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UNIVERSITY OF VAASA

Emilia Syvänen

Management of intralogistics in manufacturing industry through data visualization: a case study

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Author:	Emilia Syvänen
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ABSTRACT :

Intralogistics is part of the logistics and therefore one of the significant factors of costs structure that the companies have. Logistics is a necessity in manufacturing companies to provide the customer with their goods. The production needs materials to be able to manufacture the goods. This is provided by the logistics department. Also, the finished goods need logistics to be able to reach the customers. This is why logistics is one of the main areas in the manufacturing company. Intralogistics is the part of the logistics chain that includes logistics partners and manufacturing site. This means that the scope is wider than in the warehouse management. Therefore, intralogistics has a major part in the whole logistics operation, and it should be optimized.

This research aims to provide information on how data visualization can be implemented in the manufacturing industry and what are the benefits of this implementation. To reach this aim the theory research in the chapter 2 included theory of data analytics, materials management, logistics and intralogistics data visualization. In chapter 3 the empirical research was concluded as a case study and the case study framework was followed. The empirical research included interview research which was presented in the current state analysis. The case company has noted problems in intralogistics due lack of visibility that this thesis aims to increase. The case company and the current state of it were presented. The case company and the benchmark research emphasize the need for visualization on the warehouse related reporting. The need for reporting was mentioned in the context of determining the bottle necks and optimizing the resources. The sources for this research were collected in the literature review, interviews and data collection from the case company's ERP system. Based on theoretical and empirical study, the result options were presented. The empirical research also evaluated the impact of the options presented.

As a result of this research, the plan with two phases was formed. This plan included two phases of implementation. Phase one is the predictive dashboard including tables and graphs. Phase two is an interactive and targeted perspective dashboard including tables, graphs and maps. The solution was planned to be executed in phases to ensure fast implementation together with the most beneficial results. Even though the results were conducted based on the case company's description and current state analysis, the results may be used in other companies and industries because theoretical research was conducted from the general point of view. The evaluation of the impacts indicated that the phase 2 would have major impact in the intralogistics. For the recommendation for future research other visualizations, artificial intelligence and machine learning may be relevant.

KEYWORDS: Intralogistics, warehouse management, materials management, reporting, data analytics, data visualization

VAASAN YLIOPISTO
Tekniikan ja innovaatiojohtamisen akateeminen yksikkö

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Tutkielman otsikko:	Sisälogistiikan hallinta valmistavassa teollisuudessa datan visualisoinnin kautta: tapaustutkimus
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Tiivistelmä :

Sisälogistiikka on osa logistiikkaa ja siksi yksi tärkeä tekijä yritysten kulurakennetta. Logistiikka on pakollinen osa valmistavan teollisuuden yrityksen toimintaa, jotta ne voivat toimittaa tuotteitaan asiakkaille. Valmistus tarvitsee materiaaleja, joista valmistaa valmiita tuotteita. Tämän varmistaa logistiikka osasto. Myös valmiit materiaalit tarvitsevat logistiikka osastoa, jotta ne saavuttavat asiakkaat. Tämän vuoksi logistiikka on yksi pää toiminnoista valmistavan teollisuuden yrityksissä. Sisälogistiikka on osa logistiikkaketjua, johon sisältyy logistiikka partnereita ja tehdas alueella olevat toiminnot. Tämä tarkoittaa, että se sisältää enemmän näkökulmia kuin varaston hallinta. Tämän vuoksi sisälogistiikalla on iso osuus koko logistiikka operaatioissa ja se tulisi optimoida.

Tämä tutkimus pyrkii tarjoamaan informaatiota siitä, kuinka datan visualisointia voidaan implementoida valmistavassa teollisuudessa ja mitä hyötyjä siitä voi olla. Jotta tämä pyrkimys voitaisiin saavuttaa, teoreettinen tutkimus luvussa 2 sisältää teoriaa data analytiikasta, materiaalien hallista, logistiikasta ja sisälogistiikan datan visualisoinnista. Luvussa 3 empiirinen tutkimus toteutettiin kohde yritykseen ja tapaustutkimus kehystä käytettiin tutkimuksessa. Empiirinen tutkimus sisältää kyselytutkimuksen, joka esitellään nykytila analyysissä. Kohde yritys ja sen nykytila on esitetty. Kohdeyritys on huomannut ongelmia intralogistiikassa näkyvyyden puuttumisen vuoksi, jonka takia tutkimus pyrkii nostamaan tämän tasoa. Kohdeyritys ja vertailuarviointi tutkimus korosti tarvetta visualisoinneille varastointiin liittyvissä raporteissa. Tarve oli nostettu esiin pullonkaulojen määrittelyn ja resurssien optimoinnin yhteydessä. Lähteet tälle tutkimukselle oli kerätty kirjallisuuskatsauksella, haastatteluilla ja datan keräyksellä kohdeyrityksen ERP-järjestelmästä. Teoreettisen ja empiirisen tutkimuksen pohjalta muodostettiin vaihtoehdot tuloksille. Empiirinen tutkimus myös arvioi esitettyjen tulosten vaikutuksia.

Tuloksena tästä tutkimuksesta oli suunnitelma, joka sisälsi kaksi vaihetta. Nämä kaksi vaihetta olivat implementaation vaiheita. Vaihe yksi on prediktiivinen dashboard, joka sisältää taulukoita ja graafeja. Vaihe kaksi on interaktiivinen ja kohdennettu perspektiivinen dashboard, joka sisältää taulukoita, graafeja ja karttoja. Tämä ratkaisu toteutettaisiin vaiheissa, jotta voidaan varmistaa nopea implementointi yhdessä eniten hyötyjä tarjoavan ratkaisun kanssa. Vaikka tulokset oli toteutettu kohde yrityksen tietojen ja nykytila analyysin pohjalta, tulokset saatavat olla käytettävissä muissa yrityksissä ja toimialoilla teoreettisen tutkimuksen geneerisen näkökulman vuoksi. Tulosten vaikutusten arviointi osoitti kuinka toisella vaiheella olisi suurempi vaikutus sisälogistiikkaan. Suositukseksi tulevia tutkimuksia varten voisi olla relevanttia tutkia muita visualisoinnin keinoja, tekoälyä ja koneoppimista.

AVAINSANAT: Intralogistics, warehouse management, materials management, reporting, data analytics, data visualization

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Abbreviations

KPI Key performance indicator

ID Identifier

1 Introduction

In the section 1.1. is presented the research background and meaning. These are presented to define why this research is needed. The aim of the research, research questions and scope are introduced in section 1.2. This section states what questions the research aims to answer. The research approach, method and structure are also presented in the section 1.3. to define what methodology is used in this research to answer the research questions.

1.1 Research background and meaning

This research has a case company that the empirical research is conducted in. This case company is presented more in detail in chapter 3. There is couple of problems noted in the case company. For example, some of these are following:

- high stock levels
- not relevant materials are stored
- materials in wrong or not optimum storage locations
- complex material movement between storage locations.

The root cause for these problems is the lack of visibility to the processes. The lack of visibility leads to the fact that these noted and solved. These problems lead to different types of not wanted effects which include high number of transaction and needed warehousing space. These are in a correlation with the case company's logistics costs and effect the effectiveness in the processes. Usually, the logistics costs cover minimum ten percent of companies turnover (Engblom et al., 2012). This means that the logistics costs have direct effect on profitability. This is why this research is meaningful for the case company.

Material and information flows are becoming a trend regarding optimization, automation, integration and management of intralogistics (Rozhko et al., 2023). These are becoming trends because companies want to optimize their operation. To optimize the operations the waste is eliminated (Gazda & Osieczko, 2018). One way to eliminate the waste in processes is to note and detect the problems to make changes. The way to easily access the problems would be report that shows the errors. The report would visualize the warehouse management data. In the theoretical research the different methods and theories are evaluated regarding the data visualization.

Because the problems have multiple factors, the problems should be from viewed both materials and warehouse management perspectives. The theoretical backgrounds for both are presented in the chapter 2. This theoretical background would determine what data should be visualized. The warehouse complexity has effect on this. Faber et al. (2001) acknowledged that the complexity of the warehouse has on impact on its planning and control. The research found that high complexity of the warehouse leads to more tailor-made planning and control structure (Faber et al., 2001). Materials management is also critical part of the process because this department the balances between inventories, costs and customer satisfaction (Lee & Billington, 1992). This is why dashboards to illustrate the critical materials have been developed (Hoiten et al., 2024).

The literature research includes the data visualization and its effects. There is already research of these topics. For example, Yerra (2025) presents research of using Power BI as a tool in inventory management. Yerra (2025) considered the Power BI software from the KPI capability perspective. The research results were that there are benefits in real time KPI performance compared to traditional methods including Excel (Yerra, 2025). Another example of research in this field is Arumsari and Aamer (2021) study of system that could provide real-time process monitoring in smart warehouse. In this study the smart warehouse also would use internet-of-things. The result of this study is that the real-time data visibility increased through visualization. (Arumsari & Aamer, 2021.)

1.2 Aim of the research, research questions and scope

The main research question was formatted based on the background of the study presented in the section 1.1. The main research question is summarizing the whole purpose of the research. The main research question is following:

- How can data visualization improve intralogistics?

The main research question implicates the main essence of the research. To solve the main research question, there are four sub research questions. These questions are the following:

- What theories/models can be used in data visualization?
- How the data visualization can effect warehouse management and materials management?
- What is the current state of intralogistics data and its visualization in the case company?
- How can the current state of data visualization be improved?

The first two sub research questions are presented in the theoretical chapter 2. The third research question will be answered in chapter three. The fourth sub research question is answered in chapters 4 and 5. The main and sub research questions are being solved with the help of the research objectives. These objectives are following:

- to analyze data visualization methods
- to study the visualizations effects on intralogistics
- to investigate different ways to visualize intralogistics data

These research objectives are helping to answer the research questions. All of the objectives are included in the sub questions. Therefore, they also will help to answer the main research question.

1.3 Research approach, method and structure

The empirical research of this thesis is divided into two parts. This means that there are two methods of the research. Unit of analysis is the case company for both methods. The comparison of the two research methods is presented in the table 1.

Table 1: Two reserch methods (adapted from Helo et al., 2019, p.15)

	Interview research	Data analysis
Type of research problem	Nomothetical	Normative
Use of data	Empirical	Theoretical
Research approach	Descriptive	Decision support
Method	Survey	

The interview research aims to find out requirements of the visualizations and needed data from the future users of the report. The sample size is three persons from the factory and eight persons from other locations of the same company. The future users are primarily operational managers because the report is used for strategic purposes. Survey research is done by asking questions and receiving people's opinions of the topic (Helo et al., 2019, p. 23 & Lavrakas, 2018, pp. xxxv-xxxvii). The survey is conducted as semi-structured interview. The interview questions are presented in the appendix 1. The answers are presented in the section 3.2.

The data analysis is conducted with decision support method. This method uses normative tools to help decision makers find the optimal solution for a problem (Helo et al., 2019, p. 17). The data analysis includes the evaluation of the improvements that could be made with the presented plan. The evaluations are presented in the chapter 4.

This thesis is also a case study. Case study method is used to describe phenomena within its context (Hartley, 2004). This research covers analysis of the case company's situation. The aim in case study is to analyse context and processes what the theoretical research describes (Hartley, 2004). In this research the theoretical background of intralogistics data visualization is research in the case company's environment. Therefore, this research is suitable to be a case study. The case study framework is implemented in this thesis. Therefore, this framework is presented in the figure 1.

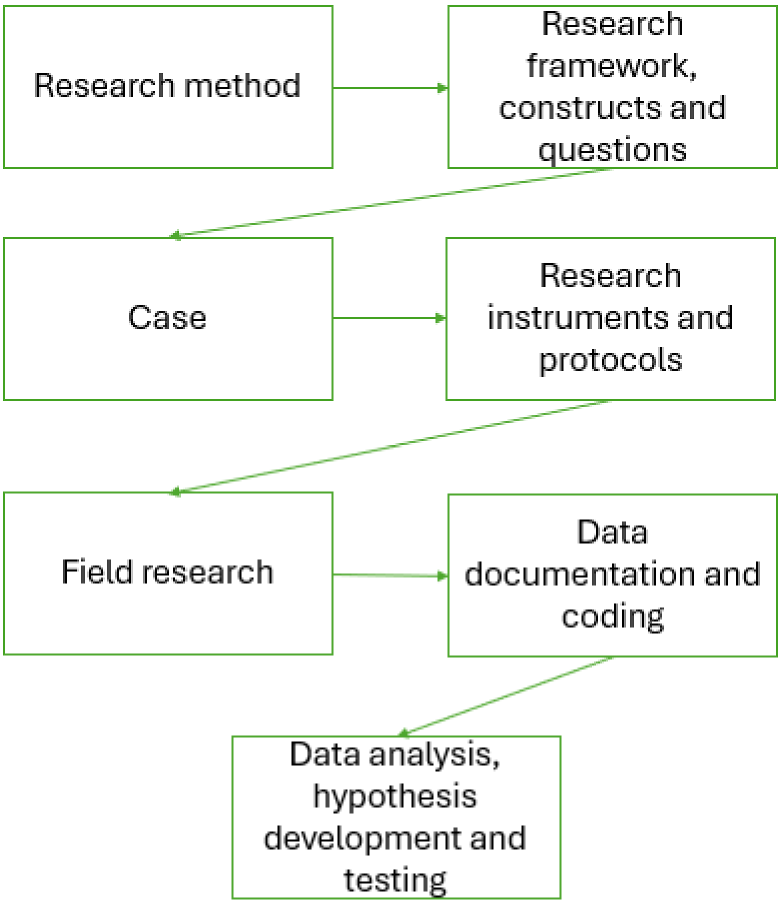


Figure 1: Case study framework (Adapted from Voss et al., 2022)

The case study framework is implemented in this research. The methodology was previously presented in this section. The questions were presented in the section 1.2. The case was presented in the section 1.1. The instruments were also presented in previously in this section. The field research, data documentation and analysis are presented in the empirical research parts in this thesis.

In the chapter 1 is presented the introduction. In the chapter 2 includes the theoretical research. This chapter includes theories of data visualization, materials, warehouse management and warehouse management data visualization. The chapter 3 includes the current state analysis. In this chapter is presented the case company's current data visualization, inventory management and logistics. This chapter included the interview research from the case company. Also, in the chapter 3 is presented benchmark research within the case company's other locations. In the chapter 4 is the presentation of two phases. The phase one includes predictive dashboard including tables and graphs. The second phase option includes interactive and targeted perspective dashboard including tables, graphs and maps. In the chapter 4 is also presented the proposal of the plan. The plan includes two phases, and it combines the two different phases to ensure plan that is easy to implement but provides the needed information. The chapter 5 includes the conclusions.

2 Literature review

In this chapter is presented data analytics, materials management and logistics. Main data analytics themes that are addressed are data and data visualization. Materials management is divided into materials planning and control and inventory management. Logistics portion is divided into intralogistics and warehouse management perspectives.

2.1 Data analytics

Data analytics can be also referred as business analytics, business intelligence or analytics (Sedkaoui, 2018, p. 44). Data analytics can be divided into descriptive, predictive and perspective analytics (Sedkaoui, 2018, p. 45). These are presented in the figure 2.

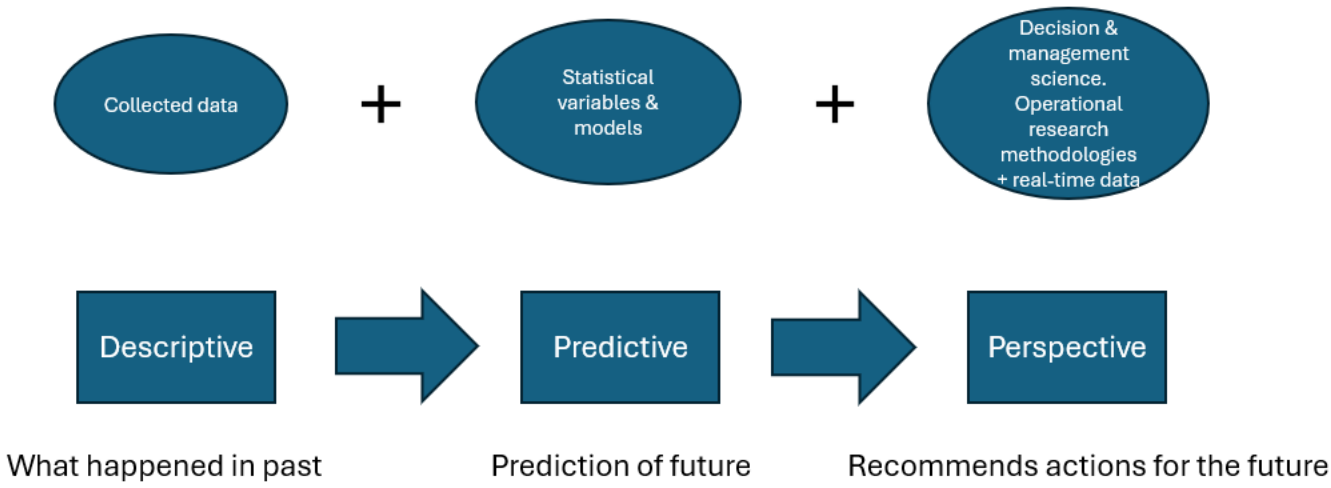


Figure 2: Different types of analytics (Sedkaoui, 2018, p.45)

The different types of analytics lead to different types of result that are possible to be made based on the analysis. The combination of three different types of analytics is referred to as business analytics (Sedkaoui, 2018, p. 46). This makes the analysis multidimensional. Combining the processing of the data to the analytics can be referred as business intelligence (Sedkaoui, 2018, p. 46).

2.1.1 Data

Different classifications of data are following (Satay 2016, pp. 10 & 11):

- qualitative (categorical) or quantitative data
- time series data or cross-sectional data
- discrete or continuous data.

Variable is a concept that is widely used in data visualization. Satay (2016, p. 11) defines variable as a "an object upon which the data are collected". This means that the variable shows the variation in the data (Satay, 2016, p.11). Therefore, variable can be the object that's variation is aimed to be illustrated through data visualization. Satay (2016, p. 15) states that statistical thinking is also part of data analysis because its purpose is to reduce variability. The statistical thinking follows principles that are following (Satay, 2016. p. 16):

> "1. all work occurs in a system of interconnected processes where a process can be seen as a series of activities or operations that turns inputs into outputs
> 2. variation – all processes and data exhibit variation which gives rise to uncertainty, and
> 3. understanding and reducing variation is critical"

As presented above, the principles of statistical thing can be considered in data analysis. These can be seen as a fundament of an effective decision making. The data visualization tools can have critical role in achieving this. (Satay, 2016, p. 16.)

Data collection is part of data analysis. Data can be collected from industrial, individual or government sources (Satay, 2016, p. 11). Because data can be collected from various sources, it can also be collected by different ways. For example, surveys can be data collection method.

One data type is big data. Bulusamy et al. (2021, pp.1-2) refers big data as large amount of data that is complex and may be arriving at high velocity. Because of this type of data, the amount of data overall is increasing rapidly. (Bulusamy et al., 2021, pp. 1-2.) This means that some actions have to be taken to be able to handle this type of data. Bulusamy et al. (2021, p.2) mentions that the large amount of data is useless if it is not transformed that way that it would have business value.

2.1.2 Data visualization

Satay (2016, pp.3 & 19) expresses that data visualization includes different graphical and visual tools to achieve data analysis and decision making. Data is summarized and presented more easier way to comprehend and communicated (Sahay 2016, pp. 3 & 19). This is done to concentrate on the essential characteristics to help make effective decisions or draw conclusions (Satay, 2016, p. 19). The concentration on the essential characteristics is done based on organizing, grouping, plotting and analysing data (Satay 2016, pp. 2019 & 2020). Tables and graphs are the most used visualization methods (Satay 2016, p.19). There are some principles in making data visualizations. One way to present these are following (Midway, 2020):

- diagram first
- use right software
- use an effective geometry and show data
- colors always mean something
- include uncertainty
- panel, when possible
- data and models are different things
- simple visuals, detailed captions
- consider an infographic
- get an opinion.

As mentioned above, these principles could be taken into consideration. On the other hand, there is also different ways to determine the principles of data visualization. The best practises in data visualization can be also formulated as following (Carson & Gutzman, 2023):

- showing comparison, relations, distribution or composition
- visual cues
- de-clutter and focus
- clear and informative tables
- avoid 3D.

As mentioned in the section 2.1.1., the amount of big data is growing rapidly, and it needs to be transformed to have benefit of it. Firstly, the data needs to be modified with tools and technologies to recognize the potential of it (Bulusamy et al., 2021, p.17). This means that the use case of this data is evaluated. Bulusamy et al. (2021, p.17) defined that following this the data is collected, stored, pre-processed and analysed. The business value of this realized when business decisions are made based on the analysis (Bulusamy et al., 2021, p.17). The business decisions are to be made when the data is understandable form. The data visualization is one way to have insights from the data regardless of the large quantities of it (Bulusamy et al., 2021, p.17).

Visual analytics is also part of the data visualization. Visual analytics mean combining different charts or graphs from data sets to provide interactive usage of the data. (Satay, 2016, p. 97.) This presentation mode could be also referred as dashboard. The design process of visual dashboard is presented in the figure 3.

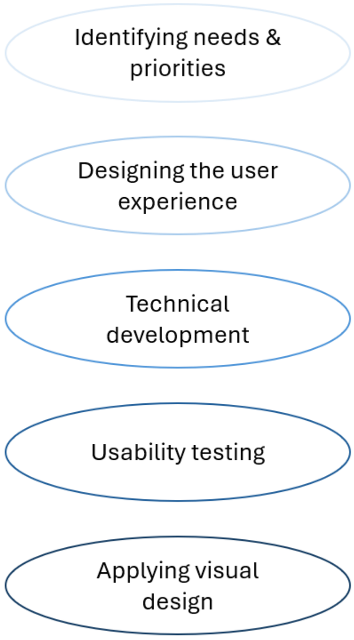


Figure 3: Visual dashboard design process (Bors et al., 2015)

Interactivity is also part of data visualization. The interactivity enables the user to see the view of the needed point of view (Jolly, 2018, p. 60). The interactivity can be accomplished in many ways. For example, these include following (Jolly, 2018, pp. 68 – 72):

- button widget
- checkbox widget
- drop-down menu
- widget
- radio button widget
- slider widget
- text input widget.

The different types of widgets are needed because they are suitable in different situations. For example, button shows only one option and drop-down menu enables multiple choices. The different options make difference in the visualization and in the options that the users have.

As mentioned above, there is need for interaction with the reports to enable to see the needed data from the visualizations. Therefore, there has been raised a need for recommended visualizations for specific users (Qian et al., 2021). The personalization of the visualization could help the user to find the needed data more easily. This personalization can be time consuming and need lots of analysis work to execute (Qian et al., 2021).

2.2 Materials management

Materials management can be described as planning, acquisition and utilisation of materials in the process of production (Bhat, 2008, p. 1). This means that materials management considers the materials whole process in the factories. The materials scope includes following (Bhat, 2008, p. 2):

- raw materials
- component parts
- assemblies
- supplies.

Materials management is multidisciplinary. Therefore, it has to take into account many various points of views. The main objectives are presented in the figure 4.

Figure 4: Materials management main objectives (Bhat, 2008, p. 6)

Materials management activities are planning, procuring, controlling, storing, handling, distribution, transportation and traffic control (Bhat, 2008, p. 7). In the next section the materials planning and control is presented more in depth. In the section 2.2.2 the inventory management theories are presented. These were chosen to align the objectives together with the logistics and warehouse management perspective.

2.2.1 Materials planning and control

Bhat (2008, p. 14) defines materials planning as “scientific way of determining the requirements of raw materials, components, spares and other items into meeting the production needs within economic investment policies”.

There are different benefits of materials planning that are following (Bhat, 2008, p. 14):
- quantity and value are equal to the production requirements
- efficiency due forecasting future material needs
- avoid shortages by materials budgeting and follow-up of suppliers to produce materials in-time
- co-operation with purchase planning to open communication of prices and costs.

Bhat (2008, p. 19) defines materials control’s purpose as “providing raw materials and parts in proper quantities and when they are needed”. There are many ways organize materials control. Bhat (2008, p. 19) mentions as one way to organize materials control is to define optimum stock requirements. This is the minimum inventory level concerning lead time of the materials. (Bhat, 2008, p. 21.) Although, this optimum stock requirement would be the most ideal way to require materials there could be situations that there could be reasons to overstock materials. These situations include price advantage, flexibility advantage, protection against market change (Bhat, 2008, p. 22). This overstocking can have different effects. Larger stock quantities can influence warehouse management.

Materials control includes different theories and procedures to determine the materials needs. One of these is bill of material. The bill of material includes the structure of the manufactured product (Bhat, 2008, p.22). This structure includes all the raw materials or parts that are needed to manufacture the manufactured product.

2.2.2 Inventory management

Inventory management can de defined as organizing stock of items to meet the customer demand (Bhat, 2008, p. 145). Inventory management includes wider scope of items than materials management. Inventory management scope includes following (Bhat, 2008, p. 146):

- Raw materials
- bought-out components or sub-assemblies
- semi-finished goods or work-in-process
- consumable stores
- maintenance spare parts
- finished goods stored or in transit.

Therefore, the scope of inventory management is wider than in the materials management. Inventory has also more diverse use purposes than materials. These functions are following (Bhat, 2008, p. 147):

- smoothing out irregularities in supply
- buying or producing in lots or batches
- to meet seasonal or cyclical demand
- to take advantage of price discount while buying items
- to maintain continuity to operations in production processes.

As mentioned above, the inventories have different purposes in the manufacturing. These purposes of inventory also lead to different costs. These are ordering/acquisition, carrying/holding and shortage costs (Bhat, 2008, p. 148).

2.3 Logistics

Ghiani et al. (2013, p. 1) defines logistics as "activities determining the flow of materials (and of the relative information) in a company, from origin at the suppliers up to delivery of the finished products". The flow of materials includes many different steps from the origin to the final customer. Logistics costs cover significant amount of the total costs structure of the whole company (Muha, 2019). This means that the management of these costs should be one priority in the companies. The logistics is divided into three different parts. These are inbound, intra and outbound logistics (World of Logistics, 2024). The relations and meanings of these are illustrated in the figure 5.

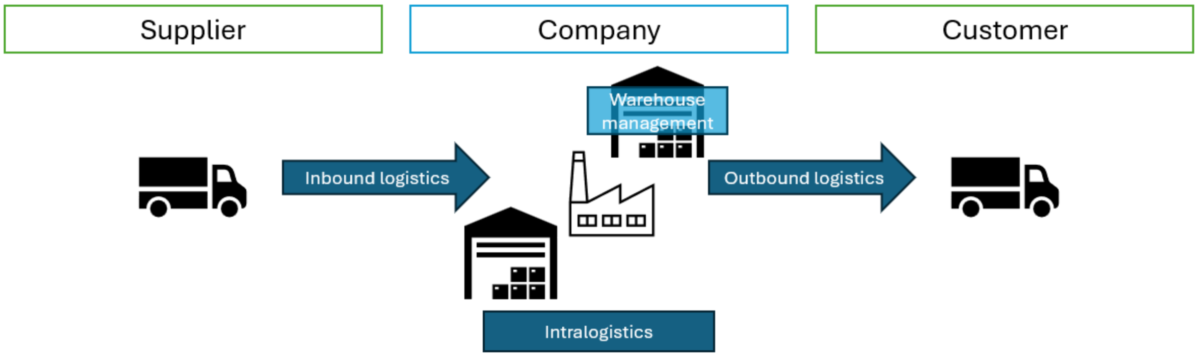


Figure 5: Logistics concepts and warehouse management (adapted from World of Logistics, 2024 & Hopstack, 2024)

The logistics relation to warehouse management is shown in the figure 5. The scope of logistics is considering the whole chain. Intralogistics in only part of the chain that is within the company.

Logistics can be seen as a cost that should be reduced even though the logistics enable the customer to use company's products (Lambert & Burduroglu, 2000). Lambert & Burduroglu (2000) mentions that logistics value to the company can be evaluated by different metrics. These metrics include customer satisfaction, customer value-added, total costs analysis, segment profitability analysis, strategic profit model and shareholder value (Lambert & Burduruglu, 2000).

2.3.1 Intralogistics

World of Logistics (2024) defines the intralogistics as “handling materials and products within own organization”. World of Logistics (2024) also mentions that intralogistics includes “management and development of the material and information flows”. In the figure 5 is illustrated the intralogistics relation of different modes of logistics and warehouse management. The intralogistics considers the whole factory and its warehouses. This means that the movements between different warehouses and factory is considered in intralogistics scope. Intralogistics can be also referred as in-house logistics (Winkel & Zinsmeister, 2019).

The intralogistics system can include different facilities. The management and planning of these need location-allocation (Ghiani et al., 2013, p. 123). The type and geographical location of the different facilities make a difference in the intralogistics setup. The flow between the different facilities is key factor to consider (Ghiani et al., 2013, p. 123). Among intralogistics been part of logistics, it is also part of supply chain. The supply chain production network can be complex and include several stages (Brandimarte & Zotteri, 2013, p. 7).

Usually, the intralogistics IT systems are part of some other system within the company (Glesissner & Femerling, 2013, chapter 9.4.). These IT systems could be for example warehouse management systems. The systems that are used effect the data and its collection.

2.3.2 Warehouse management

Warehouse management is set of processes to manage storage of physical goods and their movements in the warehouse (Hopstack, 2024). As illustrated in the figure 5, the warehouse management only considers the movements and storing of materials in specific warehouse. The warehouse can be owned warehouse, rented warehouse, public warehouse, depot, central warehouse, peripheral warehouse, distribution centre, CDC, RDC, automatic warehouse, spare parts warehouse, cool warehouse, cross-docking warehouse, quarantine warehouse or customs depot (Ghiani et al., 2013, pp. 210-212).

Warehouse management effects the business in many ways. For example, there are costs that are related to warehouses. These can be following (Ghiani et al., 2013, pp. 212-213):

- investment costs
- operating costs
- costs of risk
- running costs.

Scheider (2025) mentions that the warehousing storing costs by external partner can be divided by the unit that the costs measures. This means that the warehouse costs can be allocated by pallet, cubic footage, bin storage or square footage pricing. Ahmet and Ali (2011) present that the costs can be also allocated based on the activity of the external partner.

As mentioned in the section 1.1, the logistics costs are usually big portion of companies costs. This is the reason that the warehousing related costs should be minimized. The key performance indicators should be considered to make the warehouse operations efficient as possible. Ghiani et al. (2013, pp. 213-214) presents their view of warehouse key performance indicators. These are presented in the table 2.

Table 2: Warehouse management performance parameters (Ghiani et al., 2013, pp. 213–214)

Space utilization parameters	Surface utilisation rate ratio of used surface to total surface
	Volume utilization rate ratio of occupied volume to total volume
Load management capability	Potential receptivity maximum storable load by units

	Throughput maximum load by units in given time unit
Capability of exploiting capacity	Potential receptivity saturation coefficient % of ratio load unit on average in given time period to potential receptivity
	Selectivity index ratio of load units available to picking to potential receptivity
	Access index ratio of material handling operations in specific time period to potential receptivity
	Inventory turnover index ratio of value of outgoing goods to average inventory value (in specific time period)

Faveto et al. (2023) also presents a list of warehousing related key performance indicators. They divided the indicators to seven categories and selected the three most import ones of them by different questionnaire-based perceived importance, relative frequency, citation weighted frequency, singularity indicator and yearly weighted frequency (Faveto et al., 2023). These indicators are presented in the table 3.

Table 3: Warehousing related key performance indicators (Faveto et al., 2023)

Cost related performance	Holding cost
	Inventory costs
	Storage costs
Emission, waste, and environmental commitment indicators	Space occupation
	Energy consumption
	Pollutant emission
Generic performance	Travel distance
	Throughput

	Capacity flexibility
ICT performance	Solver iterations
	Response latency
	Algorithm reliability
Labor practice, decent work and social responsibility indicators	Work safety
	Activity automation
	Human utilization
Time related performances	Travel time
	Lead time
	Picking time
Warehouse Environmental Measures	Temperature
	Pollutant/Dirt concentrate
	Humidity

Ghiani et al. (2013) and Faveto et al. (2023) indicators have differences. The Ghiani et al. (2013) indicator only considers the warehouse performance and the storing capacity. The Faveto et al. (2023) indictors include wider scope of indicators that include more point of views to the warehousing. Indicators that are mentioned in both are throughput and space utilization. Although, the space utilization is considered from surface and volume perspective in the Ghiani et al. (2013) indicators. Also, capability flexibility is mentioned in both but in the Ghiani et al. (2013) it is looked from various perspectives. Therefore, the Favero et al. (2023) indicators include more indicators with various points of views but the Ghiani et al. (2013) indicators provide more in-depth indictors for specific situations.

Warehouse performance is crucial for the operations. The warehouse efficiency effects on time deliveries and customer satisfaction (Tang et al., 2022). This means that the warehouse efficiency effects the whole operations at the factory.

2.4 Intralogistics data visualization

In this chapter is presented the intralogistics data visualization. At first, the concept is defined. In the second section the different methods are presented. At last, the effects and possibilities are brought up.

2.4.1 Definition

As mentioned in the section 2.1.2. data visualization is used to summarize and illustrate data to efficient decision making. The material and information flow visibility adds value through data visualization (Jeong et al., 2024). In the section 2.3. is defined logistics as flow of materials and information. Therefore, the logistics data visualization adds value through data visualization. The connection of logistics and warehouse management was presented in the section 2.3. Because of this connection the data and its visualization need in intralogistics and warehouse management can be similar. Warehouse management data that is visualized can be divided as follows (Cogo et al., 2020):

- qualitative
- quantitative
- cumulative
- navigating data and improvements.

The division of data presented above, can include many different types of data. The type of data depends on the use case of the data. In the following section the methods of visualizing data are presented. The visualization needs are also effected by the different type of data.

2.4.2 Methods

As mentioned in the section 2.1.2. there are different ways to visualize data. The methods presented are tables, graphs and maps. These are presented with examples.

2.4.2.1 Tables and Graphs

As mentioned in the section 2.1.2. the tables and graphs are the most used ways to visualize data. Tang et al. (2022) divides the main points of warehouse management data visualization into three different points of views. All these points of views are visualized by different tables and graphs. These are following (Tang et al., 2022):

- monitoring
- analyzing
- evaluating.

The evaluation can be also referred as detailing (Eckerson, 2011, p. 14). Eckerson presented the MAD model that evaluates the data, its functionality and users. This is presented in the figure 6.

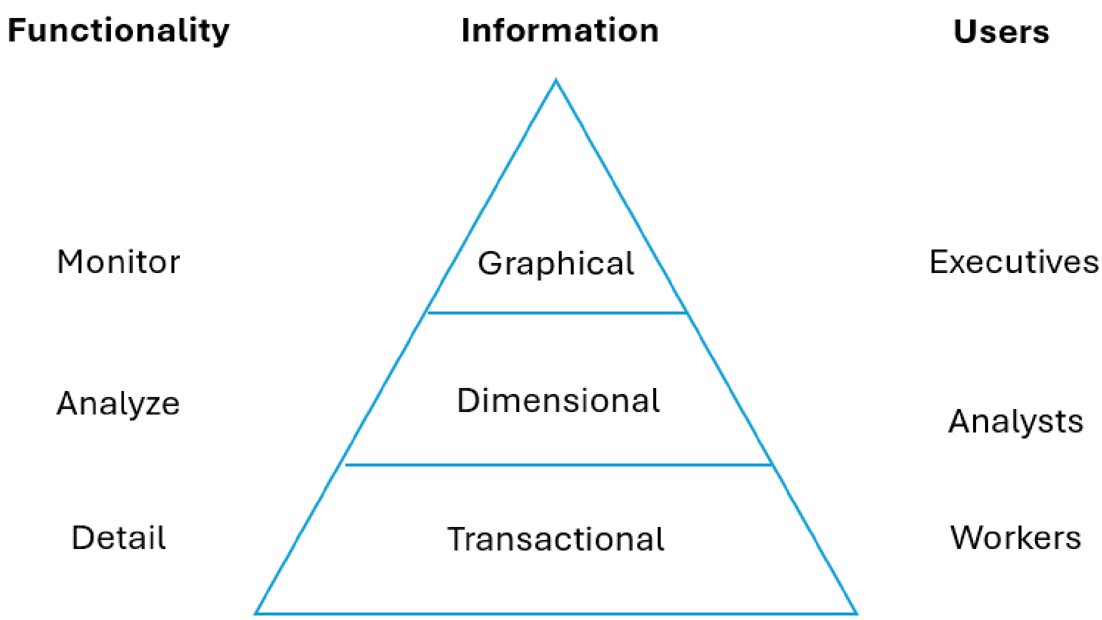


Figure 6: MAD framework (adapted from Eckerson, 2011, p. 14)

These points of views usually aim to visualize the main key performance indicators in the process. Warehouse management related key performance indicators are presented in the section 2.3.2. By monitoring, analyzing and evaluating these, there is a possibility to optimize resources and make the operation the efficient as possible. These key performance indicators can be visualized to tell the summarized situation. If there is something to take into deeper analyzation, the detailed data should be also visible for front-line employees and supervisors (Taringonda et al., 2018). The detailed data enables to make changed to the situation.

Balusamy et al. (2021, p. 294) describes methods to visualize big data. Big data can be or have same characteristics as logistics data. These methods include following (Balusamy et al., 2021, p. 294):

- line chart
- bar charts
- scatterplots
- bubble plots
- pie charts.

Balusamy et al. (2021, p. 295) describes the line and bar chart use case as trend viewing tool. In the figure 7 is presented example of intralogistics situation that these charts could be used. The line and bar charts present occupied storage space in certain weeks.

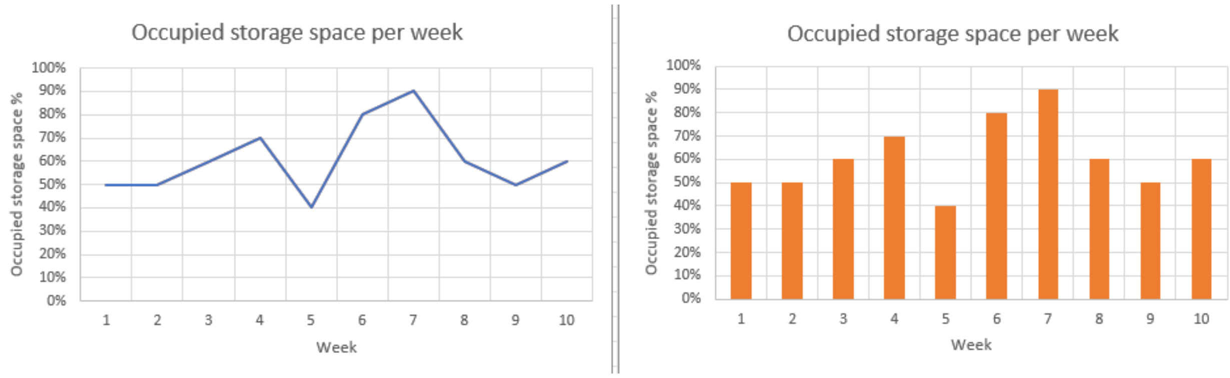


Figure 7: Modified line and bar chart to intralogistics (adapted from Balusamy et al., 2021, p.295)

The scatterplot and bubble plot describes relationship between groups. (Balusamy et al., 2021., p. 296.) The difference is that bubble plot also illustrates the one extra variable by the size of the bubble. Examples of these are presented in figure 8. This figure enables comparison between these two charts. The bubble charts bubble size presents the percentage of occupied storage in this example location compared to total capacity in the factory.

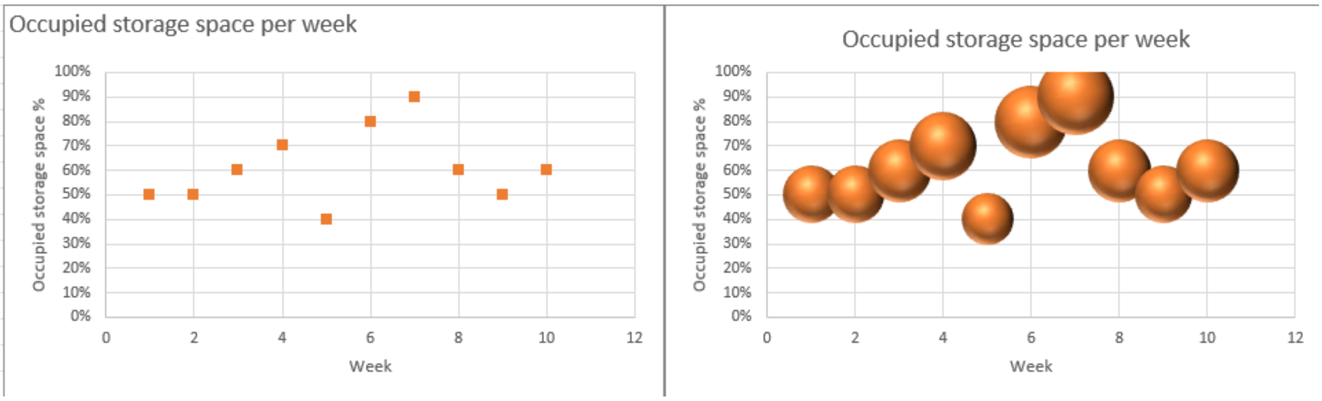


Figure 8: Modified scatterplot and bubble plot to intralogistics (adapted from Balusamy et al., 2021, p.295)

The pie chart can be used in part-to-whole comparison (Balusamy et al., 2021, p. 295). In the figure 9 is presented example of pie chart in intralogistics situation. This figure is presenting the capacity of certain location compared to the total capacity at the factory.

Figure 9: Modified pie chart intralogistics (adapted from Balusamy et al., 2021, p.295)

All these figures can be used to illustrate intralogistics set-up. As mentioned above, these visualization methods can be used to illustrate big data. This means that the intralogistics data volume is not a barrier to use these charts.

2.4.2.2 Maps

Logistics data can be visualized in different types of maps. The maps can visualize different types of data and can be used in different situations. For example, these can be following (Luzmo, 2019):

- flow map
- heatmap
- choropleth map
- routemap – network diagram (Jeong et al., 2024).?
- symbol map.

All these maps (figure 10-14) are formulated to illustrate intralogistics. To demonstrate the different maps, all the figures include one external warehouse, factory and two warehouse locations inside of the factory site. The maps illustrate situation that capacity wise the lowest to fullest warehouses are warehouse 1, warehouse 2 and external warehouse. This capacity factor can be seen in all the figures except figure 10.

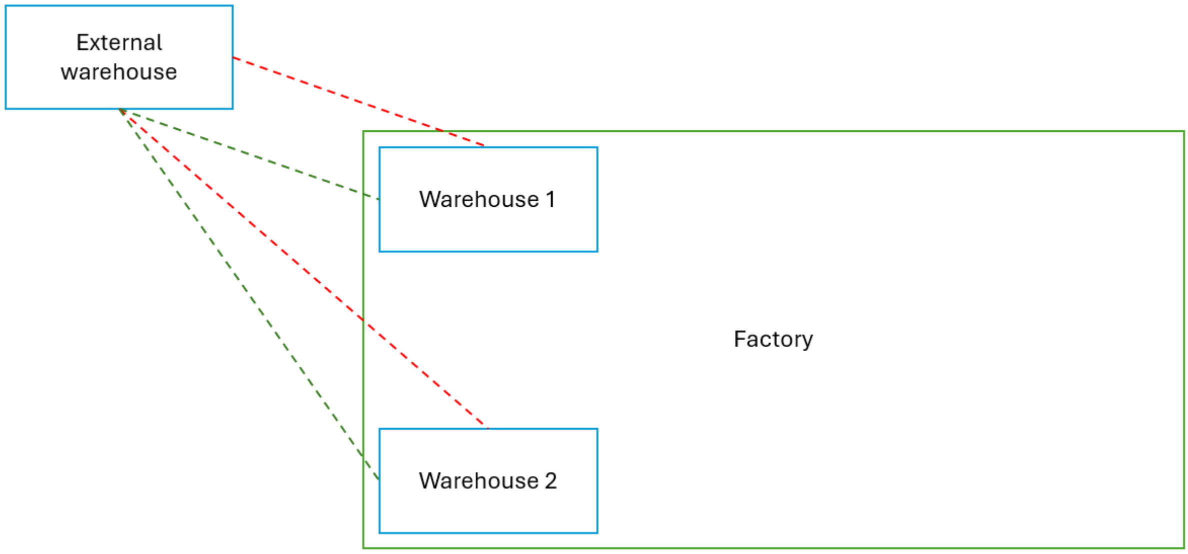


Figure 10: Intralogistics route map (Adapted from Luzmo, 2019)

In the figure 11 is presented route map. This route map illustrates the different routes that are possible to move materials between external warehouse and warehouses at the factory. Green colour indicated to desirable route based on parameters that are chosen.

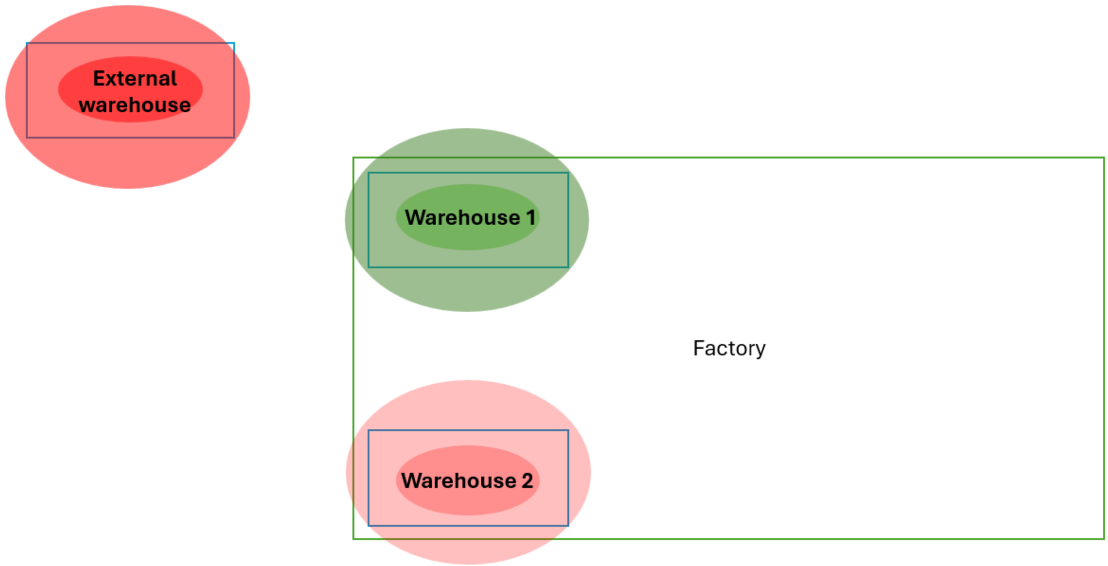


Figure 11: Intralogistics heatmap (Adapted from Luzmo, 2019)

In the figure 12 is illustrated intralogistics heatmap. The heatmap illustrated the capacity. Green shows free capacity and red shows full capacity.

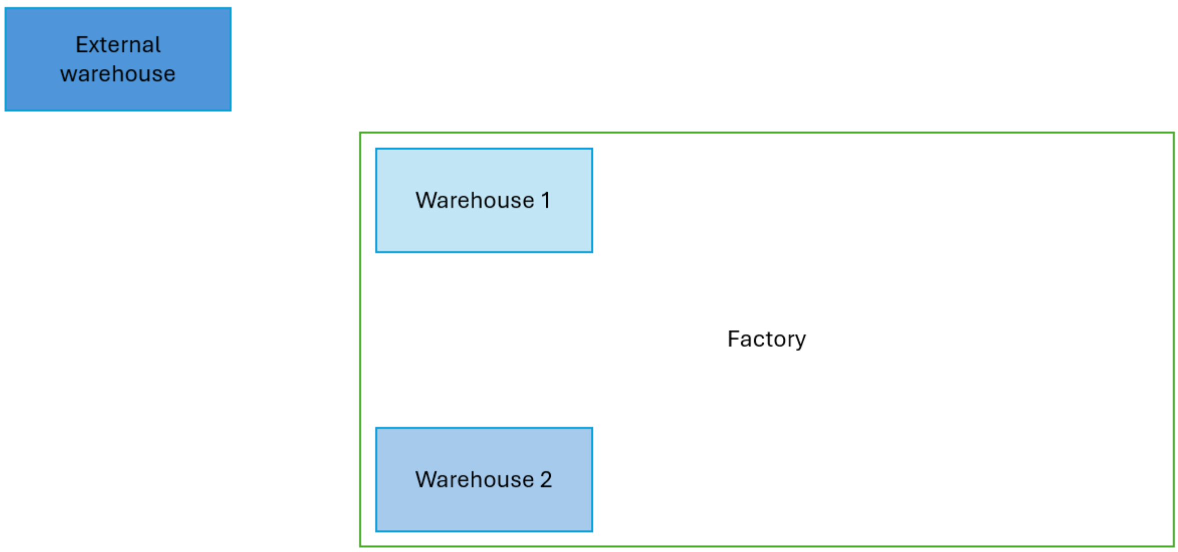


Figure 12: Intralogistics choropleth map (Adapted from Luzmo, 2019)

Figure 13 presents intralogistics choropleth map. This map illustrates capacity. The gradient of the colour describes the capacity level.

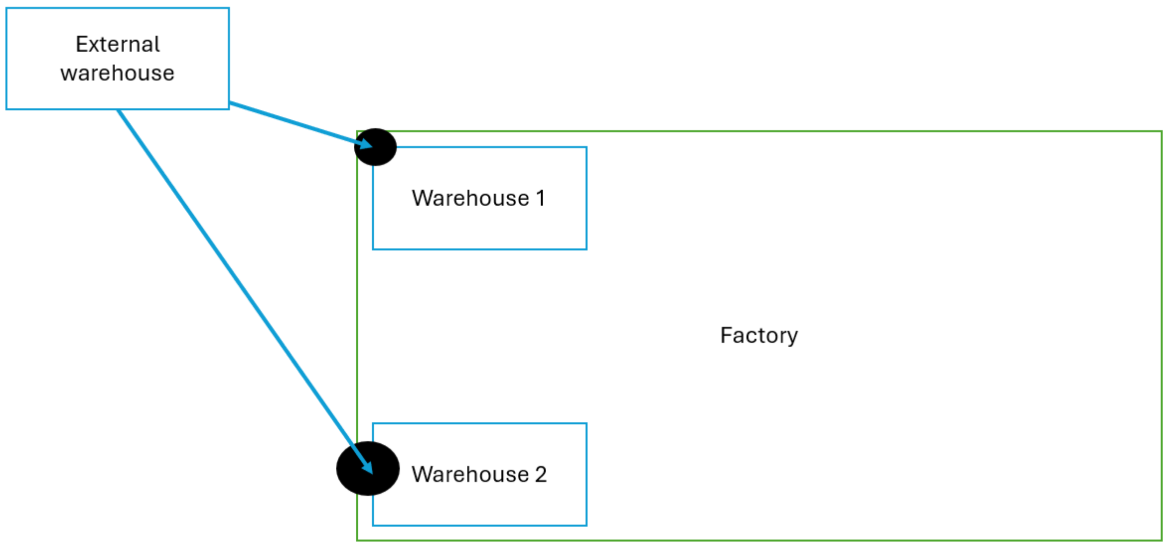


Figure 13: Intralogistics flow map (Adapted from Luzmo, 2019)

In the figure 14 is illustrated the intralogistics flow map. The arrows show the direction of the material flow. The size of the dot illustrates the amount of the material flows. This a map can be also referred as network diagram (Jeong et al., 2024).

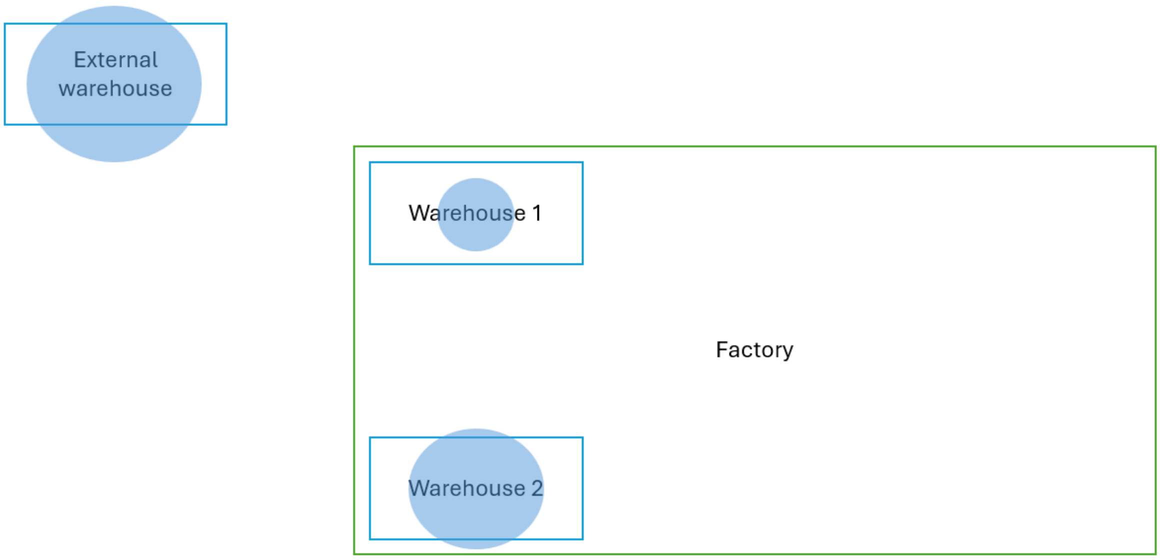


Figure 14: Intralogistics symbol map (Adapted from Luzmo, 2019)

Figure 14 shows the intralogistics symbol map. The symbol map shows capacity of the warehouse. The size of the dot illustrates the capacity.

The maps presented in the figures 10-14 can be also combined. For example, Jeong et al. (2024) have combined flow map and route map in intralogistics situation. These combinations summarize the situation to get fuller picture of the situation.

2.4.3 Applications

There are different applications that can be used in creating visualizations. One of these is Microsoft Power BI. Microsoft (2025) describes Power BI as follows: “Power BI is a collection of software services, apps, and connectors that work together to turn your unrelated sources of data into coherent, visually immersive, and interactive insights.” Power BI can be combined with data bases like Microsoft Azure to enable business monitoring with more real-time data (Yerra, 2025).

Other one on these applications is Salesforce Tableau. Salesforce (2025) describes Tableau as follows: “Tableau is a visual analytics platform transforming the way we use data to solve problems—empowering people and organizations to make the most of their data.” The Tableau enables translating data to interactive and shareable visualizations thought real-time data connectivity and many different visualization options (Pala, 2017).

These is comparison made between these software’s. Nayak (2021) made comparative analysis of these applications. The conclusion of this research was that Power BI had more customized visuals for better customer behaviour and Tableau had better performance in interactive dashboards (Nayak, 2021). On the other hand, Sahaya et al. (2024) also made comparison between these applications. The result of this comparison was that the Power BI was more user-friendly due the familiar interface of the applications, but the Tableau offered more capabilities and complexity in the features (Sahaya et al., 2024). Also, Mishra (2020) made comparison between these two. The conclusion was that Power BI was complemented on the user-friendliness due the Microsoft environment and refined visualizations were seen as Tableaus benefits (Mishra, 2020). All in all, all the comments acknowledged the Power BI for the user-friendliness and the Tableau for the different capabilities regarding the visualizations.

2.4.4 Effects & possibilities

As mentioned in sub-section 2.4.2, there are different ways to analyze data. Therefore, the benefits of data visualization also differ. Taringonda et al. (2018) presented one way to visual analytics and business dashboard design. The benefits of this kind of approach include the following (2018):

- best in class “Click to Delivery” (customer order time to delivery) performance
- improved decision-making process
- minimized operational risks
- increased customer fulfilments
- reduction in Personalization queues
- reduction in reprocessed orders
- reduction in customer care call volume
- streamlined/Centralized reporting

- assess the flow of orders by location, by lines, by units.

As mentioned in the section 2.1. there is level of data analytics. The level of data analytics effects the data visualization made based on it. The systems that the data is collected also effect the data visualization and smart systems enable more possibilities (Cogo et al., 2020). The possibilities of data visualization in intralogistics are depending on the future data analytics developments. For example, three digitalization trends in intralogistics that would be worth in inventing are collaborative robotics, camera-based identification systems, big data (Winkler & Zinsmeister, 2019).

2.4.5 Monitoring and maintenance

After the data visualization is finished the maintenance of report may need to be considered. Quanthub (2022) summarized the best practices in maintenance of dashboard. These include following (Quanthub, 2022):

1. schedule regular data updates
2. verify data accuracy and consistency
3. monitor for errors and fix them promptly
4. keep your dashboard design clen and simple
5. continuously collect and incorporate feedback.

Quanthub (2022) mentions that the regular data updates should be profitably done with automations to ensure informative decisions made based on the data. This means that the first point mentioned is needed in visualization about logistics data. As mentioned in the sub-section 2.4.1. the material and information flow are one important aspect of logistics data. This type of data needs frequent updates for it to be relevant information.

Quanthub (2022) defined the second point as double-check, validation and standardization of the data. This means that the second point mentioned is noted in the logistics setting specially when changes are happening. In the section 2.3 was mentioned the logistics set-up. If there is change in logistics set-up after the specs of the report has been made, there could be errors. Besides the logistics set-up the data can be changed in other ways too. One aspect is IT point of view. There could be IT changed happening that could affect the report that has been created.

Quanthub (2022) brought up that the point five includes implementation and communication of changes. These are important that the report stays relevant for the operations. The logistics reports can have different purposes in different situations. This means that the use case for the report can change, and the report should be changed to match the resent situation. As mentioned in the section 2.1.2, there is different ways to visualize data. The different implementations can be also made after the release of the report to improve the report.

3 Brief description of the case company and its current state

The case company is global hoist and crane manufacturer that has multiple factories. The case company is divided into three business areas. These are divided by the goods or service that they produce. There is ports or terminal crane manufacturing, the rest of products manufacturing and service operations. In addition, the case company has different smaller operations that they provide. For example, these include automatic warehousing systems.

The case company is in Germany. This factory includes the business areas of the rest of the products manufacturing and service operations. In this thesis, the service operations are excluded.

The products that are manufactured in the factory include hoist, workstation lifting systems, overhead cranes and jib cranes. In addition, the factory provides parts of these products for sale to external or internal customers. This means that the factory's production scope is broad.

3.1 Company's materials management and logistics

The case company's materials management is controlled by materials management department and logistics is controlled by logistics department. The materials management scope includes only the raw materials. The raw materials are planned on factory level. Therefore, the logistics department is responsible for placement and movements of the materials. The responsibility of materials managements is to ensure availability of needed materials. Also, the responsibility includes the scrapping of not needed materials. This is especially relevant in ramp-downs of materials. In the case company there is ramp-ups and ramp-downs on-going now. This leads to changes in the needed materials. This leads to checking if the stored materials are relevant. As mentioned in the chapter 3, the service operations are also done in the factory site. This leads to materials also needed to the service operations. The requisition of materials is done based on the paraments in ERP system. These parameters include following:

- safety stock
- minimum lot size
- planned delivery time.

The parameters above determine when and how much of the material is ordered. There are also other parameters but these one of the most important. These is also key performance indicators used in the materials management department. For example, inventory turnover and stock value are used to measure performance. The division in the key performance indicators are made by the product if needed.

Case company's logistics set-up includes now three third party logistics partners. One of these partners is in ramp-down phase and one is in ramp-up phase due change of logistics partners. After this change there is two logistics partners. Logistics partner 1 is the new logistics partner that is responsible for the main storing of the goods in the future. The logistics partner 3 was the old partner that was previously responsible for the main warehousing capacity. The logistics partner 2 was previously responsible of warehousing but the scope of the operation has been reduced. Now the logistics partner 2 only stores special materials that cannot be stored in the logistics partner 1 due the items large size. The logistics partner 2 does also special packaging for sea freight materials.

In addition to the logistics partners, the factory site includes multiple storage locations. The factory site is divided into two parts. This is due road between the two areas. The simplified layout of the factory is presented in the figure 15.

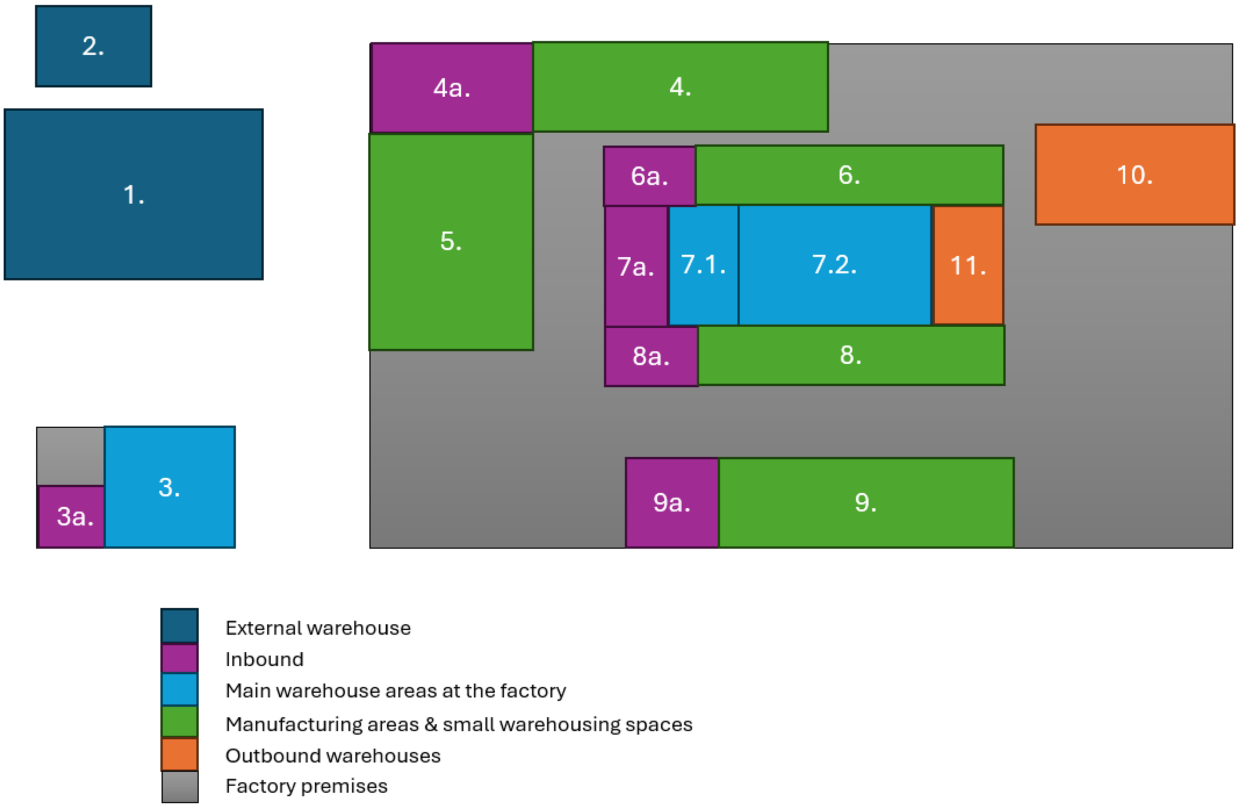


Figure 15: Simplified factory layout

In the figure 15 the numbering means following:

1. logistics partner 1
2. logistics partner 2
3. Warehouse area
4. Manufacturing & storing
5. Manufacturing & storing
6. Manufacturing
7. Automatic warehouse
8. Manufacturing
9. Manufacturing
10. Outbound outside storage
11. Outbound storage

In the figure 15, the presented inbound areas receive goods from the logistics partners or from the suppliers. The suppliers mostly deliver to the logistics partners. The area three is one of the biggest storing areas at the factory site. This area includes automatic warehouse system for small items and pallet racks. The areas four and five have multiple levels. This means that there are levels that have manufacturing and levels that is occupied with storing of the materials. The multiple levels effect the materials flow because the materials are moved with elevator. The areas six, eight and nine are mostly manufacturing areas. In the area eight there is automatic warehouse system and pallet racks. The area seven includes automatic warehouse with the biggest storing capacity in the manufacturing site. The area seven also includes small items high-level picking area. The area ten and eleven includes outbound storing area with pallet racks.

The material flows at the factory site are quite complex. The complexity has to do with the many manufacturing areas at the factory. The manufacturing areas at the factory result to many inbound areas at the factory site. The inbound areas are marked to the figure 15 with purple colour. The inbound to these areas are primarily coming from logistics partners or from other storing areas. The inbound form suppliers are mainly focused on the logistics partners but there is inbound coming to the factory site also. Warehousing location 3 also supplies the factory site areas. In the factory site, there is also movements between the areas. The outbound areas are getting goods from the different areas in the factory. The outbound of the factory is done only from the factory and primarily from the two marked outbound storage locations. Therefore, the material movements are not straightforward in the factory logistics set-up.

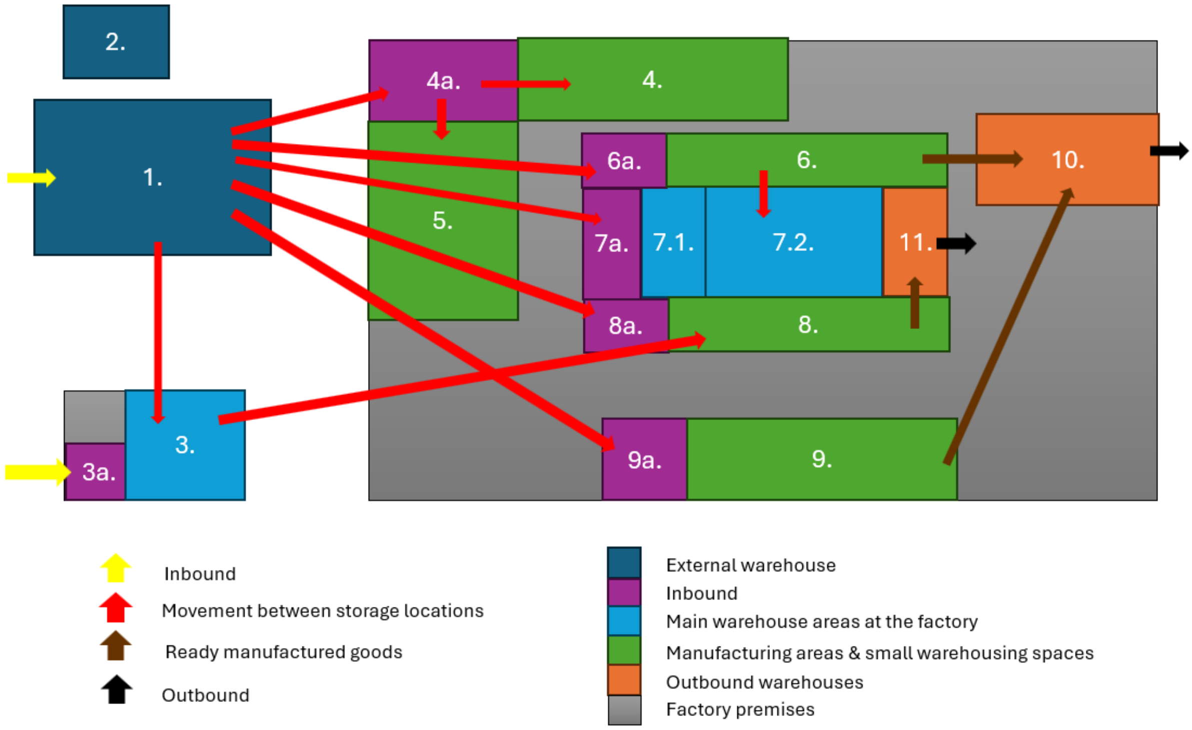


Figure 16: Case company's main material flows

As seen on the figure 16, the material flows at the factory site are not streamlined. The figure only includes the main material flows. As seen on the figure, there is many movements between the storage locations. Every movement between the storage locations lead to picking, packing, moving and receiving of the materials. There are costs and resources associated with every movement. Also, there is possibility to make error in every action.

3.2 Company's intralogistics data visualization

The case company operates currently with two ERP systems. Other system is legacy system that is in ramp-down phase. This ramp-down has started few years ago and will last still years. The ramp-up of the new system is done phases. The phases are divided by product. Now couple of products have been moved to the new system. This means that the materials are stored in two systems. There could be materials that are stored in both systems. As mentioned in the section 3.1., the case company has two logistics partners. Both partners operate in the case company ERP system. As also mentioned in the section

3.1., there is the automatic warehouse (marked as 7). This automatic warehouse operates in its own system. This own system is operated with the case company's both ERP systems. The automatic warehouses own ERP systems means that the bin information is only in this system. In the factor's ERP systems have the materials, quantity and transactions of the automatic warehouse.

In the case company, there are many different automatic reports available. For example, there are available materials management related reports of the whole factory. Usually, the reports are made to visualize performance of some department. For example, these could be used in pulse meetings. All the reports are done via Power BI and usually conducted by using background jobs from the ERP system. The background jobs provide data usually ones or twice a day. In these reports it two ERP systems must be considered. The two ERP systems means that the data needs to be combined and unified.

The logistics related Power BI reports are done from one storage location perspective. This means that the one storage location is analysed from the fill rate or some other key performance indicators perspective. The reports are built to optimize the warehousing capacity or materials stock optimization in this area. As mentioned in the section 3.1., materials management department operates on factory level. This is why there is report that visualises the materials management on factory level.

The visualizations that are used in the case company are usually tables and graphs. Other visualizations are not in use. The visualizations can be filtered by different types of criteria. For example, the criteria can be the product or location. The tables and graphs enable to visualize key performance indicators. For example, the key performance indicators that are visible in the reports include following:

- fill rate
- inventory turnover
- stock value
- count of pallets or another storing element

- punctuality of transactions
- quality indicators
- sales or purchase order lines
- backlog or workload monitors of operations.

As mentioned above, the logistics reports only cover one storage location or only other Erp systems materials. This makes hard to see what the situation is in the full factory. For example, the fill rate cannot be optimized because the optimization of storing capacity would need information of the other locations as well. Now the reports can visualize that the storage capacity is full but there is not any indication of the possible options to fix the situation.

As seen on the figure 16, the material flows at the case company are not streamlined. Because the figure included only the main material flows, the full picture is not visible in the figure. All the material flows are hard to keep track on. For example, new material flows may appear that are not noticed. This makes the responsible persons not be aware of the situation.

3.3 Interview research & benchmarking

The case company's three managers were interviewed. The questionnaire is presented in the appendix 1. The question survey was conducted with half-structured interview. The managers interviewed included materials management manager, warehouse management manager and manager of logistics, materials management and order management. As mentioned above, there is many different visualizations used in the factory. There have been different pilots done with different visualization options. One of these pilots is Sankey diagram. This diagram was fulfilled by using one time snapshot of data. This means that the Sankey diagram was not updating. The Sankey diagram visualises the flows of materials including the volume of the flows. This meant that the material flows were analysed based on the diagram and the needed actions were made. This diagram was found to be useful and aroused interest for updating visual of same kind of data. The emphasis was on frequent data updating in the needed visualization. The consumption and distribution of materials with-in the factory and its logistics set-up was seen as one aspect that could be visualized.

In the interviews, the materials management visualization was seen to be on a needed level. As mentioned in the section 3.2., the materials management department operates on the factory level. Also, previously mentioned in this section that the materials management data is already visible on the factory level. Therefore, there is more need on the logistics visualization that additions in the materials management data visualization. All in all, the materials management data could be used in the logistics visualizations as an addition.

In the interviews, the map visualizations were pointed out as one of the possible visualization needs. The need for this kind of visualization is to spot the bottle necks in the processes. This kind of visualization could enable to make conclusions and proposals for improvements. This is only possible if the data updating cycle is frequent. This means that the outputs from the previous Sankey diagram could be aimed but with continuous process.

The interviews were also conducted for the other locations in the same company. The interviews were conducted for four different locations. All the locations participated with two persons.

The location A has currently two times a day updating warehouse report. The future needs are in all warehouses combining report. The location A also would need visualization of free warehouse and pallet locations. The noticeable point that location A mentioned is that the free pallet location visualization should take restrictions into account. For example, weight limits should be automatically considered. Also, location A would need view for the future situation.

Location B uses widely different types of reports. This factory has different type of way to extract data which enables only ten-minute delay on data updating. The emphasis on future developments is on easy usage. Location B also sees as that in the future the need for heatmap would be ideal with combination of xyz-analysis. This could provide the needed help for the location optimization. The data extraction method would need to be different to get this kind of data in timely manner.

Location C uses as well different types of reports but more in some other areas than in warehousing. The need for visualizing pallet location is noted. This has been piloted by doing it manually in excel. Therefore, the need for heatmap and palletization visualization is in this location. The location C also noted that the high pallet rack storage may be hard to visualize. Also, 3D view of pallet rack storage was mentioned as one option for future.

Location D do not use currently warehouse reports. The location D mentions that there would be a need for this kind of reporting if the data updating cycle is short enough. One of the most critical points would be to have workload monitor to see the bottle necks in the operations. Location D also brought up need for combining data for other systems as well. This has been seen as factor to make value with the report instead of using the ERP system. Also, the location D has an interest to develop the warehouse reporting in the future with heatmaps and other visualizations. Because the location is not using the reporting now, first the basic data should be used and visualized to get the people used in using the report. Of course, the benefit of the report is only visible if the data is combined and processed.

Table 4: Summary of results the interview research

	Current state	**Needs for future**
Case location	- some visualizations - warehouse management is not reported on factory level - materials management reports available	- material movement visualization - frequent updating cycle - map visualization
Location A	- warehousing report that updates two times a day	- warehouse visualization of free storing space
Location B	- frequent data update of ware-house data in reports	- easy usage - location optimization
Location C	- reports that cover many areas of warehousing	- free capacity visualization
Location D	- no reports currently on use for warehouse	- warehouse reporting in general

In the table 4 is presented the summary of the results in the interview research. The table only includes the current state and the need for future visualizations to make this summarization brief. The table concludes there is need for warehouse management visualization even though the current state of the warehouse management reporting has variety.

4 Study results & analysis

In this chapter is presented the study results. The results are formed based on the theoretical analysis and current state analysis. The results are presented in figure 17.

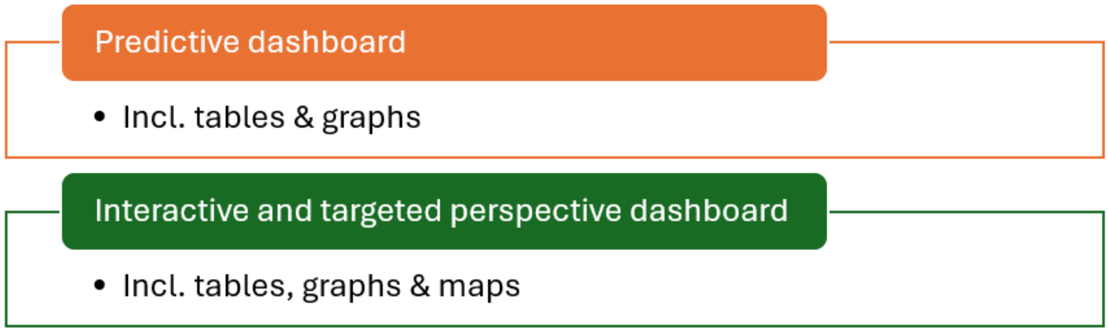


Figure 17: Result of the study

These options are presented in following sections. The options are part of visual analytics because they have element of analytics and visualization. As mentioned in the sub-section 2.1.2, the visual analytics is presentation can be referred as dashboard. Both options are executed with the dashboard type of presentation type.

Both options would be executed with Power BI because this is widely in use in the case company. The pictures of the dashboards are illustrated in Power Point to give example of the visual view of the dashboard without the real execution of the dashboard in the Power BI.

4.1 Phase 1: Predictive dashboard including tables and graphs

This is phase includes predictive dashboard. As mentioned in the section 2.1. the predictive data analysis method would mean that the statistical variables and models would help to give prediction of the future state.

As mentioned in the section 3.2., the logistics data is not visualized in factory level. This report would give perspective of the whole factory in one report. This would enable the users to see the situation on the whole factory at the same time to make decision based on the full picture. This would mean that the bottle necks in the process could be eliminated more efficiently. Also mentioned in the section 3.2., the materials management already uses predictive dashboard on a factory level. Therefore, the materials management perspective is not considered this phase.

The dashboard is presented in the figure 18. As seen on the figure, the dashboard includes KPI’s that are presented with text boxes. As mentioned in the section 2.3.2, the space utilization parameters are part of warehouse management performance parameters. These fill rate KPI’s are mean to describe the surface utilisation rate that the storages have. The surface utilisation rate is describing the ratio of used surface compared to the total surface. This means that the fill rate considers the total surface that the warehouse has. Therefore, it needs to be considered that the warehouses are various in the capacity. The total factory fill rate is considering the warehouse capacities and emphasizes the importance of the larger warehouses. The text boxes illustrating the KPI’s are marked with different colours to emphasize the fill rate of the storage. As mentioned in the section 2.1.2, the colour usage is one of the data visualization principles. Also, in the principles was mentioned panels. The panels are used in the figure 18. The header and fill rates are inside of panels. This makes division to the dashboard layout. Also, the principles included the infographic. This is implemented in the dashboard as the data updating info on the top right corner of the figure 18.

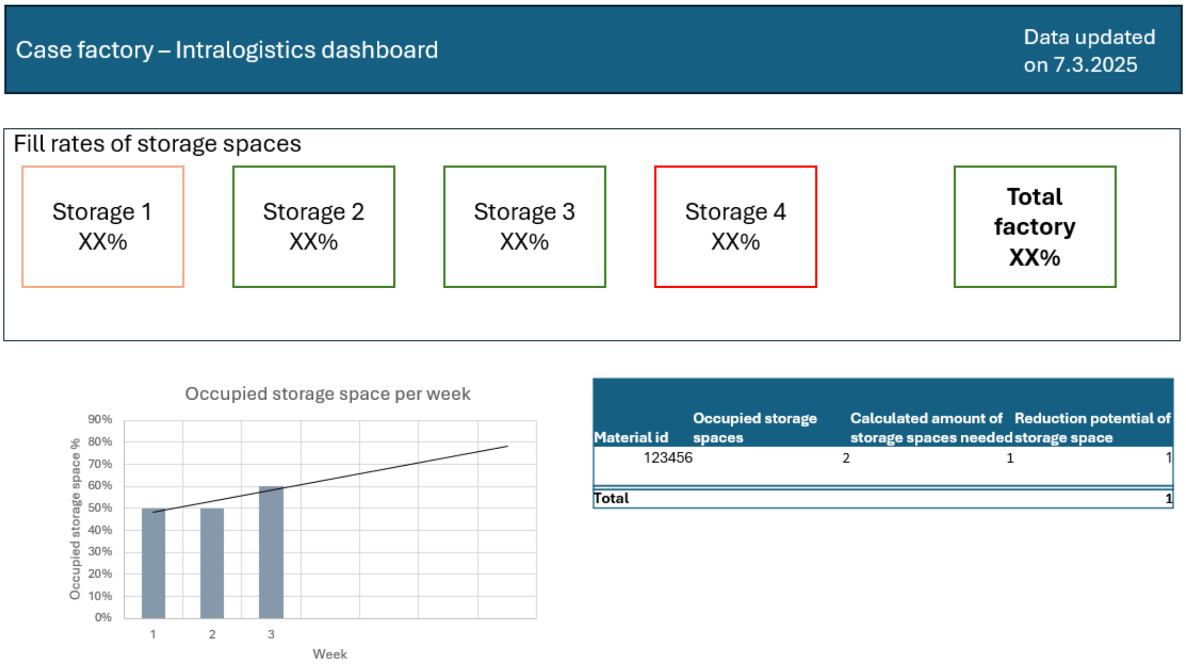


Figure 18: Intralogistics dashboard with phase 1

In this solution the tables and graphs would be implemented in the dashboard. The different tables and graphs were presented in the sub-section 2.4.2. As seen in the figure 18, there is graph of occupied storage space per week. The occupied storage space per week is illustrated with bar chart. The bar chart also includes linear trend line to predict the future trend of the occupied storage space. This trend line provides insight of the future situation and enables the user to make decisions based on it. As also seen on the figure 18, the dashboard includes table. This table includes material id and the occupied storage spaces that they have currently. The table also includes the calculate number of bins that the material would need. This calculation was done based on the maximum quantity of the material in each storage space. If there is found smaller quantities in the storage space, then the bins are merged. This leads to the calculative possible reduction of the storage spaces that is presented in the table. This analysis is predictive because it predicts what the possibility would be. The analysis is not perspective because it does not give solution how to accomplish the reduction. The material ids are not real to protect the case company privacy.

4.2 Phase 2: Interactive and targeted perspective dashboard including tables, graphs and maps

The phase includes the same data visualization principles as the solution option 1. These included colours, panels and infographics. The phase 2 adds more value by adding the perspective analysis to the dashboard.

As mentioned in the sub-section 2.1.2, there is different types of widgets that can be implemented in the dashboards. As seen on the figure 19, the dashboard includes two drop down menu widgets. By these widgets the user and system can be chosen. The user widget enables the user to select the desired view. The phase 2 is divided into two different views. The views that are chosen are the logistic and the materials management point of views. As mentioned in the section 3.2., the factory operates in the two ERP systems. Therefore, the user is enabled to select the system if necessary.

In the table and graphs change depending on the selected user. In the logistics user view in the figure 19 and 20 there is table of possibility to reduce material movements. This table includes information of material id, current storage location, possible new storage location and the reduction of the potential material movements. The potential reduction is counted automatically by the collected data from the past movements. In the intralogistics view the graph is the same as in the phase 1.

There is also button widget in the dashboard. This widget can change the map that is illustrated. In the sub-section 2.4.2 were presented different map visualization styles. The chosen styles of the maps are heat map and flow map. The heat map illustrates the urgency of the situation with the colours. As seen on the figure 19, the heat map visualizes the fill rate of the warehouses. This means that the visualization illustrates the same KPI as the phase 1. The colours emphasize the urgency of the fill rate situation. Red colour indicates that the warehouse is full. The green indicates that there is scape in the warehouse. This means that there could be possibility to move materials from the red indicated storage locations to the green indicated storage locations. The user can choose the specific storage location by clicking the map. The text boxes of the capacity, number of transactions and stock value will show then the situation in this storage location. If nothing is chosen the KPI's are showing the full factory situation. This means that the dashboard is interactive with the user.

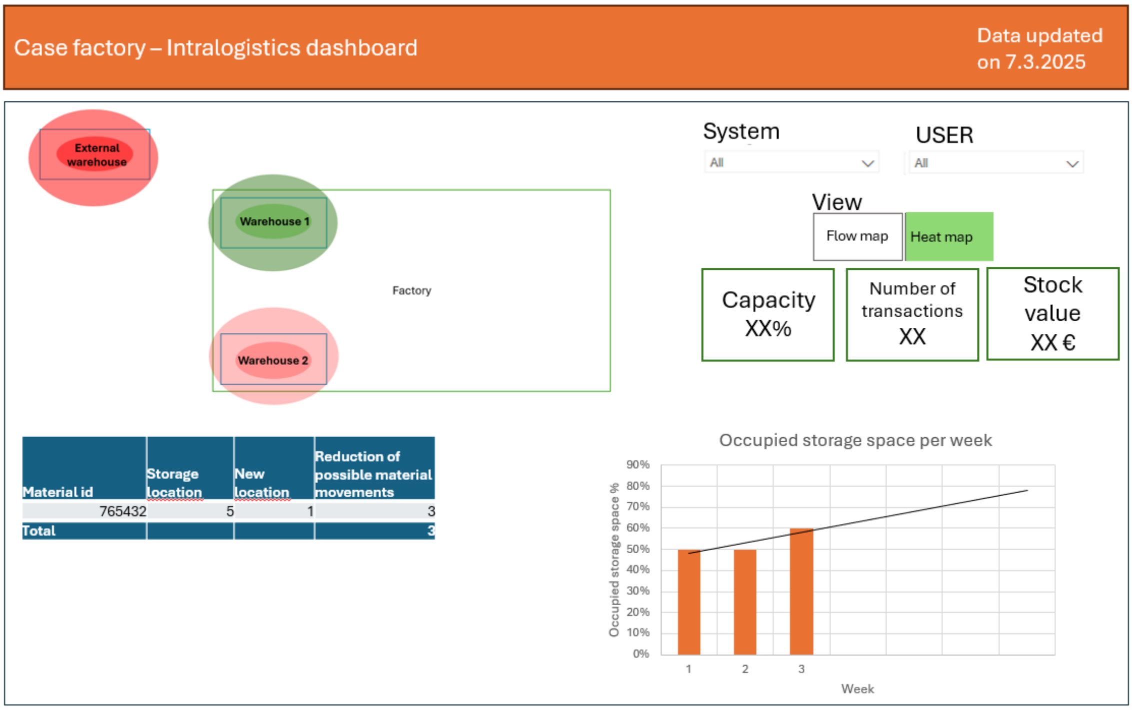


Figure 19: Intralogistics dashboard logistics perspective with phase 2 heat map view

In the flow map in figure 20 is illustrated the movements of materials between the storage locations. The size of the dot illustrates the number of transactions in the specific movement. This map helps to detect the different and new material movements. Also, new material movements can be spotted.

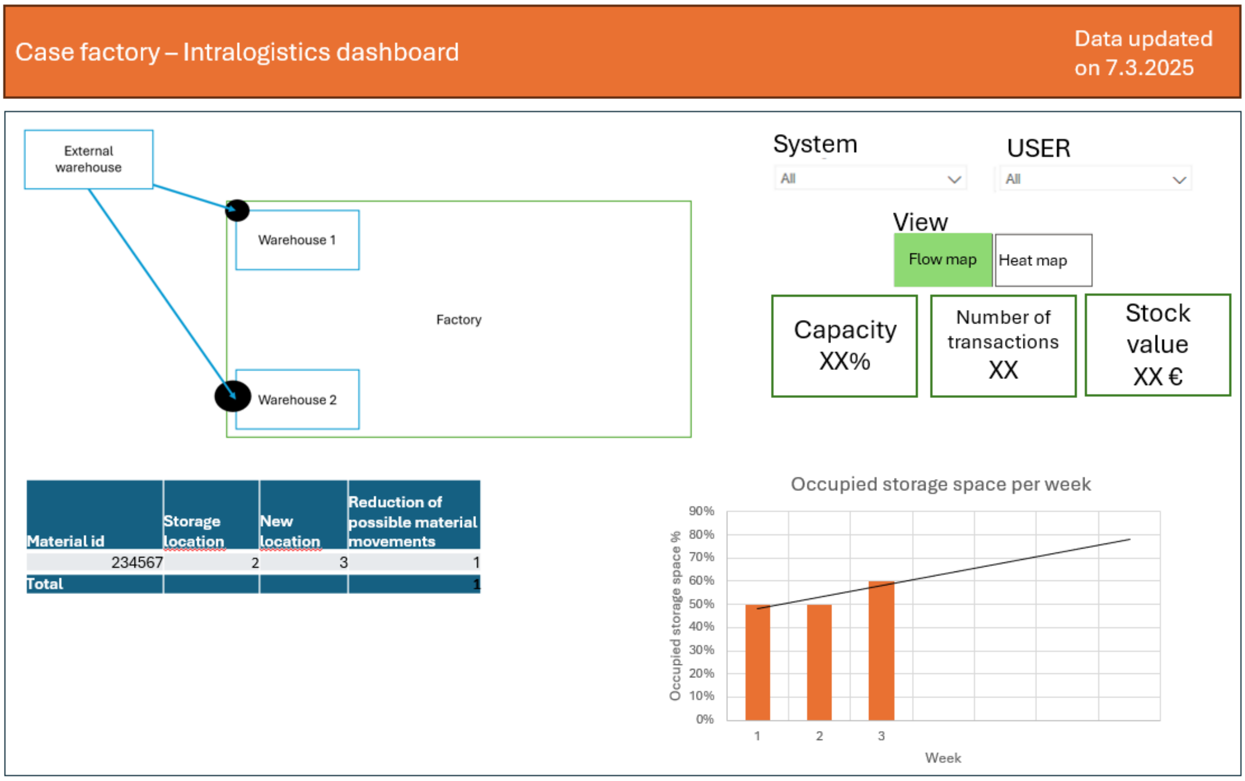


Figure 20: Intralogistics dashboard logistics perspective with phase 2 flow map view

In the figure 21 is presented the materials management perspective of the dashboard. As mentioned previously, the user is selected from with the user drop down menu widget. The graph differs from the intralogistics dashboard. The graph illustrates stock value development per week. Also, this graph includes prediction of the future stock value development.

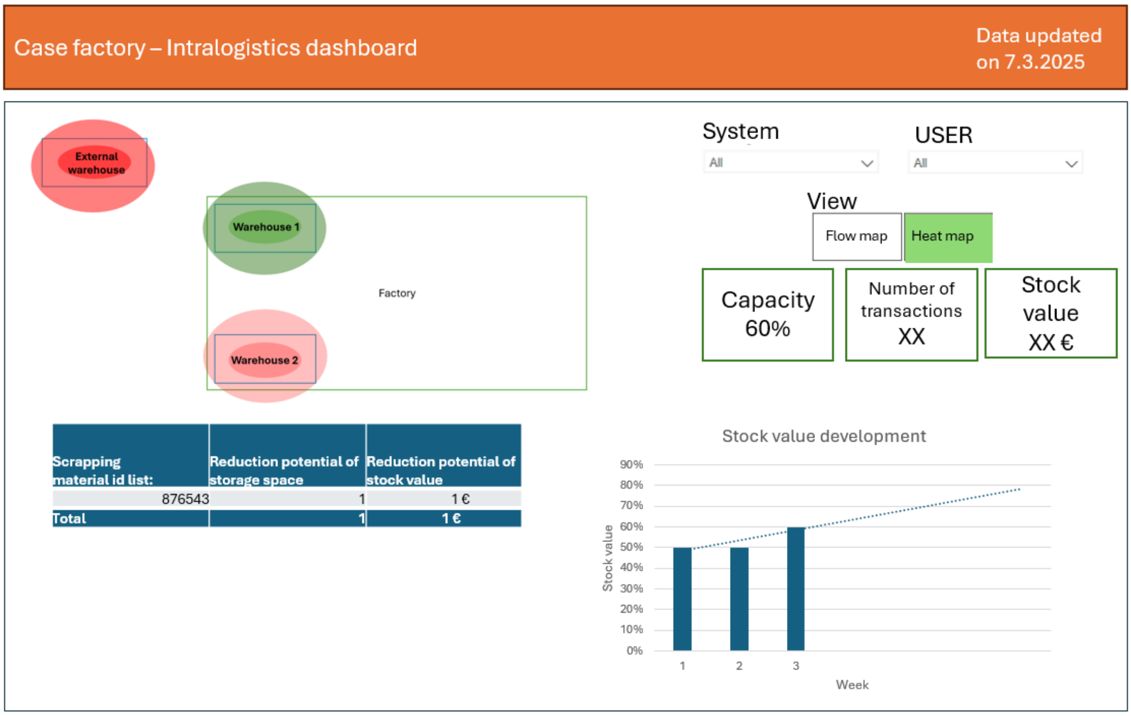


Figure 21: Intralogistics dashboard material management perspective with phase 2

As seen on the figure 21, the table also differs from the intralogistics dashboard. The table includes scrapping material id list with reduction potential per storage space and stock value. This proposal list is perspective because it recommends actions for the future. The scrapping potential list is formed based on the previous usage of the material and open orders that the material has. If there is not any usage or new orders, material can be scrapped. This helps to reduce the stock at the factory.

In all the tables and maps there is a possibility to drill down to the data. Export of the data file that the figure is based on can be visible. This visibility makes the actions possible based on the visualization. For example, the storage area that is marked with red colour in the map can be selected. This selection makes the export of the stocks in the warehouse based on the storage bins visible. This export can be forwarded to the needed persons to make actions based on it.

Proposal of the plan to improve intralogistics with data visualization is now presented. This plan includes two phases. These phases are concluded based on the information previously in this chapter. The plan with the phases is illustrated in the figure 22.

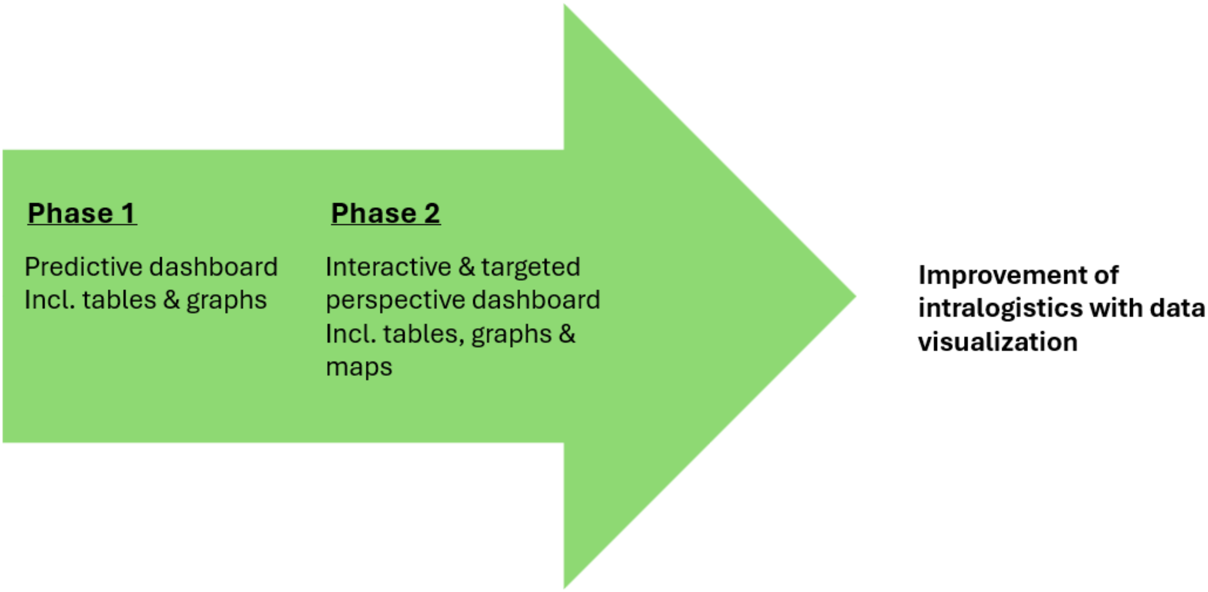


Figure 22: Plan to improve intralogistics with data visualization.

In figure 22 is presented the plan to improve intralogistics data visualization with two phases. This plan is executed in phases because the phase one is easier to implement. Therefore, the improvement of intralogistics could be started with more simpler solution first to ensure improvements already with shorter timetable.

In the sub-section 2.1.2 was presented the visual dashboard design process. The process is divided in two parts because of the plan includes two phases. This process plan is presented in figure 23.

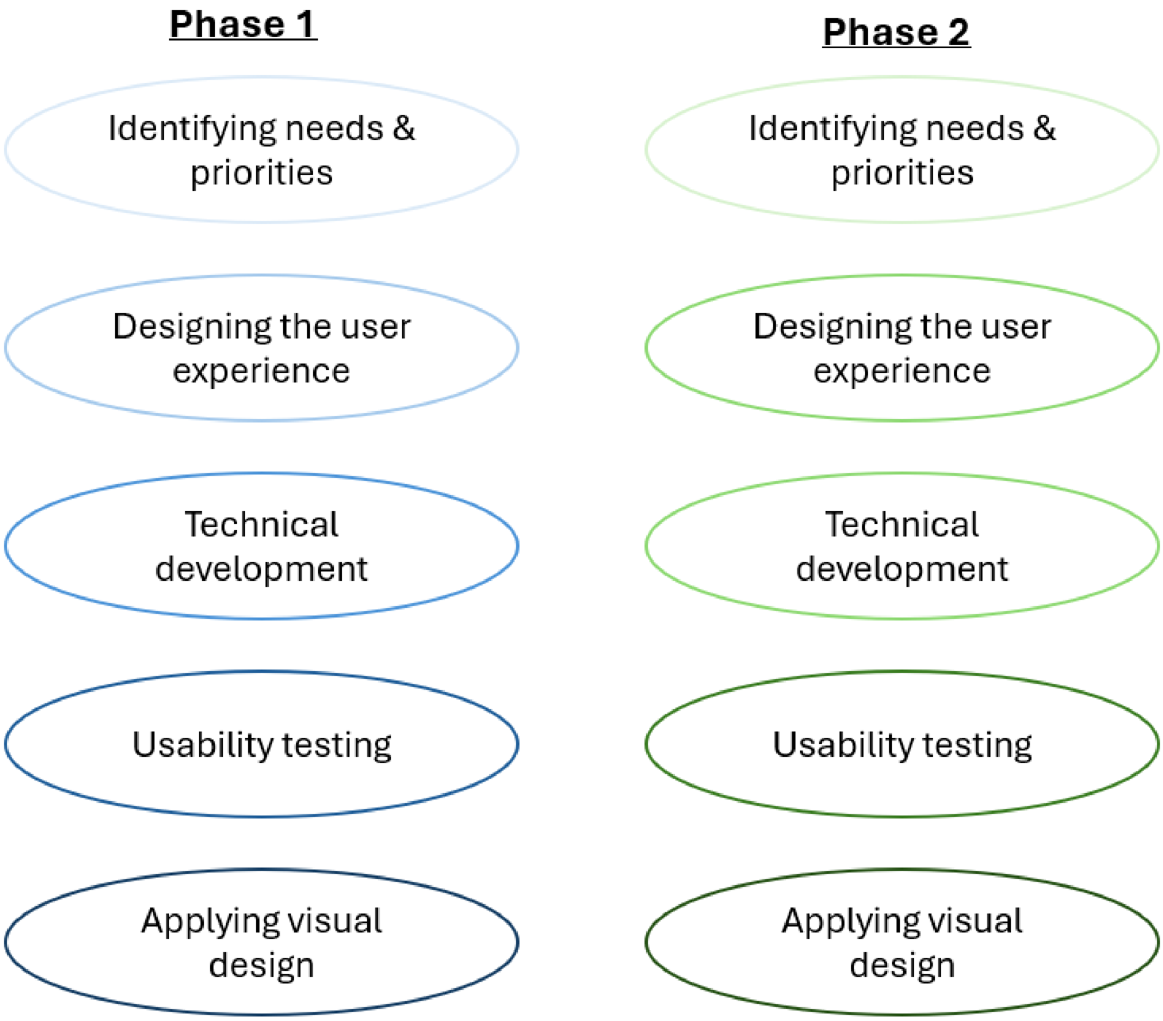
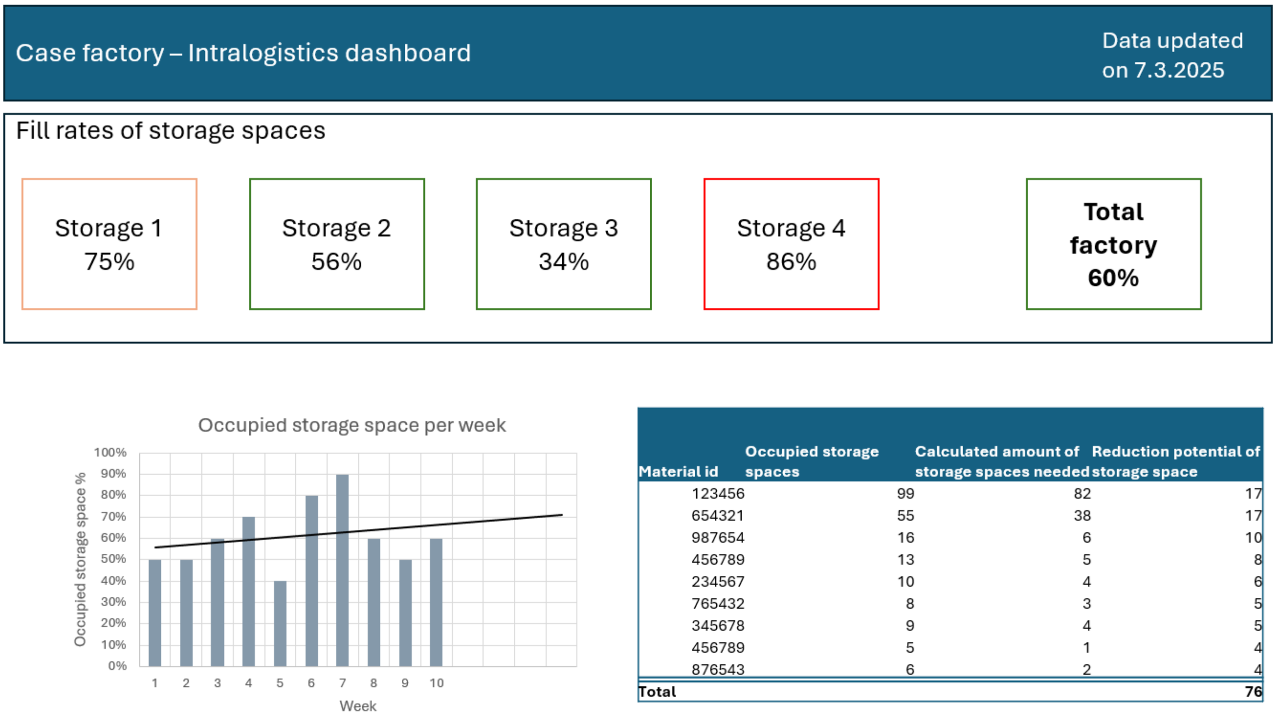


Figure 23: Process to improve intralogistics with two phases.

The identifying needs and plans were covered in the chapter three. The current state analysis described the complex intralogistics set-up that is in the case company. The complexity of the set-up makes the managing the intralogistics difficult. Also, the interviews presented in the section 3.3. aroused more needs that the managers in the case company have. The interviews emphasized the need for visibility of the material flows and bottle necks. Based on these needs the idea was also benchmarked with the case company's different locations. This benchmark research enabled to evaluate the needs and priorities of the topic within the company. This leads to the possibility to explore what has already been executed regarding this topic.

The designing the user experience is conducted on the chapter 4 where the result of the research are presented. In the chapter 4 is explained why design choices are made. The design choices are made based on the theoretical background of the research.

After the user experience is designed the technical development, usability testing and applying the visual design needs to be conducted. In the first phase all the steps can be executed fairly quickly because of the simplicity of the dashboard. In the figure 24 is presented the intralogistics dashboard phase 1 with the illustrations how the case company's data could look like. The table includes real calculations except the material id that has been changed to ensure company's privacy. The material id's have been changed also in all of the figures presented below. As mentioned in the sub-section 2.4.3, there are different applications that can be used in the data visualizations. In the section 3.2 was mentioned that case company uses Power BI. This is why the analysis are applicable to be executed in this software.



Material id	Occupied storage spaces	Calculated amount of storage spaces needed	Reduction potential of storage space
123456	99	82	17
654321	55	38	17
987654	16	6	10
456789	13	5	8
234567	10	4	6
765432	8	3	5
345678	9	4	5
456789	5	1	4
876543	6	2	4
Total			76

Figure 24: Phase 1 of the intralogistics dashboard

In the second phase the needs and priorities can be changed if in the first phase something is noted. If noting special is noted, then the plan is to execute the second phase. As well in this phase the designing the user experience was conducted in the chapter 4. After this step the technical development, usability testing and applying the visual design needs to be conducted. In the figure 25 is presented the second phase of intralogistics dashboard from the intralogistics viewpoint and heat map. This heat map is done based on the factory layout presented in the section 3.1. As seen on the heatmap, all of the storage locations in the factory can be analysed in one glance with this illustration. This enables to make decisions to reduce the bottle necks and balance the capacity. The colours on the map visualization emphasise available capacity situation.

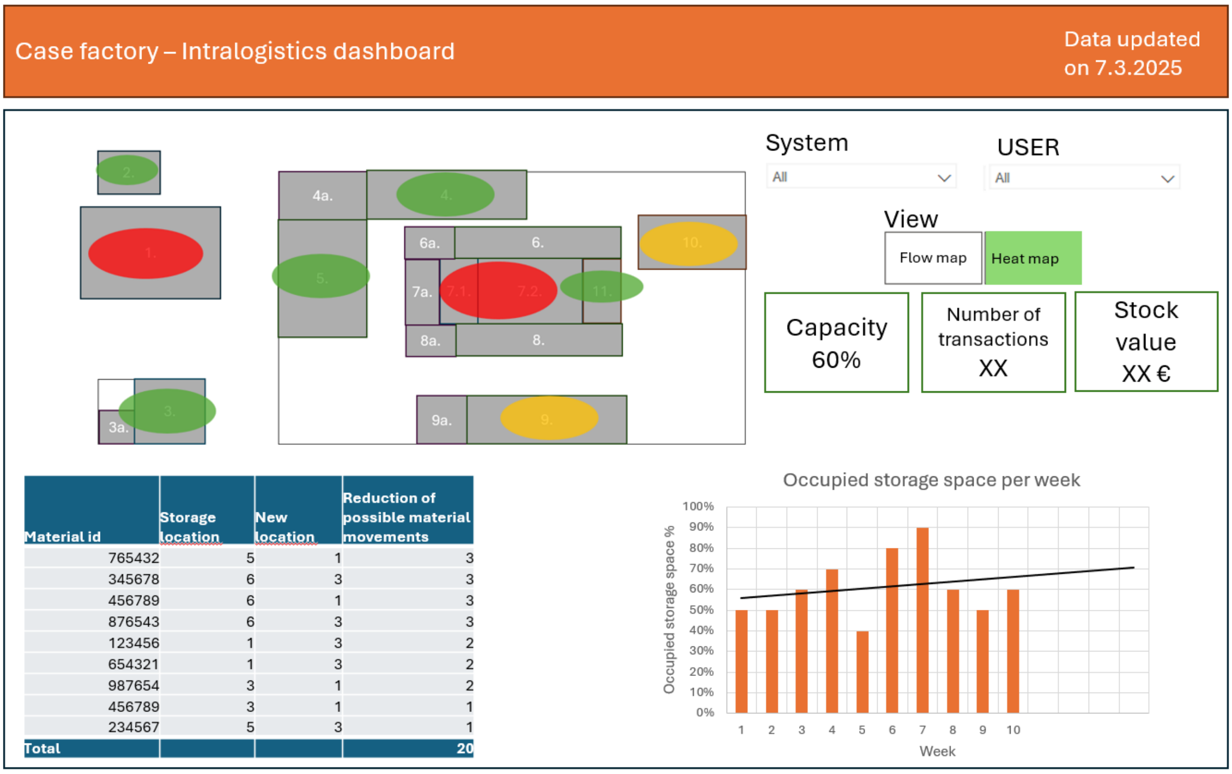


Figure 25: Phase 2 of intralogistics dashboard – heatmap and intralogistics view

As seen on the figure 25, the table is also illustrating what the possible reduction of material movements would be if the changed would be made. This perspective viewpoint makes ready solutions to the user and enables to make decisions that have impact. The graph includes information of the occupied storage space per week. This graph illustrates future scenario with a trend line. This trend line enables the user to see what the possible situation is if changes are not made. These tables and graphs are also presented in figure 26. In the figure 26 the view is changed to flow map with a widget.

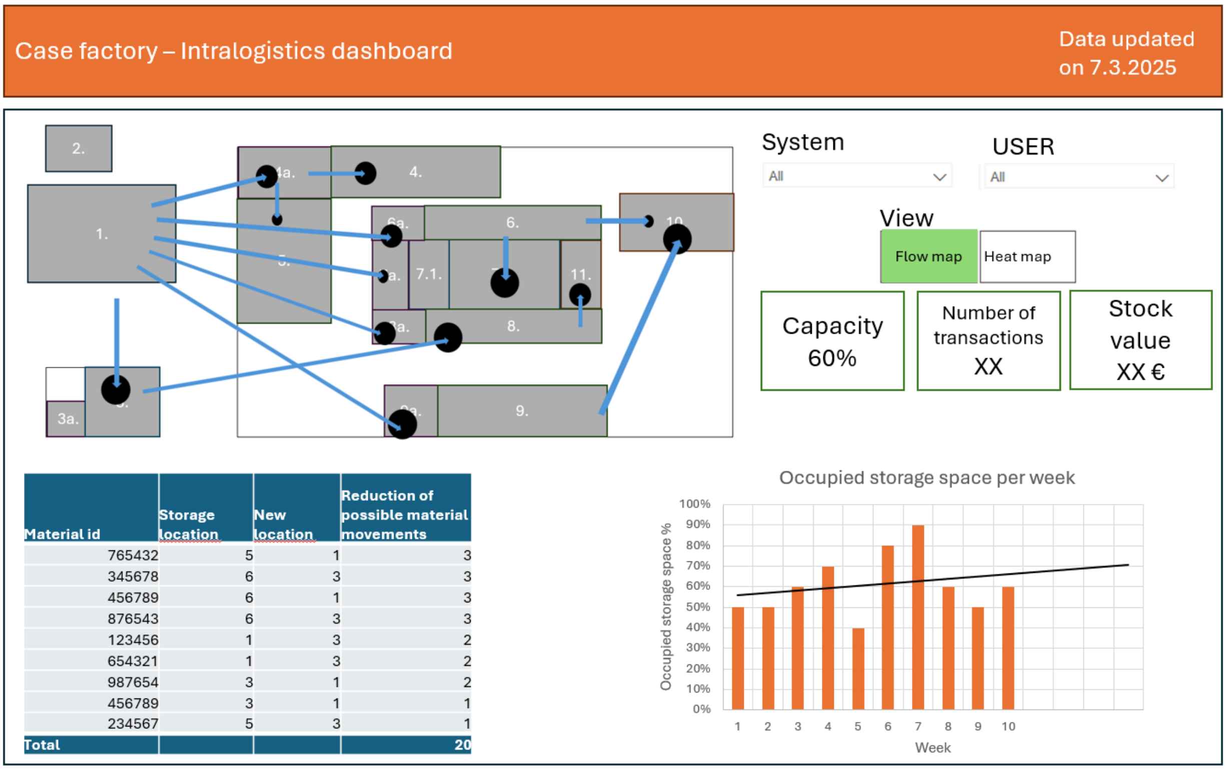


Figure 26: Phase 2 of intralogistics dashboard – flow map and intralogistics view

In the figure 26 the flow map is done based on the factory lay out as well. This means that the flow map allows the user to see the material flow within the intralogistics scope. This view enables the user to make analysis of the material flows and take actions accordingly.

In the figure 27 is presented the intralogistics dashboard from materials management point of view. The view includes table and graph regarding the materials management. The graph illustrates the stock value development including trendline. This trendline predicts what the future situation possible can be. The table includes possible scrapping list.

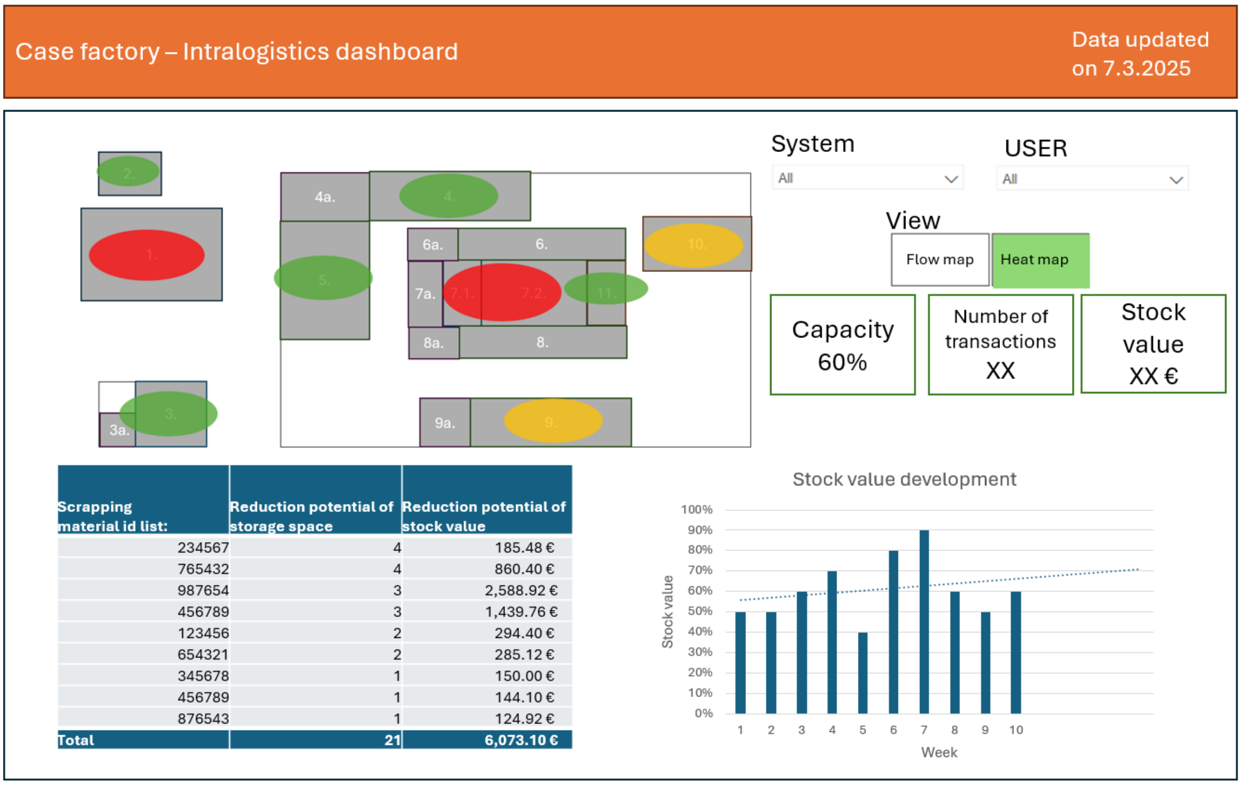


Figure 27: Phase 2 of intralogistics dashboard – heat map and materials management view

Although, in the interviews were brought up the lack of need for materials management reporting. The table that provides information the possible scrapping potential could be useful in the factory. The data provided to the table is from factory's scrapping project. These potential scrapping actions have been wound through investigation the previous usage of the material and the orders that the material has. This kind of analysis could be made automatically. Therefore, the benefit of this kind of table evident.

After the phase 2 is conducted, the phase 2 dashboards can be taken into use. The implementation of the dashboards is done to make impacts on the current intralogistics. In the following chapters evaluates some impacts that the dashboards may have.

The evaluation of the impacts of the implementation was done based on data from last year. The data was collected from the factory's two ERP systems. To conduct the analysis, the scope was reduced to only cover the logistics partner 1. This was done to have straight forward costs for transactions and storing. In the factory site the costs are more difficult to allocate. As mentioned in the sub-section 2.3.2, the storing costs can be allocated by different measures including pallet, cubic footage, bin storage or square footage pricing. The logistics partner pricing model is the bin storage pricing. Therefore, the costs are allocated for the smaller bin and for the larger bin. These need to be summed to have the total costs of storing. The equation for storing costs is following for two different bin types (adapted from Ocado, 2019):

$$\begin{aligned} Storing\ costs \\ &= average\ small\ box\ count * cost\ of\ small\ box\ storage\ unit \\ &+ average\ pallet\ count * cost\ of pallet\ storage\ unit \end{aligned}$$

The transactions include inbound and picking. The inbound costs were counted in separately depending on the source of the inbound. The costs for inbound from suppliers were determined based on the purchase order line. And the costs from the inbound from the factory was determined based on transaction line. The picking was separated depending on the destination of the picking. The picked lines for order were counted with the sales order lines. The production supply was counted based on transaction lines. The equation for transaction costs can be modified as following for the activity based costing that has four different types of activities (adapted from Brown, 2020):

$$\begin{aligned} Transaction\ costs \\ &= Inbound\ lines\ from\ supplier\ * cost\ of\ inbound\ from\ supplier \\ &+ inbound\ from\ factory * cost\ of\ inbound\ from\ factory \\ &+ picked\ lines\ for\ order * cost\ of\ picking\ for\ order \\ &+ production\ supply * cost\ of\ production\ supply\ picking \end{aligned}$$

The total costs were counted as a sum of these. In the table 4 is presented the impacts of the reduction of the storing and transactions. These are presented as percent of the total costs.

Table 5: Impacts of the reduction of storing and transactions

Percent reduction of storing or transactions	**Storing cost of total costs**	**Transaction cost of total costs**
-5%	-2%	-3%
-10%	-4%	-7%
-15%	-6%	-9%
-20%	-8%	-12%
-25%	-10%	-15%

As seen on table 3, the transactional costs have a larger impact on the total costs than the storing costs. Of course, the reduction of not relevant materials is crucial for storing capacity, but the transactions would be limited eliminating not necessary material movements. The elimination of the transaction has larger impacts, and this is why it should be a priority. The phase two of the plan enables the user to see recommendations and make actions based on these. This could lead to cost reduction.

The most beneficial situation is that both of costs would decrease. If the storing is reduced number of transactions can also be reducing. As mentioned previously in this chapter, the reducing of storing capacity is done if the material is not needed. If the material is not needed it does not have usage neither. This means that the scrapping actions do not reduce the transaction amounts.

Therefore, the second phase intralogistics dashboard would have more impact to the total costs if the flow map view would be used to reduce the transactions. On the other side the heat map view would impact the storing in other ways and would balance the storing in other ways. The materials management view is also meaningful by the reduction of the storing capacity. As mentioned, the transactions have larger impact on the total costs and should be prioritized regarding the intralogistics improvements.

The solution has also other impacts besides the cost effect. These impacts can be evaluated with competitive analysis. This is presented in table 6.

Table 6: Competitive analysis of solution options

	Phase 1	***Phase 2***
Cost effect	- May influence the storing cost	- May influence storing & transaction costs
Operational effect	- Warehousing space can be optimized	- Warehouse space and transaction amounts can be optimized
Materials management point of view	- Not included in the report	- Included in the report
Warehouse management point of view	- Included in the report	- Included in the report
Visualization	- Tables & graphs	- Tables, graphs & maps
Interactivity	- Not interactive report	- Interactivity included
Data analytics	- Predictive	- Perspective

As seen on the table 6, the phase 2 has more wider impacts on all the aspects that are evaluated in the analysis. The impacts are noticed when the dashboards are taken into use. Therefore, the impacts only evaluations of the future situation when the phases 1 and 2 are implemented.

5 Conclusion

This chapter concludes this research. The conclusion includes the results of the research and the assessments of the research results. Based on these the recommendations for future research are formed.

5.1 Results of the research

The first chapter included the introduction. This introduction included research background and meaning. The background of this research is that the case company has noted that there are different problems regarding the intralogistics. The aim of this research was to find if the visualization of the intralogistics data could help with these problems. The research questions were formed to answer to these questions. To answer these questions the research approach was formed.

The research included theoretical and empirical research. The theoretical research was presented in the chapter 2. The theoretical portion of the research was covering topics of data analytics, materials management and logistics. These topics were combined and evaluated to make theoretical background of intralogistics data visualization. This thesis empirical part was executed as a case study. The case study framework was also implemented to ensure structure to the research. The case study research methods that were chosen were interview research and data analysis.

The chapter 3 included the current state analysis. In current state analysis the current state of factory's materials management, logistics and intralogistics data visualization were presented. The material management at the factory is done by materials management department and they have different parameters that their operation is based on. The logistics operations are affected by the complex factory layout. The factory layout makes the logistics flow complex at the site.

The factory's current intralogistics data visualisation was evaluated. Currently the factory has many different reports that are executed with Power BI. Operations as well as the reporting is done at the factory level for the materials management department. The logistics is operated and reported on the storage location level. This means that the reporting would benefit on factory site level reporting for the logistics operations. To evaluate the current situation and future needs the interview research was conducted. The interview included discussion of material flow visualization and interest for map visualization. In the interviews the emphasis was on frequent data updating cycles to ensure accurate decision made based on the data.

Also, benchmarking was executed from the same company's other locations to determine what the current and future needs for the topic. The needs were considered also in the planning. Therefore, some of the findings of this research can be also implemented to the other locations if needed.

Based on the theoretical and empirical research, the results were formed. In the research two phases of the possible dashboard were presented. All the dashboards were formed based on the theoretical background and the current state analysis. The first phase is predictive dashboard including tables and graphs. This option includes predictive data analysis method would mean that the statistical variables and models would help to give prediction of the future state. Therefore, the dashboard would include intralogistics dashboard that would provide insight for the logistics about the full plant situation in one glance. For example, the dashboard would include KPI of the storage locations fill rates. This would provide information of the bottle necks in the process and would enable the user to make decision based on this. Also, this dashboard would include the graph of occupied storage space with a trend line to illustrate the possible future stage if changes are not made. The table that this dashboard would include would give a list of reduction potential of storage bins with combining the storage locations. The second option is interactive and targeted perspective dashboard including tables, graphs and maps. This option includes widgets that enable the user to modify the view that the user sees. The widgets include the selection of system, user and map style. The system means the ERP system that are used in the factory. There are two systems in use and there can be situation that only would been review of only another. The user means the materials management or logistics view. By choosing the different user the view changes. The materials management view includes table of possible scrapping materials and graph of stock value development including trend line of future state. The logistics view includes table of list of reduction potential material movements with proposing new location to the materials. The graph is the same as in the phase 1. The map widget enables the user to choose between heat map or flow map. The heat map illustrates the fill rate KPI as in the phase one but more efficiently. The flow map describes the material movement and the magnitude of the different flows. This enables the user to notice the variation between the flows and if new flows appear. This means that the phase 2 gives the user more information and the tables have perspective data with recommendation for the future.

In the chapter 4 is presented the presentation of the plan. This plan includes two phases. The phases are conducted by the visual dashboard design process. With the help of the design process the phases are executed. The phases ensure rapid implementation and maximise the project's benefits. If only the phase 1 would be done, the benefits would not be as great as in the phase 2. But the phase 2 implementation needs more time to be executed. Therefore, the phases are divided. Also, the chapter 4 included the evaluation of the impacts of the implementation. This evaluation is executed as data analysis and is the second part of the empirical research. The data analysis included the evaluation of storing and transactions costs impact on the total costs. The benefits of reducing the transactions are greater than in the reduction of the storing capacity. This means that the transaction costs reduction should be a priority. Although, the most beneficial situation would be that both costs would be reduced. Usually, the scrapping is done if the material is not needed. This means that the scrapped materials do not have usage and therefore transactions that would lead to costs. This is why the scrapping actions may not lead to reduction of transactions. Because of this result, the phase 2 dashboard would be beneficial to reduce the transaction costs. Also, the materials management point of view could lead to reduction of the storing costs. The total impact of these could not be evaluated but the relevancy in the total costs of logistics operation is distinct.

5.2 Limitations of the research

This research was conducted as a case study. This means that this research only considered one factory's situation. This means that the factory's special situations were considered in the study results and this limits this study. Of course, the benchmark research enabled boarder view of the situation amongst the other locations of the same company. This benchmark research would have been more beneficial if it would have been conducted to other companies in the same industry. This would have led to more certain results.

The sample sizes of the interview research could be more border to have more wider view of the current situation and needs for the future. The sample size could have included more people from the same organizations. For example, the scope could be boarded to also with material resource planners and logistics planners. This could have made the dashboard more relevant to the operational persons. Now the point of view is strategic.

The impacts of the plan could also be evaluated more widely. Now the impacts were considered only by the cost perspective. In the process point of view the impacts are wider than only the costs. The operation efficiency if the material flows could be streamlined could have been one view of the assessment. The other impacts of the plan could have been harder to evaluate without the implementation. This is why these were left out of the assessment.

5.3 Recommendations for further research

The same research could be executed with larger scope to ensure more variety in the use cases. The interview research could be executed with sample that could include recipients from different organizations and roles. This way the result would cover more people's needs. This also could need some filtering, so the report is staying in efficient matter.

More of the visualization methods could be researched. The different visualization methods could be more efficient and bring more useful data in the use. For example, the possibility of 3D visualizations could be useful. This kind of 3D visualization would possible be helpful in the warehouse layout situations. For example, the 3D heatmap visualization of warehouse could have possibilities.

The data that is visualized could be also further research. Because the data that is visualized was picked based on the case company's needs, the other companies could find some other data useful. Other perspectives to the data could be useful to ensure that the logistics scope is fully covered, and the main problems could be solved with the data.

Also, new visualization tools could be one option of further research. Some new visualization tools could have options that are not possible yet with the Power BI. Because Power BI was chosen as the tool because it is in use in the case company, other applications could be more useful in this situation. The visualization tools are linked to the visualization methods. For example, the previously mentioned 3D visualization could be better to execute with another application than the Power BI. This could mean that there is a need for another application.

For example, artificial intelligence and machine learning as a base data for the dashboard is one further research that could be taken into consideration. This kind of data would be needed in the cases that the data is complex, and the quantity of the data is large.

The artificial intelligence and machine learning could have possibilities that are not achieved in other methods. This means that the possibilities could be useful to research.

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Appendices

Appendix 1. Survey Questionnaire

Question 1. What is your current role in the case company?

Question 2. What are your / your operations daily/weekly/monthly tasks?

Question 3. What are the key challenges you face in your operations?

Question 4. Do you use data visualization in your operations? What kind of visualization?

Question 5. What data or visualization of data you would see as beneficial to you?

If yes:

Question 6. What benefits do you see that this data visualization would have?