees because nobody was interested at improvements. But while the improvement system was implemented, the new logistics system was brought back to work.

The overall summary of the long item logistics planning for the ABX was consistently positive. The planning of the new logistics has been conducted precisely and fast. The investments, schedule and quality has been observed throughout the planning stages. Furthermore, the planner who were directly involved at the planning were very satisfied to work with this new planning framework. Moreover, it was established to use the figures consequently that help at the daily planning, e.g. the calculation of the employee demand at the incoming goods area. The feedback of the master craftsman at the logistics was that this figures are easy to handle and precise in the results.

In summary, the case study has shown that the new framework can be practically used for the planning of logistics that handle long items and commercial goods. This framework can also be used to plan all kinds of in-house logistics processes from the incoming goods, storage, picking, delivery combination areas and through to the outgoing goods area.

Chapter 8 Conclusions and Further Work

8.1 Conclusion

The overall aim of this PhD project was to create a new framework for creating efficient and cost-effective logistics chains for long items. The building industry handles many long items such as pipes, profiles and so on. The handling of these long items is quite complicated and difficult because they are bulky, unstable and heavy. So it is not cost effective and efficient to handle them manually. Existing planning frameworks ignore these special requirements of such goods. In addition, the existing logistics systems are not planned for handling these goods. That leads to that many additional manual handling steps are currently required to handle long items. Therefore, it is very important to develop a new framework for creating the efficient and cost-effective logistics chain for long items. In this thesis, such a new framework has been proposed, designed and developed. There are three research objectives in this project. The main achievements for these objectives are as follows:

(1) The first objective of the research was to identify special requirements of the long items logistics. Long items are often handled together with commercial goods. So, processes have to be flexible to handle both types of goods. To achieve this objective, the expert interview was carried out and it revealed that requirements of dealing with how information is transmitted are very important for the customers. Besides, the requirements on the package and the product quality are also important. The package quality is more important than the product quality because on the building site, the package supports the handling. For example, a stable packaging is used to handle goods by crane. Moreover, many goods are stored outside of a building, so the packaging must be weather resistant. The product quality is only the fourth important requirement as far as the customer is concerned because the goods are cheap and little damages on the surface of the goods are often accepted. This is because long items are often cut for the installation and the damaged surface can therefore be removed. Another

reason is that these long items are raw building materials that will not be visible in the finished product.

(2) The second objective is to develop a new framework for designing and developing the logistics processes for in-house long item logistics operation. To understand why current planning frameworks are not suitable for planning long item logistics systems, the existing logistics planning frameworks have been analysed and evaluated using the SWOT analysis. The findings of the SWOT analysis constitute new possibilities that have to be considered in the creation of the new planning framework. The existing frameworks have been investigated to determine if the customer requirements are considered. It has been found that the information flow was almost unattended in the existing framework. Furthermore, planning calculations for long item equipment, such as the storage planning or picking planning for long items were not considered at all in existing planning frameworks, but they should be incorporated into the new framework. The customer's planning requirements and the results of the evaluation of the current planning framework serve as the basis for the new long item planning framework.

This new framework has five stages. These are the preliminary planning, structure planning, detail planning, implementation planning, and implementation. One general requirement of the new planning framework is that at the beginning, the data quality that is used for planning must be high. A high data quality helps to achieve a good planning reliability from the very beginning. A high planning quality is necessary because the iteration steps are much smaller. The new framework also contains the whole structure planning in an ideal way. Many planning figures are developed and can be used for the long items process planning. For example, the figures are created for planning a storage for long items. At the end of the structure planning, variants of the real planning are made. At this point, it is necessary to decide which variant should be planned in detail. Because of this decision, the detail planning only deals with one variant. At the end of the detail planning, the architects plan is drawn up and the equipment can be ordered.

The implementation planning also contains the resources planning and transition period planning. One new main aspect of the new framework is the focus on the on-the-job training. This training is essential when implementing a new logistics system. The planned processes can only work efficiently if they can be communicated to the employees working on the process.

Another new main aspect of the implementation planning is to include standards for a given job, task, or stage in the process. Every process must be equally effective, even when employees change. Thus, it is necessary to create standards.

(3) The third objective is to identify, evaluate and optimise key factors of the implementation of a cost-effective sustainable in-house logistics system for long items.

In the implementation stage, the focus of the new framework is on the key factors of a successful implementation. In the research, six different elements help to ensure a successful implementation. One of these useful key elements is involving the employees in the implementation. It could be identified that the employees' attitudes are very positive to a new logistics system if their own improvements are considered. At the implementation, only little improvements like the location of the equipment on the working bench or the changing of little process parts are made. But these little improvements increase the effectiveness of the system and the employees notice that they have improved the logistics system. Therefore, they have a positive attitude.

8.2 Contributions to the New Knowledge Generation

It is believed, that this PhD project has made 11 contributions to the new knowledge generation, as follows:

(1) The first contribution is the new framework for creating efficient and cost-effective logistics chains for long items: This project designed and developed a cost effective and efficient logistics chain for long items. This new framework considers the special requirements of long items and presents a possibility to create logistics chains for long items which are adaptable in practice. A further benefit is that the planning time and the planning costs are reduced. The process planning within the structure planning can be made in less than one day.

(2) The second contribution is proposition of the data collection and the data evaluation at the preliminary planning: The thesis demonstrates the advantages of collecting and evaluating data in this planning stage. So, the project presents new knowledge about the data management. The advantage of collecting data at this early planning stage is that repetitions are not necessary in the following planning stages. So, this is a way to eliminate waste.

(3) The third contribution is the decision for one planning variant already at the end of the structure planning: The structure planning is optimised by using the precise data from previous process stages. The new approach is to make a decision for one planning variant and therefore to save time and costs in further planning stages.

(4) The fourth contribution is the analysis and evaluation of customer requirements: This project presents the customer requirements from all parts of the logistics chain of the building industry and differentiates the requirements according to their importance. It is the first time that customer requirements have been analysed and evaluated precisely in terms of planning long item logistics chains. This knowledge about the

customer requirements can also be used in other logistic planning frameworks.

(5) The fifth contribution is the full consideration and implementation of the customer requirements in the new framework: The thesis points out the importance of considering customer requirements in all process stages. Furthermore, the reasons have been analysed and presented why certain requirements exist and how they have to be considered at planning long item logistics chains.

(6) The sixth contribution is the creation of figures and tables as planning guideline: The thesis presents the created figures and tables and demonstrates how they have to be applied. Thus, the knowledge is enriched about the planning guidelines as a practical adaptable help for daily process planning tasks.

(7) The seventh contribution is the research and further development of Minomi with regards to long items: The project presents different kinds of Minomi and reveals their scope of application. It is shown that the material provision is possible with a minimum of handling steps and only with gravity roll conveyor but without sensors or other kind of electric and electronic parts.

(8) The eighth contribution is the research on the information flow: The thesis demonstrates the importance of a transparent information flow and shows the connection to the customer requirements at long items logistics chains. The traceability is revealed to be a very important aspect at long item handling. So, the knowledge is enriched about the fact that the information flows is a very important aspect and how the information flow has to be designed, that the transparency and traceability are achieved.

(9) The ninth contribution is the research of different picking systems. The most suitable picking system can be chosen depending on the

picking order, the arrangement of the layout of the picking system, and the picking procedure.

(10) The tenth contribution is the classification of the improvements and the improvement handling at the implementation: The thesis presents a classification of improvements which leads to a successful improvement handling. In addition, the thesis presents new knowledge about the successful improvement handling at the implementation stage.

(11) The eleventh contribution is the identification of key parameters for a successful implementation of the planning framework: The project shows, which key parameter exist and how they can be considered at the implementation of the framework.

(12) The thesis shows which elements of this planning framework can be used at other planning frameworks that are applied in company planning or logistics planning. For example, this thesis shows that the Minomi concept can be used in each material provision process with a large number of repetitions.

8.3 Further Research

Due to the time and resource limitation, there are some areas that could be done to improve the quality of this PhD project.

(1) One area is to explore the manual long item storages and their capabilities. For the manual storing of long items, only two storage types currently exist. These are the block storage and the cantilever rack. These two storage types are very simple and adaptable for all kind of goods, but not exclusively adapted to the long items. Thus, further work should be done to decide which requirements support an ideal storage for long items. Furthermore, new storage types should be developed as well.

(2) Another research area is the equipment used for transporting the long items. Again, only limited solutions are currently available for transporting long items. Currently, only commercial forklifts and four-way forklifts exist for the manual transport of long items.

(3) Thus, a further research area would be to determine if the current planning frameworks effectively plan currently existing commercial goods. Furthermore, future research could be done to examine whether the framework developed for long items is also applicable to other logistics areas, such as the wood industry or the nuclear industry, such as to transport nuclear fuel rods. Theoretically, it would be suitable for any logistics that handle a variety of long items.

Bibliography

Abels, G. & Behrens, M., 1998. ExpertInnen-Interview in der Politkwissenschaft. Das Beispiel Biotechnologie. *Österreichische Zeitschrift für Politikwissenschaft*, Issue 27, pp. 131-143.

Aggteleky, B., 1987, 1990, 1990. *Fabrikplanung - Werksentwicklung und Betriebsrationalisierung.* 1 - 3 ed. München: Carl Hanser Verlag.

Ahlrichs, R., 2012. *Zwischen sozialer Verantwortung und ökonomischer Vernunft.* 1 ed. Wiesbaden: Springer Fachmedien.

Alicke, K., 2005. *Planung und Betrieb von Logistiknetzwerken.* 2 ed. Berlin Heidelberg: Springer-Verlag.

Arnold, D. & Furmans, K., 2009. *Materialfluss in Logistiksystemen.* 6 ed. Berlin, Heidelberg: Springer Verlag.

Atech-Pipes GmbH, 2013. Ruhstorf: Atech-Pipes GmbH.

Binder, C., 2006. *Die Entwicklung des Controllings als Teildisziplin.* 1 ed. Wiesbaden: GWV Fachverlage GmbH.

BITO-Lagertechnik Bittmann GmbH, 2013. *BITO PROflow, Palettendurchlaufregal der neuesten Generation.* 1 ed. Meisenheim: Bittmann GmbH.

Bornhäuser, M., Kirchner, S. & Reinerth, H., 2003. Methodik für eine vorausschauende Logistikplanung. *Werkstattstechnik online,* age - group 93(edition 3), pp. 172 - 177.

Bracht, U., Hackenberg, W. & Bierwirth, T., 2011. Monitoringansatz für die operative CKD-Logistik; Effizienzsteigerungen durch optimierte Informationsflüsse mit Elementen der Digitalen Fabrik. *wt Werkstattstechnik online,* 101(3), pp. 122 - 127.

Britzke, B., 2010. *MTM in einer globalisierten Wirtschaft, Arbeitsprozesse systematisch gestalten und optimieren.* 1 ed. München: mi - Wirtschaftsverlag.

Brockhaus_a, 1972. *Brockhaus Enzyklopädie volume 15.* 17 ed. Wiesbaden: Brockhaus F.A..

Brockhaus_b, 1969. *Brockhaus Enzyklopädie volume 7.* 17 ed. Wiesbaden: Brockhaus F.A..

Brockhaus_c, 1968. *Brockhaus Enzyklopädie volume 6.* 17 ed. Wiesbaden: Brockhaus F.A..

Brockhaus_d, 1970. *Brockhaus Enzyklopädie volume 10.* 17 ed. Wiesbaden: Brockhaus F.A..

Buber, R. & Holzmüller, H. H., 2009. *Qualitative Marktforschung.* 2 ed. Wiesbaden: Gabler GWV Fachverlage GmbH.

Bücheler, C., 2014. *Geschäftsführer Transco Süd Internationale Transporte GmbH* [Interview] (05 May 2014).

Bünting, K. D. & Karatas, R., 1996. *Deutsches Wörterbuch.* 1 ed. Chur (CH): Isis Verlag.

Clavell, J., 1988. *Die Kunst des Krieges.* 1 ed. München: Droemer Knaur.

Corsten, D. & Christoph, G., 2004. *Supply Chain Management erfolgreich umsetzen.* 2 ed. Berlin: Springer - Verlag.

Creswell, J. W., 2009. *Research Design.* 3 ed. Los Angeles, London, New Delhi, Singapore: Sage.

Dambach Lagersysteme GmbH & Co. KG, 2013. *Flexibilität beim Lagern und Kommissionieren: Schienengeführte Regalbediengeräte.* 1 ed. Bischweier: Dambach Lagersysteme GmbH & Co. KG.

Dickmann, P., 2009. *Schlanker Materialfluss, mit Lean Production, Kanban und Innovationen.* 2 ed. Berlin, Heidelberg: Springer-Verlag.

Dittrich, M., 2002. *Lagerlogistik.* 2 ed. München, Wien: Carl Hanser Verlag.

Doblhammer, G., 2004. *Beobachtung Inhaltsanalyse,* Rostock: Universität Rostock.

DOLL Fahrzeugbau AG, 2014. *3-Achs Sattelauflieger Logo 12,* Oppenau: DOLL Fahrzeugbau AG.

Dombrowski, U. & Hennersdorf, S., 2010. Systematische Methodenauswahl in der Fabrikplanung. *Werkstattstechnik online,* edition 100(4), pp. 234 - 341.

EISENMANN Anlagenbau GmbH & Co. KG, 2008. *EISENMANN.* [Online] Available at: http://www.eisenmann.com/de/produkte-und-services/conveyor-systems/elektrobodenbahnsysteme/produkt.html
[Accessed 07 April 2013].

EnBW Kernkraftwerk GmbH, 2014. *EnBW Kernkraftwerk GmbH.* [Online] Available at: http://www.enbw.com/unternehmen/konzern/energieerzeugung/kernenergie/technik.html
[Accessed 03 May 2014].

EPSILON Kran GmbH, 2014. *Holzwirtschaft,* Elsbethen-Glasenbach (AT): EPSILON Kran GmbH.

Erlach, K., 2010. *Wertstromdesign.* 2 ed. Berlin, Heidelberg: Springer - Verlag.

Ernst, S., 2010. *Prozessorientierte Methoden in der Arbeits- und Organisationsforschung.* 1 ed. Wiesbaden: Springer Fachmedien Wiesbaden GmbH.

Felix, H., 1998. *Unternehmens und Fabrikplanung.* 1 ed. München: Carl Hanser Verlag.

Flick, U., 2000. *Qualitative Forschung. Theorie, Methoden, Anwendung in Psychologie und Sozialwissenschaften.* 5 ed. Hamburg: Rowohlt.

Geberit AG, 2003. *Der Geberit.* Jona (CH): Geberit AG.

Gleißner, H. & Femerling, J. C., 2008. *Logistik; Grundlagen - Übungen - Fallbeispiele.* 1 ed. Wiesbaden: GWV Fachverlage.

Göpfert, I., Braun, D. & Schulz, M., 2012. *Automobillogistik; Stand und Zukunftstrends.* 1 ed. Wiesbaden: Gabler Verlag.

Graf, A., 2008. *Geschäftsmodelle.* 1 ed. Wiesbaden: GWV Fachverlage GmbH.

Gregersen, J., 2011. *hochschule@zukunft 2030.* 1 ed. Wiesbaden: VS Verlag.

Greiner, R., Su, X., Shen, B. & Zhou, W., 2005. Structural Extension to Logistic Regression:. *Machine Learning,* 59(59), pp. 297 - 322.

Grundig, C. G., 2013. *Fabrikplanung, Planungstechniken - Methoden - Anwendungen.* 4 ed. München: Carl Hanser Verlag München.

Gschwend, T. & Schimmelfennig, F., 2007. *Forschungsdesign in der Politikwissenschaft.* 1 ed. Frankfurt/Main: Campus Verlag GmbH.

Gudehus, T., 2005. *Logistik; Grundlagen, Strategien, Anwendungen.* 3 ed. Berlin, Heidelberg: Springer - Verlag.

Gudehus, T., 2012. *Logistik; Netzwerke, Systeme und Lieferketten.* 4 ed. Berlin Heidelberg: Springer Verlag.

Günthner, W. A., Galka, S. & Ulbrich, A., 2010. Planung und Auswahl von Kommissioniersystemen. In: B. Britzke, ed. *MTM in einer globalisierten Wirtschaft.* München: FinanzBuch Verlag GmbH, pp. 201 - 220.

Günthner, W. A., Ulbrich, A. & Galka, S., 2009. *Präsentation: Auf der Suche nach dem richtigen Kommissioniersystem, Methoden für die Planung und Auswahl.* Osnabrück, Technische Universität.

Harder, V., 2008. *Lager- und Materialflussplanung.* 1 ed. Saarbrücken: VDM Verlag.

Harms, T., Lopitzsch, J. & Nickel, R., 2003. Integrierte Fabrikstrukturierung und Logistikkonzeption. *Werkstattstechnik online,* edition 93(4), pp. 227 - 232.

Hauptkatalog SSI Schäfer Noell GmbH, 2012. *Alles AUS EINER HAND, Effizienzsteigerung mit System für Lager, Betrieb und Werkstatt. Auszug aus dem Hauptkatalog 2012 Kapitel D.* s.l.:SSI Schäfer Noell GmbH.

Hobel, B. & Schütte, S., 2006. *Business - Wissen A - Z Projektmanagement.* 1 ed. Wiesbaden: GWV Fachverlage GmbH.

Holztransporte Muffler, 2014. *Holztransporte Muffler.* [Online] Available at: http://www.holztransporte-muffler.de/holz-transport.htmlv [Accessed 01 May 2014].

Huang, H.-Z.et al., 2011. Evaluation and decision of products conceptual design schemes based on customer requirements. *Journal of Mechanical Science and Technology*, 25 September, pp. 2413 - 2425.

HUBTEX Maschinenbau GmbH & Co. KG, 2014. *www.hubtex.de / Schubmaststapler.* [Online]
Available at: http://www.hubtex.com/english/downloads1/prospekte.html [Accessed 05 January 2013].

Isermann, H., 1998. *Logistik, Gestaltung von Logistiksystemen.* 2 ed. Landsberg/Lech: Verlag moderne Industrie AG.

Jacob, R., Heinz, A., Décieux, J. P. & Eirmbter, W. H., 2011. *Umfrage.* 2 ed. München: Oldenburg Wissenschaftsverlag GmbH.

Jungheinrich AG, 2014. *www.jungheinrich.de.* [Online] Available at: http://www.jungheinrich.de/flurfoerderzeuge/schubmaststapler/etv-q20q25/
[Accessed 11 January 2014].

Jungheinrich Vertrieb Deutschland AG & Co. KG, 2013. *Datenblatt ETV / ETM 214 / 216 Elektro - Schubmaststapler (1,400 / 1,600).* 1 ed. Hamburg: Jungheinrich Vertrieb Deutschland AG & Co. KG.

KAISER+KRAFT GmbH, 2014. *Kaiser+Kraft.* [Online] Available at: http://www.kaiserkraft.de/lagereinrichtungen/gitterboxen-stapelbehaelter/langgutgestell-mit-4-eckpfosten/p/M3180/
[Accessed 04 January 2014].

Kasto Maschinenbau GmbH & Co. KG, 2014. *www.kasto.com.* [Online] Available at: http://www.kasto.com/en/products/produkte/honeycomb_storage_system/unicompact-3.html
[Accessed 01 January 2014].

Kelle, U., 2007. *Die Integration qualitativer und quantitativer Methoden in der empirischen Sozialforschung.* 1 ed. Wiesbaden: GWV Fachverlage GmbH.

Kessler, H. & Winkelhofer, G., 2004. *Projektmanagement; Leitfaden zur Steuerung und Führung von Projekten.* 4 ed. Berlin Heidelberg New York: Springer - Verlag.

Kettner, H., Schmidt, J. & Greim, H. R., 2010. *Leitfaden der systematischen Fabrikplanung.* 2 ed. München: Hanser Fachbuchverlag.

KG, V. G. &. C., 2014. *Viega Sanpress - Das wirtschaftliche und langlebige Installationssystem.-,* Attendorn: Viega GmbH & Co. KG.

Klare, J., 2010. *Kommunikationsmanagement deutscher Unternehmen in China.* 1 ed. München: VS Verlag.

Koether, R., 2007. *Technische Logistik.* 1 ed. München: Carl Hanser Verlag.

Kostka, C. & Kostka, S., 2011. *Der Kontinuierliche Verbesserungsprozess.* 5 ed. München: Carl Hanser Verlag.

Krampe, H. & Joachim Lucke, 2006. *Grundlagen der Logistik.* 3 ed. München: Huss - Verlag GmbH.

Krampe, H. & Lucke, H. J., 2006. *Grundlagen der Planung logistischer Systeme in Grundlagen der Logistik, Theorie und Praxis logistische Systeme.* 3 ed. München: Huss - Verlag GmbH.

Kraus, S., Harms, R. & Schwarz, E. J., 2007. Zur Relevanz der strategischen Planung für das Wachstum junger KMU. *Zeitschrift für Management (ZjM), H. 4, Jg. 2*, October, pp. 374 - 400.

Kühl, S., Strodtholz, P. & Taffertshofer, A., 2009. *Handbuch Methoden der Organisationsforschung.* 1 ed. Wiesbaden: VS Verlag für Sozialwissenschaften.

Kuster, J. et al., 2011. *Handbuch Projektmanagement.* 3 ed. Berlin, Heidelberg: Springer - Verlag.

Liebold, R. & Trinczek, R., 2009. *Experteninterview in Handbuch der Methoden der Organisationsforschung.* 1 ed. Wiesbaden: Verlag für Sozialwissenschaften.

Lindner, A. & Becker, P., 2010. *Wetstromdesign.* 2010 ed. München: Carl Hanser Verlag.

Linstone, H. A. & Turoff, M., 1975. *The Delphi Method, Techniques and Applications.* 1 ed. Boston: Addsion - Wesley Publishing Company, Inc..

Lipps, J., 2006. *Zusammenfassung der Magisterarbeit "TYPO3 als Open Source Content Management System - Stärken, Schwächen, Chancen, Risiken".* 1 ed. Berlin: Kontrollfeld - Agentur für binäre Medien.

Litke, H.-D., 2007. *Projektmanagement Methoden, Techniken, Verhaltensweisen, Evolutionäres Projektmanagement.* 5 ed. München: Carl Hanser Verlag.

Magnin Simulation, 2014. *Materialfluss 2.0.* [Online] Available at: http://www.magnin-simulation.ch/materialfluss.htm [Accessed 22 April 2014].

Mählck, H., 2008. *PPS-Management.* 2 ed. Sternenfels: Verlag Wissenschaft & Praxis.

Martin, H., 2009. *Transport - und Lagerlogistik.* 7 ed. Wiesbaden: Vieweg + Teubner.

Mayring, P., 2003. *Qualitative Inhaltsanalyse. Grundlagen und Techniken.* 8 ed. Weinheim: Beltz.

Meuser, M. & Nagel, U., 1991. *Experteninterviews - vielfach erprobt, wenig bedacht. Ein Beitrag zur qualitativen Methodendiskussion, in Detlef Garz / Klaus Kraimer (Hrsg.), Qualitativ- empirische Sozialforschung. Konzepte, Methoden, Analysen.* 1 ed. Opladen: Westdeutscher Verlag.

Meuser, M. & Nagel, U., 1997. *Das Experteninterview -Wissensoziologische Voraussetzungen und Methodische Durchführung- in Barbara Friebertshäuser / Annedore Prengel (Hrsg.), Handbuch Qualitative Forschungsmethoden in der Erziehungswissenschaft, pp. 481 - 491.* 1 ed. Weinheim - Basel: Beltz Juventa.

Meuser, M. & Nagel, U., 2009. *Das Experteninterview - konzeptionelle Grundlagen und methodische Anlage in Methoden der vergleichenden Poltik- und Sozialwissenschaft.* 1 ed. Wiesbaden: Verlag für Sozialwissenschaften.

Mitter, D., 2014. *Logistics Consultant* [Interview] (05 May 2014).

Motorola Solutions, Inc., 2014. *www.motorolasolutioins.com.* [Online] Available at: http://www.motorolasolutions.com/XC-DE/Business+Product+and+Services/Mobile+Computers/Handheld+Computers

/MC67#
[Accessed 10 April 2014].
Niemes, H., 2012. *Systemanalyse.* Koblenz - Landau: Universität Koblenz - Landau.
Nyhuis, P., 2008. *Beiträge zur Theorie der Logistik.* 1 ed. Berlin Heidelberg: Springer - Verlag.
Ohno, T., 2009. *Das Toyota Produktionssystem.* 1 ed. Frankfurt / Main: Campus Verlag GmbH.
Olfert, K., 2010. *Projektmanagement.* 7 ed. Herne: NWB Verlag GmbH.
Opielka, M., Müller, M., Bendixen, T. & Kreft, J., 2010. *Grundeinkommen und Werteorientierungen.* 2 ed. Wiesbaden: VS Verlag für Sozialwissenschaften.
Pawellek, G., 2008. *Ganzheitliche Fabrikplanung, Grundlagen, Vorgehensweise, EDV - Unterstützung.* 1 ed. Berlin, Heidelberg: Springer - Verlag.
Pelz, W., 2004. *Geschichte und Anwendung der SWOT-Analyse,* Norderstedt: Technische Hochschule Mittelhessen.
Pickel, S., Pickel, G., Lauth, H. J. & Jahn, D., 2009. *Methoden der vergleichenden Politik- und Sozialwissenschaft.* 1 ed. Wiesbaden: VS Verlag für Sozialwissenschaften.
Pöchtrager, S., 2011. *Qualitätsmanagement in der Agrar- und Ernährungswirtschaft, Institutionen, Strukturen und entscheidungsrelevante Faktoren.* 1 ed. Wien, NewYork: Springer.
Prahalad, C. K. & Hamel, G., 1990. The Core Competence of the Corporation. *Harvard Business Review,* Issue May - June.
Prockl, G., 2007. *Logistik-Management im Spannungsfeld zwischen wissenschaftlicher Erklärung und praktischer Handlung.* 1 ed. Wiesbaden: GWV Fachverlage GmbH.
Punch, K. F., 2003. *Survey Research.* 1 ed. London: SAGE Publications Ltd.
Rail Cargo Austria Group, 2012. [Online] Available at: http://www.railcargo.at/de/Kundenservice/Glossar/L/index.jsp [Accessed 14 02 2012].
REFA Verband für Arbeitsstudien und Betriebsorganisation e. V., 1985. *Methodenlehre der Planung und Steuerung.* 5 ed. München: Carl Hanser Verlag.

REFA, 1972. *REFA Methodenlehre des Arbeitsstudiums Teil 2 Datensammlung.* 2 ed. München: Carl Hanser.

Rockstroh, W., 1980. *Die technologische Betriebsprojektierung.* 2 ed. Berlin: VEB VErlag Technik.

Rother, M. & Shook, J., 2006. *Sehen Lernen: Mit Wertstromdesign die Wertschöpfung erhöhen und Verschwendung beseitigen.* 1.2 ed. Mannheim: Druckerei Schwörer.

Rottbeck, B., 2013. *Der Online - Wahlkampf der Volksparteien 2009.* 1 ed. Wiesbaden: Springer Fachmedien.

RWE AG, 2014. *RWE.* [Online] Available at: http://www.rwe.com/web/cms/de/183572/rwe/innovation/projekte-technologien/kraftwerke/kernkraftwerke/
[Accessed 02 May 2014].

RWTH Aachen, 2014. *Open Factory 3D.* [Online] Available at: http://www.layoutplanung.com/de/of3d.html
[Accessed 22 April 2014].

Sägewerk Wiedemann, 2014. *Sägewerk Wiedemann.* [Online] Available at: http://www.google.de/imgres?imgurl=http%3A%2F%2Fwww.saegewerk-wiedemann.de%2F01scripts%2F01pics%2F1283801009.jpg&imgrefurl=http%3A%2F%2Fwww.saegewerk-wiedemann.de%2Fproduktion.php&h=750&w=1000&tbnid=f3qRj6HfOIp2oM%3A&zoom=1&docid=w7xiYCxZqbIlNM&ei=rrlnU8S
[Accessed 03 May 2014].

Sandt, J., 2005. Prozesskostenmanagement und KVP. *ZfCM Controlling & Management,* special edition 1(01/2005), pp. 46 - 51.

Sapsford, R., 2007. *Survey Research.* 2 ed. London: SAGE Publications Ltd.

Schawel, C. & Billing, F., 2009. *Top 100 Management Tools.* 2 ed. Wiesbaden: GWV Fachverlage GmbH.

Schenk, M. & Wirth, S., 2004. *Fabrikplanung und Fabrikbetrieb, Methoden für die wandlungsfähige und vernetzte Fabrik.* 1 ed. Berlin, Heidelberg: Springer-Verlag.

Schlott, S., 2012. Lean & Green efficiency award 2012. *ATZ produktion,* 5(03/2012), pp. 138 - 142.

Schmigalla, H., 1995. *Fabrikplanung, Begriffe und Zusammenhänge.* 1 ed. München: Carl Hanser Verlag.

Schönsleben, P., 2007. *Integrales Logistikmanagement; Operations und Supply Chain Management in umfassenden Wertschöpfungsnetzwerken.* 5 ed. Berlin Heidelberg New York: Springer Verlag.

Schönwandt, C., 2004. *Sustainable Entrepreneurship im Sektor Erneuerbare Energien.* 1 ed. München / Mering: Rainer Hampp Verlag.

Seidel, W., 2001. *Werkstofftechnik, Werkstoffe; Eigenschaften - Prüfung - Anwendung.* 5 ed. München Wien: Carl Hanser Verlag.

Spath, D. & Walter, A., 2012. *Mehr Innovationen für Deutschland.* 1 ed. Berlin Heidelberg: Springer-Verlag.

SSI Schäfer Noell GmbH, 2012. *online database, keyword "Langgut".* [Online] Available at: http://www.ssi-schaefer.de/news-infocenter/logistik-lexikon/suche/ergebnis.html
[Accessed 28 February 2012].

Stadtler, H., Kilger, C. & Meyr, H., 2010. *Supply Chain Management und Adcanced Planning, Konzepte, Modelle und Software.* 1 ed. Berlin Heidelberg: Springer Verlag.

STILL Materials Handling Ltd, 2014. *www.still.co.uk.* [Online] Available at: http://www.still.co.uk/high-lift-pallet-trucks.0.0.html
[Accessed 11 January 2014].

Straub, M. & Manz, C., 2013. Kommissionierung! Einer der herausforderndsten Prozesse der Intralogistik; Das Kommissioniersystem im Spannungsfeld maximaler Flexibilität und schlanker Prozesse nach Lean Management Ansätzen. *horizonte,* 42(October 2013), pp. 32 -36.

Straub, M. & Manz, C., 2014. Effects of Using Different Types of Signal To Transport Kanban Informations. *FORUM,* ISSN 1619-9812(2013 / 2014), pp. 28 - 32.

Straub, M. & Schiepp, T., 2010. *Der praxisorientierte Weg zum schlanken Produktionssystem.* 1 ed. Trossingen: Junge Medien.

Straub, M., Zhang, S., Manz, C. & Hapeshi, K., 2014. Provision of Long Item Materials. *Key Engineering Materials,* Vol. 572(2014), pp. 257 - 260.

ten Hompel, M. & Heidenblut, V., 2011. *Taschenlexikon Logistik, Abkürzungen, Definitionen und Erläuterungen der wichtigsten Begriffe aus Materialfluss und Logistik.* 3 ed. Berlin, Heidelberg: Springer - Verlag.

ten Hompel, M., Sadowsky, V. & Beck, M., 2011. *Kommissionierung Materialflusssysteme 2 - Planung und Berechnung der Kommissionierung in der Logistik.* 1 ed. Heidelberg Dordrecht London New York: Springer - Verlag Berlin Heidelberg.

ThyssenKrupp AG, 2014. *Thyssen Krupp AG.* [Online] Available at: http://www.thyssenkrupp.com/de/presse/bilder.html&keyword=120 [Accessed 02 May 2014].

Töpfer, A., 2007. *Six Sigma, Konzeption und Erfolgsbeispiele für praktizierte Null-Fehler-Qualität.* 4 ed. Berlin, Heidelberg: Springer - Verlag.

Trinczek, R., 1995. *Experteninterviews mit Managern: Methodische und methodologische Hintergründe, in Christian Brinkmann / Axel Deeke / Dieter Völkel, Experteninterviews in der Arbeitsmarktforschung. Diskussionsbeiträge zu methodischen Fragen und praktischen Erfragungen.* 1 ed. Nürnberg: Institut für Arbeitsmarkt- und Berufsforschung der Bundesanstalt für Arbeit.

Valeva, M., 2012. *Theoretische Grundlegung ethischer Bankbetriebslehre.* 1 ed. Wiesbaden: Springer Gabler.

VDI, 2011. *VDI-Richtlinie 5200 Factory planning.* Düsseldorf: Beuth Verlag GmbH.

VEREIN DEUTSCHER INGENIEURE, 1973. *VDI - RICHTLINIE 3300, Materialfluß - Untersuchungen.* Düsseldorf: VDI - Verlag.

Viega GmbH & Co. KG, 2014. *Viega.* [Online] Available at: www.viega.de [Accessed 22 April 2014].

Visser, E. J., 2007. Logistic innovation in global supply chains: an empirical test of dynamic transaction-cost theory. *GeoJournal,* 70(70), pp. 213 - 226.

Vollmer, L., 2003. Komplexitätsfördernde Strukturplanung für eine selbstorganisierte Soloarfabrik. *wt Werkstattstechnik online,* 93(4), pp. 244 - 248.

Wagemann, B., 2004. Auf der Suche nach den strategischen Handlungsfeldern; Das Handlungsfeld - Screening: Ein pragmatische Methodik zur treffsicheren

Interpretation der SWOT - Matrix. *ZfCM Controlling & Management, 48. Jg. H. 6*, pp. 390 - 395.

Waldvogel, E., 2012. *Geschäftsführer* [Interview] (06 April 2012).

Walk Antriebstechnik bv, 2014. *Walk Antriebstechnik bv.* [Online] Available at: http://www.google.de/imgres?imgurl=http%3A%2F%2Fwww.walk-antriebstechnik.de%2Fthefiles%2Fimage%2FProd_gr04_02_tandheugel_schuin%252520vertand.jpg&imgrefurl=http%3A%2F%2Fwww.walk-antriebstechnik.de%2F66%2FZahnstangen.html&h=430&w=631&tbnid=wAnFTXUpX8UuqM%3
[Accessed 01 May 2014].

Warnecke, H. J., Bullinger, H. J., Hichert, R. & Voegele, A., 1996. *Kostenrechnung für Ingenieure.* 5 ed. München Wien: Carl Hanser Verlag.

Warnecke, H. J., Bullinger, H. J., Hichert, R. & Voegele, A., 2003. *Wirtschaftlichkeitsrechnung für Ingenieure.* 3 ed. München Wien: Carl Hanser Verlag.

Weber, R., 2009. *Lageroptimierung / Bestände-Abläufe-Organisation-Datenqualität-Stellplätze.* 1 ed. Renningen: Expert Verlag.

Weimer, G., 2009. *Service Reporting im Outsourcing - Controlling.* 1 ed. Wiesbaden: GWV Fachverlage GmbH.

Welser Profile GmbH, 2014. *Welser.* [Online] Available at: http://www.welser.com/Maerkte/Bau
[Accessed 22 04 2014].

Westhaus, M., 2007. *Supply Chain Controlling.* 1 ed. Wiesbaden: GWV Fachverlage GmbH.

Wiendahl, H. P., Nofen, D. & Klußmann, J. H., 2005. *Planung modularer Fabriken.* 1 ed. München, Wien: Carl Hanser Verlag.

Wolf, F., 2011. *Interkulturelle Integration als Aufgabe des öffentlich-rechtlichen Fernsehens.* 1 ed. Wiesbaden: Verlag für Fachmedien.

Wolters, H. A., Gille, J., de Vet, J. M. & Molemaker, R. J., 2013. Scenarios for selected maritime economic functions. *Eur J Futures Res*, 01 November, pp. 1 - 12.

Womack, J. P. & Jones, D. T., 2003. *Lean Thinking, Banish Waste and Create Wealth in Your Corporation.* 2 ed. London: Simon & Schuster UK Ltd.

Yoffie, D. & Kwak, M., 2001. *Judo Strategy: Turning Your Competitors' Strength to Your Advantage,* Boston: Harvard Business School Press.

Zollern Vertriebs-GmbH + Co., 2014. *Zollern Antriebstechnik Automation,* Herbertingen: Zollern Vertriebs-GmbH + Co..