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Simplification and Modernization of the Material Flow on Remote Multideck Final Assembly Line

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The objective of this thesis was to develop a proposal of a simpler material flow with a more modern picking process for a remote multideck final assembly line. The aim was to develop the current material flow, so that it allows paperless picking. As a base and justification for this need, worked a platform for product and material management named *MatFlow*, which integrates the stock to the ERP-system used in the case company.

This thesis is based on three rounds of data collection, in the of form discussions, interviews, internal documents and self-observation. The thesis was conducted according to a structured approach that first investigated the current state of the of the material flow for the assembly line, then explored best practices of moving materials through supply chains, and finally build an initial proposal and validated it.

The key findings of this thesis revealed that the picking process is non-real time, because of the outdated paper picking method. The position of the materials also proved to extend around the entire factory. Fortunately, there was the opportunity to implement the MatFlow platform, providing real-time material flow. One of the requirements for that was cabinet-specific picking, which demands relocation of the materials.

The outcome of this thesis was a proposal of a simpler material flow with a more modern picking process, divided in two parts: relocation of materials and real-time material flow. The first part provided new storage locations for the materials, to simplify their transportation route from warehouse to the assembly line. The second part concentrated on the implementation of a real-time material flow with practical work tools. The outcome is expected to provide paperless picking in a warehouse with real-time material flow.

Keywords	MatFlow, material flow, picking, warehouse, supermarket, assembly line, layout

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Tämän insinöörityön tavoitteena oli kehittää ehdotus yksinkertaisemmasta materiaalivirrasta nykyaikaisemmalla keräilyprosessilla keskuskoneellisten hyllyköiden kokoonpanolinjalle. Tarkoituksena oli kehittää nykyistä materiaalivirtaa siten, että se mahdollistaa paperittoman keräilyn. Perusteena ja perusteluna tälle tarpeelle toimi MatFlow-niminen tuote- ja materiaalihallinnan alusta, joka integroi varaston yrityksessä käytettyyn toiminnanohjausjärjestelmään.

Tämä insinöörityö perustuu kolmeen tiedonkeruukierrokseen keskusteluiden, haastatteluiden, sisäisten asiakirjojen ja itsehavainnoinnin muodossa. Opinnäytetyö tehtiin jäsennellyn lähestymistavan mukaisesti, jossa ensin selvitettiin kokoonpanolinjan materiaalivirran nykytilaa, sitten tutkittiin parhaita käytäntöjä materiaalien siirtämisestä toimitusketjujen läpi ja lopulta rakennettiin ensimmäinen ehdotus ja validoitiin se.

Tämän insinöörityön keskeiset havainnot osoittivat, että keräilyprosessi ei ole reaaliaikainen vanhentuneen paperikeräilymenetelmän takia. Materiaalien sijoittelu osoittautui myös ulottuvan koko tehtaan ympärille. Onneksi oli mahdollisuus implementoida MatFlow-alusta, jotta voidaan tarjota reaaliaikainen materiaalivirta. Yksi alustan vaatimuksista oli kaappikohtainen keräily, joka vaati materiaalien uudelleensijoittelua.

Insinöörityön tulokseksi syntyi ehdotus yksinkertaisemmasta materiaalivirrasta nykyaikaisemmalla keräilyprosessilla jaettuna kahteen osaan: materiaalien uudelleensijoittelu ja reaaliaikainen materiaalivirta. Ensimmäinen osa ehdotti uusia varastointipaikkoja materiaaleille, jotta voidaan yksinkertaistaa niiden kuljetusreittiä varastosta kokoonpanolinjalle. Toinen osa keskittyi reaaliaikaisen materiaalivirran implementointiin käytännön työkalujen avulla. Lopputuloksen odotetaan tarjoavan paperittoman keräilyn varastossa reaaliaikaisella materiaalivirralla.

Avainsanat	MatFlow, materiaalivirta, keräily, varasto, supermarket, kokoonpanolinja, layout

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List of Abbreviations

BOM	Bill of materials. A list of all the sub-assemblies, components and parts required in total to produce all the goods listed in the master's schedule.
CSA	Current state analysis. A process management system to analyze and evaluate the current situation of a company or a specific process.
ERP	Enterprise resource planning. A transaction-based information system that are integrated across the whole business.
FIFO	First in first out. A method that assumes that the oldest unit of inventory is the consumed first.
JIT	Just-in-time. A set of management philosophies that aims to meet demand instantaneously, with perfect quality and no waste.
LIFO	Last int first out. A method that assumes that the last unit to arrive in inventory is consumed first.
MRO	Maintenance, repair and overhaul. Consists of items needed to operate, as equipment and machinery, and items needed for maintaining equipment and infrastructure.
MRP	Materials requirements planning. A computerized system for predicting materials requirements on basis of a company's master production schedule and bill of material for each product.
RFID	Radio frequency identification. A tracking system that uses intelligent bar codes to track items in a store or warehouse.
SWOT	Strengths, weaknesses, opportunities and threats. An analysis of the internal strengths and weaknesses, and external opportunities and threats, to identify and evaluate strategic options.
VAL	Value-added logistics. The creation of a higher added value in a logistics chain.

WIP	Work-in-progress. Inventory including items that are currently being processed.
WMS	Warehouse management system. A software system that controls the activities within the distribution center.

1 Introduction

One of the cornerstones in the manufacturing industry is the picking process. Generally, it is the picking of the products needed to execute the customer's order. The products are collected from specific locations in a warehouse and sorted into orders for distribution. It is a logistic warehouse process and has an important role in the productivity of the supply chain. It might sound like a simple concept, but in fact, it is one of the most laborious action in a warehouse. And, because picking adds no value to the end product, the expenses of picking is a critical topic.

Usually, the picking is based on paper picking lists that specifies the name, location and number of items to be picked. This is a flexible and thrifty way to handle the picking, but unfortunately it is prone to errors, especially in picking environments where multiple orders are being picked at the same time. Although, it is important that the picking is time efficient, it should also be accurate.

That is why, the target of this thesis is to develop the internal material flow so that it allows paperless picking. By using an accompanying device that is constantly online, it is possible to get rid of the outdated picking style. When an employee is online, it becomes also easier for warehouse and logistic personnel to control the work and manage changes. This development should result in a higher general performance according the accuracy, speed and usability.

1.1 Business Context

The case company of this study is an industrial company located in Porvoo that manufactures refrigeration equipment. It belongs to a family-owned German Group and is one of the leading international manufacturers of heating, industrial and refrigeration systems. This enterprise was founded in 1917, has 12000 employees and a turnover of 2,5 billion Euro.

The Porvoo plant manufactures refrigeration equipment, including refrigerators and basins, as well as service counters. The company operates both in Finland and internationally and the customers are mainly commercial food companies i.e. grocery stores, kiosks and service stations. The manufacturing of the products is made on a customer order basis and the products are customizable. The company's production strategy is to be flexible and agile, so that the customers wishes according the cabinet can be fulfilled as well as possible.

Currently, the case company is running a huge development project, according production arrangements. The aim is, to get all the activity under one roof, since it is at presently distributed to many properties. It requires physical changes in the production spaces, but also new ways of working and processes. The goal is to be the first choice for the customers, employees and partners.

1.2 Business Challenge, Objective and Outcome

The reason to conduct this study is the obsolete material flow tracking in the internal logistics operations in the case company. Currently, the material flow is not real-time in the ERP-system, and the balances are consequently not reliable. These operations should be under control and transparent, for a fluent workflow for every personnel group – but they're not. This can be regarded as the main business challenge to be improved in this thesis.

Therefore, is the main objective of this study to develop the current material flow, so that it allows paperless picking. As a base and justification for this need, works a platform for product and material management named *MatFlow*, which is integrated the stock of the ERP-system used in the company. The case company has already invested in this platform and implemented it to other departments, but now it is expected to be implemented as a part of this objective. This requires an improved material flow with a cabinet-specific picking process.

The outcome of this study is an improvement proposal of a simple material flow with a more modern picking process for a specific assembly line in the case company.

1.3 Thesis Outline

This thesis is restricted to paperless picking in a warehouse with real-time material flow. The current operating way will be examined, and a renewed structure will be proposed. The study is also limited to develop the flow of the material and their concrete route. The aim is not to reduce costs, but to make the material flow smoother and more truthful.

This study is divided into seven sections. In the first section there is an introduction of the thesis and an overview of the case company and its challenges. The second section introduces the methods and materials used to conduct this study. In the third section, the company’s current process is explained and analyzed. The fourth section concentrates on literature and available knowledge of the subject, with a conceptual framework as result. The fifth section comprises the building of the proposal and the outcome and in the sixth section there is the final validation of the outcome. Finally, section seven, which includes the conclusion of this thesis and a general evaluation of the project.

2 Method and Material

This section gives an overview of the methodology applied in this study, to explain how this thesis is conducted. It will be presented in three parts including the research approach, research design and data collection and analysis. First, the research approach concept will be introduced, and the chosen approach style will be explained. Then the research design will be presented, by giving and description of how the study was conducted. Lastly, a brief description of the data collection and analysis will be shown.

2.1 Research Approach

Research have a reference to seeking information. It can also be defined as a scientific and systematic search of certain kind of information. The purpose is, to find answers to questions by applying scientific procedures. To find out the hidden truth, there are different research types and approaches. (Kothari, 2004)

The basic types of research are usually divided in applied versus fundamental research. *Applied research* is practically utilized and is useful solving practical problems whereas *fundamental research* is the one that adds further information to the actual information. (Kothari, 2004) The application of the findings of basic/fundamental/theoretical research to produce a research, refers to terms like applied, clinical, practical and product research, with the intention to answers focused and problem-specific questions. A research that is focused on discovering fundamental principles and processes ruling physical and life phenomena, refers in turn on terms like as basic, fundamental and theoretical research. (Abraham & De Geest 2006)

There are different ways to approach to conduct a study, depending on the type of study. Most of the studies relies on the two basic methods of research, namely quantitative and qualitative research. The *quantitative research* requires existing phenomenon, theories or models that are understandable and operating as the subject of the research. The *qualitative research* tries to understand the research target phenomenon and its structure, with all their factors. When it is time to choose methodology for a research, there are different criteria to think about. For example, the ratio between theory and practice, the objective of research, the research role and type of questions together with the answers. (Kananen, 2013)

Design research, action research and case study are other research approach methods, which utilizes quantitative and qualitative methods and are consequently regarded as approaches and not methodologies. *Design research* are described as a philosophic umbrella of science, including data gathering, analysis and interpretation methods. It aims as well as action research to make an improvement or change, in action research there is just more action and active research. (Kananen, 2013) *Action research* can also be described as a way to combine practice and theory, since it investigates changes and their effects, without stopping the researcher from action. But understanding the phenomena of the real-world setting is significant for both action research and case study. The major difference is that there is a greater role for defining the pointed issues in action research. (Blichfeldt & Andersen, 2006) The approach of a case study research is to focus on one phenomenon to provide an intense relationship or process that happens on that specific phenomena. The strength for a case study is that every research approach has its own strengths by using a quantity of sources and data. (Hancock & Algozzine, 2017)

This study concentrates on an applied business problem and the aim is to find an improved solution for it, i.e. an applied research. The research methods are mostly qualitative, with a multiple data collection techniques, such as interviews and documents. The chosen research approach is design research, as the objective is to propose a practical solution for a business challenge.

2.2 Research Design

A framework of the chosen research methods and techniques constructs a research design. The research design of this study is shown in Figure 1 below, visualizing the five stages that the study is conducted in, but also the used data sources and the intended outcomes for each stage.

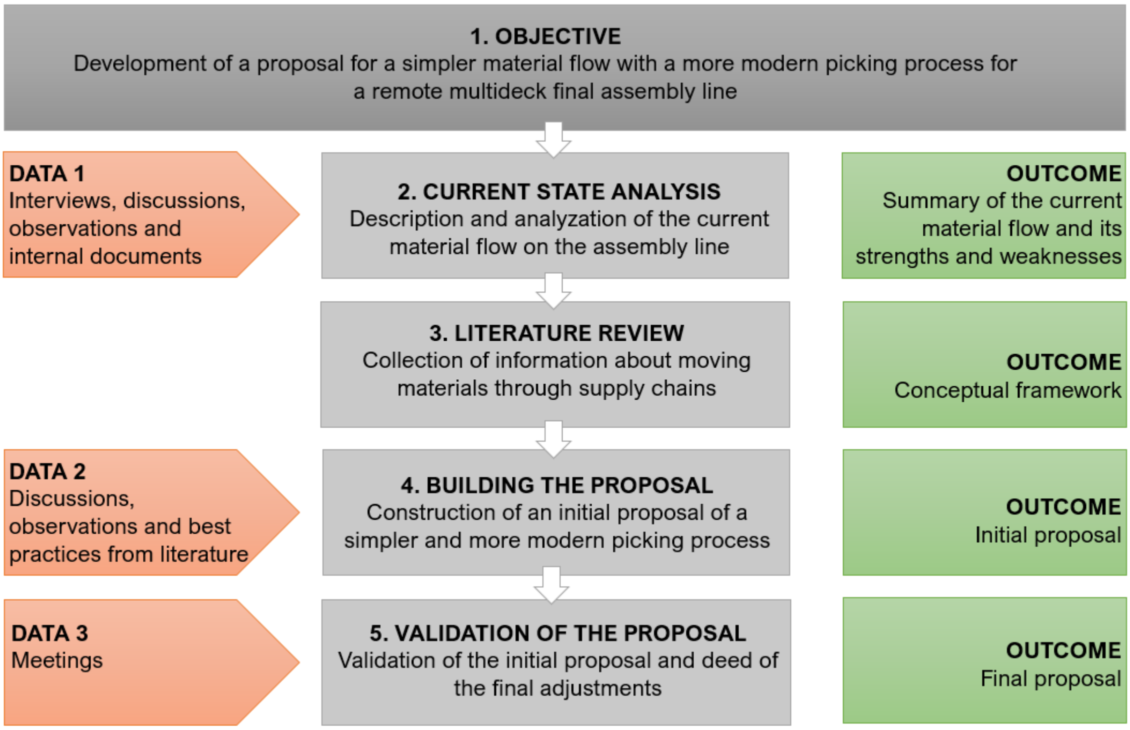


Figure 1. The research design of this study.

As the figure demonstrates, this study started by setting the objective. This was done with a kick-off meeting with the logistics manager from the case company. During this meeting, the existing business challenge in the enterprise was clarified and the objective was set on a basis of that. Later, there was also a meeting with the logistics manager and the thesis instructor, to clarify the target further.

After this, the actual research started with an analysis of the current state. By discussing and interviewing knowledgeable persons, the specific process passage was defined, with all its details. By adding some self-observation and exploiting some internal documents the weaknesses and strengths were identified and based on them the performance was measured. Then, the key findings were stated and the chosen areas for improvement also. The outcome of this stage was then the overview of the process and the evaluation of the pros and cons of it.

In the next stage, the study focused on finding available knowledge and best practices according the subject in form of a literature review. The chosen topics to focus on were related to the material flow, including literature of it. The outcome of this stage was a conceptual framework, presenting the key elements of the investigated subjects. The purpose was to find the best practices, to exploit the ideas and enable to build a proposal. The building of the proposal happened then, utilizing the former investigated information and collaborating with competent people at the company. The outcome was an initial proposal that was further validated at the company and on basis of that, the final adjustments was done. Lastly, a final proposal was offered.

2.3 Data Collection and Analysis

The procedure of gathering information for a research by using validated techniques are called data collection. The data collection and analysis of this study is shown in Table 1 below. It is divided into three rounds, with different types of data sources to ensure the credibility. The table presents the sought content, used source and informant, timing of each section and the outcome.

Table 1. The data plan of this study.

	CONTENT	SOURCE	INFORMANT	TIMING	OUTCOME
DATA 1: *Current State Analysis*	Description and analyzation of the current material flow on the assembly line	Interviews Discussions Observations Internal documents	Logistics team leader Logistics manager Experienced pickers	*March - April 2020*	Summary of the current material flow and its strengths and weaknesses
DATA 2: *Building Proposal*	Construction of an initial proposal of a simpler and more modern picking process	Discussions Observations Internal documents	Logistics team leader Logistics manager Experienced pickers Development specialists	*May - July 2020*	Initial proposal of an improved material flow

DATA 3: *Validation*	Validation of the initial proposal and deed of the final adjustments	Meetings	Head of logistics Logistics manager Head of project management office Change management team	*August - September 2020*	Final proposal of an improved material flow

As shown in the data plan above, the first data collection round was completed to collect information of the current situation in the case company. Information was collected about the current material flow, to identify its features. Data 1 was mainly gathered by discussing and interviewing with the logistics team leader and manager. Some internal documents with necessary information were also utilized as well as self-observation by concretely following the process. The timing of this was in March-April and the outcome was useful, with a clear understanding of the process and its weaknesses and strengths.

The second data collection round was done, to collect insights from people working closely with the topic for building an improvement proposal. The Data 2 was then gathered by numerous discussions and observation, in terms of weekly meetings with the logistics manager for a status report as well as frequent in-depth discussions with various team leaders and experienced pickers about the subject. Tips were also received from the development specialists in the case company. The duration of this section was in May-July and the outcome was an initial proposal of an improved material flow.

The third data collection was conducted for the validation of the initial proposal. Data 3 was gathered in a meeting with the change management team, head of project management office, logistics manager and head of logistics in the case company. The persons that were present are somehow involved in the process and were therefore chosen as audience. After the presentation, participants were encouraged ask and comment on the topic. In addition, a second meeting was held with the logistic manager, to clarify the improvement suggestion. On basis of those remarks was the final proposal created. The phase from initial proposal to the final proposal did last from August-September.

3 Current State Analysis

In this section, the current situation of the material flow on the assembly line in the case company will be presented. At first, there will be a brief description of the current state analysis stages and then a description of the current structure on the assembly line. After that, the actual material flow of the different picking categories will be identified and analyzed. It will also be illustrated and measured by distance and time. Finally, the key findings and selected areas for improvement will be presented.

3.1 Overview of the Current State Analysis Stage

The main object of this current state analysis is to recognize the strengths and weaknesses of the current material flow in the picking process, as a premise for progress. The aim was to find out what is currently working and what isn't, based on different sources to get a wider perspective of it.

In the case company, there was at the time of review no official description of the picking process or material flow routing. Instructions for pickers were found to be given verbally by experienced pickers or managers. That is why, the current state analysis was made based on both interview and discussion results, but also using own observation and some internal documents.

3.2 Description of the Current Structure on the Assembly Line

On the assembly line in question, they produce remote multideck cabinets of a certain model. This model is one of the largest in range, which means that the assembling happens in many steps as well as the picking. The material needs are accordingly extensive. The structure of the assembly line has mostly been mapped with the help of the logistics team leader on the area but also by the pickers.

The material needs for this production line is divided into nine different pickings and the cabinet is produced in nine steps. The picking is currently mainly done for a various amount of cabinets at a time. The nine different pickings are divided into following categories:

- Key bars
- A-trolley
- Long profiles
- Evaporators
- Electrical boxes
- B-trolley
- Foamed end panels and painted end plates
- Glasses and mirrors
- Doors.

A and B trolley are picking entities including raw, painted and plastic parts among other things.

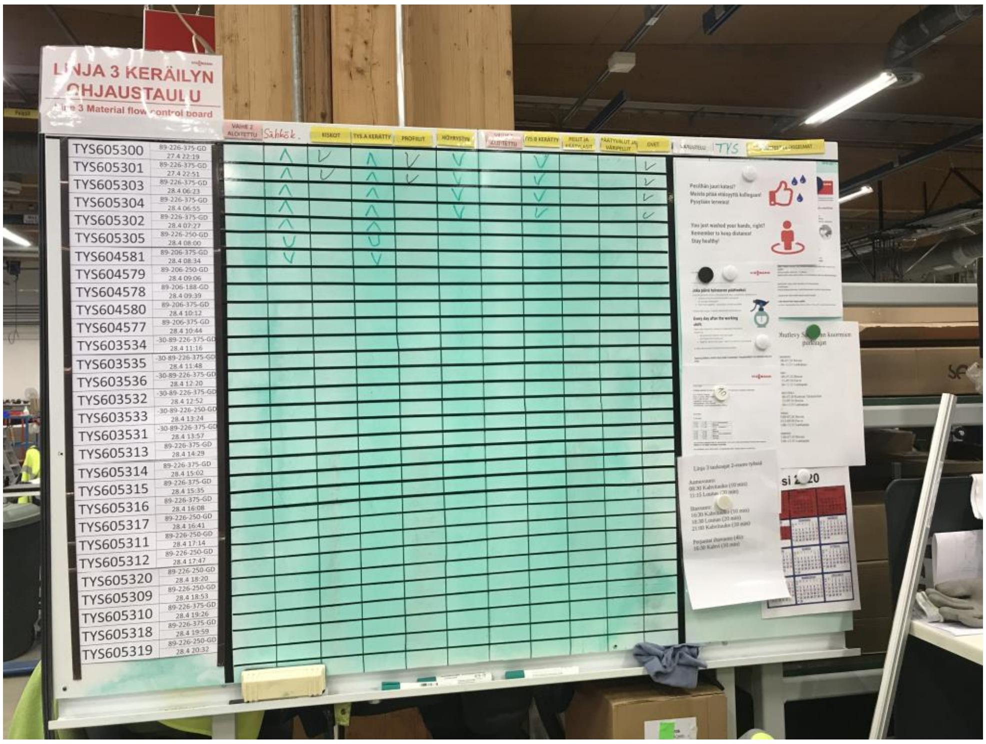


Image 1. Material flow control board.

Currently, there is eight employed pickers on the assembly line, but four pickers working per shift. In addition to the team leader. The picking happens on basis of a material flow control board and the production program, mostly one shift ahead. The control board includes necessary information about the material flow, but there is also a section with up-to-date information, see Image 1 above. The order picking method in this case is *Pick-by-Paper* that is picking on basis of a paper pick list. The list defines the material, the number and the location of each item to be picked. In this case, there is nine different pickings to the nine different assembly steps.

The vehicle used for picking in this warehouse is an order picking trolley i.e. pick cart. The trolley is exactly what it sounds like: a shelf or a multi-tiered bin on wheels. The trolleys can look very different and do so in this case: there are both trolleys, carts and racks. They do still move in the same way, by simply pushing it forward through the warehouse to the production line.

In all its simplicity, the workflow of the picking process can roughly be described as follows. When a picking list is printed, the picker gets a suitable trolley and start picking. All the required parts form the list are picked from their own places and some of them are also preassembled at this point. Then, fully picked trolleys are parked at the correct production phase and the picked entities are marked to the control board and later finished from the production program. Then the same round goes all over again.

The following pictures, Image 2 - Image 11, exposes the format of the picking carts and some of their content on this production line.

Image 2. Key bar – rack.

Image 3. A-trolley.

Image 4. Long profiles - trolley.

Image 5. Evaporator - trolley.

Image 6. Empty cabinet trolley.

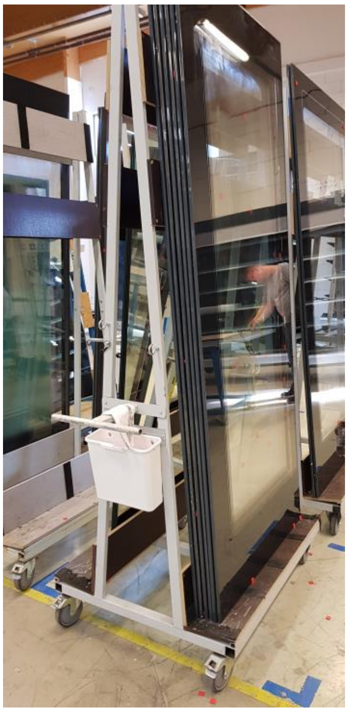


Image 7. B-trolley.

Image 8. Glasses and mirrors - rack.

Image 9. Foamed end panels and painted end plates – trolley.

Image 10. Electrical boxes – trolley.

Image 11. Doors - rack.

On the assembly line, the assembly happens in nine steps, with nine assembly workers. The structure of the assembly line can be viewed in Image 12 below.

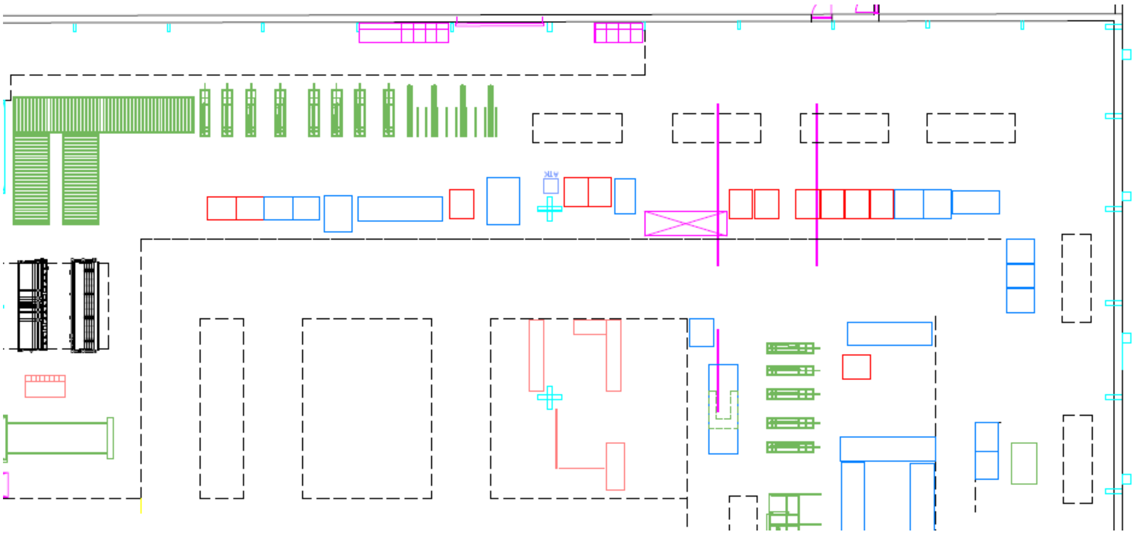


Image 12. Layout of the final assembly line.

Step one to four are the so-called jog assembly. The first step is the foaming of the roof and the bottom. In the second step these two are compounded, the sub-assembly of the *key bars* are done and their connection to the frame and then the parts of the A trolley are connected. In the third step the assembling of the A trolley parts continues and in addition to that, the *long profiles* are added. The same things continue in the fourth step, but here the evaporators are also inserted. After that the cabinet is raised upright on an empty cabinet trolley.

Step five to nine are the end of assembly. In the fifth step the parts from B-trolley are connected for the inside panel. B-trolley parts are also used in the sixth step for the shelving and in the seventh step for the shelf features. In the seventh step the *long profiles* are also compounded. In the eighth step the ends are compounded, including the glasses and/or mirrors, the foamed end panels and painted end plates. Merge of the doors and the coupling of the electrical boxes are made in step nine. After this all parts are connected, and the cabinet is ready for testing and accessorizing. In the testing section the electrical safety and the functionality are tested and also the final visual inspection of the cabinet. The last add-ons before departure are added in the cabinet accessorizing department.

3.2.1 Supermarket Area

An essential part about the structure of this assembly line is, the supermarket area next to it. It is an intermediate stop, between the warehouse and the assembly line. This concept and operation will be clarified in this section, mapped by an interview with an experienced picker together with some discussion. The logistics team leader does also have a special role in this process and therefore, his perspective has also been taken into account – acquired by a conversation about his roles and responsibilities.

The supermarket concept can be explained as the supply of downstream processes through a decentralized warehouse. (Battini et al., 2010) In this case it is a smaller area, with the fast-flowing items for the final assembling. It is located close to the assembly line, to make the operations visible. It works like a food supermarket, where all the needed parts are being picked for a while at a time.

The location of the supermarket area is marked by a red square in the floor plan below in Image 13.

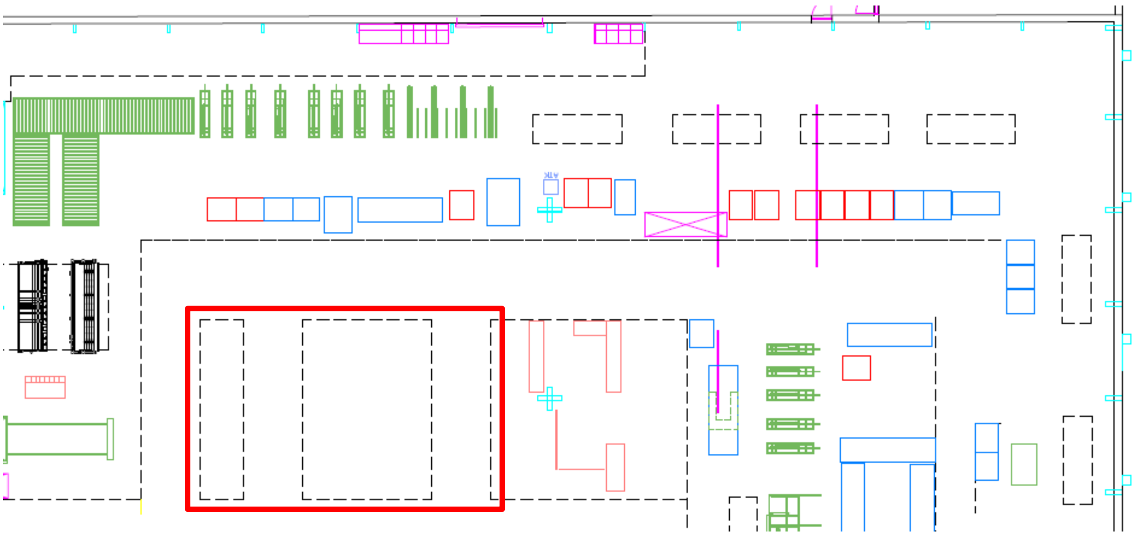


Image 13. Supermarket area.

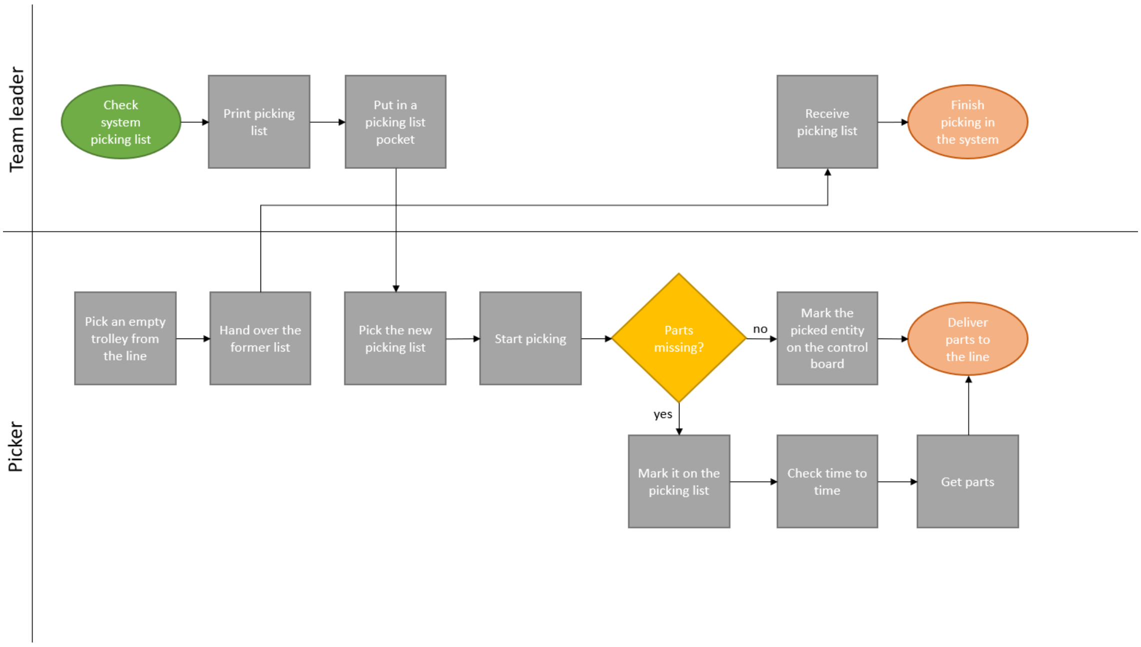


Figure 2. Flowchart presenting the current picking process on the supermarket area.

The general picking process for the assembly line was roughly described previously and it is largely true for the supermarket picking as well. It will still be described more specific at a later stage in the text. But a hint of the process going is visualized as a flowchart in the Figure 2 above. As shown, the team leader does also have a role in this picking process and therefore, it is worth mentioning his responsibilities. On the assembly line, it has namely been proved as the best alternative that the team leader handles with the picking lists for the A and B pickings. That is why, the team leader prints the lists from the system and put them in a pocket for the pickers to take and later finishes them via the production program.

From the team leader point of view, there is both advantages and disadvantages in the current operating way. The good part is the control that the team leader is having, while handling with the printing and finishing of the lists. The picking lists overall works in way, since the information is easy to hands for anyone, while being connected to each trolley. The picking list includes all the information of the cabinet and the possible missing parts, without any further seeking. The downside is kind of in conflict with this and related to the business challenge of the whole thesis, namely the paper picking method. It creates non-real-time material flow, but also paper loss. The printing and finishing the lists does also take a lot of the team leader working time, since each entity is handled individually, and all the changes are done manually. Besides, sometimes there is no time for finishing the lists. In worst case they are finished two days later, which is a living example of the non-real time material flow. In this case, it causes errors to correct in the ERP-system, since the cabinets may be checked as ready before the parts are even checked as picked.

3.3 Mapping of the Current Material Flow for the Assembly Line

The material flow of the mentioned picking categories will be described in three parts: From warehouse to the assembly line, from warehouse to the supermarket area, and supermarket area to the assembly line. The reason to this division is the different kinds of picking methods used on the assembly line. The material flow will also be analyzed by identifying the potential weaknesses and strengths, which is one of the major things in a current state analysis. The knowledge is mapped on basis of discussion and interview results with experienced persons. The interview questions are presented in Appendix 1 and Appendix 2.

3.3.1 Warehouse to the Assembly Line

The material flow from warehouse to the assembly line is the most common picking method on the assembly line. The warehouse in this case is big with different departments. The picking categories picked in this way are: Key bars, long profiles, evaporators, foamed end panels and painted end plates, glasses, mirrors and doors. Their material flow will be described in this section, as well as their potential weaknesses or strengths. A floor plan with routes of the material flow are described in Appendix 3, for a clearer understanding.

The material flow of the *key bars* extends from the painting unloading area to the assembly line. The key bars are painted on a color basis and placed on a rack at the unloading area thereafter. Because of the big size and heavy weight, these are picked on an own rack and is thus its own picking category. Next, the rack is manually delivered to the production line. The challenge here is the poor disposition and mode of operation. The painting unloading area is located beside the busiest aisle in the whole factory and the painted key bars are located there too. There is no room for the picking, which means that it happens almost in the middle of the aisle. This causes a jam and dangerous situations with other traffic, as forklifts and pallets jacks.

The material flow of the *long profiles* consists of several stages, including picking from a few different places to the assembly line. The first stop with an empty trolley for the long profiles is at the V-stock, where the raw parts and some plastic profiles are picked. The next stop is at the painting unloading area, where the painted canopies are picked. Then the rest of the plastic profiles are picked at a certain shelf location and in exceptional cases, they can also be picked from outside or from the separate A-hall. After this, the trolley is filled with parts for a various amount of cabinets and is so on transported to the assembly line. The multistage material flow here, is a weakness. The needed parts for this picking, are divided into several locations, which makes the picking path long and time consuming. During the transport route the parts can also be damaged, since they are so long and can easily hit something.

The material flow of the *evaporators* goes from lamella production to the assembly line. They are produced in the ALP factory, which is one of the three factories in the Porvoo operations. There, they are loaded cabinet specific onto a trolley after the production and transported by milk run to the A-hall. From there, the trolley is simply pushed straight to assembly line. The routing of the evaporators is the challenge here. The path is long with a few stops, which increases the processing and so on the chances of processing errors. This is also a slow procedure and takes both time and effort.

The *foamed end panels and painted end plates* material flow goes from the painting unloading area to the assembly line. After the foaming of the end panels, they are placed randomly on a certain shelf beside the painting unloading area, where they are picked from. The painted end plates in turn, are picked from a shelf in the painting unloading area, after the painting. These parts are picked on an empty trolley and transported straight to the assembly line. The issues here are first of all, the big size and heavy weight, which makes them hard to handle and easy to damage. The needed parts are also supposed to be picked from a narrow shelf, which is not in order. Moreover, the shelves are located beside the busiest aisle in the factory. These factors make the picking difficult and might create processing errors.

The material flow of the *mirrors, end glasses and doors* pass from the V-stock to the assembly line. These products arrive to the V-stock, in pack of ten pieces, which can't be separated. The picking starts by unpacking these packages and handling with the garbage thereafter. Then, all of the ten mirrors/glasses/doors are rose to a fitting rack, which is a two-man job because of the big size and heavy weight. After this, the rack is transferred to the assembly line. The picking of these parts is also a pain in the picking process. Because the range is so wide, there must be many different sizes and models of these parts i.e. glasses, mirrors and doors. Therefore, these parts aren't currently being picked cabinet specific, as the other parts are. This creates a bunch of different parts beside the assembly line and requires extreme precision from the assembly worker to constantly be up to date. The picking itself does also take time, because of the unpacking, the tricky lifting and the long path. One must not forget that this does also increase the possibility for processing errors.

3.3.2 Warehouse to the Supermarket Area

The material flow from warehouse to the supermarket is its own category, because of the huge variation of items on the supermarket area. The items are pre-picked to the supermarket area, with empty boxes as a visual trigger, and later picked to the A and B trolleys. The traveled routes for filling the area, are revealed in Appendix 4 as clarification.

The items brought to the supermarket area can be divided into three categories: Purchased, Painted and Accessory. The purchased items are bought from an external supplier and relocated to the X-stock, A-hall or the shelve beside the incoming goods, after arrival. The painted parts in turn, are sought from the unloading area, where the parts are painted and put in a trolley on a production line basis. Sometimes painted parts comes from a supplier as well, in which case they are put along the aisle near the supermarket area. The accessory items are brought to the supermarket area from the accessorizing department.

This is one of the areas which is working well, probably because of the smart supermarket concept. Because of the pre-picking, the parts are within arm's reach when the real picking is happening for the A and B trolley, which makes the picking of these parts fast.

The downside is the large spread of the items and the affecting factors of it. The items are spread all over the factory in different warehouses and brought one box at a time, with an empty box as a trigger. The route taken to retrieve materials for one day is long and so on time consuming, with routes back and forth.

The material flow of the *electrical boxes* takes place from its production to the supermarket area as well. The electrical boxes are produced in the electrical box assembly department, which are located on the other side of the factory. After the production they are packed into carriages, on a production line basis, and transported by an internal train to the supermarket area. On the supermarket area, they are picked to the A trolley. There are no challenges in this category, vice versa - this is one of material flows that are actually working. The internal train is a functional concept and the plan is to later implement this transfer style to the material flow of the other categories too.

3.3.3 Supermarket Area to the Assembly Line

The material flow of the A and B trolley is described above, but only the pre-picking from warehouse to the supermarket area. The actual picking for the *A and B trolley* until the assembly line, happens on the supermarket area. In this case the supermarket area is located next to the assembly line and divided into two aisles, A and B. They include different kind of items and are so on two separate pickings. The picking method is however the same with cabinet specific picking, but with their own picking routes. A more detailed version of the floor plan with the routes are presented in Appendix 5.

To explain the routing, there is two different routes, with the same principle. So, in the both instances, the picking process starts by retrieving an empty trolley from the assembly line. The trolley is connected with a former picking list, which are exported on the way to the team leader for finishing. A new picking list is obtained at the same time, and the trolley are brought to the own picking aisle. The trolley is accessorized with boxes for flow through parts, which are filled at first. Thereafter, the required parts from the list are picked in order through the aisle and on the A aisle, there is additionally the preassembly step. Then the trolley is transported back to the assembly line and the picked cabinet is marked to the control board. If something is still missing at this stage, it is marked visible on the front of the picking lists and one picker is specifically assigned to ensure that these parts are added to the trolley as soon as they arrive. This means that the work que does not primarily change, if a part is missing during the picking phase. The trolley is put at the end of the line and the default is that the part arrives before its turn for assembling, otherwise secondary alternatives done.

This supermarket area is one of the key things on the whole production process and something that will be utilized more in the future. The A and B trolley are generally a working concept and the only product-specific pickings on this assembly line. The area is structured and organized in a way, where the parts are picked in order to the picking lists. This makes the picking fast and prevents unnecessary steps for the picker, resulting an easy orientation of new employees too. One more functioning thing according to this, is the manual demand tracking. A and B trolleys are pushed to the assembly line when they are picked, and when they are empty again, the pickers know that they can take the trolley and pick the next one. An empty trolley works as a visual trigger for the picker.

To mention a few disadvantages, it would be the pre-assembly on the A-aisle and the painted parts on the B- aisle. There is a time-consuming pre-assembly step at the A-aisle, which could be done on the assembly line as well. On the B- aisle in turn, there are challenges with the big selection of painted parts, which can be found for each color, size and model. They are brought from two different places, either from the painting unloading area or from the incoming goods area, packed on a pallet. The pallets are brought somewhere along the aisles next to the supermarket area, because there is no room for them on the area, since there can be dozens of pallets at once. This can be regarded as a push process, instead of pull process that would probably be more convenient in this case. In addition to this, is the picking of the heavy painted parts up on a trolley from pallets on floor level anything but ergonomic.

3.4 Material Flow Routing

As it has emerged, do the material of the different pickings flow through different routes in the warehouse, until it reaches the final assembly line. Next, the previously mentioned illustrations of the routes are utilized further, and their common distance and time are calculated. The information is collected on basis on discussion with the logistics team leader and experienced pickers on the production line, but there were also a few other helping hands.

As already mentioned, the floor plan with the routes are revealed at the end of the text. In Appendix 3, the routes with the material flow from warehouse to the assembly line are shown. In Appendix 4 from warehouse to the supermarket area and in Appendix 5 supermarket area to the assembly line. The routing was done with assistance of an expert in the field in the company, using AutoCAD. The program did also calculate the distance for each route, which permitted the calculating of the daily transportation distance for all the routes together. The calculations are made for one shift and 16 cabinets. Additionally, the capacity per each trolley for the different picking categories has been considered, to be able to count the daily amount of walking the route.

Using this background information together with the AutoCAD distances the average distance of the current material flow per day on the production line was counted. The calculations are divided into three sections for the three different material flow routes, and then calculated into one average daily transportation distance. The calculations are presented below in Table 2, Table 3 and Table 4. They include the picking category in question, the transportation distance, the number of pickings per day and its total length. From that total sum, the average transportation distance per day is obtained – with transportation back and forth. In total, for all of the pickers per shift.

Table 2. Distance per shift from warehouse to assembly line.

Warehouse to assembly line			
Category	**m**	**pcs**	**Distance**
Key bars	35	2	140
Long profiles	204	2	816
Evaporators	79	8	1264
Electrical boxes	114	2	405
End plates	111	4	888
Glasses/ Mirrors	176	4	1408
Doors	163	8	2608
Distance per shift		7,5 km	

Table 3. Distance per shift from warehouse to supermarket.

Warehouse to supermarket			
Category	**m**	**pcs**	**Distance**
Purchased	95	2	380
Purchased	22	10	440
Painted	13	5	130
Painted	73	5	730
Purchased	102	3	612
Accessory	122	2	488
	Distance per shift	2,8 km	

Table 4. Distance per shift from supermarket to assembly line.

Supermarket to assembly line			
Category	**m**	**pcs**	**Distance**
A	55	16	880
B	34	16	544
	Distance per shift	1,4 km	

When these three distances are known, their common length can be calculated. And as shown below, the outcome in this case was 11,7 km per day, i.e. for one shift. The calculation is presented below in the Table 5. When this information is known, also the time spent for this can be calculated. The time is not measured by clocking, since it is not human to clock people while walking these routes with their trolleys. Therefore, the used method is: 1 step is 1 meter which takes 1 second. By calculating this way, the average transportation time per day on the production is obtained. In this case, the outcome is approximately 3,3 hours of walking these routes in total in one shift. This is also introduced in the Table 5 below.

Note that this is only the time spent for transportation, not the whole picking time. The aim with this is, to show the effect of the goods being so spread around the factory – 3 hours of effective work time could be used for something else, if the parts would be located closer to the assembly line.

Table 5. Average transportation distance and time per shift.

Picking to the line	7,5 km
Picking to the supermarket	2,8 km
Supermarket picking	1,4 km
Average transportation distance per day on the production line	11,7 km
Average transportation time per day on the production line	3,3 h

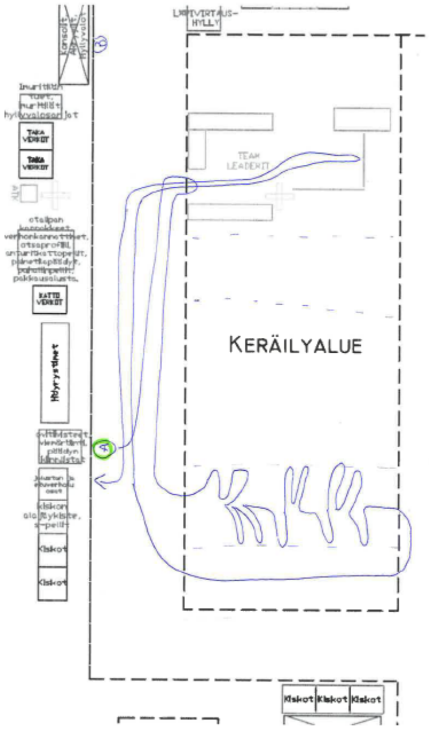
3.4.1 Supermarket Analysis

The above-mentioned facts are mostly collected by discussion and interviews of how things go according to the protocol. That is why, these things have been observed in action, to get reliable information of the processes. The observation in this case, was done on the supermarket area for the picking of a certain model, namely a multideck cabinet with an external length of 2500 mm, with doors. The picking was done for all the items required for this cabinet, from the supermarket area, including the preassembly step. As test persons, there were both beginner and experienced pickers.

The distance per shift from supermarket to assembly line is calculated in the previous section, on basis of the routes made on AutoCAD. The routes are in turn made, based on an oral explanation by the pickers of how the route is going. An explained route is though seldom identical to the genuine route. That is why, this thing has been double-checked – by observing the pickers in act and creating a spaghetti diagram of the exact routing on the supermarket area. A spaghetti diagram is a visual representation with a continuous flow line, to trace the pickers path through the picking process. This is done to identify the excess movements in the workflow.

The actual picking process is also described previously, and the observation is made for the same process going. As a recap, the starting point is when the picker gets an empty trolley from the assembly line, hand-over the former list to the team leader and gets a new one. Then the picker picks everything required and marks the picked entity on the control board and the trolley is transported to the assembly line with the picking list.

These two routes are observed and documented in Image 14 and Image 15, examining each phase on the area and performing the meters and steps walked by the picker.



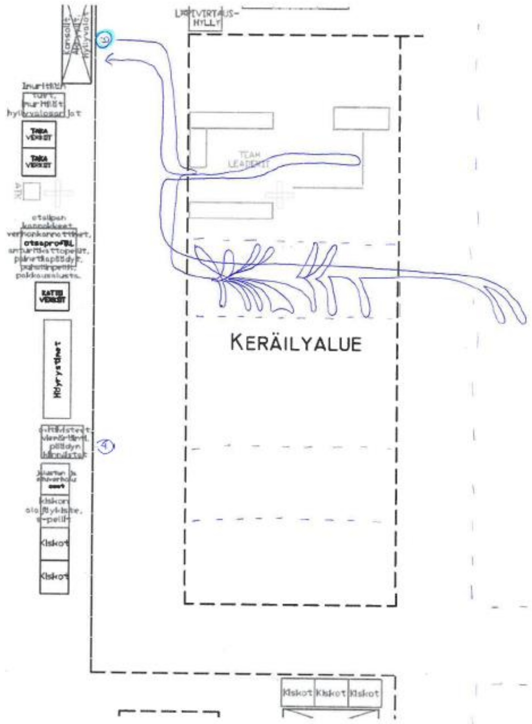


Image 14. Spaghetti diagram of the picking route for the A-trolley.

Image 15. Spaghetti diagram of the picking route for the B-trolley.

By observing the routes on a square paper, in relation to one meter per square, the actual walking distance can be estimated. In this case, the routes are approximately 130 m for A and 120 m for B, which is way more than the previously calculated distance. The observed reason to this, is that the features of the trolley are not utilized, the trolley is roughly just parked in the middle of the lane and the items are being picked by walking back and forth between the shelves and the trolley. A positive observation is that you can clearly see that picker is walking in the right direction – with just a few pointless moves.

During the observation of the routes, the recording time was set down too. On basis of that, the time consumed picking process for both A and B can be estimated, including the preassembly on A. This was done twice, for both an experienced picker and beginner picker, to further test if the picking is as simple as said. In this case a person with one week's experience, is counted as a beginner. The chart with the minutes, taken for the picking of one certain cabinet on the supermarket area, is shown below on Figure 3 and Figure 4.

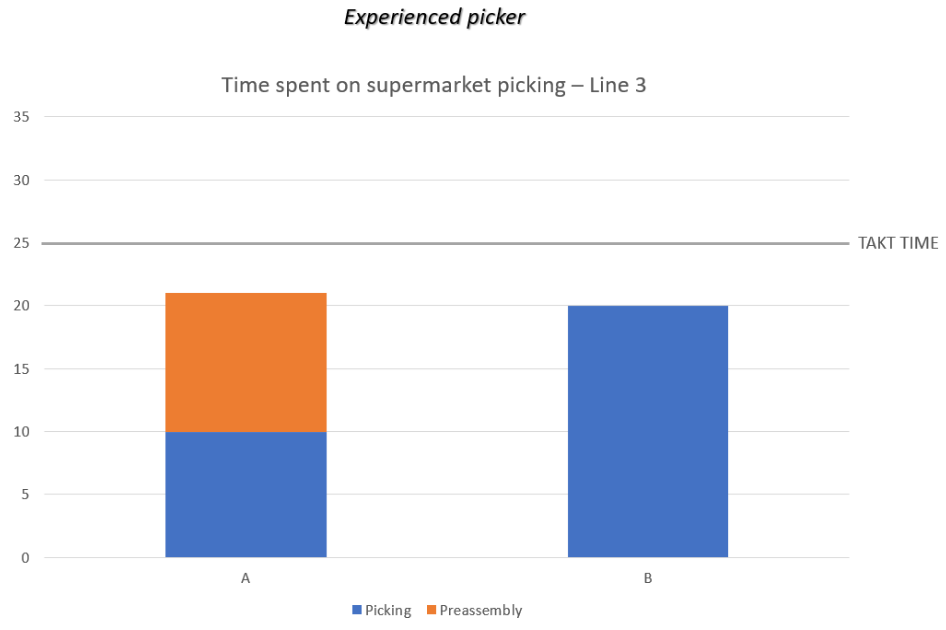


Figure 3. Time spent on supermarket picking for an experienced picker.

Figure 4. Time spent on supermarket picking for a beginner picker.

As interpreted from the diagrams, the time differs almost by one third between the experienced picker and the beginner. We can conclude that the supermarket picking works as it should for an experienced picker. Because the picking of both A and B are even and less than the takt time. But this does not happen in the case of a new picker, where the picking time exceeds the takt time. This means that the picking on the supermarket may not be enough simple that also a new person could handle it. In fact, also the distance was longer in the case of the beginner.

One observed reason to the extended routes and the time elapsed for it, might be the non-existent storage locations for the items – the picker is assumed to know where the required items are located on the supermarket area. Although the area is well organized, it may not be enough. As an additional proof of that, according to the ERP-system there is at the supermarket area regularly over 200 items – without any shelf locations. This can be interpreted as a challenge for a new picker, since the picking takes both time and consumes more steps. The number of items on the area is showed in the Image 16 below.

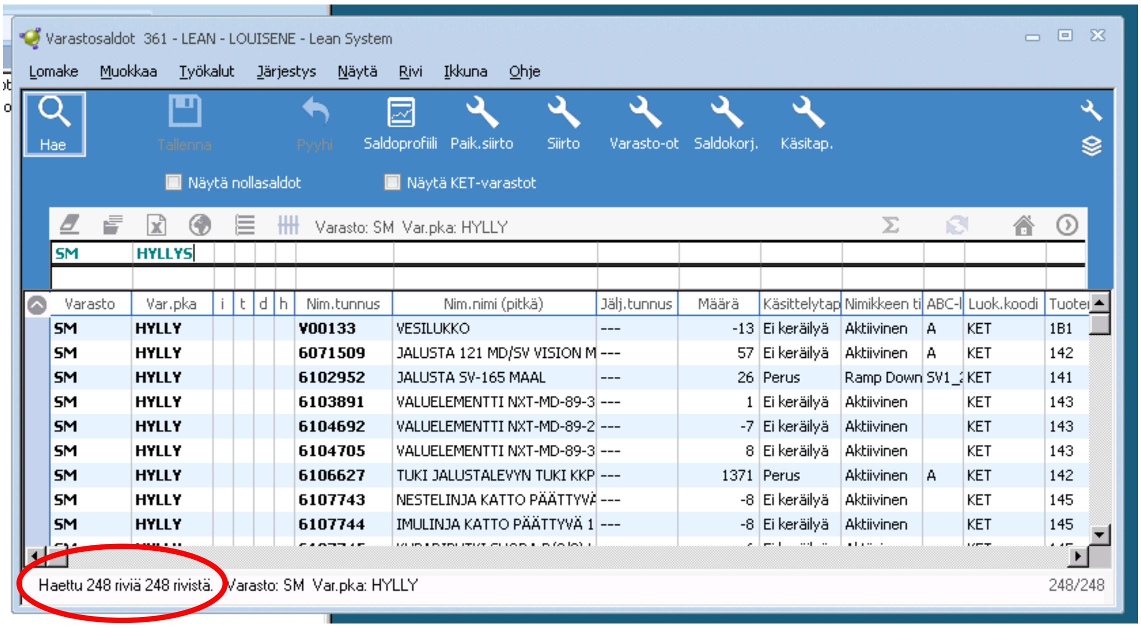


Image 16. The number of items on the supermarket area.

3.5 Key Findings and Selected Areas for Improvement

In order to improve the current process in the case company, the above-mentioned issues need to be handled. The issues were overbearing, but a few strengths did appear also, and they are even more urgent - since it is important to understand those parts that are working and doesn’t need improvement.

The main issues in the current process will be summarized and the areas for improvement chosen thereafter. The strengths will also be taken into consideration, by keeping in mind their sensible factors. In addition to this, the founded opportunities for this process will be mentioned as well as the possible threats to consider. These factors will be reviewed in form of a SWOT analysis, with the key strengths, weaknesses, opportunities and threats of the current mode of operation. After this, the selected areas for improvement will be presented.

To begin with key *strengths* discovered during the current state analysis, the first one is the *supermarket area*. It is one of the more urgent things that will be more utilized in the future. The cabinet specific picking, according to the target, is the major topic here. The picking occurs in an organized way, with many visual triggers as assistance. Some smaller disadvantages have been mentioned concerning this, but in the big picture it is a working concept, only needing some minor repairs. However, the maintenance of a complete bill of material (BOM) has been successful for the items on this area – and it is recommended to keep at a good level.

Another working concept is the *material flow control board*, located beside the assembly line in question. It is currently used in the last stage of the picking process, to mark the picked entity. It forms an ensemble that visualizes all the ensuing orders and their picked items, to control the material flow. This system makes it easy to keep track where the picking is going and is so on a very useful tool for anyone working in the area. It could of course be more modern, but the basic idea is working.

The main *weakness* detected in this picking process is the *non-real time material flow*, because of the wrong kind of picking method that is paper picking. This is generally a working way to pick, but the material flow is not real time, which causes balance errors and other misunderstandings. The fact that the picking is mostly done for a various amount of cabinets at a time, creates a bigger risk than needed. Regarding this, also the picking vehicle is displeasing, with multiple different kinds of bad quality picking trolleys. A developed version would perhaps be more exploited during the picking process.

Another key issue is the *positioning of the materials*, which extends around the entire factory and in some cases even beyond. From this point of view, the different picking categories are in illogical and incompetent locations, although there are certainly reasons for that. Some categories are located very far from the assembly line, some are placed on unsafe locations and some require multi-staged picking from different locations. The seeking of these parts takes time and the parts are also prone to damages during this process. This applies to almost all the picking categories located far from the assembly line, to highlight the painting unloading area at its center. In this context, we can conclude that the mode of operation in many cases is need of a development.

Opportunities in turn, in the mapped process, is the possibility of implementing a *platform for real-time material flow*, a.k.a *MatFlow*. The platform would solve the misunderstandings according stock balance information and result in many advantages, with the integration of the stock and the ERP-system. The implementing of this platform requires though cabinet-specific picking and some other justifications. While doing these justifications, the *relocating of the materials* could be considered, for a smoother and safer picking process.

Additionally, an opportunity is to *modernize some of the current operations*. The supermarket area for instance, could be developed in order to enhance the minor issues detected, with some more modern operations. The filling of the boxes could e.g. utilize Kanban or a two-bin system, to clarify its approach. Storage locations could also be added there. The same thing applies to the material flow control board, which could be even more functional or even digitalized.

The *threat* in the current operating way is the prospective *inaccurate inventory* and its consequences. This might be the case, if the practices continue in the same way. It will cause problems like maintaining inappropriate stock levels and growth of obsolete inventory. It does also affect the picking, while relying on inaccurate information and causing ineffective processes. In the long run, these factors might incur *costs* with increased expenses, lost revenue and low productivity as a result. Digitalization might be one of the key factor for solving this kind of problems.

These factors can be reviewed in the SWOT analysis in the Figure 5 below.

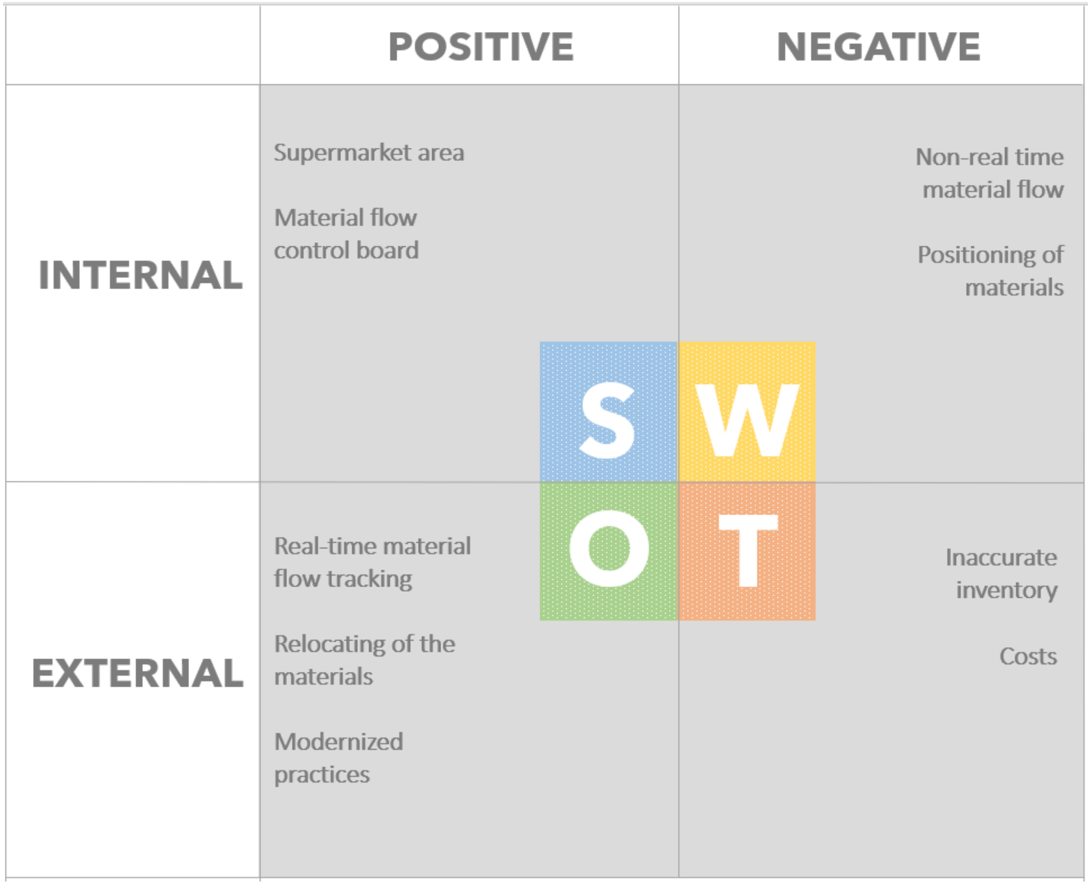


Figure 5. SWOT analysis.

On basis of the SWOT and the key findings a few wider areas to improve have been chosen. It is a conclusion made together with the logistics manager and the logistics team leader, with the best possible improvement in mind. As a result, the selected areas for improvement have been divided into two key areas.

The first area to concentrate on, is the *relocating of the materials*. As inspected, the distances of the material flow routing are way too long, which takes both time and effort of the picking process. That is why, this improvement will focus on finding new places in the warehouse closer the assembly line, to set the needed materials on. This would hopefully minimize the time spent on transportation of the materials that could rather be spent on something more useful. The practicality of the picking itself, will also be considered. Related to this topic, some improvements for the supermarket area will be done as well – to make those operations more efficient.

The second area to focus on is achieving *real-time material flow.* It is the main objective of the whole thesis and therefore the most critical factor to concentrate on. The aim is thus, to move from paper picking to online picking, for a real-time material flow. The major thing is to get the inventory changes real, i.e. the finishing of the pickings must be done immediately. The tool that will be used for this is the platform named MatFlow. Before the implementation, some of the platform's requirements must be considered, and compromises done thereafter. In this context, the material flow control board could be improved as well. The current material flow control board is a working concept with necessary information, but there is still factors to improve. Therefore, another goal for this improvement is to make it even more useful with additional features. One idea is to digitalize it on one big touchscreen and compound it to the online picking – to have the material flow on a big screen easily visible.

4 Best Practice of Moving Materials through Supply Chains

The best practices and available knowledge of moving materials through supply chains are explored in this section, to reinforce the understanding of the selected topics. First, the definition of logistics and supply chains will be clarified and then ways of controlling material flows. Then, specifications of inventory management, warehousing and material handling will be handled. The principle of MatFlow will also be clarified. The aim is to provide relevant information for solving the key issues identified in the current state analysis and create a conceptual framework. On basis of that, the initial proposal can be done.

4.1 Logistics and Supply Chains

The aim of every organization is to supply products that satisfy the customer demand. For creating and delivering these products, an efficient material flow is required. Logistics is the function that is answerable for the movement and storage of the materials. Materials are transferred from suppliers to organizations and through operations to the customers. This is a fundamental function in every organization, and it can be stated that each of them is linked to a broader supply chain. A supply chain contains a series of linked activities and organizations that products run through, from the initial supplier until the final customer. (Waters, 2009: 28-29.)

4.1.1 Definition of Logistics

Logistics can be defined in many ways. One definition is the material flow management of the raw material source to the end customer, serving the product in the right place at the right time, while minimizing costs and other disadvantages as environmental or safety risks. It means planning of materials and services together with productive and cost-effective purchasing management, warehousing, transportation, distribution, implementation and monitoring, considering the customer needs. (Logistics)

Logistics is accountable for moving and storing the materials, from the original suppliers until the final customers. All the things needed for making a product are called materials, both in the form of raw materials and information. Products in turn, is the mix of goods and services passing to the customers from an organization. (Waters 2009: 6.) The flow of materials and products from suppliers, within the organization and out to customers can be divided into inbound, inhouse and outbound logistics. Inbound logistics starts by procurement and follows by reception, checking, unloading and shelving of the goods. Inhouse logistics includes the handling materials and products inside the organization. Outbound logistics is both picking and packing from warehouse and outgoing from the loading dock distribution and transportation. (Ritvanen et al., 2011: 20-21.) This concept is visualized in Image 17 below.

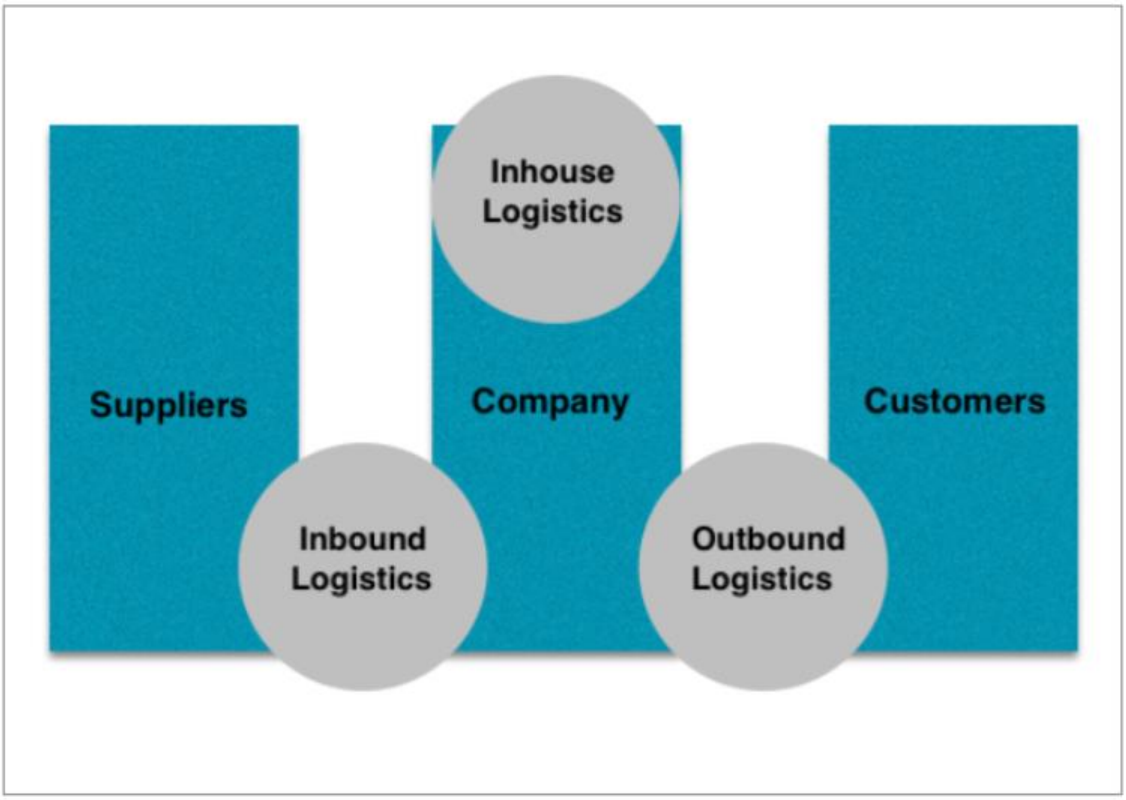


Image 17. Inbound, inhouse and outbound logistics. (Inbound, inhouse and outbound logistics)

4.1.2 Supply Chains

Logistics is described above, as the movement of materials through a single organization. But the journey is greater than that, since every organization do work both as a customer when materials are bought from the supplier, and as a supplier when materials are delivered to the customer. For example, a wholesaler is in the role of a customer when goods are bought from a manufacturer and then in the role of a supplier when the goods are sold to a retailer. The raw materials of a manufacturer are in turn bought from a supplier, and then assembled to a finished product, and sold to a wholesaler. This phenomenon creates a chain, with the most common term supply chain. It consists of a series of activities and organizations that materials move through, all the way from the initial supplier to the final customer. (Waters, 2009: 8-9.)

A supply chain is a group of companies, consisting of three or more parties, whose mutual interaction is associated with delivery of goods, service performance, information exchange and money transactions. The specialized expertise of the parties is needed for sourcing goods from producers and delivering them to customers, but no common agreement or guidance between the parties are necessary. (Sakki, 2009: 14.)

4.2 Controlling Material Flow

The aim of a supply chain is to deliver materials at the right time at the right place. To be able to give a timetable for logistics to move the materials, planning is required. There are in principle three ways to generate these plans: traditional planning, material requirements planning and just-in-time operations. (Waters, 2009: 298.)

4.2.1 Traditional Planning

The perspective for all planning decisions about logistics is set by the logistics strategy. Traditional planning starts by decisions about capacity and continues gradually with more details, to get lower-level plans. They lead down to the most common strategic plans for supply chains, which are aggregate plans, master schedule and short-term schedules. Aggregate plans are tactical plans that summarizes the relevant activities by month at each location. Master schedules are tactical plans that gives timetables for each activity by week. Short-term schedules are operational plans that gives detailed timetables for all jobs and resources by day. (Waters, 2009: 232.)

The objective of short-term schedules is to organize the necessary resources for the master schedule, by offering low costs, high utilizations, and other performance measures. Scheduling is a surprisingly difficult skill, since there can be so many timetables to consider. For instance, if there are 10 tasks that must be fulfilled on one day, the number of ways to organize them is more than imagined. The first task can be any of the ten tasks, the second task can be any of the remaining nine, the third task can be any of the remaining eight, and so on. By calculating this way, the amount of ways to fulfil the tasks is:

$$10\ x\ 9\ x\ 8\ x\ 7\ x\ 6\ x\ 5\ x\ 4\ x\ 3\ x\ 2\ x\ 1\ =\ 3{,}628{,}800$$

(Waters, 2009: 268-269.)

One tool for this is to use scheduling rules, which are simple rules that experience suggests give fair results. These are used in everyday life in banks and hospitals for example, where they occur as “first-come-first-served” or “most urgent first”. These are included in the four common rules, for organizing jobs in a reasonable order:

1. *First come, first served* - Jobs are taken in the order they arrive, providing fairness.
2. *Most urgent job first* - Jobs are processed in order of urgency, enabling higher priority on the most important jobs.
3. *Shortest job first* - Smaller jobs are taken first, minimizing the average time spent in the system.
4. *Earliest due date first* - Jobs that are due earliest are processed first, minimizing the maximum lateness of jobs.

(Waters, 2009: 269-270.)

4.2.2 Material Requirements Planning

The traditional planning has some drawbacks too. It is, among other things, slow to react on changing conditions and an urgent delivery must wait until the following planning cycle. Another issue is the fact that the traditional planning is based on forecasts on independent demand. Independent demand means that the demand from one customer does not relate to the demand of another customer, which makes it difficult to create forecasts.

But when the actual demand is known, approaches like dependent demand can be used. Dependent demand means that the demand for different products are related to each other and is linked through the master schedule. (Waters, 2009: 272-273.)

Material requirements planning (MRP) is a system based on dependent demand, which explodes a master schedule for giving timetables for deliveries of materials. A clear difference between the two approaches is related to the nature of material stocks. With independent demand systems, stocks are kept high enough to ensure potential demand. With MRP, stocks are directly connected to production and so on generally low, with deliveries done right before start. When the deliveries are related to the actual requirements, costs can be reduced and customer service improved, by using MRP. (Waters, 2009: 273-274.)

A lot of information about schedules, products, materials and suppliers are used by MRP. The information comes from three main sources:

- *Masters schedule* – the amount of each product to be made in a period.
- *Bill of material* – an ordered list of the needed materials to make each product.
- *Inventory records* – the available materials and related details.

(Waters, 2009: 274.)

By combining the masters schedule and the bill of material, a timetable for the materials needed is at hand i.e. the gross requirements. The inventory records show the available materials and the timetable for ordering any materials needed can be designed based on it (Waters, 2009: 274.). A more advanced version of this concept is presented in the Image 18 below.

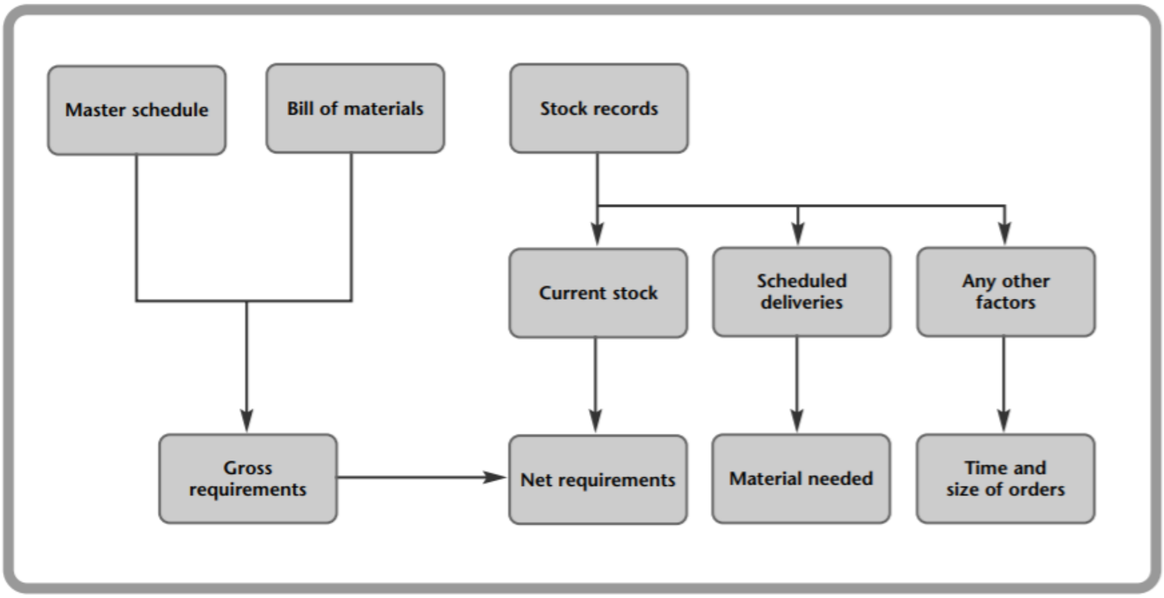


Image 18. Summary of MRP calculations. (Waters, 2009: 276.)

4.2.3 Just-In-Time

The material flow is controlled by designing schedules in both traditional planning and material requirements planning. Just-in-time (JIT) works differently, by organizing all activities to occur at exactly the time they are needed, without any rigid plans. The activities are not done too early or too late, since it would result in materials lounging around until they are needed or poor customer service. As an example of this scenario, a taxi order until 8.00. If the taxi arrives at 7.30, the customer is not ready, and the taxi driver must wait. If the taxi arrives at 8.30, the customer is dissatisfied and will not use the same service again. But if the taxi arrives right on time at 8.00, no time is wasted on waiting and nobody is dissatisfied. (Waters, 2009: 285.)

The main purpose of stock is to work as a safety buffer between the operations. In that way, operations can continue nonstop even when something unexpected occurs - delivery is delayed, some equipment got to pieces, demand is surprisingly high, or some other incident. Therefore, many people think that stocks are essential to guarantee smooth operations and keep the stock high enough to cover possible difficulties. But when conditions are uncertain and the stock levels are kept high, it is related to costs. To reduce the amount of costs, MRP uses master schedule to match the arrivals of materials more closely to the demand. There is always some stock, but the closer the supply of materials are matched to the demand, the less stock need to be carried. The principle of JIT goes to the next level and delivers materials straight to the operations to the exact time. It means that the supply of materials must match exactly to the demand and like that eliminate the necessity of any stocks at all. (Waters, 2009: 286.)

A comparison of these three mentioned types of control, are presented in Image 19 below.

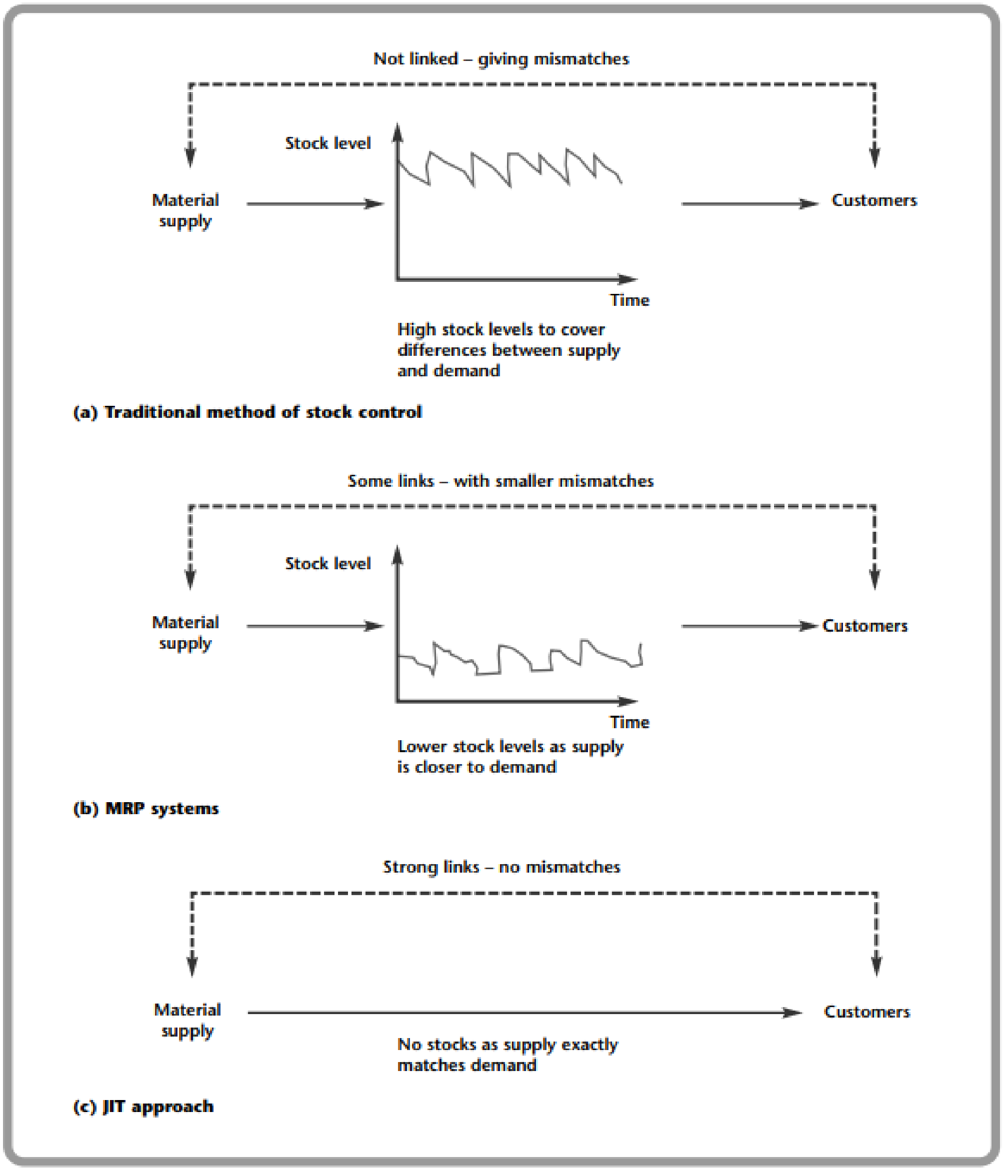


Image 19. Stock levels with different types of control. (Waters, 2009: 287.)

For manufacturing to operate according to JIT, it requires some way of arrangement. JIT offers a method for achieving this by ‘pulling’ materials through operations, namely a *pull system*. So, when one operation is performed for a product, it passes a message back to the previous operations informing the need of one more unit. The previous operations will not pass materials forward until it receives this request. Like this, the earlier operations do not push work forward, but later operations pull it through. For instance, a take-away sandwich bar. With the traditional push system, sandwiches are done as a batch and put to the counter until someone buys them. With JIT pull system, a customer orders a particular sandwich and it is specially made based on the request and at the same time eliminating the stock of work in progress. (Waters, 2009: 288.)

In addition to pulling the materials through the operations, a way of passing a message back to previous operations is required. The simplest way of organizing this is to move the materials into containers. When a next stage needs materials from a previous stage, it simply passes the empty container back as a signal to fill it with materials and return it. But this method is not trustworthy enough for most operations and therefore another alternative is to use a ‘demand pull’ approach called *Kanban*. Kanban systems uses circulating cards to control the flow of material through JIT operations that organizes the ‘pull’ of materials through a process. Kanbans can be used in many ways, either with paper cards or with electronic ones. Traditionally, there are two types of cards: *production Kanban* that send signals about need of production and *movement Kanban* that send signals about the need of movement. (Waters, 2009: 289-291.)

Based on U.S. supermarkets, have the concept of *Kanban supermarkets* been developed. Kanban supermarket is a central storage location, where the raw materials are stored near their point of use, ready to pull when needed. It works in conjunction with the Kanban cards, presenting every position in the supermarket area with all required information about the items. The aim is to minimize transactions costs, facilitate visual management and constitute the framework to switch to a Kanban system. (Gross & Mcinnis, 2003) Another form of Kanban is the *Kanban board*, which is a tool for workflow visualization. The major processes and steps must be identified first and then divided into separate columns depending on their status. The status is either to do, work-in-progress or done, according to the general division. (Klipp, 2014)

4.3 Inventory Management

In a supply chain, the procurement triggers the flow of materials. The ideal is that the materials move smooth and controlled, but in actuality, there is always delays when materials stop moving. When the material stops in the supply chain, they form stocks. A stock is a store of materials that are kept in an organization. (Waters 2009: 336)

Every organization hold stocks of some kind. The most common assumption of stock is that they are waste of resources and should therefore be eliminated or reduced. (Waters 2009: 336) However, the matter is not so simple, because of the arising logistical conflicts, introduced in Image 20. A wide selection in a company leads often to a better customer service and sales but binds a lot of capital in the selection. Large batch sizes assure smooth production when the raw material availability is secured but leads to a high stock level. If the stock level is kept low in turn, capital is not committed as much, but the transportation costs might increase. Therefore, it is important to look at the ensemble, instead of sticking to the examination of an individual function. (Ritvanen et al., 2011: 24) So, the size of a stock is a two-sided affair, but at least the existing one could be controlled properly. It is possible by stock control i.e. inventory management, which is the concept of being responsible for the control of stock levels in an organization. (Waters 2009: 337)

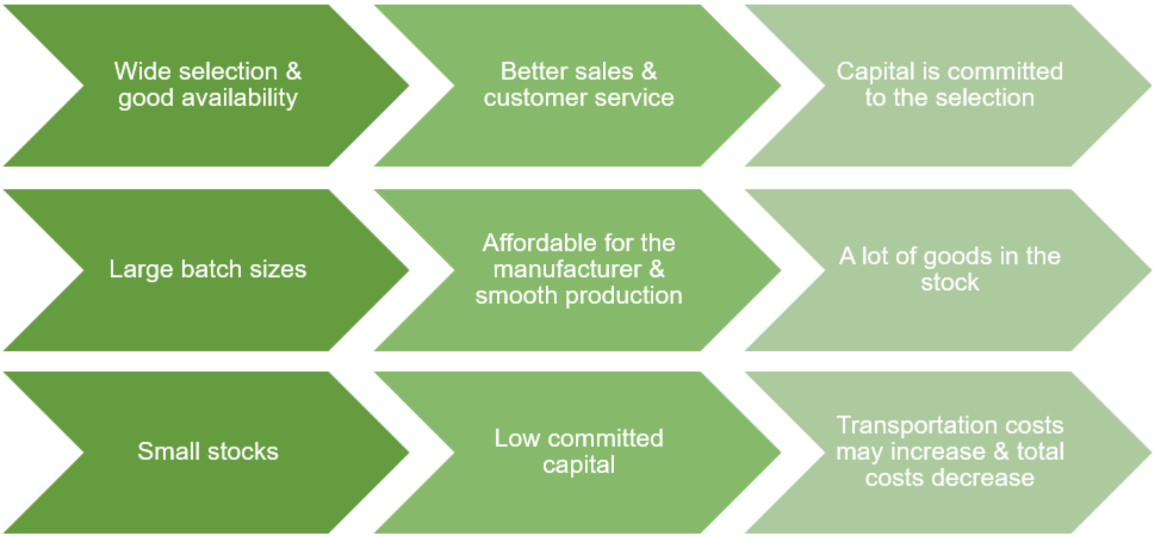


Image 20. Logistics conflicts. (Toimitusketju ja kilpailukyky – Adapted version)

4.3.1 Inventory Types

Inventory can be divided into four classifications in general, namely raw materials, work-in-progress, finished goods and MRO goods. Depending on the industry, it can further be grouped into smaller divisions on a company basis. (Pontius, 2020)

Raw materials are inventory items that are used to produce finished goods in the manufacturing process. The perception of a raw material depends on the industry, since a raw material for one company might be a finished good for another. Components for machinery are finished goods for one company and raw materials for company producing a machinery, as an example. Raw materials can thus be paper, steel, nuts, bolts, chemicals, wheels, or something else. (Pontius, 2020)

Work-in-progress (WIP) inventory consists of items that are currently being produced. WIP inventory may as well be raw materials in the manufacturing process for finished goods as finished items waiting for final inspection or quality check. Only after that, the finished items are counted as finished goods. *Finished goods* is the composition of all the completed items, ready for the final customer. (Pontius, 2020)

Maintenance, repair, and operating supplies (MRO) goods are items needed for operating, as equipment or machinery, as well as items necessary for maintaining equipment and infrastructure. It might include items considered as raw materials, as nuts and bolts, but int that case in form of spare parts. Otherwise, MRO inventory can be janitorial supplies such as cleaning solutions, like mops, brooms and gloves, or office supplies, like paper, pens and printer ink. (Pontius, 2020)

4.3.2 Inventory Control Methods

Traditionally, materials are controlled by inventory control, where the information of the need of order comes from the warehouse based on material accounting. Inventory control suits best for continually consumed products, aside from seasonal variation, but for any kind of industry. (Sakki, 2014)

For replenishing the stock there are two ways: *order point method* and *order interval method*. In order point method the goods supplement is conducted when the stock level reaches a predefined limit i.e. the order point. The ordered batch usually remains the same, but the ordering occurs irregularly. In order interval method the stocks are replenished regularly, but the batch size varies. When planning a stock replenishment, three factors need to be known: *acquisition time*, *expenditure during the acquisition time*, and *safety stock*. The acquisition time includes the total time spent for placing an order and delivering the goods. The expenditure during the acquisition time is an estimate of the average expenditure. The safety stock is the expected minimum amount, under which the stock level should fall only in exceptional cases. (Sakki, 2014)

Order point is a predefined stock level, under which there is time to procure the product in question within a normal delivery period. If everything goes according to the plan, there is still the goods in the stock, with the amount of safety stock, when the delivery arrives. And if the expenditure is higher than expected during the delivery period, the delivery capacity can rely on the safety stock. The order point is obtained with the following formula:

$$T = DL + B$$

(Sakki, 2014)

In practical procurement work, the orders are usually set regularly, for instance once a week. In that case, the order point must be raised so that the stock suffices both the delivery time and for the length of the review period. Then, the formula is:

$$T = D\left(L + \frac{P}{2}\right) + B$$

(Sakki, 2014)

In the formulas above, T is the order point. D is the average expenditure in goods units in a certain period of time, for example in a week. L is the acquisition time i.e. the delivery time, in weeks. P is the length of the review time and B the safety stock in goods units. (Sakki, 2014)

The Image 21 visualizes the mode of setting the order point, which presents the stock changes for one product. M is a new delivery that has just arrived in stock and is at its peak. The stock decreases in use and at point T the order point is achieved. At point S the order arrives and increases the value of the inventory. (Sakki, 2014)

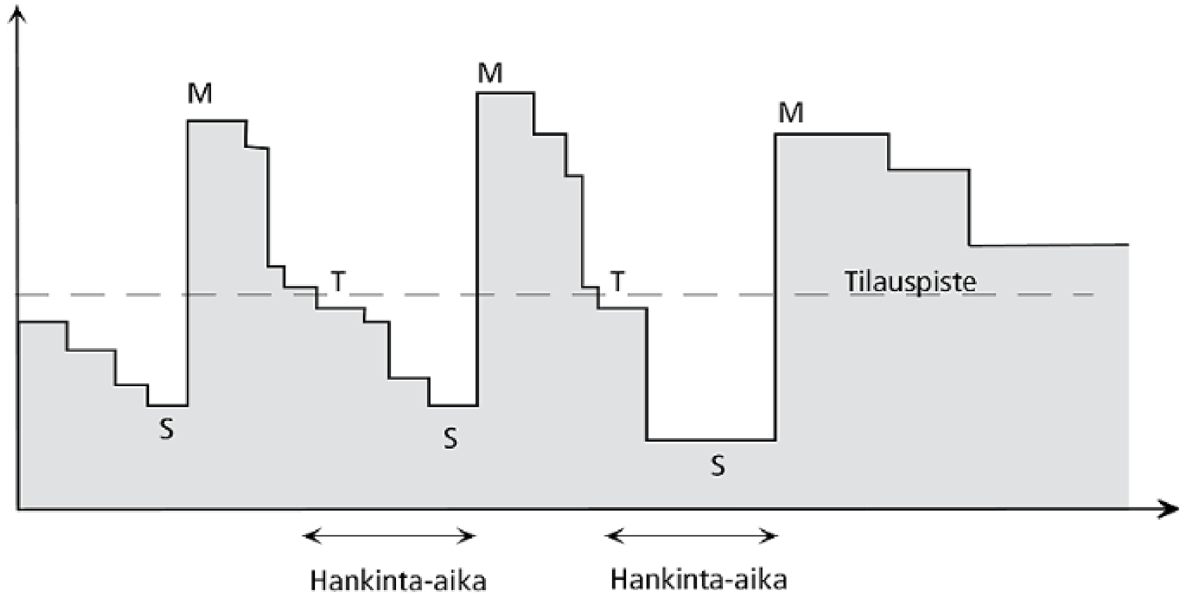


Image 21. Order point method. (Sakki, 2014)

Two-bin method is a practical application in inventory control. The method is suitable for products with continuous consumption. The idea is that an order point is defined for the products and a corresponding amount is placed to a separate place, shelf or box. Those products are used, only when the rest is consumed. Usually, the last box is marked with a subscription card, on the basis of which the supplementary order is placed. When the order arrives, the last box is filled, and the rest of the items are put in the normal stock. (Sakki, 2014)

Min-max method works for products that need upper and lower limits, within which the stock level is moving. If the stock level is between the limit at the review time, no order is placed. If the stock level goes under the lower limit, an amount that lifts the stock level to the upper limit is ordered. The ordered amount varies in this method. The limit value and order batch can be defined in the following ways:

$$
\begin{aligned}
&\textit{The maximun storage} \\
&\qquad = \textit{safety stock} \\
&\qquad + \textit{expenditure between review time and aqcuisition time}
\end{aligned}
$$

$$
\begin{aligned}
&\textit{The minimum storage} = \textit{order point} \\
&\qquad = \textit{average expenditure during aqcuisiton time} + \textit{safety stock}
\end{aligned}
$$

(Sakki, 2014)

The order batch is obtained by reducing the current stock and potential upcoming orders from the maximum storage. The review time in turn, can be defined with the annual consumption and the optimal batch - by dividing them the amount of orders in a year is obtained and by dividing the annual 52 weeks with the amount of orders the review time is obtained in weeks. (Sakki, 2014) This method is revealed in Image 22 below.

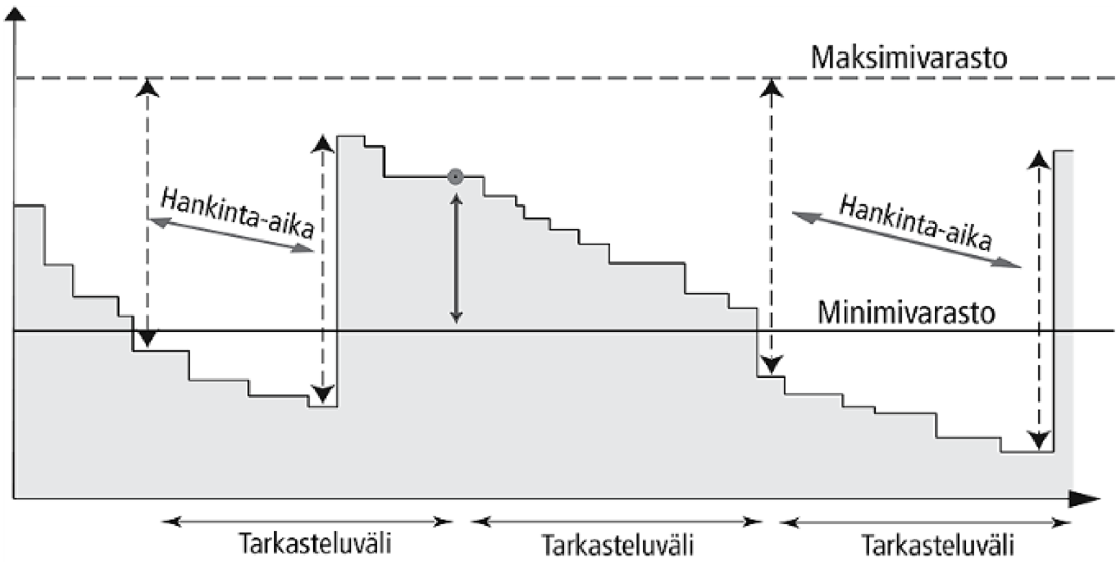


Image 22. Min-max method. (Sakki, 2014)

The right order batch is obtained with a suitable *order interval.* The batch size can be optimized with the s-c. Wilson formula. The optimal batch is often called EOQ, economical order quantity, and its formula is:

$$EOQ = \sqrt{\frac{2 * \mathrm{D} * \mathrm{TK}}{\mathrm{H} * \mathrm{VK}}}$$

(Sakki, 2014)

In the formula, D is an estimation of the future annual sales in goods units, for example in pieces. TK is the variable cost for one order batch in euro or some other currency. H is the unit price and VK the annual cost of inventory in percentages of the average value of the inventory. The calculated optimal batch is a coarse approximation, since the used sales and costs is either estimations or averages. (Sakki, 2014) This concept is presented in the Image 23.

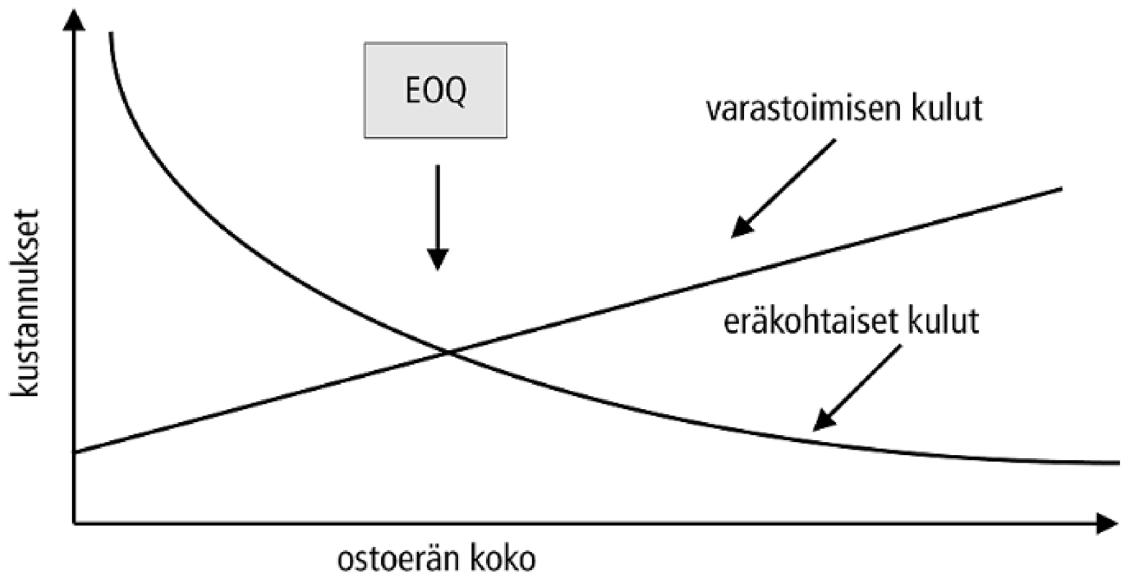


Image 23. When the order batch increases, the stock and its costs grow, but less arrivals lead to lower costs. The optimal batch can be found at the point of intersection. (Sakki, 2014)

4.3.3 Inventory Control Systems

Inventory control systems offers functions to help companies manage different types of inventory. The systems are usually inventory management apps connected with barcode tags, for identifying inventory assets together with data about each item that is stored in a central database. The barcode label informs the item’s price, number of items in stock, location of and item among other things, by checking the code on a computer system. (Pontius, 2020)

The most favorable inventory control apps are mobile based, with a companion device that allows tracking and managing inventory on the way. There are many different inventory management apps, but the ones offering features accommodating the company's need, should be chosen. Decisions should be made depending on whether there is a need of alerts when the inventory level reaches a pre-defined limit, re-ordering capabilities, or analysis and report to support functions like forecasting. (Pontius, 2020)

There are two main types of inventory control systems that is perpetual inventory system and periodic inventory system. They can further be divided in the two main types of inventory management systems, namely barcode systems and radio frequency identification (RFID) systems. Their purpose is to back the whole inventory control process. (Pontius, 2020)

A *perpetual inventory system* updates the inventory records repeatedly and is responsible for corrections in the movement inventory items. This system is preferable for some organizations, since the inventory information is up-to-date and handles well the counts of minimal physical inventory. It is also advisable for inventory tracking with accurate results continuously. This kind of system works best in combination with a database that are updated with real time information about inventory quantities and locations, by warehouse workers using barcode scanners. (Pontius, 2020)

A *periodic inventory system* tracks the inventory level in predefined periods and do, so to say, not track inventory daily. The system works based on physical inventory counts that are balanced in the purchases account shifted to the inventory account and adjusted to match the cost of the ending inventory. The calculations of the cost of the ending inventory can be done with the inventory accounting methods last-in-first-out (LIFO) or first-in-first-out (FIFO). (Pontius, 2020)

Barcode inventory systems are inventory management systems that uses barcode technology. These systems are more precise and efficient than the ones with manual processes. When they are used together with an overall inventory control system, the barcode system registers the inventory levels automatically when the barcode is scanned by a warehouse worker, either with a barcode scanner or a mobile device. (Pontius, 2020)

Radio frequency identification inventory systems operate with active and passive technology for managing inventory movements. Active RFID technology use fixed tag readers across the warehouse. This means that the movement is recorded to the software as soon as the RFID tag pass the reader. This is ideal for organizations that insist real-time inventory tracking. Passive RFID technology in turn, use handheld readers to track the inventory movement. So, the data is recorded by the software when the tag is manually read. The reading range of RFID technology is roughly 40 feet passive and 300 feet active. (Pontius, 2020)

When an inventory control system becomes topical, either perpetual inventory system or periodic inventory system should be chosen first. Only then, it is time for a barcode system or RFID system, for using them in conjunction with the inventory control system. This creates an absolute solution, enabling visibility into the inventory for enhanced precision in scanning, tracking, recording and reporting the movement of inventory. (Pontius, 2020)

4.4 Warehousing and Material Handling

Inventory management account for ways of handling stock levels. But the way that the stocks are stored in practice is a different matter. For the most part stocks are stored in a warehouse, which is any location where stocks are held during the supply chain. There are many different forms of warehouses, with different activities in addition to storage. (Water, 2009: 372.)

Warehouse management or warehousing includes the maintenance and control of all the elements in a warehouse. It contains everything from layout set-ups, inventory control, equipment maintenance, incoming and outgoing goods – tracking, picking and packing goods, shipping products, to the implementation of an automated warehouse management system (Kanya, 2020). Warehousing concern a lot of processes and here, only a fraction will be reviewed.

4.4.1 Warehouse

Any location where stocks of material are kept during their way through the supply chain, are called warehouse. Warehouse is the label for any storage areas, but in practice, there are many different arrangements for storage. It might as well be an open area with raw materials as sophisticated facilities or databases with stocks of information. The intention of a warehouse is to promote the wider logistics function, by storing materials until they are needed, taking into account low costs and high customer service. (Waters, 2009: 372-375.)

4.4.2 Warehouse Processes

Improvement comes from simplifying processes and procedures. The processes must be adjusted and work optimally in order to improve efficiency and corollary reduce costs within the warehouse operations. The essential processes remain the same, although warehouses differ overall in terms of size, type, function, ownership and location. These processes include receiving, put-away, storage, replenishment, picking, shipping, cross-docking and value-added logistics. (Richards, 2014: 58.) In the following Image 24 these activities and flows are revealed.

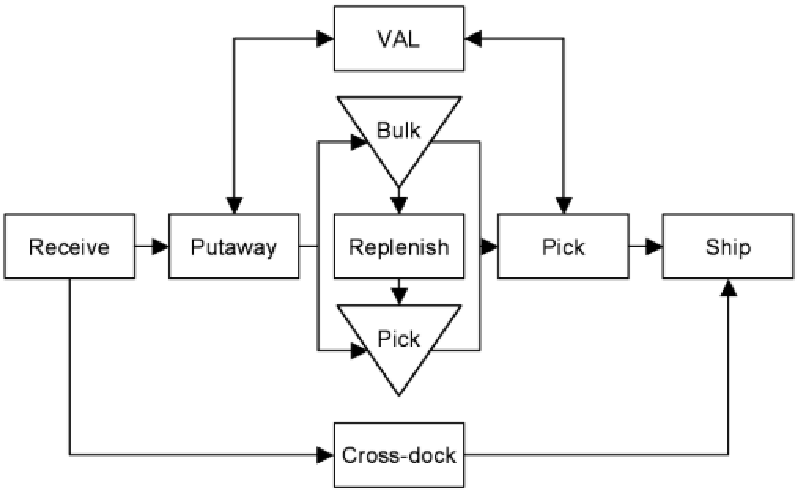


Image 24. Activities and flow in a warehouse. (Van Den Berg, 2007: 60.)

The first activity is *receiving* that is the process of unloading an incoming truck as well as identifying, registering and possibly repacking the goods. It continues with the *put-*

away process, by moving the goods to a storage location from the unloading area, which is either at the bulk or at the pick area. In *storage*, other activities might happen at the same time, e.g. inventory is counted, or goods are moved to other locations. If the inventory level is running low, it is *replenished* from the possible bulk area. Full pallets are then *picked* from the bulk area and smaller amounts picked from the pick area. After picking the product is prepared for *shipping* in form of packing, consolidating and staging. When the shipment is completed, it is moved to a departing truck. (Van Den Berg, 2007: 60-61.)

However, some of the goods are not moved into storage at all. Those products are *cross docked* to a shipping dock after reception, perhaps through a temporary buffer, to combine different orders that are going to the same shipping address. In some distribution centers there is also particular *value-added logistics* services (VAL), like customer specific or country specific packing and labeling. (Van Den Berg, 2007: 61.)

4.4.3 Layout Planning

Layout planning of a warehouse depends on the whole, formed by the product range to be stored, warehousing technology, the size and shape of the plot, and the principle of the material flow. These factors affect both the planning of the warehouse processes and the shape of the building and the internal layout. In the internal layout, things according the activity and technology must be taken into account, such as warehouse type, shelves, equipment and material flows. If there is not enough space, unnecessary relocations must be done, which increases the possibility of processing errors. (Ritvanen et al., 2011: 84.)

Product placement has a great impact on the efficiency of the operations and depends on the direction of the material flow. The two common flow solutions are through-flow warehouse and U-flow warehouse. Through-flow means that the movement is from one end of the warehouse to another. In this case the warehouse can be as long or wide as wanted, but the main aisle must be particularly wide for the forklifts to manage. The plot must also be big, since there have to be space for driving in the both ends of the building. In U-flow, both the incoming and outgoing goods passes from the same side of the building. Here, the products can be placed along short picking distances, since there are many main aisles. With this practice the plot can be smaller, but more corridor space is needed. (Ritvanen et al., 2011: 85-86.) The principle of through-flow is presented in Image 25 and U-flow in Image 26.

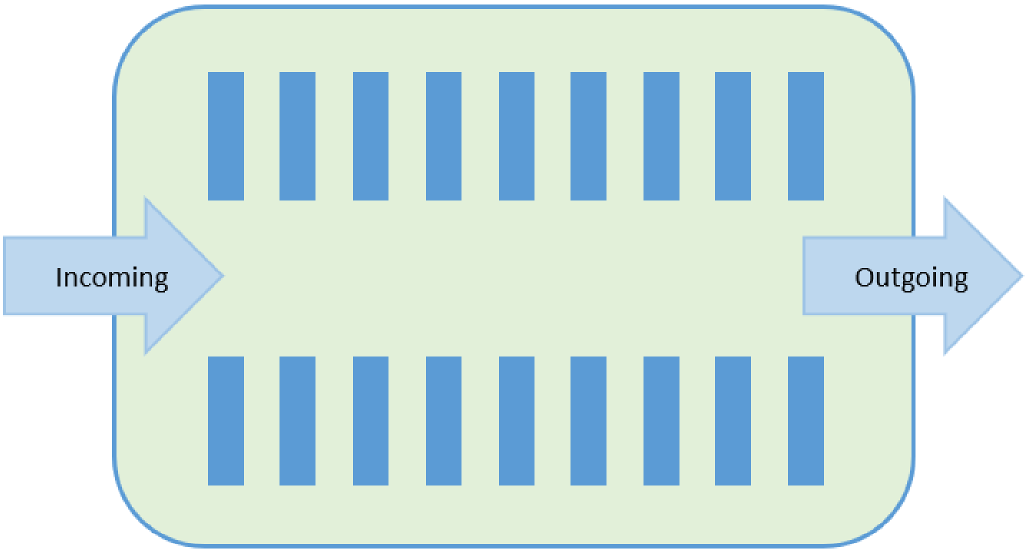


Image 25. The principle of through-flow. (Ritvanen et al., 2011: 85. – Adapted version)

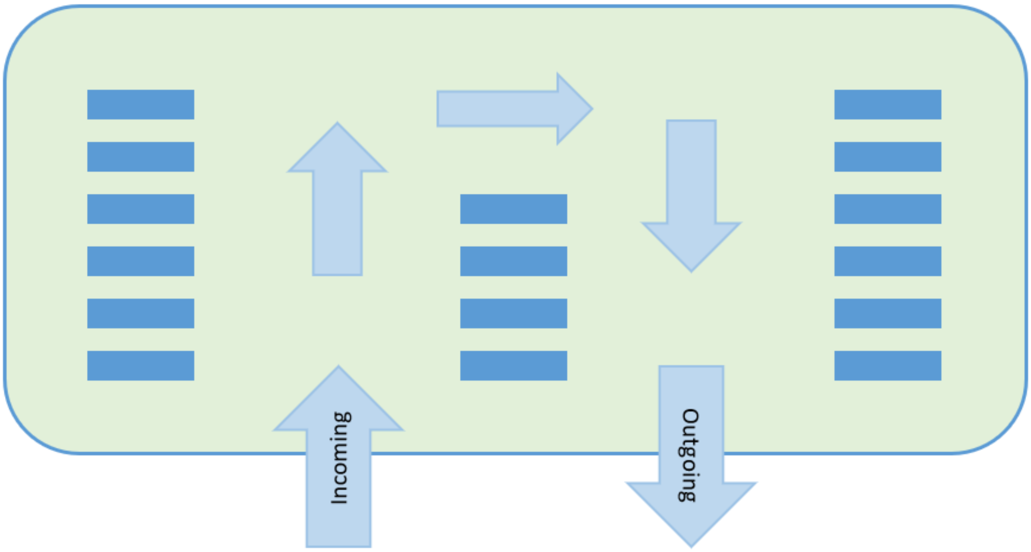


Image 26. The principle of U-flow. (Ritvanen et al., 2011: 86. – Adapted version)

Warehouses can also be placed in existing buildings. Then, it is important to utilize the plot or the limited space, by putting shelf units on top of each other or by creating warehouse spaces in many levels. (Ritvanen et al., 2011: 86.) If a lack of space nevertheless occurs, there are several other options available. For example, to expand the warehouse, rent additional space or to create more space within the existing facilities. If none of these options are possible either, a potential solution is to reduce inventory levels. To justify it, the slow and non-moving stock should be identified. (Richards 2014: 218.)

4.4.4 Material Handling

The movement of materials into, through and out of a warehouse is described above, but the details of the movement is generally described by material handling. Material handling deals mostly with the movement of materials for short routes in warehouses, but also between storage areas and transport. (Waters, 2009: 390-391.)

The fact is that every time an item is moved it causes harm – it costs money, takes time, and is receptive for damage. So, the movements are reduced to a minimum and made as easy as possible, in efficient warehouses. A set of moderate targets for material handling presented next:

- Move materials around the warehouse as supposed
- Move materials fast and eliminate the amount and length of movements
- Increase storage density, by utilizing existing space
- Reduce costs, by using effective operations
- Make less mistakes, with effective material management systems

(Waters, 2009: 390-391.)

These targets are largely dependent on the choice of equipment, since it defines the speed of movement, type of materials to be moved, costs, layout, number of employees, and so on. The handling equipment can be anything between a supermarket basket and an industrial robot for instance. (Waters, 2009: 390-391.)

In a store of medicines, the material handling is done by hand, since each item is small and light, with exception of some small equipment as trolleys and baskets. It gives a first level of technology, which is close to manual. A warehouse that stores engineering equipment, performs the movements by fork-lift trucks or other tools. This gives a second level technology, which is mechanized. A warehouse, where all movement is controlled by a central computer and nothing done by hand, gives a third level technology, namely automated. These three levels of technology generate warehouses with totally different features. (Waters, 2009: 390-391.)

4.5 MatFlow

MatFlow is a mobile user interface, integrated with the RoimaSoftware Lean System for material flow management. With the MatFlow system it is possible to get real-time inventory transactions, faultless stock balances, improved internal logistics and clear function-specific interfaces within an organization. (Reaaliaikainen materiaalitarkastelu, 2016)

4.5.1 MatFlow System Information and Functions

MatFlow is a warehouse management system (WMS) that offers real-time transactions in each warehouse process as the main benefit. The aim is to support the daily warehousing by bringing transparency to the warehouse. Warehouse processes that MatFlow are capable of handling are:

- Material check-in
- Shelving
- Material transfers and refill requests between warehouse locations
- Picking
- Online inventory taking

(Reaaliaikainen materiaalitarkastelu, 2016)

The activities of MatFlow in a production process, is visualized in Image 27 below. The green boxes represent the warehouse processes and their placement in the chart reveal the stage where MatFlow could be utilized within the production process. The stages are in the purchasing and sourcing department the reception, in production the transfers between stock, inventory management and picking and in the sales and invoicing department the final picking and packing. (Reaaliaikainen materiaalitarkastelu, 2016)

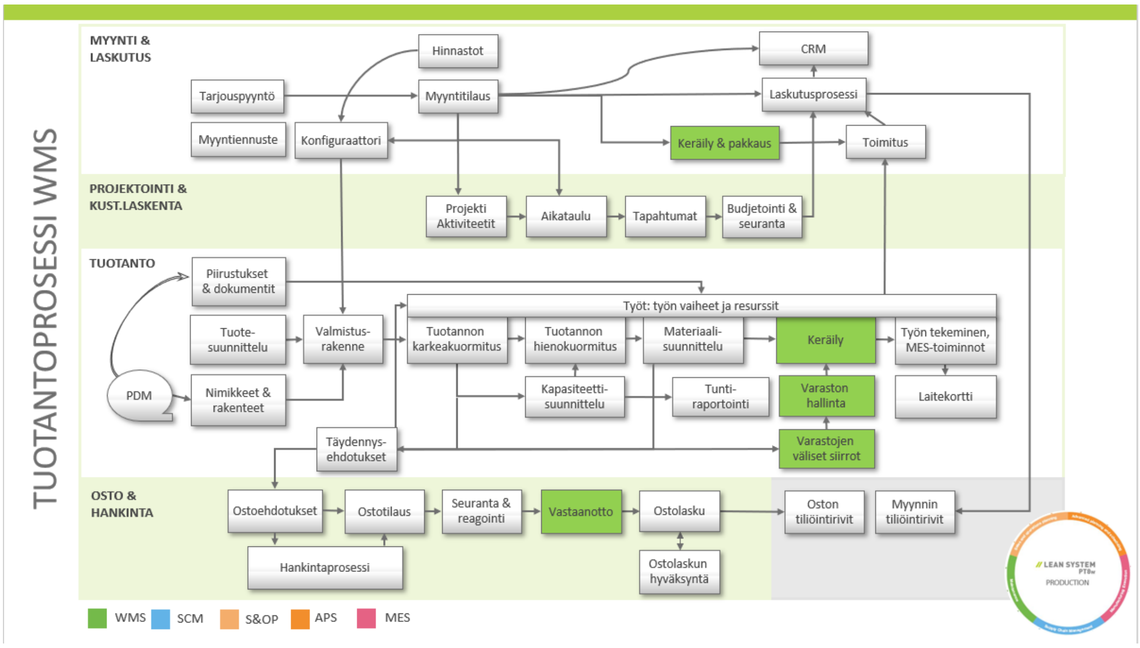


Image 27. Warehouse management system in the production process. (Reaaliaikainen materiaalitarkastelu, 2016)

MatFlow works with roles and each role has its own work queue. Each work queue is then created based on the actions of the next link in the supply chain. This principle is presented in Image 28 below. As it can be interpreted as well, is the material flow control based on the pull principle and allows so on personnel to order materials to be delivered just in time. (Reaaliaikainen materiaalitarkastelu, 2016)

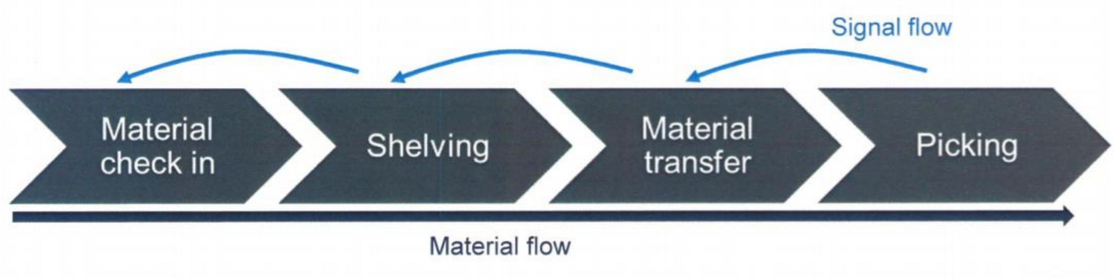


Image 28. Material flow based on signals. (Reaaliaikainen materiaalitarkastelu, 2016)

Moreover, when all the warehouse transactions are recorded with an accompanying device, is all the information up to date and available anywhere. The MatFlow mobile solution can be seamlessly integrated with the ERP-system (RoimaSoftware Lean System) and scales to almost any device with HTML5 support in a web browser. Functioning wireless network on the workplace area is then required for the device to work. (Reaaliaikainen materiaalitarkastelu, 2016)

MatFlow is designed to use on touch screen and an example of the device appearance is presented in Image 29 below. In the image the main menu of MatFlow is revealed, presenting the main activities. (Reaaliaikainen materiaalitarkastelu, 2016)

Image 29. MatFlow main menu. (Reaaliaikainen materiaalitarkastelu, 2016)

4.6 Conceptual Framework

As a summary of the best practices and the key findings in the current state analysis (CSA), a conceptual framework of this study has been formed. It consists of the selected areas for improvement and related theory to it. It forms framework for developing a simpler material flow a proposal of a simpler material flow with a more modern picking process for a remote multideck final assembly line. The conceptual framework is presented in Figure 6 below.

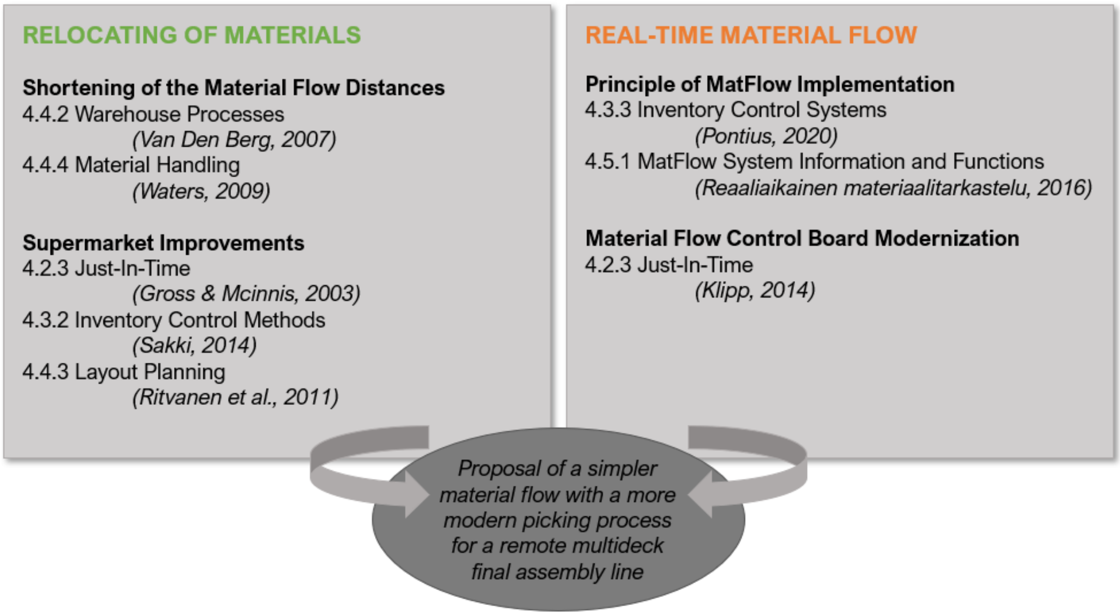


Figure 6. Conceptual framework of this thesis.

5 Building Proposal for a new Improved Material Flow

In this section, the building of the initial proposal is described. The proposal is built based on the key findings from the current state analysis and the conceptual framework as well as the data collection 2. A brief overview of the proposal building stage will be presented at first and then the actual building of the proposal will be described, including the benefits derived from it. The aim is to build an initial proposal of a simpler material flow with a more modern picking process for the remote multideck final assembly line. Lastly, a proposal draft will be presented, as a summary of the proposals.

5.1 Overview of the Proposal Building Stage

The goal of this section is to build a proposal based on the selected areas for improvement. The selected areas were divided into two areas namely relocating of materials and real-time material flow, with the intent of tackling the challenges of the excessively long and inconvenient picking process as well as the non-real time material flow. Based on those areas, existing knowledge were explored to support the achievement of the goal. Regular discussions have been taken place with both the logistic managers and team leaders, but also conversations with the pickers, to obtain the best possible result. The knowledge of the development specialists in the company have also been utilized. In addition to this, have own observation together with theory have also been exploited.

Furthermore, as previously mentioned, is the case company currently running other development projects according the structure of the plants, which has affected the proposal building of this study too. In order to achieve a common outcome, numerous compromises have had to be made. For this reason, the ideas developed could not be put into practice during the timeframe of this thesis work and therefore remained only at the theoretical level.

5.2 Relocation of Materials

The first part of the proposal is built to relocate the materials, which was one of the selected areas for improvement. Issues were identified according the placement of the materials and therefore, the main goal of this proposal is to provide new storage locations for the materials, to simplify their transportation route from warehouse to the assembly line. The way of handling the materials has also been considered, in terms of providing more practical ways to operate. This is a prerequisite for the main objective of this thesis, since cabinet-specific picking is not possible with the current arrangements. Existing knowledge been utilized, for the best possible proposal.

5.2.1 Shortening of the Material Flow Distances

In the CSA, it was found out that the materials are flowing through numerous different warehouses until the final assembly line. The transportation distance of the materials is long and so on time consuming. This section will then propose an improvement proposal of more practical places to locate the materials, considering the other modifications that executes in the case company during the thesis work.

According to the suggestions of the conceptual framework, in Section 4.4.4, it was stated that every time an item is moved it causes harm and therefore the movements should be reduced to a minimum. Typically, it might mean eliminating the amount and distance of movements, but in this case, it is not so simple since the storage space is more limited than before. That is why, secondary alternatives had to be made.

The proposed solution is then to relocate the storage facilities and only keep parts for one-day-need close to the final assembly line in the RCO factory. This decision is done relying on the other arrangements going on in the company, since there is simply not enough space to store the entire range under same roof as the final assembling happens anymore. Because of this structural change, the format of the proposal will have a different division than the CSA. The new proposed routes are mainly done based on the different origin of the materials, they are either sourced from a subcontractor or produced internally – sometimes both.

5.2.1.1 Subcontracting

Currently the subcontracting items are arriving from different suppliers, to different warehouses in the case company. The items are the purchased A and B items, long profiles, glasses, mirrors and doors. But due to the changes, some of the warehouses will be occupied and other will become vacant. Therefore, the proposal is to move all the incoming goods to one place, in this case Coolex, which is one of the company's properties that will be emptied and would therefore suit well for this purpose. Coolex would then work as a central warehouse, with the storage of the entire range.

The idea is that the daily need would be transported to RCO once a day from there. The replenishment would happen on basis of a supplementary request, which works in conjunction with the ERP-system. On basis of the request, the needed goods would be pre-picked in Coolex and distributed to the right department in RCO where the fine picking for the assembly line would happen. The transportation would take place by a milk run that is internally used in the company, from Coolex to RCO.

To clarify, the layout of the company's different properties is presented in Image 30 below. On the layout S = RCO, P = PCO and P2 = Coolex. RCO is thus where the company's main activity happens and the transportation there would run through the doors marked by the red circles in this case.

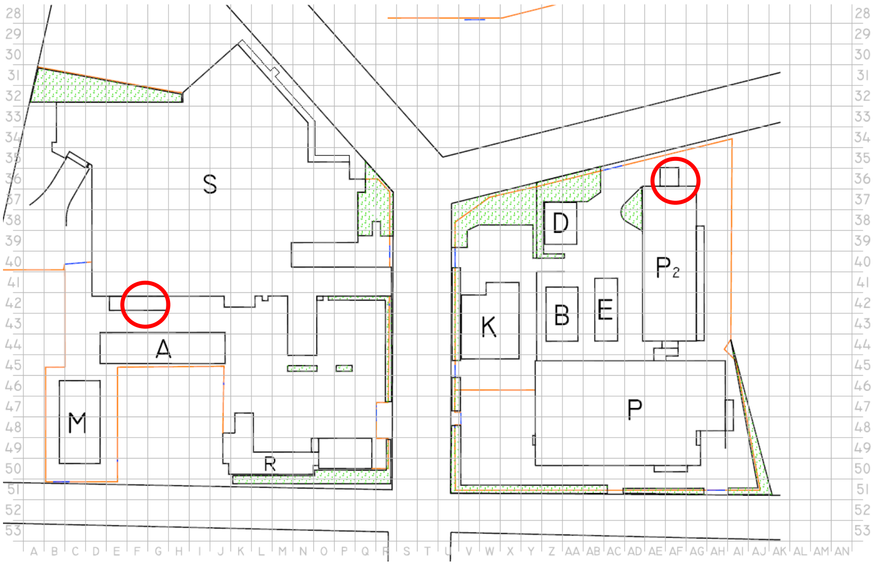


Image 30. Layout of all the properties.

The purchased *A and B items* would end up in the supermarket straight after the arrival from Coolex. From there they would be picked cabinet specific in trolleys together with the other parts and pushed to the line, just like before. The only change according this proposal is the pre-picking that would now be done in Coolex for one-day-need. This would minimize the retrieving of parts back and forth, since the A and B items could be organized in Coolex in a single cell, from where the daily need would be picked once a day. This would save both time and effort.

The same frame would work for the *long profiles*. One-day-need would be pre-picked in Coolex and transported to the cross-docking area, where they would be compounded with the other profiles to one trolley and then forced to the line. Here, the multistage picking would be eliminated and save both time and effort, since the daily profiles would be pre-picked on a trolley from one shelf in Coolex. To prevent the profiles from being damaged along the way, they could be protected with a tarpaulin.

The *glasses, mirrors and doors* would even follow the same pattern. One-day-need would be pre-picked in Coolex and transported to the F-stock in cardboard boxes, for the fine picking for the final assembling. The biggest change will happen here, with a new planned area in F-stock. On that area, there will be an own area for the unpacking with a separate plastic and cardboard compactor to use. On the same area, there is room for the picking utilizing an existing lift, to facilitate the lifting of the heavy glasses, mirrors and doors as well as a parking lot for the fine picked entities. The area is planned so that the existing shelving units will remain, but the lowest shelves will be removed, with exception of the end shelves that will be completely removed. This arrangement allows keeping trolleys with the needed parts beneath and other parts on the top shelves above. The only unsolved issue here is the inseparable door packages. It could possibly be solved by new designed trolleys, but no position is taken on it. Instead, the parking lot will offer a spot for the potential overflow parts, so that the unnecessary parts can be retrieved back, instead of standing beside the assembly line for too long.

A view of the current situation in the F-stock is presented in Image 31 below and thereafter a draft of the new proposed layout on the area compared with the current layout in Image 32.

Image 31. The current situation of the F-stock.

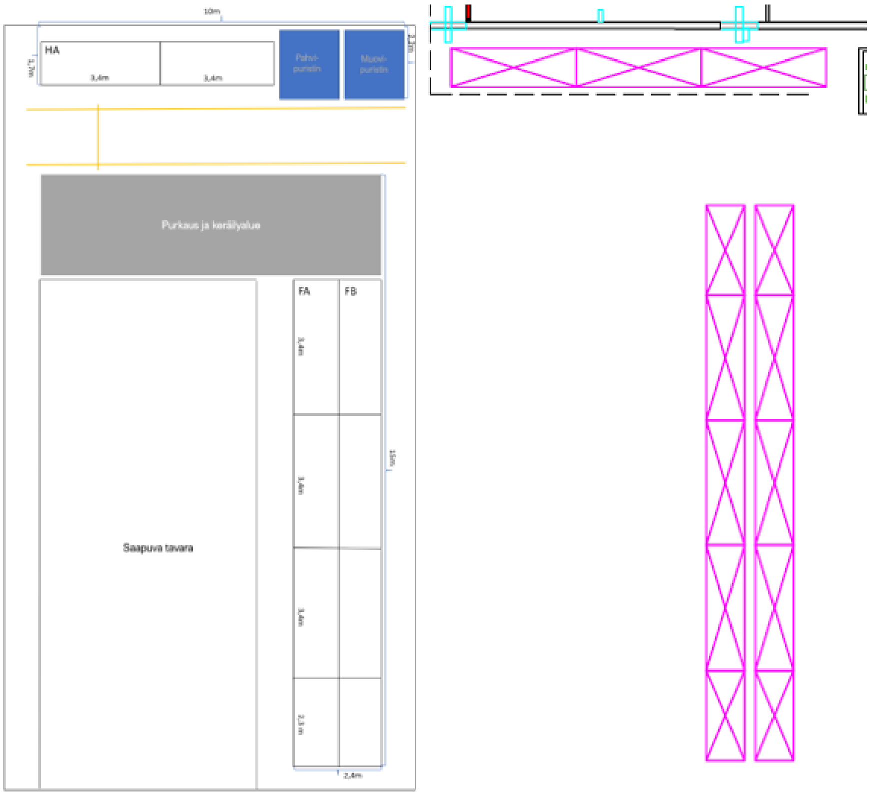


Image 32. The new proposed layout versus the current layout in F-stock.

5.2.1.2 Internal Production

At present, there is internal production in all the three factories RCO, PCO and ALP factory. But as a result of the changes, there will be activity in only PCO and RCO factory. The electrical box assembly department will move to PCO and the lamella production will move to RCO together with the painting and foaming line. The internally produced items needed for the assembly line in question are the painted key bars, A and B items, long profiles and end plates as well as the foamed end panels, in addition to the electrical boxes and the evaporators.

To achieve a smooth flow between these, the proposal is to add an area for cross-docking the internally produced goods, properly speaking the painted parts, in RCO factory. Instead of having a various material flow routes until the assembly line, the painted parts would be pre-picked from the painting unloading area to the cross-docking area for one-day-need, where the fine picking for the line would happen. The cross-docking would help to simplify the warehousing and distribution of the parts from one central location. In this case, the area would be located next to the supermarket area. This proposal relies on the theory about cross-docking explained in Section 4.4.2, with the intention of combining materials with the same end stop.

For this idea to work, it would be favorable that the painted parts would be unloaded into line-specific trolleys, maybe even in the order of the production that could just be pushed to the area. The line separation would fasten the picking process, while knowing which line is in question and the unloading on trolleys, would eliminate the unergonomic pallets and the need of using excess tools as pallet jacks. Painting in order of the production, would minimize the overflow of painted parts, but achieving it is easier said than done. Anyway, could the painting line then paint in their own pace and the logistics would only pick the daily need from there for each line.

A few other new areas are also a part of the plan, with the intent of utilizing the space remaining in the factory for a few carefully considered purposes. First there is as mentioned in the previous section, a new area for the glasses, mirrors and doors in the F-stock (1). Then, there is an overflow area for the excess painted parts at the painting unloading area (2), since there has not been enough space for them before. From that area and the painting unloading area, would the daily need be pre-picked to the cross-docking area (3), where some of the subcontracting parts would be compounded also.

Another new area is the parking lot of the evaporators (4), due to the new location of the lamella production. The proposed areas are marked with numbers, intended to operate as extensions to the existing areas besides, visualized in Image 33 below. The red circle is the door from which the arrivals from Coolex and PCO run through.

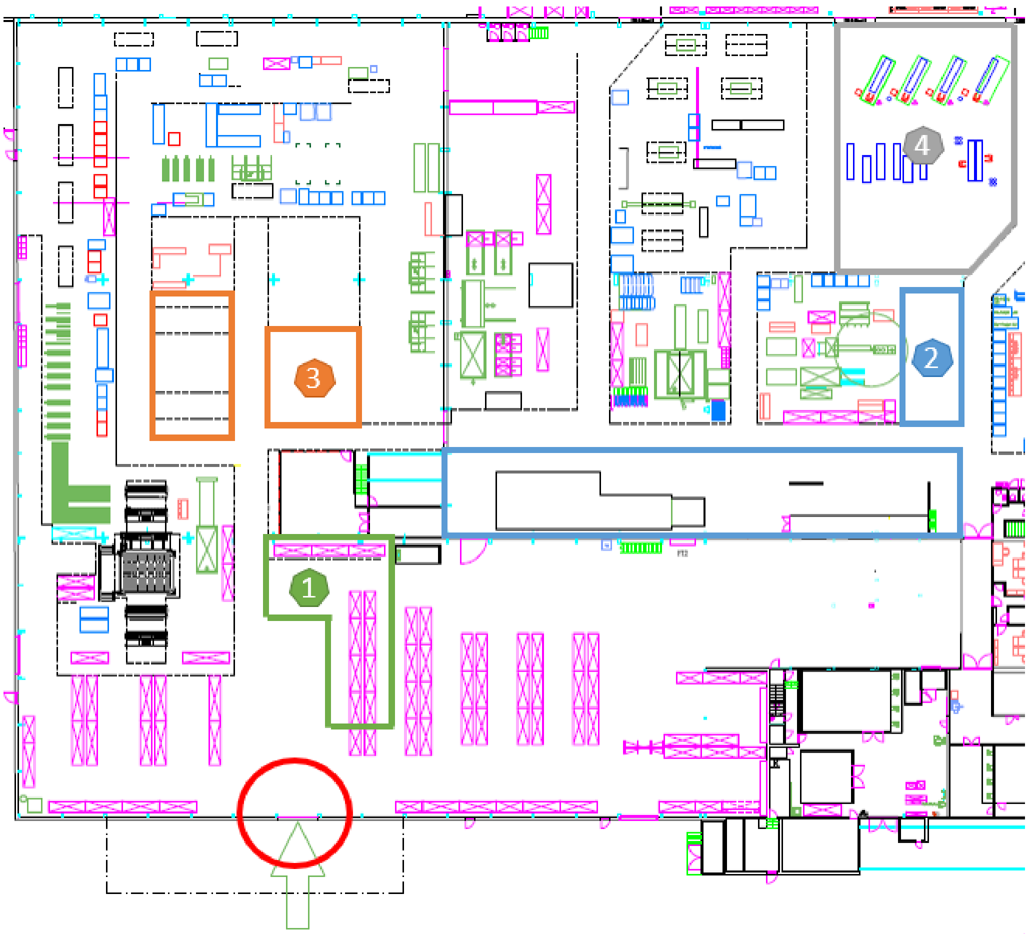


Image 33. The new proposed material flow areas.

The internal production in PCO, applies only for the *electrical boxes*. They will arrive to RCO by milk run in trolleys and transported straight to the supermarket where they are connected to the A and B trolleys. In the CSA it was established that the material flow of the electrical boxes was working well and did not need changes. But this change was a compromise, due to the need of space for the lamella production. In cases like this, it is important to remain the situation unchanged, or at least not worsen the situation. Therefore, the other activities will remain the same, to maintain the same standard.

The lamella production of the *evaporators* will be in RCO. After their production they are parked in a parking lot marked to them and from there, they are brought to the assembly line according to the need. As a result, their transportation path will be significantly shorter than before. This will save time and potential processing errors, because of the shorter path with less steps in the supply chain.

The painting and foaming in RCO will continue, with the painting of the *key bars, A and B items, long profiles* and *end plates* as well as the foaming of the *end panels.* The aspiration is that the painted and foamed parts would be unloaded into line specific trolleys at the painting unloading area. From there, the trolleys with the daily need would be brought to the cross-docking area, where the parts are fine picked and compounded to the other parts before going to the line. For all these painted parts, this arrangement would result in many advantages and solve most of the issues. It would also enable cabinet-specific picking.

The potential benefits of the proposal for the *key bars* are that the issue according the dangerous picking in the middle of the aisle would be eliminated. The wide selection of the painted *A and B items* would have more space with the expanded unloading area and could for that reason be on one location and facilitates their pre-picking. And if they would be unloaded on trolleys, unnecessary processing and unergonomic picking from pallets would be avoided. The multistage picking process for the *long profiles* would be reduced in steps, since the purchased and painted would be merged at the cross-docking area before the line. The issues of the *foamed end panels and the painted end plates* would solve with the same changes also – parts organized in line specific trolleys. There would be no tricky picking from the narrow shelves in the middle of the aisle.

To draw a conclusion, all the categories would in practice run from their origin, i.e. from their arrival or production, through one temporary storage until the final assembly line – thus all the unnecessary steps are reduced. A visualization of the new proposed routes is revealed in Appendix 6, as a confrontation to the visualization of the material flow routing in the CSA. The main point here is, since the material flows are shorter and the necessary parts closer to the final assembly that the cabinet-specific picking is now closer.

5.2.2 Supermarket Improvements

The supermarket area was stated as one of the key strengths in the SWOT analysis in the CSA, mostly because of the cabinet specific picking and the visual triggers there. Nevertheless, was the picking on the area stated as not simple enough, with longer routes than expected and thus more time consuming. Therefore, will this section propose some minor improvements for making the operations smoother and enable the use of MatFlow.

One of the requirements of MatFlow on the supermarket area, turned out to be the determination of storage locations, to determine the picking order. Considering the current issues detected at the area, would storage locations at the same time simplify the picking and shorten the picking route, when each item has its specific location. It would also support the concept of a Kanban supermarket, presented in Section 4.2.3, while offering the materials near their point of use. To achieve this goal, were a proposal of a layout change with added storage locations done. Simplification has been taken into consideration in the planning, but fluency has not been paramount, since the main objective here is to meet the requirements of MatFlow to enable its use.

In the following Image 34 a draft of the current shelf layout on the supermarket area is revealed. As can be interpreted from the image is the structure of the area not so clear, with an indeterminate order to pick, which is illustrated with example storage locations. To simplify the structure, a new layout was done by slightly moving the existing items around, removing unnecessary and adding a few useful pieces of furniture, revealed in Image 35. The nature of the items has also been taken into account in the layout planning, in terms of filling the shelves and picking among other things. The area would then be equipped with storage locations to create a new flow direction, namely a U-flow presented in Section 4.4.3, with the aim of preventing the picking back and forth through the aisle. The movement will not be fully realized according this flow, considering the fast-flowing painted parts to be searched from the cross-docking area, but the goal with this is after all to create a standard.

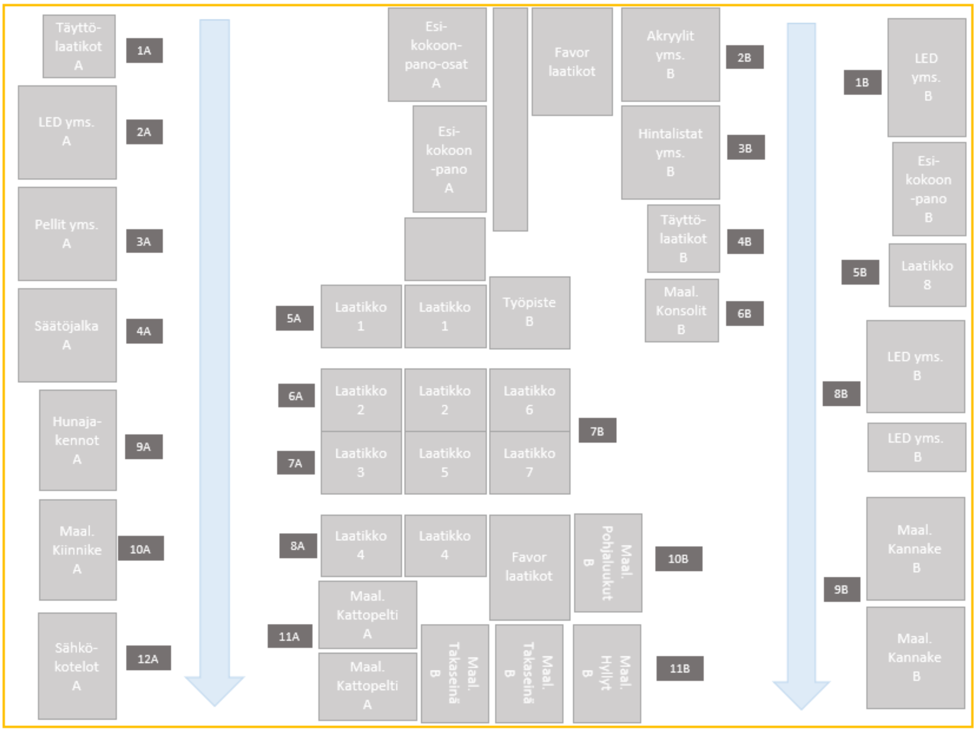


Image 34. Current supermarket layout.

Image 35. Proposed supermarket layout.

To see how it would look like in reality, an experiment was conducted, by placing storage location markings. The markings were placed on the floor, to allow easy movements of the trolleys and the layout overall. What it looked like is shown in Image 36 below.

Image 36. The new marked storage locations.

As proposed in the previous chapter, the subcontracting parts would arrive to Coolex with storage of the entire range, from where the daily need would be transported to RCO. In order to receive the daily need to the supermarket area, is some kind of inventory control method required for the multiple subcontracting parts. The choice of method depends on the circumstances and in this case, there is different kind of parts, arriving from different suppliers, stored in different ways – for which reason a few different will be proposed. However, the unifying factor is that all the shelves are on wheels i.e. on trolleys, which facilitates their transfers. There are both shelves with compartments and flow-through shelves with boxes.

The simplest way is probably to use the existing ERP-system, where it is possible to determine transfer proposals between stocks. By using this tab, Image 37, a resource in Coolex can clearly see which parts needs to be transferred to the supermarket area for a certain period. This is method is presumably also used for the other subcontracting items. In keeping with this style, order interval method revealed in Section 4.3.2 could also be used, since the desire is to get the necessary parts daily. This method could also be utilized in conjunction with the ERP-system, by determining the needs of the day depending on the output of the day, with one day buffer.

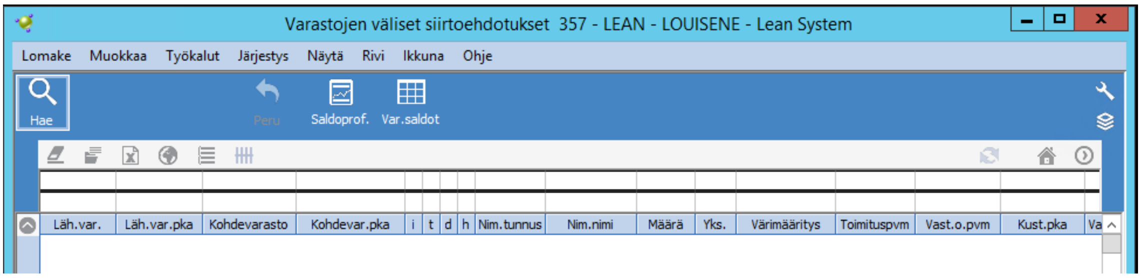


Image 37. Transfer proposal between stocks in the ERP-system.

Another way to control the inventory, or as an addition to the previously mentioned, in the supermarket area is to use the two-bin method, also presented in Section 4.3.2. The concept is about two rotating bins - when the first bin is emptied, an order is placed to refill it and then the second bin is used, until the order of the first bin arrives. This method would work ideally for the flow through shelves that would remain in place, but the boxes would rotate. In practice, there would be two trolleys for the rotation, one in Coolex and one at the supermarket area. When the picker detects an empty box at the supermarket area, it is putted in the trolley. At the end of the day the trolley with the boxes is sent to Coolex and replaced by an empty trolley. During the next day the empty boxes are filled in Coolex and sent back to the supermarket area and again replaced with the second trolley filled with empty boxes. This way the boxes are rotating in the flow-through shelf. The same practice would work for the other shelves if wanted, i.e. trolleys as well, but there the whole trolley would rotate. This means that the number of trolleys should be doubled, so that one trolley is on the supermarket area and the other one in Coolex for filling.

The destiny of the internally produced parts, in this case the painted parts, relies mostly on the proposed cross-docking area. That area would work as an extension of the supermarket area, to retain the large selection of the painted parts. From there, the needed painted parts would be filled to the supermarket, with the principle of always having one trolley for each variety. It will not remain on a regular basis, but it can be considered as a target. The inventory control method here will then remain visual, with empty trolleys as triggers.

To streamline this, an additional suggestion is to add markings on each trolley of painted parts. Because considering the added storage locations, it would be desirable to be able to move the balances with one transfers, when moving the trolley on a certain location. At present it is not possible, since the balances of all the painted parts are in one storage location. This means that if one trolley with painted parts according the current practices would be pushed to one of the storage locations, each part in the trolley should be individually searched for in the balance and moved to the location. But if each trolley in turn would be marked, it would be possible to move the balance with one transfer, from one location to another. It would also support the idea of a real-time material flow, when putting the painted parts in order.

To show what this would look like in reality, an example of the intended markings on a painted parts trolley is revealed in Image 38 below.

Image 38. Trolley marking.

5.3 Real-time Material Flow

The second part of the proposal is built to enable real-time material flow, to meet the other selected area for improvement and the main objective of this thesis. Challenges have arisen within the non-real-time material flow, which has led to a multiple disadvantages. For that reason, is the purpose of this proposal to ensure the functioning of MatFlow and support its use. To succeed, have best practice about the subject been utilized.

5.3.1 Principle of MatFlow Implementation

Under existing arrangements, it is not possible to implement MatFlow in its entirety. The main issue is the current picking method that happens for a various cabinets at a time, which is inconsistent with the requirements of MatFlow. But on basis of the given proposals, the implementation ought to be possible to some extent. To ensure it, a virtual pilot and a small-scale implementation will be performed. Together it will form the principle of MatFlow implementation and work instructions for future use.

The most favorable way to control the inventory is to use a companion device, according the theory in Section 4.3.3. This reflects to the MatFlow, with the aim of supporting the daily warehousing by bringing transparency to the warehouse, presented in Section 4.5.1. This supports also the objective of this thesis, and as a first step towards it was a virtual pilot performed. It was executed together with persons familiar with the subject in the case company. The reason to conduct it was to secure its functionality, to avoid major mistakes during the implementation. The test object was the A picking on the supermarket area.

The first step was then to log in to MatFlow. It happened with a numeric username and numeric password i.e. a PIN-code, view shown in Image 39.

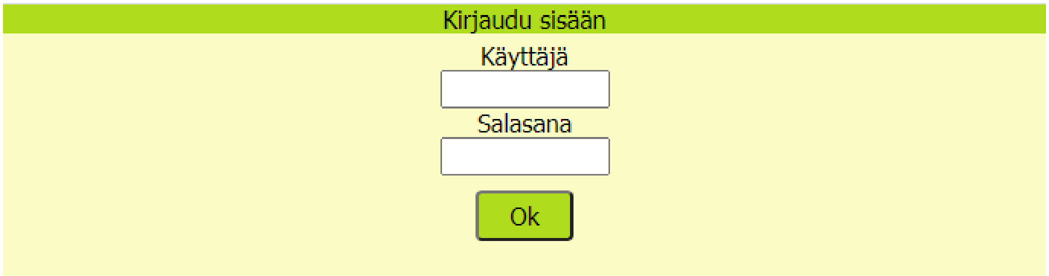


Image 39. Login view.

After that, the storage area was chosen. In this case it was picking for the remote multi-deck final assembly line, designated as S03 in the company, which also appoint the storage area, introduced in Image 40.

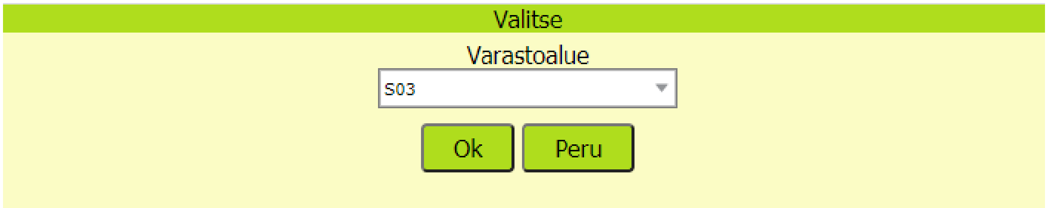


Image 40. Choose storage area.

Then there was the main menu, containing all the pickings for S03, presented in Image 41.

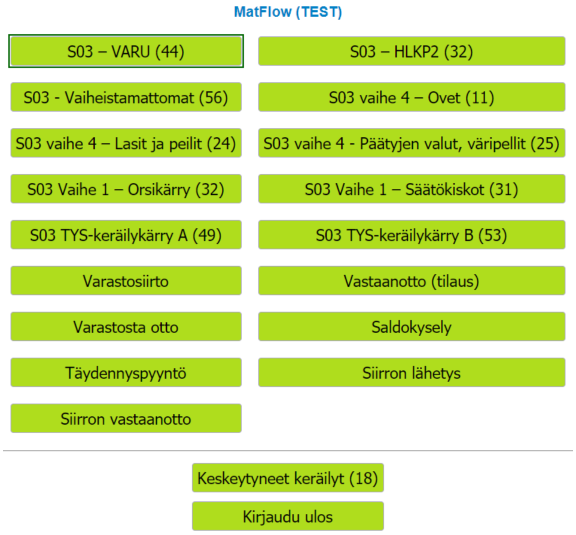


Image 41. Main menu.

From the main menu was the A picking selected for the piloting phase. The selected view shows the picking work queue, introduced in Image 42.

Image 42. Picking work queue.

The desired work was chosen, and its necessary items were listed according to the created storage location. When an item was picked, the quantity and location were confirmed, before pressing the pick-button. The view is shown in Image 43 below.

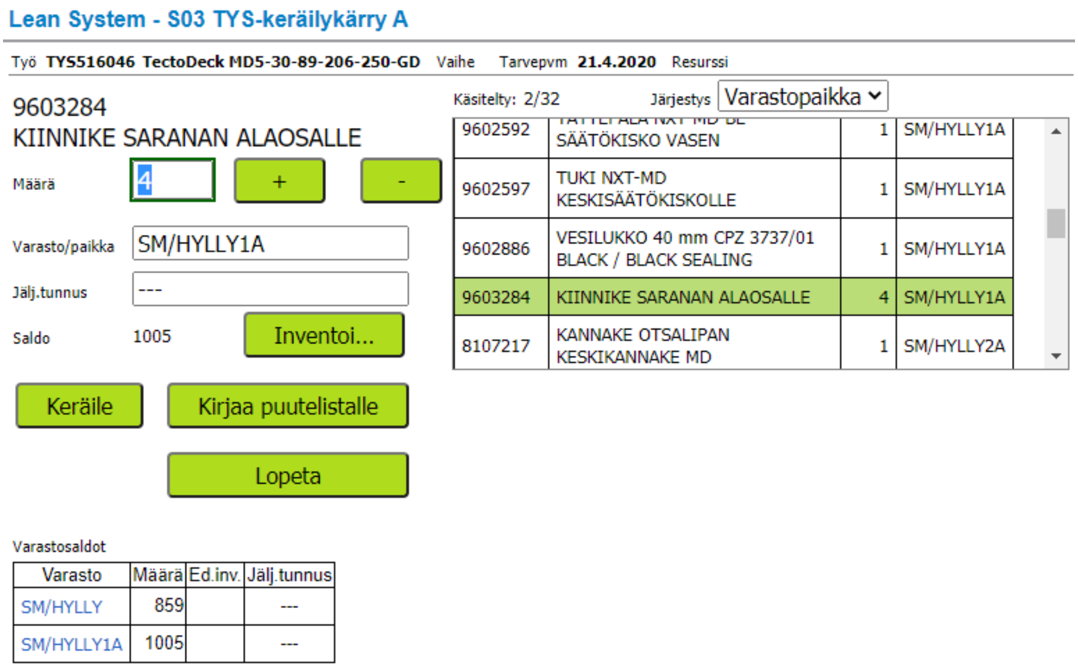


Image 43. Cabinet-specific picking.

For the credibility of this proposal, it was decided to implement this piloted part as well, since no issues occurred in the virtual pilot. At the of moment of implementation, the picking with MatFlow was observed, for potential issues. To fulfill the implementation, the picking was further tracked for a few day tracking to provide support and collect data. Data was collected in form of time and distance, as a reference to the data collected in the CSA, but also other observations were noted. Due to changed work conditions, testing with an experienced and beginner picker was not possible, for which reason two pickers from the area were selected by coincidence for the test.

In outline, the implementation went well, with no major issues. But a few important observations were still made within the picking with the MatFlow device. Before the implementation the items on the area were manually transferred to the new storage locations, as a part of the supermarket improvements. Its purpose was to determine the picking order, which was already found to be working in the virtual pilot. This succeeded in principle, but not perfectly. The reason was that all of the items had not been moved in specific storage locations, and were still on the one old storage location, which messed up the ideal U-flow picking order. But the ones that were on their location did come in order, which confirms that the idea of using storage locations for defining the picking order worked.

Additionally, a few previously identified challenges were repeated. One of these was picking based on routine. Even though the items were now placed on storage locations, the pickers did not look at the locations of the item, but on the item code and picked then basis of knowledge. The pickers did not either utilize the features of the trolley. But on the other hand, the combination of having a personal routine and using the picking device, might be the reason to that the picking did take less time than before with the paper picking lists.

The result of the tracking period of the picking is presented in the Figure 7 below. In the figure, the development of the picking time is shown, compared to the picking time in the CSA. As it can be interpreted, the picking time decreases progressively over time. In addition, time is saved, since there is no need to print and check the paper picking lists or fill the material flow control board, because everything is up to date. This time saved can be used for something else, more necessary.

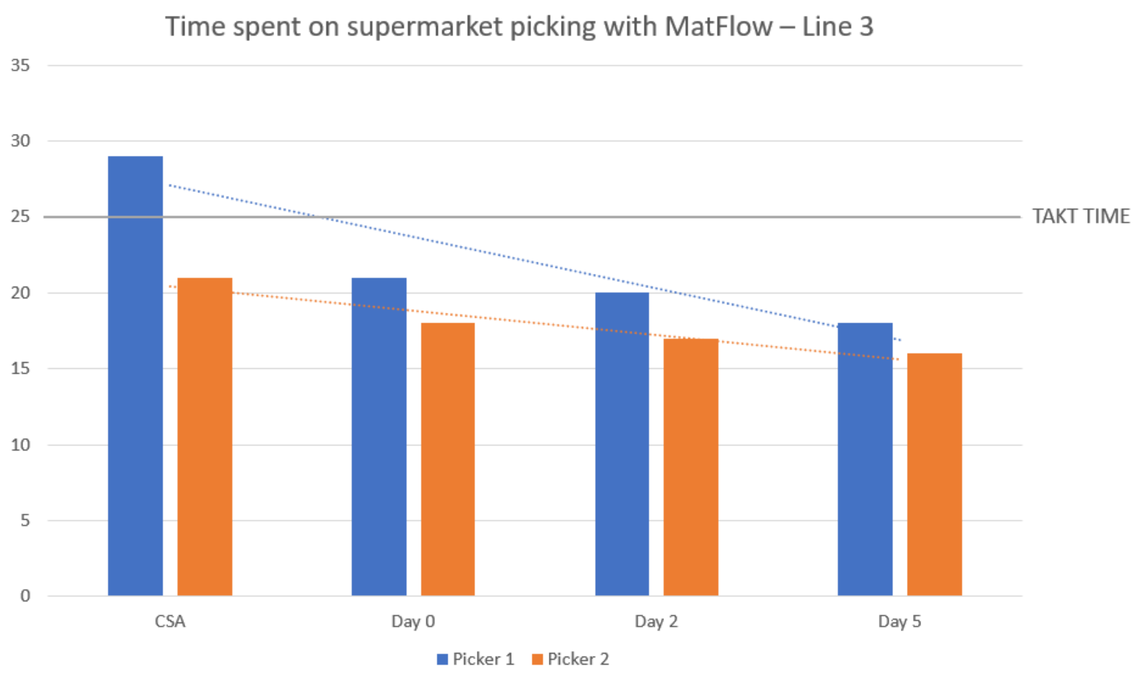


Figure 7. Time spent on supermarket picking with MatFlow.

5.3.2 Material Flow Control Board Modernization

Currently, the picking happens in connection with the production program and the material flow control board. The production program is connected with the ERP system, which is in turn connected with MatFlow. The current material flow control board is though completely manual and contains only information that someone has filled in it. To create a functioning entity of it, will this section offer a draft of a board, combining the existing operating factors with something new.

The idea of this material flow control board is the Kanban board mentioned in Section 4.2.3. That board consists of three columns that describes the work status: to do, work-in-progress (WIP) or done. This board will include the job number and its picking categories, and the position of the board is to indicate their status. The status is presented by colors: to do is red, work-in-progress is yellow and done is green. As an addition, a section has been added that informs the available resources, to facilitate the division of labor.

In order to truly benefit from the control board, is the proposed solution to make it digital. More specific, a touchscreen with only the urgent information on the front page. By clicking on the needed data, the information would pop up on the screen. The screen would work in connection with the ERP-system and MatFlow, which means that all the material transfers are up to date and easily available. By following the above-mentioned colors, the status of the material flow is clear. The view of the screen would resemble the production program, but the control board is intended for logistics tracking. An indicative view of the material flow control board is revealed in Image 44.

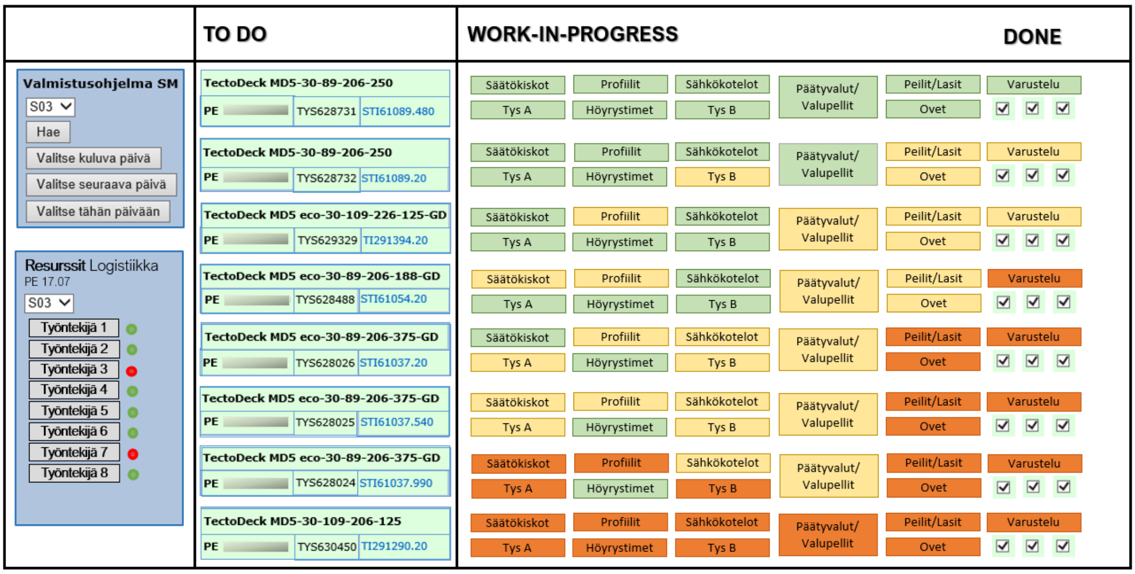


Image 44. The front page of the material flow control board.

Each project has a backlog of things to do and a series of process phases to get through before it is done. By using a control board, it is possible to see how the things are proceeding through the process. Here, the similarity with the production program and the simple visualization, enables to easy spot the bottlenecks within the process before it is too late. The bottlenecks will reveal the inefficient areas and by eliminating them, the process will get smoother and more efficient. And instead of craving extra resources when there is too much to do, ought to take advantage of what is already available. When the mindset is changed to this pattern, it will naturally lead to increased productivity.

Considering the amount of work with the current material flow control board and this one, it would clearly save employees time. The team leader would save time within this change, since there would be no need for printing the picking lists and filling the control board. The pickers in turn, would save time since they would not need to update the control board and search for information. For instance, the missing parts would be readily available on the board.

This digitalized material flow control board would bring a lot of benefits by visualizing the workflow. Especially considering the Kanban practice that emphasizes the importance of visualization, even though this board does not represent the typical Kanban board.

5.4 Proposal Draft

A proposal draft was created as a summary of the given suggestions - the initial proposal. It is divided in three columns, introducing the key findings from the CSA, the proposals and its expected benefits. Presented in Table 6.

Table 6. Proposal draft.

KEY FINDINGS FROM CSA	PROPOSAL	EXPECTED BENEFITS
Impractical positioning of materials	RELOCATION OF MATERIALS **Shortening of Material Flow Distances**	*Shorter picking paths* - Saves employees time and effort *More practical ways to pick* - Prevents processing errors and unergonomic picking
Complex supermarket area	**Supermarket Improvements**	*Storage locations* - Simplifies the picking and determines the picking order
Non-real time material flow	REAL-TIME MATERIAL FLOW **Principle of MatFlow Implementation**	*MatFlow working instructions* - Enables the use of a MatFlow device *Real-time material flow* - Provides actual information and eliminates the need of correcting errors
Outdated material flow control board	**Material Flow Control Board Modernization**	*Visualization of the workflow* - Spots the bottlenecks and saves employees time

The main objective of this thesis was to develop the current material flow, so that it allows paperless picking. Comparing this target to the built proposal, the objective can be stated to be partly met. The reason is that cabinet specific picking is not yet entirely possible and MatFlow implementation cannot be fulfilled either. So, picking based on paper picking lists will continue partly, after the implementation of this proposal.

But in total, it can be stated that the listed expected benefits bring the company closer to the objective. The small-scale implementation of MatFlow proved that principle behind did work. This means that by implementing the rest of the proposal in the same way, it approaches the picking with MatFlow. Therefore, to complete this project, the improvement work will continue.

6 Validation of the Proposal

The validation of the initial proposal is presented in this section. An overview of the validation stage is presented at first and thereafter, the developments to the proposal based on validation feedback are exposed. On basis of the improvement suggestions of the feedback, the final proposal is created. The intention of the final proposal is to offer a meaningful and validated recommendation for the case company to improve the material flow.

6.1 Overview of the Validation Stage

The main object of the validation stage is to finalize the initial proposal. The goal was to present the development suggestions to key persons in the case company and gather feedback. It was executed in two meetings.

The first meeting was performed in form of a thesis presentation. The presentation started with an introduction into the subject and then the approach toward an improvement proposal was presented. Then the two-part proposal was introduced and summarized with a proposal draft. After that, feedback was received from the audience.

Additionally, was a separate meeting held with the logistics manager to clarify the improvement suggestions. Based on the remarks, the validation of the research was obtained. As a result, a final proposal was formed.

6.2 Developments to the Proposal Based on Validation Feedback

The initial proposal was presented to the change management team, head of project management office, logistics manager and head of logistics. A summary of the received feedback and potential development suggestion for the initial proposal is presented next.

The audience did agree about the suggestions according the *relocation of materials.* The new proposed locations for the materials in the *shortening of material flow distances* section were approved, with an eye-opener of the reduction of steps in the supply chain.

The replenishment for these materials were perceived to be executed with the transfer proposals between stocks in the ERP-system. It was seen as a great transformation, since previous replenishments have been performed over the phone. But what the audience did long for, were the visibility of numbers. Things that are pointed out to be more efficient, would be good to prove as measurements too.

The same consideration applies for the *supermarket improvements*. The demonstrated savings in the picking time, could have been calculated further. That is, how it affects the entity and what kind of savings it results in. But the created storage locations were approved, and the criticality of the painted parts was noticed. Their markings were found to be mandatory in terms of functionality and clarification of the balances. Additionally, the most effective inventory control method was stated. Two-bin method for the flow-through shelves and transfer proposals between stocks for the rest.

The *real-time material flow* suggestions were also accepted. The *principle of MatFlow implementation* was considered as useful, with all its benefits. The virtual pilot was suggested to be further modified into clear work instructions as induction for new employees. The time saved by using the device, was suggested to be used for development work. In any case, the real-time resulted from this proposal was noted as valuable.

The same aspect applies for the *material flow control board modernization.* This proposal was rated as a high standard and it was found that with further customization, it could suit the other assembly lines as well. It would generate significant benefits, both for the daily picking and the daily management meeting. The transformation from manual monitoring of missing parts to automatic monitoring was noted as outstanding. As well as the resource management online.

In addition, a few general advices were received. One of them was given according the mentioned benefits of the digitalization. In the initial proposal, many highlights were targeted on savings of the human resources, when using electronic devices. It is a reasonable outcome, but if the thought goes beyond that, it does also save the environment. The digitalization will result in less paper waste, since the information is available online. It is remarkable.

Another remark was given according the use of the word impossible. The lesson was that anything is possible, impossible just takes a little longer time. It is about proving to be right, with clear motives. Whether it is about a lack of budget or lack of confidence. As Nelson Mandela said, “It always seems impossible until it’s done.”. In this context, also other negative wording was recommended to be avoided.

All in all, the initial proposal was well received and stated as a successful entity.

6.3 Final Proposal

The final proposal is created by merging the initial proposal with the validation feedback. It is a developed version of the initial, with proposal descriptions and the steps involved as an addition. The outcome of this study is also stated - a simpler material flow with a more modern picking process for the remote multideck final assembly line.

The final proposal is presented in Table 7 below.

Table 7. Final proposal.

KEY FINDINGS FROM CSA	PROPOSAL	EXPECTED BENEFITS	STEPS INVOLVED
Impractical positioning of materials	RELOCATION OF MATERIALS **Shortening of Material Flow Distances** Relocate the storage facilities to Coolex and only keep parts for one-day-need close to the final assembling line, utilizing a cross-docking area	*Shorter picking paths* - Saves employees time and effort *More practical ways to pick* - Prevents processing errors and unergonomic picking	Redefine the incoming goods area to Coolex Relocate the existing items Determine the limits for the replenishment request
Complex supermarket area	**Supermarket Improvements** Create storage locations to determine the picking order and to fulfil a requirement of MatFlow	*Storage locations* - Simplifies the picking and determines the picking order	Mark the storage locations Relocate the existing items Define an inventory control method
Non-real time material flow	REAL-TIME MATERIAL FLOW **Principle of MatFlow Implementation** Provide work instructions for using the MatFlow device and ensure the functioning of the system.	*MatFlow work instructions* - Enables the use of a MatFlow device *Real-time material flow* - Provides actual information and eliminates the need of correcting errors	Invest in MatFlow and its solution building Reach the requirements and pilot MatFlow Implement MatFlow and orient it for the employees
Outdated material flow control board	**Material Flow Control Board Modernization** Make a digital material flow control board for real-time logistics tracking	*Visualization of the workflow* - Spots the bottlenecks and saves employees time	Investment in a digital display Investment in a consultant for solution building
Simpler material flow with a more modern picking process for the remote multideck final assembly line			

7 Conclusion

In this section, the thesis is summarized and concluded. First, an executive summary is introduced and then, the next steps and recommendations toward implementation is declared. After that an evaluation of the thesis results is conducted, following with the closing words.

7.1 Executive Summary

The reason to conduct this study was the obsolete material flow tracking in the internal logistics operations in the case company. The material flow was noted as not real-time in the ERP-system, and the balances were consequently not reliable. For a fluent workflow, this kind of operations should be under control. Therefore, this was stated as the main business challenge to be improved in this thesis.

In this regard, the objective of this thesis was to develop the current material flow, so that it allows paperless picking. The study was also limited to develop the flow of the material and their concrete route, to make the material flow smoother and more truthful. A platform for product and material management, named *MatFlow*, worked as a base for this need. For its functionality, there were a few requirements to be met.

The study was executed in seven sections. In the first section there was an introduction of the thesis and an overview of the case company and its challenges. Then the objective was set, and the expected outcome was defined. The aim with this section was to lead to the topic, by presenting background information.

The second section introduced the methods and materials used to conduct this study. The study was noted as an applied research, since it concentrated on an applied business problem with the aim of finding an improved solution for it. The research methods were mostly qualitative, with a multiple data collection techniques, such as interviews and documents. The chosen research approach was design research, as the objective was to propose a practical solution for a business challenge.

In the third section, the company's current process was explained and analyzed. The aim was to recognize the strengths and weaknesses of the current material flow in the picking process. The key findings were impractical positioning of materials, complex supermarket area, non-real time material flow and outdated material flow control board. Based on these subjects, two areas were selected for improvement - relocation of materials and real-time material flow.

The fourth section concentrated on literature and available knowledge of the subject, with a conceptual framework as result. Literature of the best practices of moving materials through supply chains were explored. It was examined at a relatively rough level, to provide an understanding of the entire supply chain. However, the intention was to explore existing knowledge to support the achievement of the goal.

The fifth section comprises the building of the proposal. It is built based on the key findings from the CSA and the conceptual framework as well as the data collection 2. The proposal was divided in two parts, with four sections: shortening of material flow distances, supermarket improvements, principle of MatFlow implementation and material flow control board modernization. The outcome was an initial proposal, presented in form of a proposal draft.

In the sixth section there was the validation of the initial proposal. The development suggestions were presented to key persons in the case company to gather feedback. Based on the feedback, final adjustments were done to the proposal. The outcome was then a final proposal of a simpler material flow with a more modern picking process for the remote multideck final assembly line.

Finally, in section seven, the conclusion of this thesis and a general evaluation of the project is given.

7.2 Next steps and Recommendations toward Implementation

A hint of the steps involved to achieve the given suggestion, were already showed in the final proposal. Here, the next steps and recommendations toward implementation will be explained step-by-step.

For the *shortening of the material flow distances*, the next step is to redefine the incoming goods area to Coolex. The entire range of the subcontracting parts should then be transferred to Coolex and parts for one-day-need to RCO. The internally produced parts for one-day-need should be moved to the proposed cross-docking area in RCO. Then, the limits for the replenishment request should be set in the ERP-system.

For the *supermarket improvements*, a layout change needs to be done first, according the proposal. Then, the storage location markings need to be set and the existing items on the area relocated according the plan. The materials must also be transferred in the ERP-system to the new storage locations. Lastly, an inventory control method must be defined and its limits set.

The *principle of MatFlow implementation* has already started as the company has invested in the system. To get it work, the numerous requirements of the system must be achieved. One of them is the cabinet-specific picking, which will be partly met by the relocation of materials. When the necessary requirements are met, MatFlow can be piloted and implemented. For daily use, the MatFlow work instructions should be presented for the pickers as an induction.

Material flow control board modernization requires an investment in a digital display. To make the display work as intended, an investment in a consultant is all also needed for the solution building. After that, it is up to the employees to use it as a practical work tool.

To make the picking with MatFlow possible for all picking categories – improvement proposals are still needed. With the suggested proposal, the cabinet-specific picking will not be entirely smooth. Which is why, it has been decided to continue with the development work. The goal is to achieve an entirely simple material flow with a more modern picking process for the remote multideck final assembly line in the case company.

7.3 Thesis Evaluation

This thesis is evaluated according to four criteria: validity, reliability, relevance and logic.

Validity is the quality of being correct. Validity in design research, means that data collection is planned, results are documented, and data is collected from different sources. (Kananen, 2013) In this thesis, data was collected through interviews, discussions, meetings, internal documents, and observation. Regular reviews were also held, to get feedback along the way. The aim was to ensure that the results meet the expectations.

Reliability is the quality of being trustworthy. If a research is replicated, the same results can be achieved. (Kananen, 2013) In this thesis, data was collected both orally and in writing, to avoid contradictions between different parties. An approach like this guarantees that no one's personal opinions can escape the reality stated in the documents.

Relevance is the quality of being appropriate. This thesis is based on real business challenge in the case company and created in regular communication with the logistics manager. The result of the regular communication is that the importance of this proposal has emerged, and the case company wants to proceed with the implementation. To ensure the relevance, the sources used for the conceptual framework, are mostly based on proven facts.

Logic is reasoning conducted to strict principles of validity. This thesis is structured in way, where every section is logically linked to next one. The results of the current state analysis lead to the literature review. It formed a conceptual framework, which was utilized while building the initial proposal. Then, the initial proposal was validated, and a final proposal was created.

7.4 Closing Words

It is important to make accurate decisions when implementing changes. Especially, when it is about processes occurring simultaneously and with interdependencies in-between. When a process improvement is investigated in the manufacturing industry, many critical questions often arises. Whether it is about a layout change or an introduction of modern technology in a warehouse. The question is often about the consequences that might affect negatively on the performance.

This phenomenon has emerged during this thesis work. But the fact is that almost all quality improvement comes from simplification of the existing processes. It is about continuous improvement, not about the things that are done well - that is called work. Continuous improvement is about eliminating the things that get in the way of the work, the headaches and the delays.

The validated proposal did not provide a ready-made solution for the stated business challenge. But based on a proper mapping of the current state, guidelines toward a simpler way of act were offered. Therefore, the outcome can be considered as a starting point for next steps in the continuous improvement. Continuous improvement might also be the key to keep away the case company’s challenges associated with the internal material flow in the future.

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Appendix 1: Interview questions about the material flow

Haastattelu: Materiaalivirta varastosta tuotantoon

Interview: Material flow from warehouse to the production

Haastattelija: Louise Neuvonen

Interviewer: Louise Neuvonen

Haastateltava: Logistiikkapäällikkö

Interviewee: Logistics Manager

Haastatteluaika ja -paikka: 6.4.2020, Porvoo

Interview time and place: 6.4.2020, Porvoo

Haastattelu kysymykset:

Interview questions:

1. Kerro yleisesti materiaalivirrasta varastosta tuotantolinjalle.
   Describe generally the material flow from warehouse to the production line.
   a. Miten varastointi tapahtuu?
      How does the storing happen?
   b. Miten keräily tapahtuu?
      How does the picking happen?

2. Analysoi yleisesti materiaalivirtaa varastosta tuotantolinjalle.
   Analyze generally the material flow from warehouse to the production line.
   a. Mitkä ovat vahvuudet?
      What are the strengths?
   b. Mitkä ovat heikkoudet?
      What are the weaknesses?

3. Onko olemassa aiheeseen liittyviä dokumentteja?
   Are there any available documents according the subject?

Appendix 2: Interview questions about the supermarket area

Haastattelu: Supermarket alue

Interview: Supermarket area

Haastattelija: Louise Neuvonen

Interviewer: Louise Neuvonen

Haastateltava: Kokenut keräilijä

Interviewee: Experienced picker

Haastatteluaika ja -paikka: 16.4.2020, Porvoo

Interview time and place: 16.4.2020, Porvoo

Haastattelu kysymykset:

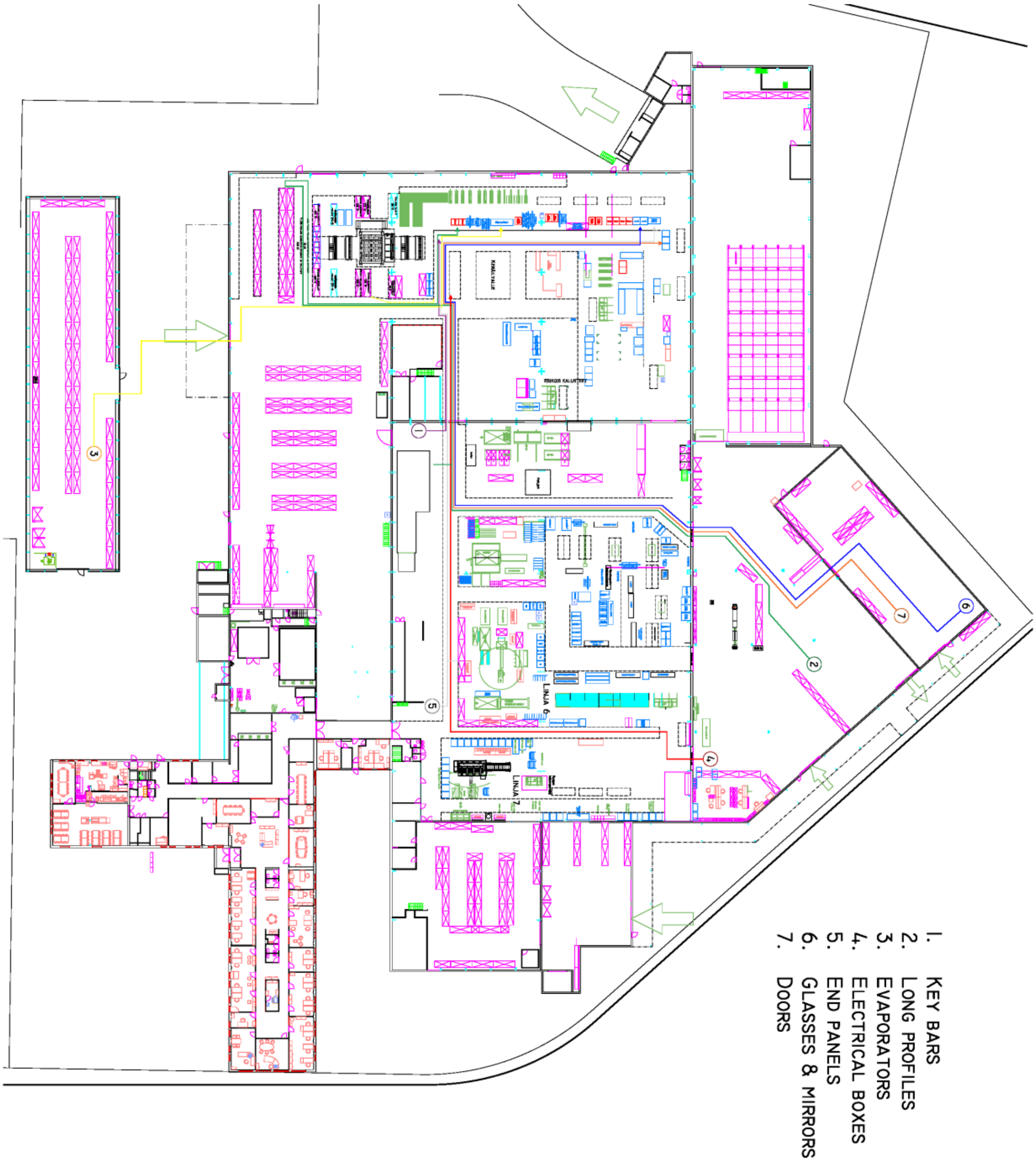
Interview questions:

1. Kuvaa yleisesti supermarket aluetta.
   Describe generally the supermarket area.
   a. Miten keräily tapahtuu?
      How does the picking happen?
   b. Miksi se tapahtuu juuri niin?
      Why does it happen in that way?

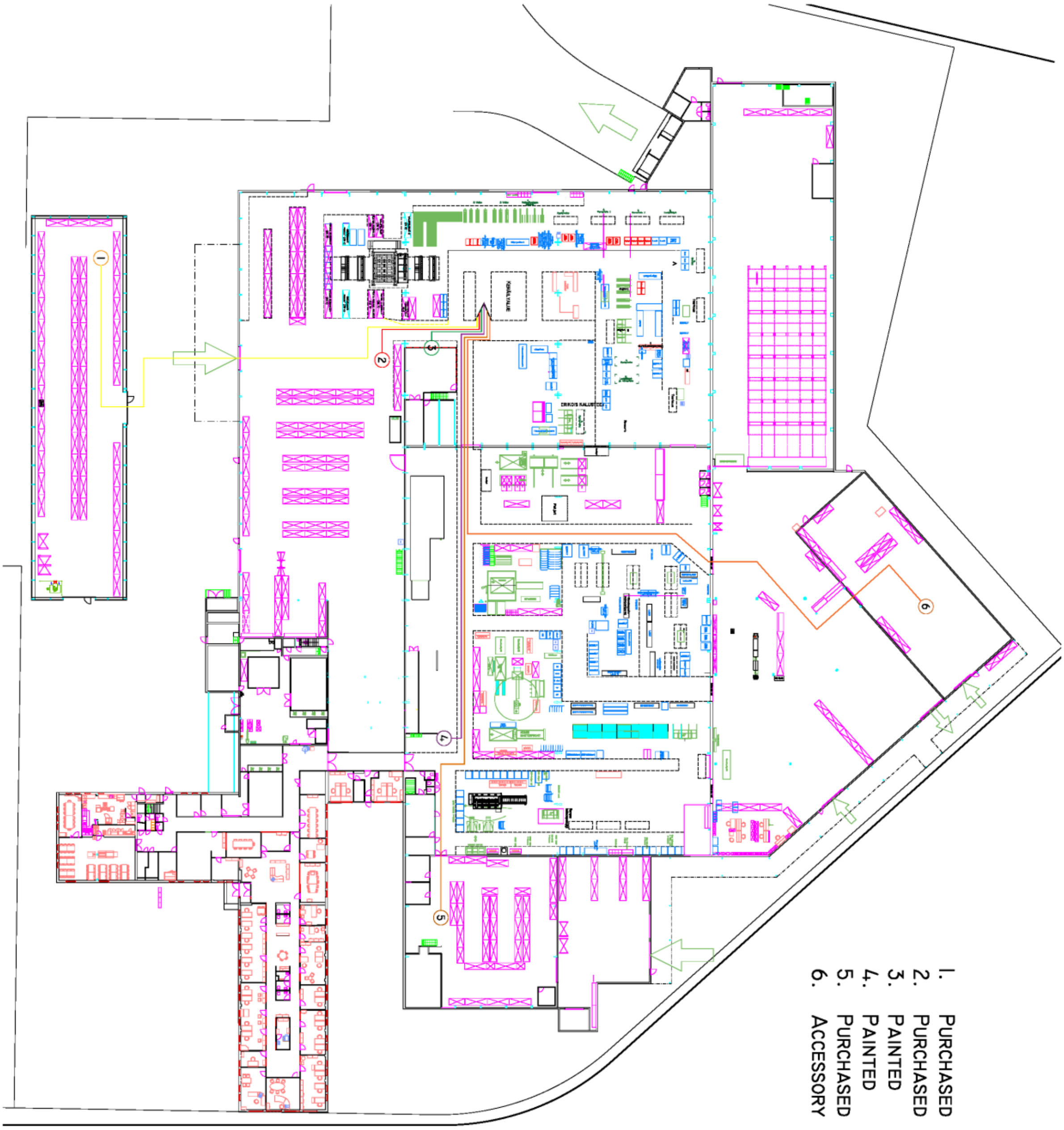
2. Analysoi yleisesti supermarket aluetta.
   Analyze generally the supermarket area.
   a. Mitkä ovat vahvuudet?
      What are the strengths?
   b. Mitkä ovat heikkoudet?
      What are the weaknesses?

3. Kuvaa keräilyreitti.
   Describe the picking route.

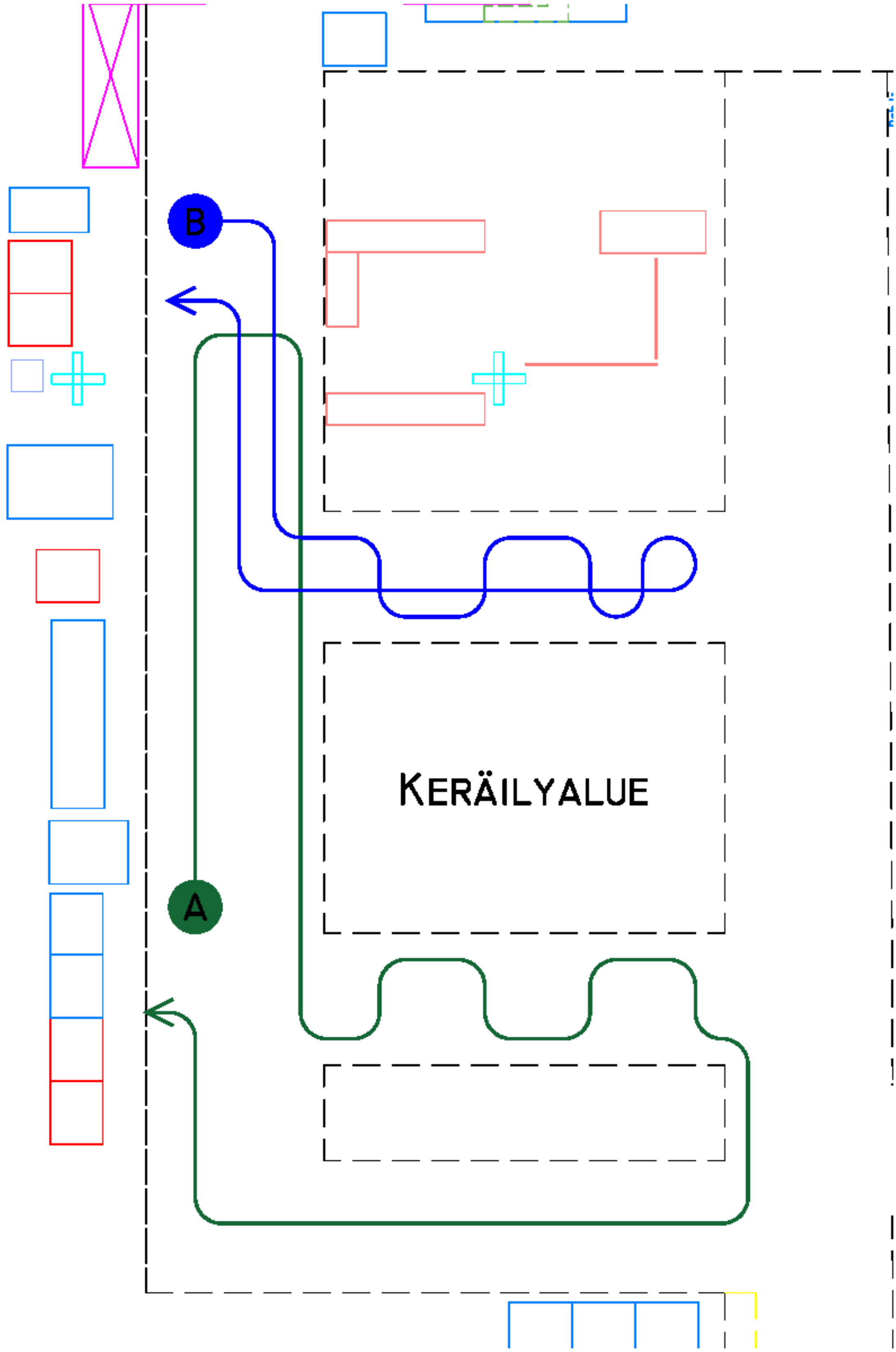
Appendix 3: Material flow from warehouse to assembly line



Appendix 4: Material flow from warehouse to supermarket



Appendix 5: Material flow from supermarket to assembly line



Appendix 6: New material flow routes