Creating insight into the performance of the warehouse processes of a logistics company with a dashboard

Bachelor Thesis Industrial Engineering and Management

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Glossary of abbreviations

In this report, abbreviations are used to make the report reader-friendly. To avoid misunderstandings by the reader and to ensure a pleasant reading experience a list of definitions of these abbreviations is created below. This list also helps the reader understand the report better.

BPMN – Business Process Model and Notation
DSRM – Design Science Research Method
KPI – Key Performance Indicator
WMS – Warehouse Management System
LPN – Licence Plate Number

Preface

Dear reader,

Thank you for taking the time to read this thesis. This thesis *"Creating insight into the performance of the warehouse processes of a logistics company with a dashboard"* was written to graduate from the Bachelor Industrial Engineering & Management at the University of Twente. This assignment was carried out at a company that wants to remain anonymous to implement a dashboard to gather more insight into the performance of their warehouse. I have worked on this thesis for the better part of this year, starting in February 2022. A project like this is definitely challenging but it is very fulfilling to complete such an assignment. I would also like to take a moment to thank the people that supported me during this time.

First of all, I want to thank the employees at Company X for always being eager to help me. Both my supervisors were always ready to answer questions, so a special thanks goes out to them. For me, it was the first time working in a real office and working in such a professional environment taught me a lot.

I would also like to thank the supervisors from the University of Twente, Abhistha and Wouter van Heeswijk. Abhistha is my first supervisor and I had the most meetings with him and I would like to thank him for guiding me through the process of writing a thesis. I would like to thank Wouter for providing constructive feedback on my thesis.

Of course, I also want to thank my family and friends for being around and talking about my thesis, providing feedback and distraction when necessary.

Ivo Bakker,

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Management Summary

Company X is a large business-to-business supplier of a vast variety of products, ranging from industrial supplies and tools to office supplies. Company X differentiates itself from competitors in the variety of products they offer. If a client shops at Company X, he only has to go to one place to get everything he needs for his company instead of ordering from multiple spots. Company X is a one-stop shop, so to speak. The Dutch division has one location. At this location, both the office and warehouse are located. From this warehouse, products are shipped to all of Europe.

The core problem of this thesis was that the logistics manager had poor insight into the performance of the warehouse processes that happen at Company X. In this case, performance means a lot of things. Basically, all of the important information about the warehouse processes. So, for example, how long it takes before an order is ready on average or what the division of delivery countries is. A performance measurement system needs to be introduced to the company in order to gain more insight. With this insight, the manager can back his decisions with the information from the dashboard, whereas before he could not. Company X has been collecting data about the processes for a long time but has not yet analysed this data. A performance measurement system should give them insight into this data. This insight can then be used to make decisions or predict the future. It can also be used to track the performance of specific parts in the warehouse, such as a specific section of the warehouse, or a specific destination country or carrier.

In order to concretize this, a research question is set up: *How can a performance measurement system help improve the insight into the performance of the warehouse processes at Company X?*

A literature study is conducted to find what performance measurement system would best fit Company X's needs. It turns out that a dashboard fits the wishes of the logistics manager the most. A further literature review is done to identify KPIs that should go on the dashboard, how to visualize these KPIs and what the ways for designing a dashboard are.

Analytic Hierarchy Process is a decision method used in this research to identify what KPIs should go on a dashboard. The dashboard is made in Excel with the help of the Power Pivot add-in. With the add-in, it is possible to query data from a database in Microsoft's SQL Server, the database server that Company X uses.

The dashboard has one main sheet where the settings and main KPIs are shown. In the settings, the date can be changed as well to view KPI results specific to that selection of dates. Furthermore, the dashboard can be sliced down more, as the user also has the option to select for what destination country, carrier and warehouse location he wants to view the KPI results. On other sheets, some other KPIs are presented in tables, which take up more space and are not practical to place on the main dashboard. The other sheets in the Excel file are used to calculate the KPIs which are shown on the dashboard.

The dashboard was evaluated by the logistics manager, the primary user of the dashboard. After being presented with the dashboard, he was extremely positive about the dashboard as the dashboard is already fully operational and could immediately be used by the employees. Furthermore, he was enthusiastic about the possibilities it offered him. His last feedback was that the dashboard is user-friendly and easy to understand.

The conclusion to the research question is that the dashboard adds to the insight is that it provides an overview of KPIs that were not available before. The dashboard gives the logistics manager a handy oversight that was not available before. This overview is automatic and can be refreshed each morning, the KPIs will then update automatically. Next, this dashboard is adaptable. This helps with

insight in the sense that it can be changed quickly to add a new KPI that gives the manager new insight. If a new form of data is collected, this can quickly be added to the database and the dashboard. In the old situation, it was quite hard to introduce a new KPI that would give the manager more insight. Now it is possible to do it quite easily. Another thing that the dashboard adds is comparability. As the date can be changed quickly in the dashboard, the performance of different months or years can quickly be compared. This was not possible before the introduction of the dashboard. Therefore, it is easier to track the performance and verify whether the performance is improving. The dashboard also introduces the possibility to add targets to KPIs. Target scores add massively to the insight, as it will be possible to view with one glance whether the warehouse is performing properly or not. The increased insight that this dashboard gives can be used to back decisions with actual numbers or to forecast, for example, the number of stickers needed per week. The dashboard can also introduce a new daily routine; reviewing the previous day's results of the dashboard and explaining where improvement is needed.

The following are the recommendations for Company X:

- Invest in specialized dashboard software with more possibilities
- Add more data, specifically about the time the order arrives. This data is currently unavailable, so only the time from the moment the order is picked up is counted
- Add target scores to the KPIs
- Keep evaluating the dashboard
- Introduce the warehouse dashboard in other countries where Company X operates
- Introduce an individual performance overview of employees in the dashboard

Chapter 1: Introduction

This chapter introduces the reason for the research and the company. Furthermore, the problem cluster and core problem are described. The research question and sub-questions are elaborated for this core problem, as well as the chosen problem-solving approach. A description of the research design follows this. This chapter ends with an explanation of the chosen theoretical perspective for this research.

1.1 Introduction

This research is about creating a company dashboard for Company X to increase the insight they have into the efficiency and performance of the warehouse processes. Dashboards are used by many companies and are a handy decision-support tool. A dashboard visually displays real-time data in telling charts and graphs. The main function of a dashboard is to provide insightful information at a glance, which would have been hard to interpret if you only had access to the rows of database data. A dashboard often summarizes the information from databases in the form of Key Performance Indicators (KPIs). These are indicators that have been selected by the company that provide information on the company's current performance in various aspects. Depending on what you are interested in, a dashboard could include a whole range of different Key Performance Indicators. The KPIs tell you how well the process is performing without having to look at the underlying data. As for the exact definition of warehouse performance, performance can mean a lot of different things, depending on the selected KPIs. Different people may find different KPIs important. In section 5.3, the selected KPIs will be elaborated and it will be explained what they tell about the performance of the warehouse.

To understand how a dashboard can help with gaining insight into the performance of warehouse processes, it is necessary to first explain what exactly warehouse processes are. In literature, many different perspectives exist about what exactly warehouse activities are. In general, the consensus is that the warehouse processes consist of six separate activities. This is also the case for the company for which the dashboard is created, which will be called “Company X” in the rest of the thesis for confidentiality reasons.

Underneath you will find paragraphs that will give a brief overview of the six processes, to give a general understanding of what exactly happens in a warehouse.

1. The first activity is receiving. Receiving means verifying that the received inbound order is correct. This means that the order quantity and quality are checked as well as whether the right products were delivered.
2. The second process is putting away the received products in the correct place in the warehouse. At Company X, the warehouse employees scan the barcode on a product and the hand terminal will then show the location where they need to bring the product.
3. The third process is the storing of the products. The place where products are stored must be strategically decided, such that every product is stored in the most efficient place. Fast-movers should be at the front, while slow-movers should be at the back. Fast-movers are products that get ordered a lot, while slow-movers are products that are not ordered as frequently. What is also part of this step is inventory counting to check for any mistakes in the system. The actual inventory is compared with the number in the database. If this is not similar, the database inventory is corrected to the actual number.
4. The fourth process is the picking of an outbound order. With the order picking process, the following things happen; first, the pick ticket needs to be printed and then an employee needs to claim this ticket and start picking. The pick ticket tells the employees what product to get

from what place in the warehouse. This pick ticket often consists of multiple product lines, where each different line in the ticket relates to a unique product, together with the quantity. After the employee gathers the pick ticket, this employee starts picking the order and scanning the products they have picked. When they finish picking, they deliver the products to the right place in the warehouse.

5. The packing of the order is the fifth process. At Company X, the ordered products get placed in a cardboard box if it is small enough and if the order is large in size, the products will be placed on a pallet. After the products have been packaged, the products need to be loaded in the correct truck.
6. The sixth and last step in a warehouse is the shipping of the order. This step is not the responsibility of Company X but that of the carriers. Company X does have contracts with carriers, for example about how often they come, but the transportation is all done by the carriers.

The employees of Company X use a hand terminal and scan the barcode of the order at every process step. This means that all of the data about each specific order is logged. This data is uploaded to the Warehouse Management System (WMS). The WMS software application allows the company to keep track of warehouse processes. Because the barcode is scanned for each process step, the system can follow the orders throughout the process and can view exactly where the order is. The data in the WMS will be used to create the dashboard.

1.2 Problem identification

1.2.1 Introduction to the company

As written in section 1.1, because of confidentiality, this thesis is anonymized and the company will be referred to as "Company X" for the rest of the thesis. However, some background information about the information can be provided to give a better understanding of what kind of company, Company X is. The company for which the research will be performed is a company that operates in the Netherlands and other European countries. However, the research will specifically be performed for the warehouse in the Netherlands. This company is a large business-to-business supplier of a vast variety of products. More specifically, it offers products to companies in the following categories: Industrial supplies and tools, Outdoor Areas, Office Supplies, Packaging, Safety, Health, and Warehouses. It differentiates itself from competitors in the variety of products they offer. If a client shops at Company X, he only has to go to one place to get everything he needs for his company instead of ordering from multiple spots. Company X is a one-stop shop, so to speak. The Dutch division has one location. At this location, both the office and warehouse are located. From this warehouse, products are shipped to all of Europe.

1.2.2 Reason for research

Company X wants to gain a better insight into the performance of its internal logistical processes. By the internal logistical processes of Company X, we mean the processes that happen in the warehouse. As described before, these processes are receiving, putting away, picking, and packaging. The company is currently more interested in the performance of the internal logistical processes, so the shipping step and information that comes with it are not part of this research. This is because the company does not influence what happens once an order is put inside the delivery truck. Insight into the efficiency of Company X's warehouse process means the possibility of tracking real-time information on the warehouse processes and seeing summarized information gathered from the thousands of data entries in the database.

Currently, the productivity of the warehouse is defined as the number of product lines picked per person per hour. A product line consists of a single item and the number of times Company X's

employee has to gather that product. If for example, a client has ordered a rack, this order will consist of multiple order lines. The employee will see a new line for a stand, for the bolts and for a shelf.

However, a lot of interesting data is missing here that would be useful for the management. The logistics manager would like more insight into the performance other than the KPI “productivity” they already have access to, while the “productivity” KPI can also be expanded to show productivity for more transactions. For such a dashboard, a database is needed. In this database, all of the necessary data for the KPIs needs to be present. This database is already present in the company as a Warehouse Management System. However, the data will first have to be cleaned and prepared for the dashboard, as it is likely that the data is not fit for the dashboard when it is extracted. From this database, a performance dashboard can be created. A dashboard is needed to provide a quick, handy and uncluttered presentation of the most important data.

After gaining more insight into the performance of internal logistical processes, the management also wants to act based on that improved insight. This part comes sometime after the dashboard is implemented. This is not part of the research project. This is because it will first take some time for the logistics manager to learn the patterns and average values of the KPIs. If the KPIs then differ from this, the logistics manager can analyse where it went wrong. The idea of this thesis is to deliver a working dashboard to the logistics manager. The logistics manager and employees can then play with the dashboard and learn to understand it. After this, he can make decisions based on the dashboard or change things in the dashboard to improve the dashboard to his liking. If the dashboard is a success, the company can investigate the possibility of introducing such a dashboard in other countries.

1.2.3 Problem cluster

To find out the core problem of Company X a problem cluster is created. A problem cluster can be used to identify relations between problems. Identifying the core problem helps with solving the issue that Company X is currently facing. If you solve action problems of a core problem, the core problem will remain to exist and will continue to cause issues for the company. If you solve the core problem, however, the idea is that the symptoms of the core problem disappear. The goal of this thesis is to solve the core problem that appears in the problem cluster. The problem cluster can be found in Figure 1 and a detailed textual explanation of the problem cluster can be found below as well (Heerkens et al., 2021). The problem cluster was created after conversations with both supervisors at Company X.

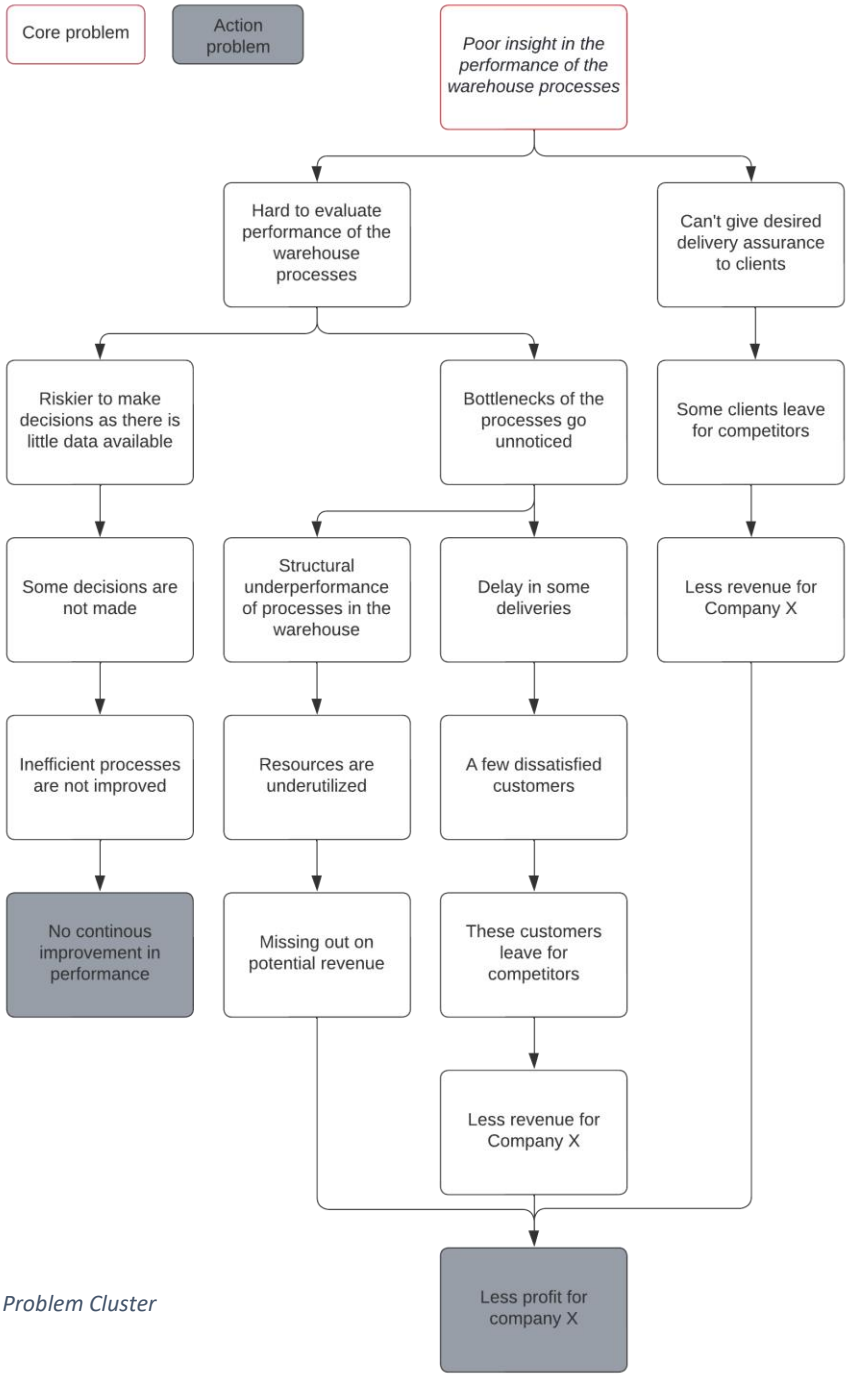


Figure 1: Problem Cluster

As seen in the problem cluster, the problems start with the fact that the company does not have a good insight into the performance of the different warehouse processes. This problem was described earlier in section 1.2.2. The company thinks that this is because they currently do not have a dashboard that gives that insight into the performance of the warehouse processes. They only have the stored date of all warehouse transactions, but nothing is done with that data at the moment.

The problem cluster ends in two main action problems. These two problems are the lack of continuous improvement for Company X and Company X realises less profit because of the poor insight. Poor insight into the performance of the process directly causes two things in the company. First, the poor insight makes it hard to evaluate the performance of the logistical processes and the company cannot give the desired delivery assurance. Because it is hard to evaluate the performance of the processes, two more problems arise. The first is that bottlenecks go unnoticed as anomalies in the data are not detected quickly. Secondly, it makes it harder for the management to make decisions, as they cannot support these decisions with data, making them riskier.

Because it is impossible to give the desired quality assurance, some clients leave for competitors. This is because clients value quality and delivery assurance a lot. If some company cannot give the assurance of deliveries that clients want, clients go to another company. Following this line of reasoning, it is logical that fewer clients also mean less revenue. In this company's case, each client is a paying client, so missing clients means missing revenue. Generating less revenue also means that company X's profit will be lower. It has several consequences for the company when bottlenecks go unnoticed. First, it means there is structural underperformance of processes in the warehouse and there could be a delay in some deliveries. When deliveries arrive later than communicated, the particular customers are left dissatisfied. When customers are dissatisfied multiple times, they leave for competitors. Structural underperformance means that the resources of Company X are underutilized, as it is possible with the available resources to handle more orders per hour. This, in turn, means that the company is missing potential revenue and profit.

If it is hard for the distribution centre manager to make decisions, certain decisions will not be made because the risk is too big. Consequently, it means that inefficient processes are not improved but instead kept the way there are. Therefore, there is no continuous improvement in performance. This is, of course, something that managers and the company does not want. Therefore, the goal of the company is to improve its performance each year.

1.2.4 Identification of the core problem

From the problem cluster, the core problem can be deduced. In this case, there is only one core problem present, so no decision has to be made on what core problem will be solved. The singular core problem in the problem cluster will become the problem we solve in this research. The core problem in the cluster is "*Poor insight into the performance of the warehouse processes*." This research aims to create a system that provides insight into the performance of the warehouse processes and so, following the relations of the problems, the other problems present in the problem cluster will also be solved to some extent.

1.2.5 Problem quantification

From the core problem, it is apparent that the current situation needs improving. To improve the current situation, the core problem of the problem cluster will be solved in this thesis. Company X wants to implement a dashboard to solve this core problem. However, implementing a dashboard is not quantifiable or measurable in the sense that is hard to immediately say that the problem is solved after the introduction of the dashboard. Saying that implementing the dashboard solves the problem is too short-sighted as the dashboard has to increase the insight in order to be useful. As there is no time to evaluate the impact of the dashboard after a few months, an evaluation interview will be held

with the logistics manager when the dashboard is ready and presented to him. As the logistics manager will be the only person using the dashboard, solely his opinion is relevant regarding the extent to which the dashboard helps him. The interview is meant to evaluate the dashboard and whether the dashboard helps the company.

1.2.5.1 Norm and reality

The reality is that Company X does not have a specialized performance measurement tool to analyse the considerable sum of available data. Currently all there is available is one KPI "*productivity"* which does not give the logistics manager a lot of insight into the performance of the warehouse processes. The norm for this research is to introduce an operational performance measurement tool to the company, which will increase the insight into the data, help the logistics manager analyse the data and that the tool can form a basis for decision-making.

1.3 Research method

1.3.1 Problem-solving approach

As the main element of this research is building a dashboard, the Design Science Research Methodology (DRSM) is the most fitting problem-solving approach, because this method is specialized for research where an artefact is created to solve a problem. In this research, the dashboard can be seen as the artefact that will solve the core problem. There are six steps in the DSRM. A figure of the DSRM is shown in Appendix A (Peffers et al., 2007). The full detailed methodology for this research will be explained in Chapter 3.

1.4 Research question and sub-questions

The main research question and corresponding sub-questions are formulated in this section of the report. First, the main research question will be stated. Then, the sub-questions that are related to the research question are described.

1.4.1 Research question

To improve the current situation of having poor insight into the performance of Company X's internal logistical processes, the following research question is formulated. The company stated beforehand that it wants a dashboard, but first, research has to be performed to verify whether this is indeed the best solution and how it can be used to improve and increase insight into the performance.

How can a performance measurement system help improve the insight into the performance of the warehouse processes at Company X?

1.4.2 Sub-questions

To answer the research question, several sub-questions have been established. The sub-questions are all related in some way to the research question. The answers to the sub-questions will provide the knowledge required to answer the research question. The sub-questions can be found below, with an explanation of why these sub-questions contribute to answering the research question and how the sub-questions can be answered.

1. *How are the warehouse processes organised in Company X?*

In order to improve the current situation, first, an analysis of the current situation is needed. The way all current processes work and are organised needs to be mapped out in detail so that we have a good understanding of the way the processes work in the company and how they interact. This overview can also provide important aspects for the performance of the processes. This question can be answered through semi-structured interviews and exploratory research. This question is part of the first step of the DSRM.

2. *What is the company's current level of insight into the processes in its warehouse?*

This research aims to improve the insight the logistics manager has into the performance of different processes in the warehouse of Company X. To improve the current situation, an understanding of the level of insight into the performance of internal logistical processes is needed. Furthermore, it needs to be investigated how the company currently gathers the data used for the insight, what data is used, and where this data comes from, as this will also be how the data for the dashboard will be gathered. This question can be answered through interviews and exploratory research. This question is also part of the first step of the DSRM.

3. *What systems for performance measurement exist in the warehouse sector?*

The goal of this thesis is to improve the insight into the performance of the warehouse processes and in order to do that a performance measurement system will be introduced. The company thinks a dashboard is the best performance measurement system, but other systems might exist that are better suited. That is why a literature study is performed to research the different performance measurement tools and decide with the company on the one that best suits the goal. This is part of the third step of the Design Science Research Method.

4. *What are appropriate KPIs for Company X to gain insight into the performance of the warehouse processes?*

A dashboard is created with the help of Key Performance Indicators (KPIs). However, there is no set list of KPIs that should be included in every dashboard. On the contrary, there is a lot of variety in KPIs; for different sectors, different KPIs are appropriate. A literature study should be conducted to form a list of possible KPIs fit for the goal of this thesis. Again, first, a systematic literature review has to be done to select sources that can help with generating a list of potential KPIs. From this list of possible KPIs, together with the Company's proposed KPIs a final list will be created of the most interesting and useful KPIs for Company X. Company X is a unique company, so the selection of KPIs should be shaped according to their wishes. This question belongs to the third step of the DSRM.

5. *How can the KPIs be measured and visualized?*

The data used to visualize the KPIs in the dashboard can be stored in many separate places. The data must be able to be extracted in order to be used to calculate the KPIs and this data needs to be managed and measured correctly because the data used to calculate the KPIs must be accurate. Otherwise, the KPIs are useless. Furthermore, the KPIs have to be visualized accurately so that they are interpreted in the right way. This can be done together with the supervisors of the company, as they will have preferences for how the KPIs are visualized. A lot of different graphs and charts exist, and some will portray the information in a better way than others and some might be preferred over others by the logistics manager. This question is part of the third step of the DSRM.

6. *How to design a dashboard that monitors the performance of the warehouse processes of Company X?*

The purpose of this thesis is to introduce a dashboard that significantly increases the insight Company X has into the performance of internal logistical processes. A literature study is conducted in order to investigate how the dashboard should be designed, find out whether there are rules of thumb and what the do's and don'ts are. In order to perform the literature study, a systematic literature review is first done to gather useful sources, which can then be studied. This question is part of the third step of the DSRM.

7. *How should a dashboard be implemented within Company X?*

Company X is a big company with many information systems already in place and the ICT is already established. Implementing a dashboard with many systems already present can be quite a hassle. Together with the supervisors, it should be discussed how the dashboard can be implemented correctly. A good understanding of the ERP system of Company X will be needed to implement the dashboard. The dashboard should be ready to use by the people that need to use the dashboard at the end of the project. This question is part of the fourth step of the Design Science Research Method.

8. *To what degree did the dashboard meet the objectives of the research and thus improve the insight?*

To evaluate whether the goal of the research has been reached, the old situation will be compared with the new situation. This will be done with the help of an evaluation interview with the logistics manager. Based on the interview this question can be answered. This question is part of the evaluation step of the DSRM.

1.4.3 Intended deliverables

After all the steps from the DSRM have been followed, several deliverables will be ready to display. The first deliverable is a set of Key Performance Indicators. This set consists of the KPIs that are present on the dashboard. Next, a dashboard will be introduced in the company, this is also a deliverable. This dashboard serves to provide more insight into the performance of the warehouse processes. This dashboard has to be implemented correctly in the company. Therefore, instructions on implementing and using the dashboard will be provided. This manual will describe how to work with the dashboard, how to interpret the data visible on the dashboard and how to add or delete data to the Power Pivot table. Furthermore, the manual will explain in detail how the dashboard was set up and how changes can be implemented in the dashboard. The last deliverable is the research itself. The research will be delivered in the form of this written report and presentation that will be given at the colloquium.

1.5 Research design

In Table 1 the research design is elaborated. In the table the research type, population and strategy are explained for the sub-questions. Furthermore, the data gathering and analysis methods are also described for each subquestion. In the last column, the activity plan is written down.

Knowledge problem	Type of Research	Research Population	Research Strategy	Data Gathering Method	Data Analysis Method	Activity Plan
How are the warehouse processes organised in Company X?	Descriptive	Company	Qualitative	Interviews with employees and observation	Written or visual representation	Observation of the situation, interviews and then an overview
What is the company's current level of insight into the processes in its warehouse?	Descriptive	Company	Qualitative	Interviews with employees and observation	Written explanation	Observation of the situation, interviews and then an overview
What tools for performance measurement exist in the warehouse sector?	Exploratory	Databases	Qualitative	Systematic Literature Review	Content Analysis	Use literature to find different tools for performance measurement

What are appropriate KPIs for Company X to gain insight into the performance of the warehouse processes?	Exploratory	Databases	Qualitative	Systematic literature review and meetings with the company	Content analysis	Identify a list of possible KPIs from the literature, discuss them with the company, and come up with a final list
How can the KPIs be measured and visualized?	Exploratory	Databases	Qualitative	Systematic literature review and meetings with the company	Content analysis	Use literature to find all the ways the KPIs can be visualized. Then have meetings with the company to discuss what techniques they like.
How to design a dashboard that monitors the performance of the warehouse processes of Company X?	Exploratory	Databases	Qualitative	Systematic literature review	Content analysis	Use literature on what ways there are to design a dashboard and choose a method
How should a dashboard be implemented within Company X?	Exploratory	Company	Qualitative	Meetings with employees and systematic literature review	Content analysis	Find literature about implementing dashboards. Also, have meetings with the ICT department about the implementation.
To what degree did the dashboard meet the objectives of the research and thus improve the insight?	Evaluative	Company	Qualitative	Meetings with employees and observation	Descriptive analysis	Observe the result of the implementation and discuss this with the company.

Table 1: Overview of research design

1.5.1 Limitations of research design

There are several limitations to this research. The first limitation is the time restriction for this research. The time in which this research is performed is not unlimited. The research is classified as a bachelor's thesis, so in theory, it should be doable in ten weeks. This time restriction confines the possibilities of the research. At some point, the decision must be made to finalise the document and dashboard and hand in the thesis.

Moreover, there could be a limitation regarding the data available for the dashboard. Company X is currently in the process of changing Warehouse Management Systems. At the moment of writing this, it looks like all data will be available for analysis, but it could be that problems arise during the changeover. As it is unknown what data will precisely be available, it could be that not all data will be available to use, which means that the dashboard would be less insightful. It could also be the case that gathering all of the data will take too long so at one point the decision must be made to create the dashboard with the data available at that time.

1.5.2 Assuring validity and reliability

Reliability and validity are essential for good research. When performing a thesis, the research must be both valid and reliable. Exact definitions differ from source to source but most boil down to the same. Cooper and Schindler (2014) describe validity as whether a measure accomplishes its claims. ITC E-Learning [J.M.G. Heerkens] describes validity as to whether you are actually measuring what you think you are measuring. Both definitions are the same, so it can be said that that definition is accurate. Another source explains that validity refers to how consistently a method measures something. For a source to be considered valid, the same result should be achievable when the same methods are used, with identical circumstances (Middleton, 2022).

To assure the validity of this research, the data must be interpreted correctly. To ensure this, KPIs are lined up to make it easy to interpret the data. These KPIs will tell the managers everything they need to know about the performance of the different processes in an easy-to-understand dashboard. The list of KPIs is discussed with the company to ensure the KPIs accurately portray the performance.

Cooper and Schindler (2014) use the following definition for reliability. According to them, the reliability of research is concerned with estimates of the degree to which a measurement is free of random or unstable error. If there is a random error, the results are also random. Reliable instruments are used confidently so that situational factors are not interfering and the results are thus valid. Reliable instruments are robust; they work well at different times under different conditions. ITC E-Learning [J.M.G. Heerkens] defines reliability as the ability to produce the same result with repeated measurements. If the results are always the same, the research is reliable.

The reliability of this research is assured because the data used for the research comes straight from the Warehouse Management System. The data in these databases are filled in automatically during the different processes. Therefore, the data can be assumed to be reliable and thus the research as well.

1.5.3 Research scope

The scope of this research will be limited to the available data distributed by Company X. This data will determine what information can be displayed on the dashboard. With this dashboard, the aim is to tackle the bottlenecks. This dashboard will be created solely for the Dutch warehouse and department of the Company. However, if it is successful, the dashboard might also be implemented in other departments and countries.

Furthermore, this research will not look at the performance of the last step, which is shipping. This research will focus solely on the internal logistical processes, so shipping is not part of the research scope. This is because the company does not have any influence on the shipping step.

1.6 Theoretical perspective

This research aims to use a dashboard to improve insight into the productivity of warehouse processes. Two theoretical perspectives fit well with this goal: Lean management and Six Sigma. Lean management is a theory that focuses on waste reduction, while Six Sigma focuses on creating effective processes (Yam, 2006, Charron et al., 2014). Both theories are often used together, so often that a new term and theory was created for combining the two theories. This theory is called Lean Six Sigma and fits well in this research for several reasons. George (2002) describes Lean Six Sigma as a methodology that maximizes shareholder value by achieving the fastest improvement in customer satisfaction, cost, quality, process speed and invested capital. This theory fits well because it focuses on eliminating wasteful steps and errors in a process. That is what is needed to make the warehouse processes effective and perform well.

Takeaway Chapter 1

The company for which this research will be performed is a multinational B2B supplier, supplying a business with everything they need, ranging from cleaning products to desks. Company X uses a Warehouse Management System to track and store data from the warehouse. Every transaction that happens in the warehouse is tracked and stored, however, nothing is done with that data. The company desires more insight into the performance of the warehouse and to add more KPIs to the current selection, as only one KPI is available at the moment. A main research question is set up in order to help Company X with its problem. The question is the following: *How can a dashboard help improve the insight into the performance of the warehouse processes at Company X?* Next to the main research question, eight sub-questions are also set up to help answer the main question. The deliverables for this thesis consist of this report, an implemented dashboard, a manual for the company on how to use and update the dashboard and a list of KPIs.

Chapter 2: Background

Chapter 2 serves to inform readers of the essential information necessary to understand the rest of the thesis. First, the warehouse processes at Company X are described in written form and are presented in BPMN models. The models provide an easy overview of what happens inside the warehouse. Furthermore, the current and desired level of insight Company X has into the performance of the warehouse is explained. Finally, this chapter establishes a theoretical framework for performance measurement systems.

2.1 Warehouse processes at Company X

In section 1.1, the six warehouse processes are explained shortly. These six processes are receiving, putting away, storing, order picking, packing and shipping. While in section 1.1 a more general explanation was given, the purpose of the following paragraphs is to explain in detail what exactly happens during these six phases at Company X. To visualize the process, two business process models are made. A more abstract model can be found in Figure 2, while the more detailed model is included in Figure 4.

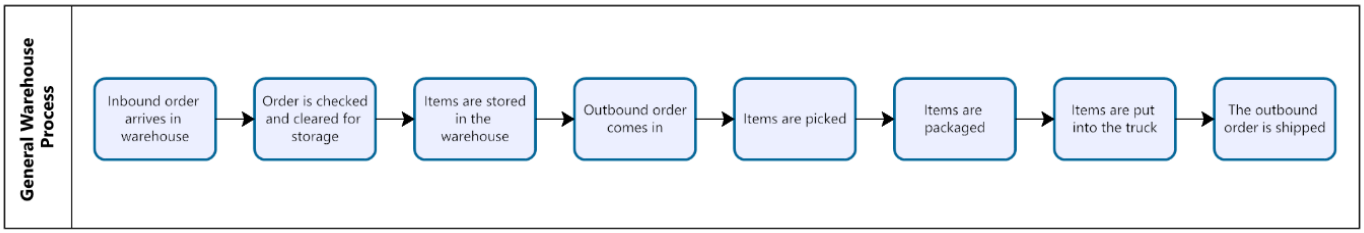


Figure 2: Abstract model of the warehouse process

Receiving

The location of Company X in the Netherlands consists of two separate warehouses, which are about one hundred meters apart. Products are received at either one of these warehouses. The products stored in each warehouse differ. One warehouse stores the large products and the other stores the smaller products. Trucks arrive at one of these warehouses depending on the products they are carrying. When the truck arrives, the products are unloaded from the truck to the warehouse. When the truck is fully emptied, the inbound order is checked. A list of supposedly delivered products is printed and this list is checked with the actual arrived products. The type of product is checked, as well as the quantity. The actual number of products and the product type should be the same as on the list. Furthermore, the quality is checked, as damaged products cannot be sold to clients. Any discrepancy is noted and reported back to the supplier. When there are no problems with the order, the next step in the warehouse begins. The employee that checked the inbound order will then signal on the terminal that the order is complete and ready to be put away.

Putting away

When an order has been checked and cleared, the products must be put away swiftly and in the correct place. The employee that received the order can signal that the order is complete and ready to be put away. Another employee can scan the Licence Plate Number (LPN) which is visible on each order that belongs to the order with their mobile terminal. What helps with the swift storing of products in the correct place is that the terminal will tell employees exactly where the products need to be put and in what warehouse, when they scan the LPN. Almost all products are on stored the warehouse's shelves, but exceptions exist. For example, sometimes, the word “cross-dock” appears on the order paper. “Cross dock” means that the arrived products have already been ordered and thus will be leaving the warehouse soon. Therefore, they are not put on the shelves but kept at the front of the warehouse. When the employee has put away the order, he signals that the products have been

put away in the mobile terminal. That way the status of the products is updated and the WMS knows that the products have been put away.

Storing

The mobile terminal helps the employees with putting them in the correct place. However, determining what the correct place is to store each product is also a vital warehouse process. At Company X, the products are stored according to the ABC method. With this method, the products stored are segmented into three categories: A, B and C. Products that belong to the A category are the most important for the company and move the fastest, these are the most frequently sold products. They are therefore placed in the area that is easiest to access and closest to the front. These products are called fast movers because of the high turnover rate. Category B products have a medium turnover rate and are placed between categories A and C in the warehouse. Category C products are the so-called slow movers and have the lowest turnover rate. In the case of Company X, these products are put on the first floor far away. Because products are stored according to the ABC method the movement in the warehouses is kept as limited as possible. It is hard to evaluate the performance of this step, so the performance of this step is not included in the dashboard. Together with the logistics and business intelligence manager, it was deemed outside of the scope of this thesis, as it was too big of a project to tackle next to introducing a dashboard.

Order picking

When an outbound order is received, the items of this order need to be picked up before they can be put in the truck. For Company X, there are two distinct order streams. First, the orders with small products are picked with the help of a conveyor belt. In this case, the order system knows exactly what size of cardboard box is necessary to fit the ordered products. A barcode for this order is then put on the box and this box is put on the conveyor belt. This barcode is scanned by the lasers on the conveyor belt. Then, the box is moved along the conveyor belt to the closest place to the products that need to be picked. The system knows where what products are stored and can thus determine exactly where each box needs to stop. When the box arrives at the correct place, an employee again scans the barcode and the terminal will tell them what products to pick and from where. When employees are done picking the order, they again scan the barcode of the box. If more products are in separate locations that also need to be picked, the box moves there, or it moves to the packing station.

Orders with more oversized products are picked by employees using low-level order pickers. In this case, pick tickets are printed and an employee scans the barcode on this pick ticket. Again, the mobile terminal will tell them what products to pick. However, sometimes the employee will have to change the order of the products as more oversized products need to be picked first to make it easier to stack up the products of the order. When an order has been fully picked, it is brought to the correct place. It will then be made ready to load into the correct truck. The order will then be packed accordingly. When pickers notice that a product is almost out of stock, a picker can make a replenishment order in the mobile terminal.

Order packing

The small products that are put in cardboard boxes do not have to be packaged, as they are already put in a box. However, air cushions are put in the box to protect the products. The box is then sealed and ready to be put in a truck. For larger orders, an extra sheet of plastic foil is often used for packaging the orders and protecting them from damage as they are too big for cardboard boxes. When the orders have been packaged correctly, they are put into the right truck.

Shipping

Shipping is not part of the scope of the research, but it will be described briefly for a better understanding of the warehouse processes. From the location in the Netherlands, their products are shipped to multiple countries in Europe.

All of the previously mentioned steps and every intermediate step are logged in the Warehouse Management System. As every step is tracked and for each order, the employees can easily track where the order is and who is busy with what order.

2.2 Business Process Model

To better visualize the process of a product going through each of the steps in the warehouse, a Business Process Model and Notation (BPMN) is made. A BPMN gives a quick and understandable overview of the processes in a graphical model. This business process model for the warehouse process of Company X can be found in Figure 4.

There are various objects in the model, and they will need some explanation about what they represent. The first object is a pool, a pool represents the entire department where the processes happen. Each pool then consists of swimming lanes. Each swimming lane represents another participant or role in the process. In each model, symbols are present to help the viewer easily understand what is going on, without needing a lot of text. The meaning of these symbols is explained below:

- Events are represented with a circle and these circles can be green or red. A green event signals the start of a process and a red event signals the end of a process.
- Next, there are activities, represented by a horizontal rectangle. An activity describes a single task of the process. A new activity object should be created for each new task in a process.
- Furthermore, there are gateways in the BPMN, which are diamond shaped. A gateway can be exclusive or parallel. An exclusive gateway means that only one direction can be followed, depending on the situation when the process arrives at the gateway. In the case of a parallel gateway means that both paths are followed. In the warehouse processes of Company X, there are only exclusive gateways.
- Arrows represent all these flows between events, activities and gateways.

These symbols can be found in Figure 3.

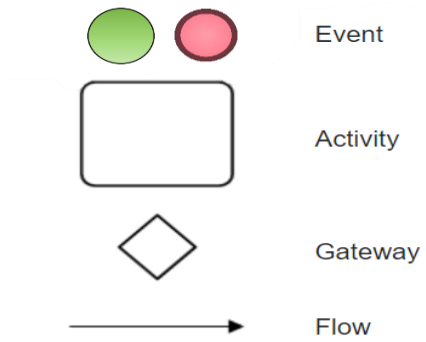


Figure 3: BPMN Language

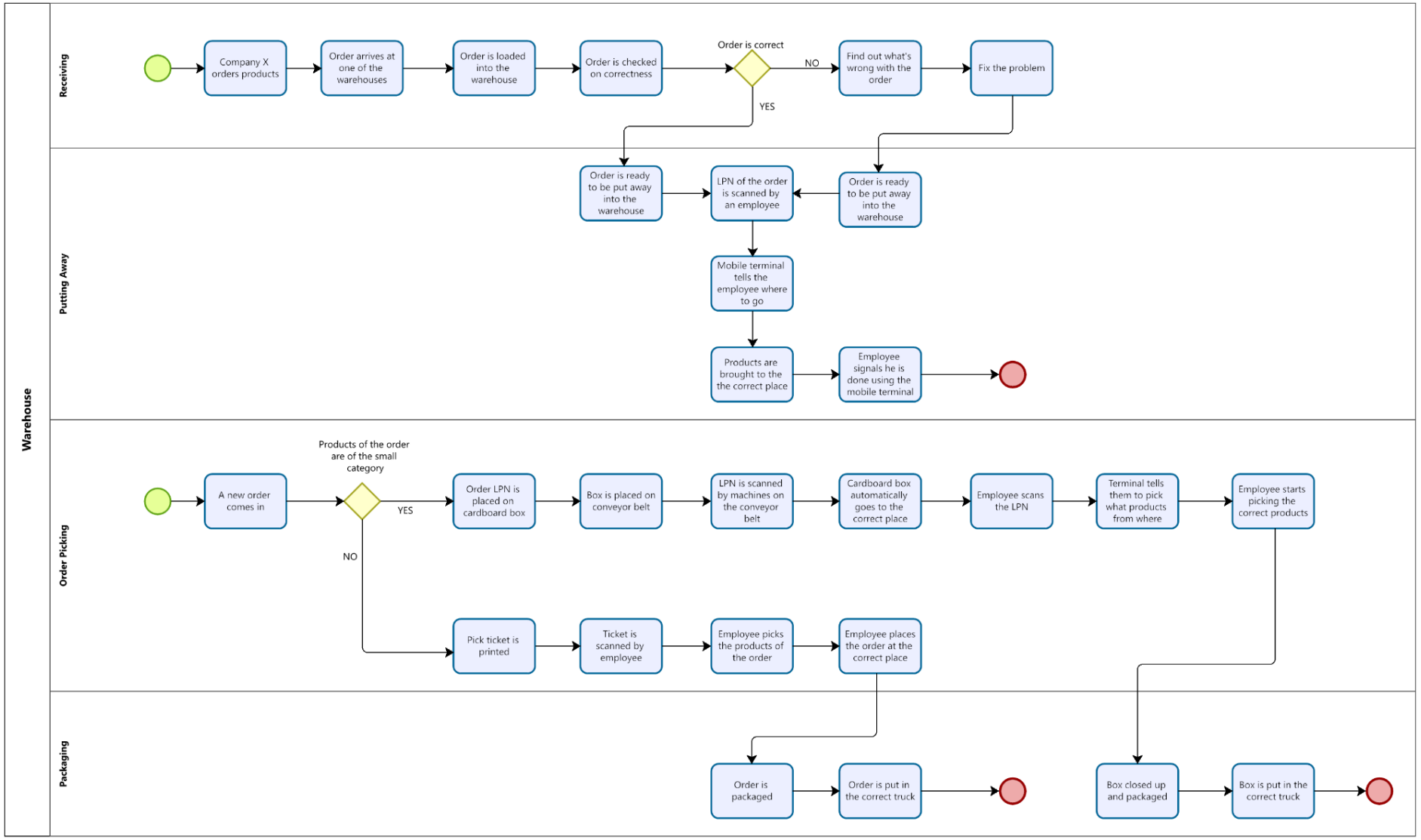


Figure 4: Detailed model of the warehouse process

2.3 The level of insight into the performance of the warehouse

2.3.1 Current level of insight

As written before, every transaction of the warehouse process is logged in the WMS. However, in the WMS, there is no output of KPIs and it is not feasible as a dashboard. The WMS is just used to store and track the data. The data that is stored is elaborate and detailed. Data stored includes but is not limited to information about the employee, time stamps, location details as well as specific information about what task is being performed.

Currently, an Excel sheet exists with information about the warehouse processes. There is just one KPI on this sheet that tells the managers about the performance of the warehouse processes. This KPI is called "*productivity.*" The KPI is defined as the number of order lines picked per person per hour. This KPI is calculated for each day. The company has two warehouses with distinct kinds of products, so the KPI is shown for the two different warehouses. This KPI is hard to interpret as it only tells the managers the overall productivity and no drilling down is possible. Furthermore, it does not tell anything about the other warehouse processes.

Of course, the managers are also present at the warehouse and therefore, they can spot problems from there. However, it is much harder to look at the big picture and the progress over time without a dashboard. A dashboard can also be used to support gut feelings the managers might have.

2.3.2 Desired level of insight

Before researching what kind of performance measurement system is the best fit for Company X, it is good to look at the wishes of Company X for this performance measurement system. The logistics manager, who will be the person who will use the performance measurement system, has a few requests for the artefact that will be built. The wishes are categorized into three categories: general, information and visualization. The dashboard will be used to gain insight into the available data. Because no such insight existed before, there are no targets for the KPIs. Therefore, the dashboard will first be used to gather information on typical situations. Then, in the future, targets can be included and the KPIs can be compared against their targets.

General

The following things should be possible in the new performance measurement system.

- The performance measurement system should use real-time data and be able to be updated to the latest available data at every moment.
- The performance measurement system should show the values of the KPIs based on the selected date range. The possible date range that can be selected should be from one day to multiple years.
- The performance measurement system should show the values of KPIs based on the selection of the country of destination of outbound orders.
- The performance measurement system should show the values of KPIs based on the selection of carriers for outbound orders.
- The performance of storing is not to be present in the dashboard, since the logistics manager thinks it will be too hard to evaluate the performance of that step and he is more interested in generating insight into the performance of the other steps.

Information

The performance measurement should include at least the following KPIs. The KPIs are written as just bullet points here, but an explanation of the KPIs can be found in section 5.3.

- The number of transactions per hour for each possible transaction type
- Inbound
    - Average dock-to-stock time
    - Average putaway time
    - Average receiving productivity
- Outbound
    - Average order-picking productivity
    - The average number of transactions per order
    - The average number of people that work on the same order
    - Order handling time
    - Warehouse time order
    - Throughput of items, oLPNs and orders per hour
    - The number of pallets that are made per day
    - Average pallet creation time
    - Distribution of carriers
    - Distribution of destination countries

Visualization

- The KPIs should be easy to read
- The KPIs should be easy to interpret
- The settings should be easily changeable
- It should be easy to refresh the data

2.4 Performance Measurement Systems

Although the company specifically requested a dashboard to improve the insight into the performance, other performance measurement systems also exist. Therefore, literature research is performed to find out what performance measurements exist and if they might be a better fit for the company. Two main types of reporting tools exist that are used to analyse performance measurement data (Wolk et al., 2009). The first is called a dashboard and the second is called a balanced scorecard.

A dashboard is a graphical user interface that shows the user an overview of selected key performance indicators. It helps the company measure the performance of processes and individuals over time. It consists of graphs and charts that communicate to the user the outcome of the data collected from the databases. (Smith, 2003). Few (2006) describes a dashboard as a visual display that shows the most vital information needed to reach goals. This is all displayed on a single screen and all of the information can be monitored at a glance.

A balanced scorecard is a performance measurement system that uses a set of goals and specific measures to give managers a quick overview of the business and its progress. It was founded by Kaplan and Norton (1992) to present managers with a balanced presentation of both financial and operational measures. The template for a balanced scorecard can be found in Figure 5. For the balanced scorecard, a business strategy is chosen and this strategy is translated into goals and measures. The company is divided into four main perspectives: financial, customer, internal business and innovation and

learning. For each of these perspectives, goals and measures are set up by the company. The idea is that the performance of different company parts are brought together into one report.

Furthermore, a balanced scorecard guards against suboptimization. By describing the measures together, it can be seen whether an improvement in one section meant a loss in another. (Kaplan & Norton, 1992).

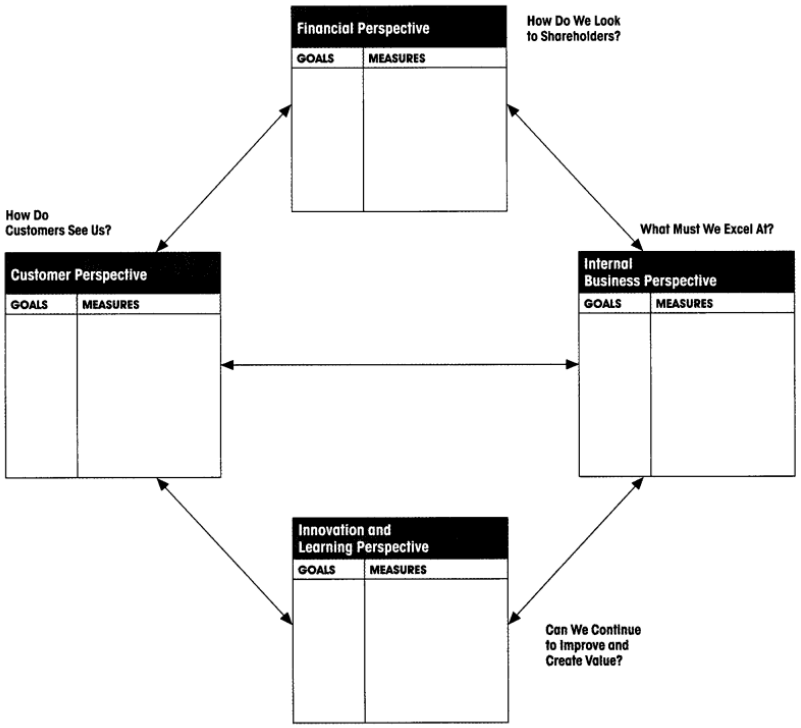


Figure 5: Balanced Scorecard

It might look like a dashboard and a balanced scorecard are pretty similar, but there are significant differences. A scorecard is a performance management system, while a dashboard is a performance monitoring system. As such, a dashboard is used to measure performance, while a scorecard is used to measure progress and view whether the set-up goals have been reached. Next, a scorecard is meant for the company to monitor the business strategy's progress. A dashboard is more aimed at individual use by managers. Furthermore, dashboards provide the user with information about current performance and are updated constantly, while a scorecard shows progress over time and is updated periodically (Smith, 2003). Therefore, it was decided that a dashboard best fits Company X's requests. Dashboards use real-time data, are aimed at specific sections of a company and are better at measuring performance. These points all fit the company's wishes as they want to measure the real-time performance of the warehouse. Also, a balanced scorecard is more aimed at measuring the performance of different parts of the company and this thesis is only focused on the warehouse performance. So, the artefact that will be built using the Design Science Research Method is a dashboard.

Takeaway Chapter 2

The current situation is undesired by Company X as they lack insight into the performance of warehouse processes. To improve this situation, a dashboard is built. This performance measurement system fits the goal of Company X best for a few reasons. Dashboards use real-time data, are aimed at specific sections of a company and are better at measuring performance. These points all fit the company's wishes as they want to measure the real-time performance of the warehouse.

For this dashboard, the logistics manager has a few desires. They want the information to be included:

- The number of transactions per hour for each possible transaction type
- KPIs with information about the inbound orders
- KPIs with information about the outbound orders

Chapter 3: Methodology

Now that it has been found that a dashboard is the most helpful performance measurement system in the case of Company X, the six steps from the Design Science Research Method can be elaborated and explicitly explained for a dashboard as an artefact (Peffers et al., 2007).

Activity 1: Problem identification and motivation

In this step, the specific research problem is defined. Furthermore, the importance of the problem is highlighted. Activity 1 is explained in section 1.2 of this report. The core problem is found with the help of a problem cluster.

Activity 2: Define the objectives for a solution

In this stage, the objectives for the solution are defined. The objectives can be seen as the goals and deliverables. For this research, a goal has been set, to be compared with the current situation at the end of the research. The goal of this research is to introduce a working dashboard at the end that gives the logistics manager more insight into the performance of the warehouse processes. Furthermore, a list of deliverables is also created. The goals for this research can be found in section 1.2.5.1. The explanation of the deliverables for this research can be found in section 1.4.2.

Activity 3: Design and development

In this step, the artefact is created. Company X proposed a dashboard, but other performance measurement systems also exist. To make sure a performance measurement system was chosen that fit the goals the best, literature research was performed. This can be found in section 2.4. In this case, it was concluded the artefact should indeed be a dashboard. Before the dashboard can be created, further literature research has to be done. This literature research is done to find KPIs that are often used in the warehouse performance sector and to find KPI selection methods. See sections 4.1 and 4.3 for this. Then, the KPIs that will be shown have to be decided. This is done by first looking at KPIs from literature and KPI suggestions from the warehouse manager. The result of this is a list of possible relevant KPIs for the dashboard. The second part is selecting the method that will be used to select the final KPIs from the preliminary list, as there will not every KPI found in the first research question will be relevant or can be calculated. When a method has been chosen, this method also has to be applied to come to the final list of KPIs that will be used in the dashboard.

Once the KPIs have been selected, the dashboard can be created. However, before the dashboard can be created, a literature study has to be conducted researching theories about dashboard software, dashboard design and KPI visualization. When this is done, the dashboard can be created and the decisions made can be supported by theory and literature. The creation of the dashboard is done in Excel. Once a draft version is ready, this will be discussed with the logistics manager. Based on the feedback, the dashboard will be improved.

Activity 4: Demonstration

In this step, the use of the artefact is demonstrated. The dashboard should thus be implemented in the company during this activity. The people that should have access to the dashboard should be able to use it without any problems. The definitive version of the dashboard will also be included in this thesis, with an elaboration on the design and KPIs. Furthermore, a guide on how to use the dashboard is also expected in this step. In case, the dashboard was shown to the logistics manager first and he gave feedback on this. After this, a presentation about the working of the dashboard was given to some employees of the warehouse and the boss of the logistics manager was also present.

Activity 5: Evaluation

In this step, the effectiveness of the artefact is assessed. The dashboard was meant to improve insight into the warehouse processes and the data that was collected for that. In this step, the result of implementing the dashboard will be measured against the previously established goals. This will be done with a semi-structured interview, as only one person will be using the dashboard. Therefore, using statistics or surveys to evaluate the dashboard makes no sense.

Activity 6: Communication

In this step, the problem and artefact have to be communicated, in this case, communicating the problem and artefact is done by uploading the thesis on the website of the University of Twente. Next, the results and findings of this research and the deliverables will be presented at the colloquium. The artefact is communicated with Company X by uploading the dashboard and manual to their shared OneDrive so that the correct people have access to the documents.

Takeaway Chapter 3

In this research, the Design Science Research Method (DSRM) is followed. This method is specialized for research where artefacts are created in order to solve a problem. In this case, the artefact is a dashboard that will give Company X more insight into the performance of the processes in their warehouse. The DSRM consists of six steps; Problem identification and motivation, Define the objectives for a solution, Design and development, Demonstration, Evaluation and Communication. These steps are also followed in this research to create the dashboard and implement it successfully in Company X.

Chapter 4: KPI selection, measurement, visualisation and dashboard design

In Chapter 4 literature review is done on five topics to generate the knowledge necessary to build a good dashboard. The four topics are finding, selecting, measuring, and visualizing KPIs and dashboard design.

4.1 KPIs in literature

Company X is interested in the performance of the warehouse and its processes and wants to gain more insight into this performance. To gain this insight, a dashboard will be created to function as the performance measurement system. This dashboard will visualize the warehouse KPIs. The question remains what KPIs are useful for Company X. A literature study is conducted to find KPIs used to measure warehouse performance to answer this question. Three different papers have been found that describe warehouse performance indicators. Each of these papers describes a list of KPIs useful for measuring warehouse performance. These lists will first be elaborated on. Next to the literature studies, the KPIs that come after a brainstorming session with the logistics manager will also be put on a list. After all of these lists have been elaborated, a final list will be made where duplicate indicators will be deleted and definitions might be changed to fit better the case of Company X. This list will also lack any KPIs from the literature part for which is already known that they are currently not relevant or that the data is not available to calculate them. Changing what data is gathered would take too long and is outside the scope of this thesis.
This list of KPIs can then be investigated together with the company to decide on a final list of KPIs for the dashboard. How this will be done precisely is described in section 4.3.

Staudt et al. (2015 A) performed a literature review on key performance indicators for warehouses to acquire a clear list of indicators and definitions. Instead of classifying the indicators according to the warehouse activities, Staudt et al. (2015 A) classify them according to the time, cost, quality and productivity dimensions. Not every indicator mentioned in this paper is relevant for Company X and this research, as currently, they are more interested in the activities in the warehouse and not necessarily in the shipping activity. Therefore, only the possible relevant indicators for this research are mentioned in the table. The list of KPIs from the study of Staudt et al. (2015 A) can be found in Appendix C.

F. Staudt et al. (2015 B) also performed another research on key performance indicators that are used to measure warehouse performance. While most of the KPIs and definitions are the same, a few differ; therefore, this research from Staudt is also relevant. F. Staudt et al. (2015 B) again do not classify the indicators according to the warehouse activities but to the dimensions of time, quality, cost and productivity. A large part of this research is also about defining definitions for each indicator and a mathematical expression for each one. However, this is not necessary for Company X as this company will have their own definitions and calculations for each KPI.

Furthermore, not every indicator mentioned in this paper is relevant to Company X and this research, as they are currently more interested in the warehouse and not necessarily in the shipping activity. Therefore, only the possible relevant indicators for this research are mentioned. The list of KPIs from the second research of F. Staudt et al. (2015) can be found in Appendix C.

Kusrini et al. (2018) also researched to generate a list of warehouse performance indicators. Instead of the previously mentioned dimensions of time, cost, quality and productivity Kusrini et al. (2018) use the Frazelle Model for warehouse key performance indicators. This model includes 25 KPIs based on five different warehouse activities that are often used in the warehouse industry. This model can be found in Appendix C. In this model, the “packaging” activity is missing. Kusrini et al. (2018) prepared a

questionnaire with pairwise comparisons to determine the most important KPIs for each activity. Five warehouse managers answered it. The results of this questionnaire were analysed using an Analytical Hierarchy Process. The conclusion is the following: for the activity receiving, the most important KPI is receipts per man-hour. For the putting away process, the most important KPI is the putaway cycle time. For storage, utilization is most important. This translates into the KPI of the percentage of location and cube occupied. For order picking the most essential KPI is order picking cycle time. Lastly, the most important KPI for shipping is orders prepared for shipment per man-hour. These five KPIs can also be found in the other studies, confirming that these are prominent KPIs in the warehouse performance sector.

A combined list can be created from these three studies so the company can assess that. The three studies provide an extensive list of Key Performance Indicators that are used in the warehouse sector. This list combines all of the KPIs from the three separate papers. The list can be found in Appendix C.

4.2 Company KPIs

The company has some wishes regarding the dashboard, including KPIs that should be present in the dashboard. Some of them are also found in literature, but not all. The KPIs that Company X would like to include in the dashboard but are not found in the literature are put in Table 2. This table, together with the Tables in Appendix C, the literature KPIs, forms the list that will be assessed in the KPI selection process. This KPI selection process will be explained in section 4.3.

KPI	Definition
Order handling time	The time from when an order gets picked up to when it is put in a truck
Order Warehouse Time	The time from when an order arrives in the warehouse to when it is put in a truck
The number of transactions per order	The number of transactions that are tied to a unique order
The number of people that work on the same order	The distinct amount of people that work on the same unique order.
The number of pallets per day	The number of pallets that are created in the warehouse per day
Pallet creation time	The time from the first scan relating to creating a pallet to the last scan
The number of transactions per hour for each transaction type	The count of the number of transactions for each possible transaction
Order distribution of carriers	Shows the order distribution of the carriers that are used for outbound orders, meaning that exact numbers are shown for how many orders each carrier transports each day
Order distribution of destination countries	Shows the order distribution of destination countries of the outbound orders, meaning that exact numbers are shown for how many orders go to each country each day

Table 2: Explanation of Company X's KPIs

4.3 KPI Selection Methods

In the previous sections of this chapter, a list of possible KPIs has been lined up to be assessed by the company. The list still has to be assessed by the company because each company will have different preferences for what KPIs are important and what KPIs might be relevant. The list described in Appendix C will be narrowed down to only the most useful KPIs for the company and these KPIs will be included in the dashboard. The dashboard should give a quick overview of the performance and if the dashboard is overflowing with KPIs, this principle no longer holds.

To assess the list, the list will be discussed with the relevant stakeholders of the company. That is because they know the warehouse the best and also know what information they are currently lacking. The warehouse managers clearly know what they want in the dashboard. Furthermore, a scientific selection method from the literature will be selected to help assess the list of KPIs and to narrow the list down to only relevant and insightful KPIs. That is because often the selection of KPIs is done based on intuition or by consultants rather than scientific principles (Hester et al., 2016). Deriving KPIs is not a simple task and stakeholders with a deep understanding of the context are needed for it to be successful. Since KPIs will be selected based on more than one criterion, multi-criteria decision-making methods are helpful here. These methods are useful when there are many criteria to consider for a decision.

Three main methods exist to help select KPIs. The first method is from Horst and Weiss (2015). They developed a list of twenty criteria against which a KPI can be assessed and suggest that companies use this list when assessing criteria. These twenty criteria are: aligned, balanced, standardized, valid, quantifiable, accurate, timely, predictive, actionable, trackable, relevant, correct, complete, unambiguous, automated, buy-in, documented, comparable, understandable, and inexpensive. The first step in their method is to select the KPIs that will be assessed and select the relevant effectiveness criteria from the list or add new criteria yourself. The second step is to score each criterion, usually on a scale from 1 to 10. This is done to rank the importance of criteria. The scoring is also done for the KPIs against each criterion. After this, each KPI is given a score using the following equation:

$$E_{ik} = \frac{\sum_{j=1}^{M} W_{jk} E_{ijk}}{\sum_{j=1}^{M} W_{jk}}$$

Where M is the number of criteria, E_{ik} is the i^{th} KPI score from the k^{th} stakeholder. E_{ijk} is the i^{th} KPI score, from the k^{th} stakeholder, for the j^{th} effectiveness criterion. The weight of the j^{th} criterion, from the k^{th} stakeholder, is given by w_{jk}.

After each KPI is scored, the results are discussed with the stakeholders and the KPIs with the highest scores are selected. The number of KPIs that are selected depends on the company and its idea of an ideal number of KPIs.

The second method is from Hester et al. (2016). Their KPI assessment method consists of two phases: KPI Characterization and KPI Alignment and Balance. In their paper, only Phase 1 is elaborated on. The first phase consists of eleven steps. These steps are shown in Figure 6. Most of the steps speak for themselves, but some steps might require elaboration. In the fifth step, the criteria are ranked using a rank-sum method. The criteria are provided by Hester et al. (2016) and this list is a reduction from the criteria of Horst and Weiss (2015). In the sixth step, the rankings are translated into weights. The authors of the paper propose the use of the rank sum method. In the eighth step, the stakeholders score each of the KPIs for all of the criteria. One thing to keep in mind here and be aware of is decision fatigue (Baumeister & Tierney, 2012). The key to battling decision fatigue is ensuring there are not too many KPIs to rank. The final two steps are to discuss the results and possible problematic outcomes of the KPI assessment and improve them.

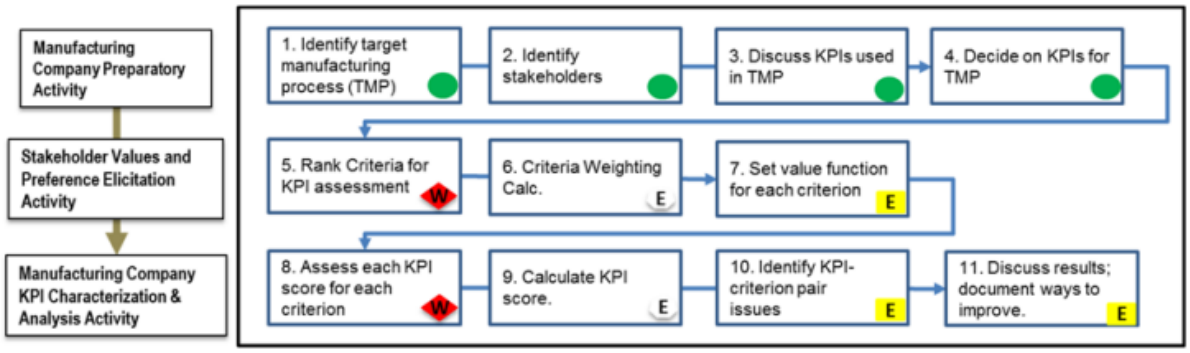


Figure 6: KPI Selection Method from Hester et al. (2016)

The third and final method is the Analytic Hierarchy Process (AHP) (Podgórski, 2015). The main difference between the previously mentioned methods and this method is that instead of a numerical ranking of the weights for the criteria, the AHP method determines the weight by relative importance. With this method, it is possible to show how much more important one criterion is than the other, as weights of the criteria are determined. The more important a criterion is the higher the weight is, instead of an equal weight for the criteria. The first step of the AHP method is to compare the SMART criteria with each other. This is done in a five-by-five matrix. This way, each possible combination of criteria is compared. Each pairwise comparison is represented by a score. A score from 1 to 9 is possible. These scores indicate the level of importance of one criterion over the other. The exact definitions of the numbers can be found in Table 3. From this matrix, the exact weights of each criterion can be determined. How this is done exactly, is explained in Appendix D.

Once the weights of the criteria are determined, the KPIs scores can be calculated. This is done by giving each KPI a score for each of the SMART criteria. This score can only be between 1 and 5. The score for each criterion is then multiplied by its weight to end up with a total score for each KPI. A cut-off score can then be determined to decide what KPIs will be selected and which will not be included. As already mentioned in the previous paragraph, when using the AHP method, a popular set of criteria is often used. This set of criteria is known as the SMART criteria. This stands for Specific, Measurable, Achievable, Relevant and Timebound. The exact meaning of these criteria can be found in Table 4.

Number	Definition
1	Equal
2	Between equal and moderate
3	Moderate
4	Between moderate and strong
5	Strong
6	Between strong and very strong
7	Very strong
8	Between very strong and extreme
9	Extreme

Table 3: Definitions of numbers for the AHP method

Criterion	Definition
Specific	The KPI should measure precisely what you want to measure
Measurable	The KPI should be able to be measured with the available data
Achievable	The resources necessary to collect the data for the KPI are available and it is possible for the timeframe of the thesis
Relevant	The KPI should contribute to achieving the objective
Time-bound	It should be possible to determine the period in which a given value of the indicator may be achieved

Table 4: Definitions of SMART criteria

An essential step in the Analytic Hierarchy Process is to check the consistency of the ranking. Inconsistencies can occur, but this must be noticed in time to get rid of them. For example, it cannot be the case that the "Specific" criterion is scored to be more important than the "Measurable" criterion, and the "Measurable" criterion is scored as more important than the "Achievable" criterion, while the "Achievable" criterion scored to be more important than the "Specific" criterion. If this is the case, something went wrong in scoring the criteria. The consistency index and ratio are calculated to ensure the results are consistent. For the results to be assumed to be coherent, the consistency ratio should be less than 0,1.

As the AHP method allows weights to differ between criteria, this seems like the best and most representable method for scoring KPIs. Therefore, it was chosen to use the AHP method to select the KPIs for the dashboard.

4.4 Measuring the KPIs

The data used to calculate KPIs often comes from a company's database. Every company has a different IT and BI architecture. In the case of Company X, MicroStrategy is the used business intelligence platform. The ERP system used is called A/X. In the warehouse, WMS is used to check live data for the warehouse process. The database Company X uses is Microsoft's SQL server.

Company X has an extensive database system with a lot of tables in it. Fortunately, not every table is needed for the dashboard as the database also contains a lot of tables with information that is not about the warehouse process. There is one specific table needed for this thesis and this table is called "WMS_PROD_TRAN_RAW" and the data used for the dashboard is retrieved from here. In this table, all of the Dutch warehouse transaction information is stored. Company X is an international company with also a subdivision in France. This subdivision is responsible for storing all data collected from the mobile terminals and each scan they do. However, the table did not contain all of the wanted data at the start of this thesis. It is possible to add new columns to the table, however SQL server is quite a difficult programme and the Dutch department does not have a lot of knowledge of that. The French division does have expert knowledge of SQL Server and the idea was that they were going to add the correct columns. However, this process proves to be quite difficult. As the communication between France and the Netherlands is slow, as their priority is not the dashboard that was being created for the warehouse in the Netherlands. After reminding the French department a few times, they did ultimately add some columns to the table.

Once there is access to the database, the data has to be extracted from the database. The data is loaded into Excel using Power Pivot. The data is loaded into Excel because the dashboard will also be created in Excel. Using Excel makes for a smoother creation of the dashboard and changes in the future. Power Pivot can retrieve the data from the SQL server with a query. The data can be refreshed in Excel itself. The SQL server automatically refreshes the data every night.

The quality of this data will not always be perfect. In this case, perfect means that the data is complete, consistent and precise. However, the data quality must be perfect and without errors to be useful. When this is not the case, decisions are not based on the actual situation and this can lead to problems. So, to be used for the dashboard, the data must be cleaned. This will be done in the following way: entries with no beginning date are deleted. Those entries are deleted because the time element is vital for analysis, so transactions with a beginning date are useless. For other instances, it is impossible to screen them and delete entries with null values in a specific column. This is because not every column needs to be filled for an entry to be valid.

Table 5 describes what information is saved in Power Pivot. Not everything is used currently, but columns might be interesting in the future, so that is why they are kept there. Other columns that are not included also help identify a transaction, so that is also why some columns are included in the table.

Title in Excel Column	Definition of the title
TRAN_TYPE	Code for identifying what type of transaction module it is.
TRAN_CODE	Code for identifying what type of transaction it is within the module
TRAN_NBR	The transaction number
SEQ_NBR	What transaction it is in the sequence of transactions for that order.
WHSE	What warehouse the transaction happened in
CNTR_NBR	Container number.
NBR_UNITS	The number of units picked
WKSTN_ID	What workstation the transaction happened at
RSN_CODE	The reason code is filled in whenever something is changed, deleted or modified. Each code refers to one specific thing that went wrong.
BEGIN_DATE	The beginning date and time of the transaction
END_DATE	The end date and time of the transaction
MODULE_NAME	The module name for the transaction
MENU_OPTN_NAME	The description of the transaction
CREATE_DATE_TIME	The time the entry has been put into the database
MOD_DATE_TIME	The last time the data entry has been modified
USER_ID	The ID of the user that did the transaction
PLT_ID	The ID of the pallet
TASK_ID	The ID of the task
ITEM_ID	The ID of the item with which the transaction happened
TC_ORDER_ID	The ID of what outbound order the transaction belongs to.
FROM_LPN	The LPN for the order

ITEM_NAME	Another ID to identify the item with which the transaction happened
D_COUNTRY_CODE	The country code of the destination of the order
SHIP_VIA	The carrier of the order
DESCRIPTION	More specified description of the carrier
DSP_LOCN_FROM	The location in the warehouse from which the item is gathered
DSP_LOCN_TO	The location in the warehouse the item is supposed to go.

Table 5: Explanation of the Excel columns

The MENU_OPTN_NAME describes the transaction. In Table 6, an overview of all the possible transactions is given as well as a description of the transaction.

MENU_OPTN_NAME (Type of transaction)	Definition
Cancel OLPN	Cancel an Outbound LPN.
Cancel Order	Cancel an Order.
CARTON UIT LADING	Take one item from the truckload that was already loaded into the truck.
CREEER LPN	Create an LPN.
CYCLE COUNT BULK	Count a bulk location and check if the indicated amount is correct.
CYCLE COUNT PICK	Count a pick location and check if the indicated amount is correct.
Fill {Actv}	Bring items from a bulk to a pick location.
Fixed Station Returns	Handling of orders that have been returned.
Generate Replenishment	Indicate that an item at a pick location needs to be refilled from a bulk location.
INSL LPN	Bring an LPN from the dock to the stock location.
INSL MANUEEL BULK	Bring a bulk item to the correct location from the dock.
INSL MANUEEL PICK	Bring a pick item to the correct location from the dock.
INSL PLATEAU	Bring an item to the plateau.
LADEN TRAILER	Load one oLPN into the truck.
Modify iLPN	Modify an iLPN.
ONTV. LPN	Receive an LPN.
ONTV. XDK CROSSDO	Receive an LPN for cross dock.
PALLETISEER CARTONS	Put cartons on a pallet for one client.
PICK CARTON	Pick an item.
REA Fill Actv	Bring items from bulk to pick locations.
REA Fill Actv Dyn	Brings items from the bulk locations to a selected place right in front of the shelves.
Replenish Active	Bring items from the bulk to pick locations.
RF Close Trailer	Close the truck.
SHIP-PALLET MAKEN	Create a pallet.
SPLITS CARTON	Create an extra box if the order does not fit into one box.
SPLITS/ COMB. LPN	Put multiple boxes into one box.

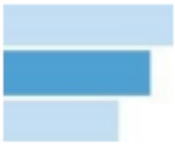
Task: Pull Case List INT2	Take one full pallet for an order.
Weigh oLPN	Weigh and package one outbound LPN.

Table 6: Explanation of each type of transaction

One possible threat to the data quality is that the employees do not scan the transaction at the right time. For example, one employee scans one item to signal that it is ready for pickup but is not ready yet. This would mean that the time entries of this transaction are flawed. However, there is no reason to assume that this happens in the warehouse as this would not benefit the workers. As all of the other information in the database is automatically uploaded and no one can interfere with this data, there are no other threats to data validity and quality. Each person has their own terminal, so therefore the name that is linked to each transaction is also always correct.

4.5 Visualizing the KPIs

Dashboards are a visual representation of data and often include many graphics. There are many ways that the underlying data of a dashboard can be visualized. Various media displays can be used to portray the data. Sometimes mistakes are made when selecting the display of a KPI as the wrong display might confuse the user more than that it gives him useful information. An overview of the possible displays is presented in Table 7 to ensure the correct displays are chosen in the dashboard for Company X. Together with the overview, there is an explanation of each display and when it is most valuable, this is to avoid selecting the wrong display media. To help understand what the display looks like, a generic example picture is added as well. This picture shows how such a display might look on a dashboard (Alexander & Walkenbach, 2013, Evergreen, 2019, Few, 2006).

Category	Media Display	Picture	Explanation
Graphs	Bullet graph		Display a single key measure.
	Bar graph		Display multiple instances of one or more key measures.
	Stacked bar graph		Solely use to display multiple instances of a whole and its parts.
	Combination of bar and line graphs		This combination should be used only when some data can be displayed best using bars, with an emphasis on individual values and local comparisons, and some using a line, emphasizing the overall shape of the data.
	Line graph		To emphasize patterns or changes in data over time.

	Scatterplot		Displays whether or not, in what direction, and to what degree two paired sets of quantitative values are correlated.
	Tree map		To spot particular conditions of interest.
	Pie chart		To represent parts of a whole. Not recommended as humans are not good at comparing 2-D areas or angles.
	Doughnut chart		Similar to a pie chart but with a hole in the middle. Also not recommended.
	Radar chart		Each category has a separate axis and the values are placed upon this axis. Again, not recommended.
Icons	Alert		Use to draw attention to one specific point on the dashboard
Text or numbers			To report a single measure
Images			Often unnecessary as there is no data displayed
Drawing objects			Use to connect pieces of information
Organizers	Tables		To arrange data in columns and rows
	Spatial Maps		To tie data to physical space, like a geographical map.
	Small multiples		Useful when using the same graph multiple times, only changing one variable.

Table 7: Explanations of media displays

4.6 Dashboard design

There are multiple parts to dashboard design. There is the actual creation of the dashboard and what steps to take there, what tool will be used for the dashboard, and some rules of thumb for visually designing the dashboard. All three parts will be discussed in the following paragraphs.

4.6.1 Dashboard building

Janes and Sillitti (2013) have created an approach to obtain a useful dashboard. This approach consists of two steps. The first step is to choose the correct data for the dashboard and the second step is to

choose the proper visualization for this data. For choosing the correct data, a Goal-Question-Measurement model is used and extended. This extended model will also be used in this research. In this case, the goal defines what is to be studied and why. This is the "object of study." The questions define what parts of the object of study are relevant and what properties of these parts characterize the assessment. This might sound a bit vague, but the idea is that the questions help define what aspects need to be studied in order to verify whether the goal is reached or not. The measurement level defines what data needs to be collected to answer the questions. As written before, Janes and Sillitti (2013) use an extended GQM model. The extended model is different in that it adds a goal hierarchy motivated by the organizational strategy. Furthermore, it creates a new model, the measurement model. This model links the business goals to the measurement goals.

As for choosing the proper visualization, the decision is often between the push and pull techniques. With the push technique, the information is pushed to the user, while with the pull technique, the user uses the dashboard to obtain specific information. Together with the company, it will have to be decided which technique best fits the goal.

Read et al. (2009) go more into depth about the dashboard design. They studied the user preferences for dashboard menu design, which is also essential when creating a dashboard. The research found that a frame-based menu was a better design than an expendable index. A frame-based menu allows all sub-menus to be visible simultaneously, while an expendable index only expands to a submenu when a user clicks on it. Another research also discusses dashboard design and introduces six steps for the dashboard design process (Kopp & Orlovskyi, 2021). These steps are shown in Appendix B.

Pauwels et al. (2009) also describe five dashboard development stages, which are a bit different from the steps Kopp and Orlovskyi (2021) describe in their figure.

They are the following:

Stage 1: Selecting the Key Metrics
Stage 2: Populating the Dashboard with Data
Stage 3: Establishing Relationships Between the Dashboards Items
Stage 4: Forecasting and Scenarios
Stage 5: Connecting to Financial Consequences

Furthermore, they have described a framework for the adoption and success of dashboards. This framework can be found in Appendix B. Another source also adds information about dashboard design. Yigitbasioglu and Velcu (2012) did a literature view and presented the most important findings in a figure. This figure can be found in Appendix B as well. In this figure, relationships between different parts are visualized.

Few (2006) also wrote about dashboard design. This book contains much information about the specifics and rules of dashboard design. Few (2006) describes the following as characteristics of a well-designed dashboard:

- Exceptionally well organized
- Condensed, primarily in the form of summaries and exceptions
- Specific to and customized for the dashboard's audience and objectives
- Displayed using concise and often small media that communicate the data and its message in the clearest and most direct way possible

He also describes two goals of dashboard design. They are the following:

1. Reduce the non-data pixels
2. Enhance the data pixels

Non-data pixels are not used to display data, excluding the blank background. As for reducing the non-data pixels, it comes down to first eliminating all unnecessary non-data pixels and secondly de-emphasizing the remaining non-data pixels. Almost the same principle holds for enhancing the data pixels. Here firstly, unnecessary data pixels are eliminated and the second part is highlighting the essential data pixels. Designing a dashboard is an iterative process. This means that the dashboard will be refined and revised until the dashboard fully accomplishes its goals. Based on feedback on a draft version of the dashboard, the dashboard will be improved based on this feedback (Few, 2006). The chosen design for the dashboard will be explained in section 5.4.

4.6.2 Dashboard Software

Many different options exist when deciding what software to use to create the dashboard. Some options are specialized for creating dashboards, such as Power BI or Tableau. They have both a free and premium version. However, this free version is too limited to use for this research. On the other hand, the premium version would cost quite a lot of money. Furthermore, this programme would be completely new to employees. This would mean that time would have to be invested for employees to learn the programme. This time is simply not there for the thesis. So, another option would be to use completely free software or something that would not cost Company X more money. An example of this is Excel. As Company X already has the license for Excel, it would not cost them extra money to make the dashboard on Excel. Furthermore, Company X's employees already regularly work with Excel and are thus experienced with the programme. Excel has an add-in called Power Pivot that makes Excel suitable for creating dashboards. With this add-in, data can be gathered easily from Microsoft's SQL server. Choosing a free option might be the wisest decision, as the impact of the dashboard is unknown at the start. If the impact is not as big as hoped, no money was wasted in the process. If the dashboard turns out to be a success, Company can always invest in specialized dashboard software later on.

As Company X already has a Microsoft license to use both Excel and SQL Server, it seems that using Excel to build the dashboard is the best choice. The benefits are that the employees are already experienced with this tool and it does not cost the company more money. It still leaves the option open for the future that the company does invest in specialized software. However, choosing the correct application is a process that takes a long time. The pros must be weighed against the cons and the decision must be well overthought. As there is time pressure for this thesis, this is another reason Excel is the best option in this case.

4.6.3 Common mistakes when designing a dashboard

Dashboards have to portray a lot of data and information in a small space while still being easy to interpret. Designing such an artefact is challenging and mistakes are often made, even when the proper media display is chosen. The following section will describe the most common mistakes that Few (2006) mentions in his book to ensure they are avoided during this research.

- Mistake 1: Exceeding the boundaries of a single screen

The ability to see everything at once is one of the benefits of a dashboard, as this encourages comparison. When there are multiple dashboards, it is hard to see the bigger picture. As for scrolling, people often assume that any information that requires scrolling is less worthwhile or important,

while this may not be the case. Therefore, the need for scrolling needs to be limited as much as possible or be explained to the user.

- Mistake 2: Providing inadequate context

Context is needed in order to judge KPIs. Without context, the numbers do not mean anything. The user of the dashboard needs to be able to compare the number and also interpret whether the number is good or bad. The right amount of context helps the user quickly understand the dashboard.

- Mistake 3: Using excessive detail

Too much detail and information slow the user of the dashboard down as they spend time filtering out information that is not important. Often details like more decimals or time in seconds are unnecessary and distract the user.

- Mistake 4: Using a deficient measure

Sometimes it is better to give the user the degree of variances instead of the actual numbers, as then the user is left to calculate the variance themselves. For example, it might be handier to give the difference in a percentage than actual numbers, as humans cannot calculate this difference easily. When a deficient measure is used, it wastes limited space on a dashboard.

- Mistake 5: Introducing meaningless variety

People often hesitate to use the same media display for a dashboard. However, the variety of the displays is not important for the dashboard, but choosing the best display is. Trying to vary the displays increases the chance of choosing inappropriate display media.

- Mistake 6: Encoding quantitative data inaccurately

The graphs and charts used in the dashboard should be encoded correctly. For example, when a user sees the graph in Figure 7, the user assumes that the revenue is about four times the costs in January. However, the scale starts at $500 000 and not $0; therefore, the revenue is closer to twice the costs. Therefore, when encoding the displays, the data should be encoded properly, so there is no need to look at the scale to interpret the graph correctly.

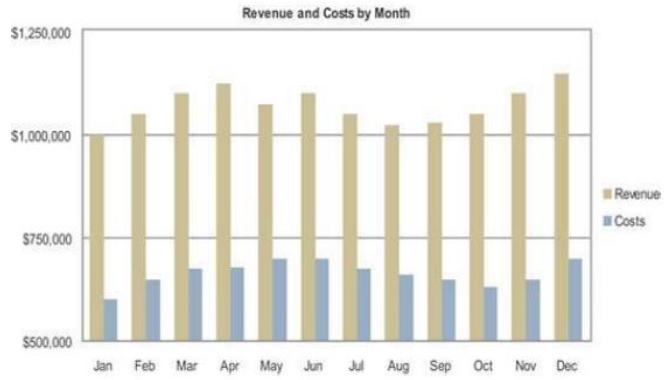


Figure 7: Example of a wrongly encoded bar graph

- Mistake 7: Arranging the data poorly

The top left of the dashboard is the most important part of the screen as that is the first part of the screen users look at. Therefore, the most vital information should be displayed there. Furthermore, the location of the media displays is also important. Graphs next to each other are often compared,

so this should be taken into mind. As well as the desired viewing sequence. Humans start looking at the dashboard in the top left and end at the bottom right, so when placing the graphs, the order in which the user will look at them should be considered.

- Mistake 8: Highlighting important data ineffectively

The users' eyes should be directed to the most important parts of the dashboard and these parts should be highlighted. When unimportant parts are highlighted, this confuses the user. However, this does not mean that the dashboard should be unattractive. A dashboard should still be pleasant to look at, as it is looked at often. The best way to do this is to display the data attractively.

- Mistake 9: Introducing useless decoration

While decoration might be nice the first time, users will most surely get bored with every design within days. The purpose of a dashboard is not to look nice, but to tell the most important KPIs quickly to users. Often decoration is a waste of space as data could have been displayed there.

- Mistake 10: Misusing colour

Bright colours should only be used to highlight content and be kept to a minimum. For other parts, less saturated colours should be used. Furthermore, the background colour should be pale, but not pure white, to soothe the users' eyes. Colour must also be used with an awareness of the surroundings, as the surroundings influence what we see. For example, in Figure 8, the word "Text" is much easier to read in the blue square than in the red square, while the colour of "Text" is the same.

Figure 8: Influence of surroundings on colour

Takeaway Chapter 4

In this chapter, research is performed to gather the knowledge necessary to build the dashboard. First, a literature review was performed to find KPIs for warehouse performance. These KPIs can be found in Appendix C. Next, the list of KPIs from the company was set up. Furthermore, KPI selection methods were researched in literature and the most prominent ones were compared. It was deemed that the Analytic Hierarchy Method (AHP) was the best method to use for KPI selection, as this method gives weights to criteria based on importance. With this method, a final list of KPIs is set up in section 5.3. The data structure of the available data was researched and explained. The definition of important columns in the data set was explained, as well as the business intelligence structure at Company X. As for dashboard design, a list was given of all possible graphs and charts that are commonly used in dashboards with a little explanation of when it is best to use them. Lastly, tips for dashboard building and common mistakes are listed. This knowledge is taken into mind when building the dashboard. The final dashboard design is determined in section 5.4.

Chapter 5: Solution design

In this chapter, the solution design will be elaborated. First, the chosen performance measurement system and the tool will be explained. Next, the process of the KPI selection will be explained as well as an explanation of the final KPIs. Finally, the design of the dashboard will also be shown.

5.1 Chosen Performance Measurement System

Company X wants to use a dashboard as a performance measurement system, but after performing a literature review a balanced scorecard also appeared as a candidate for a performance measurement system that could help solve Company X's core problem. The main differences between these two systems are that a dashboard gives constant updates about the performance and a balanced scorecard is used periodically. Furthermore, a balanced scorecard is often used to track progress while a dashboard is used to view the performance. Since the main purpose of the performance measurement system for Company X is to gain insight into the performance of the warehouse processes, a dashboard is the best fit for the wishes of Company X. Also, a dashboard provides a constant update of the performance which gives the logistics manager more insight than the periodical update from a balanced scorecard.

5.2 Tool selection

Several tools exist that help with building and designing a dashboard. For this research, the dashboard will be designed in Microsoft Excel. There are a few reasons for this, firstly every employee at the company already has access to Excel. This is convenient for two reasons. First off, it means that Company X will not have to go through the process of installing a new dashboard building tool on every employee's computer, which will undoubtedly take a lot of time and secondly it means that no extra money has to be invested into buying the license for a dashboard tool. As it is unknown how big of an impact the dashboard will have, spending a lot of money on a tool is an unwanted risk. If it turns out that the dashboard is a success, the decision can always be made later to switch to a professional dashboard-building tool.

Excel is favourable for another reason. Both Excel and SQL Server are from Microsoft. SQL Server is the programme that Company X uses to store data in the database. Since both programmes are from Microsoft, the applications are extremely compatible with each other. With the Power Pivot add-in in Excel, it is possible to load the database data from the SQL Server directly into Excel. This makes the loading of data step quite easy.

As mentioned briefly before, another option was to buy dashboard software, as Company X does not currently have a license for such a programme. But the process of selecting the best programme and implementing it would take too long and be the more expensive option. Currently, the warehouse managers already use Excel to monitor the performance, so they are already experienced with this programme and will understand how to use the dashboard quickly. Excel is not the best option, as it is not a programme specialized for dashboard design. However, Excel can definitely be used to build the first dashboard. When the results are positive, another more specialized tool can be chosen.

5.3 KPI Selection

To select the final KPIs from the list of possible KPIs, the Analytic Hierarchy Process method is used. For this, first, the weights of the criteria are determined. How this is done is described in Appendix D. The weights were determined after a meeting with the company supervisors. The weights for the SMART criteria are found in Table 8. The consistency check is performed in Appendix E.

Criterion	Weight
Specific	6.33%
Measurable	31.75%
Achievable	13.30%
Relevant	42.65%
Time-bound	5.98%

Table 8: Weights for the AHP criteria

After determining the weights for each criterion, each KPI is then scored on a scale from one to five for each criterion. The meaning of the numbers can be found in Table 9. The scores for each criterion are multiplied by the weight of the criterion to come to a final score.

1	2	3	4	5
Poor	Insufficient	Neutral	Sufficient	Good

Table 9: Definition of the 1-5 scores

In Table 10 the determined scores for the KPIs can be found.

	S	M	A	R	T	Total
Literature KPIs						
Receiving Time	5	3	1	5	5	3,83
Putaway Time	5	5	5	5	5	5,00
Order picking time	5	5	5	5	5	5,00
Queuing time	5	5	5	5	5	5,00
Dock to stock time	5	5	5	5	5	5,00
Equipment downtime	5	1	1	3	5	2,35
Inventory costs	5	3	1	2	5	2,55
Order processing cost	5	3	1	2	4	2,49
Labour cost	5	3	1	2	4	2,49
Cost as a % of sales	5	3	1	2	4	2,49
Maintenance cost	5	3	1	2	4	2,49
Receiving accuracy	5	3	3	3	5	3,25
Picking accuracy	5	3	3	3	5	3,25
Storage accuracy	5	3	3	3	5	3,25
Labour productivity	5	3	3	4	5	3,67
Throughput	5	5	5	5	5	5,00
Warehouse utilisation	5	3	1	2	3	2,43
Inventory space utilisation	5	3	1	2	3	2,43
Outbound space utilisation	5	3	1	2	3	2,43
Picking productivity	5	5	5	5	5	5,00
Storage productivity	5	4	4	3	5	3,70
Receiving productivity	5	5	5	5	5	5,00
Turnover	5	3	3	2	5	2,82
						0

Company KPIs						
Order Handling Time	5	5	5	5	5	5,00
Warehouse Time Order	5	3	1	5	5	3,83
# transactions per order	5	5	5	4	5	4,57
# people on the same order	5	5	5	4	5	4,57
# pallets per day	5	5	5	3	5	4,15
Pallet creation time	5	5	5	3	5	4,15
# transactions per hour for each transaction type	5	5	5	5	5	5,00
Distribution of carriers	5	5	5	5	5	5,00
Distribution of destination countries	5	5	5	5	5	5,00

Table 10: KPI Selection

Each KPI with a score higher than four was selected to be on the dashboard, as a score of 4,00 was seen as the cut-off point between a relevant and irrelevant KPI. The cut-off point of 4,00 was decided as this was seen as the point from which KPIs became relevant. This cut-off point was decided on together with the logistics manager. The idea was that a higher cut-off point might have meant that interesting KPIs were not included in the dashboard and a lower cut-off point would mean that the dashboard would become clustered with insignificant KPIs that would not give the manager more insight. The cut-off point could have been higher, to select only the most essential KPIs, but since the company is not experienced with dashboards and the manager did not have a clear vision of what is and isn't relevant, it was decided to keep the cut-off point a bit lower to include more KPIs. This way more KPIs could be included in the dashboards and some might turn out to be more meaningful than previously thought. In dashboard building, it is always easier to delete KPIs from a dashboard than to include new ones.

In the paragraphs below it will be explained in detail what the KPIs actually mean and what they calculate. Also, it is explained how the KPI is calculated from Company X's stored data and how the KPI will be visualized in the dashboard.

Order handling time = "Gem doorlooptijd outbound"

This measure shows the average time it takes for Company X to handle a single outbound order. In this case, this means the time from the moment an employee starts working on the order until the order is put in a truck. The time that the order has not yet been picked up but has already come through the system is thus not included in this KPI. Because a timestamp is saved at the moment of each scan, both the beginning time and end time of a transaction are known. Each transaction also has a name to specify what the transaction was. For the outbound orders, only specific transactions are needed to track when the order has been picked up and when it is finished. To then calculate this KPI, the earliest beginning time of an Order ID is taken as well as the latest ending time for the same Order ID, only for the specific transactions that occur when picking up an order. The time between those is the order handling time. The KPI on the dashboard shows the average for all of the orders that fit the settings. This is shown in a bar graph with the specific time in red on top. Red is a very visible colour that attracts your attention. This helps the dashboard user quickly see the average outbound order handling time without having to look at the axis.

For this and some other KPIs, the idea is that in the future target are introduced to the KPIs so that it can easily be viewed whether the company is performing well or not. Instead of a simple bar graph, the KPI would then be visualized with a bullet graph. As currently no performance measurement system exists at Company X, the logistics manager does not have data on average KPI scores. As such, they do not have target times for the KPIs and these can only be introduced when they have collected data after working with the dashboard for a few months.

Putaway time = "Gemiddelde Doorlooptijd Inbound Order"

This KPI is the time it takes from when an item is ready to be put away to when it has been put in the correct place. This KPI works the same as the previous one, but this time for the inbound order. As the transactions are labelled in the data, this KPI can be calculated with transactions that are specific to this task. The first transaction in an inbound order is always "ONTV LPN" and the last transaction is always "INSL LPN." For each order ID, the first instance of "ONTV LPN" and the last instance of "INSL LPN" is selected and the time between these two is seen as the Putaway time. The KPI on the dashboard shows the average time for the orders that fit the settings. This KPI is also shown in a bar graph with the KPI value in red.

Number of transactions per order = "Gemiddeld Aantal Transacties Per Order"

This KPI shows the number of transactions per order. The calculation for this KPI is simple. The number of transactions belonging to a unique Order ID is counted. This number is then written down for each individual order. The KPI is then shown on the dashboard as an average for all of the orders that fit the selected dashboard settings. This is also shown in a bar graph with the KPI value in red.

Number of people working on the same order = "Gemiddeld Aantal Personen Dat Werkt Aan Een Order"

This KPI shows the average number of people that work on the same outbound order. For this, per unique Order ID, the number of unique User_IDs is counted. As such, the number of individuals that worked on an order with the same ID is calculated for each outbound order. This KPI is shown on the dashboard as an average for all the orders that fit the selected dashboard settings. This is also shown in a bar graph with the KPI value in red.

The number of transactions per hour for each transaction type = "Overzicht transacties per uur"

The name of this KPI might sound a bit vague but it is quite a simple KPI actually. As written in section 4.4, there are a limited number of transactions possible and each transaction has a name. This KPI simply shows an overview of the number of scans for each transaction name in a table. The number of scans is shown per hour, per day. This KPI is shown in a table, as this is the most compact and uncluttered way to show this KPI, as there are a lot of entries to this KPI. In this table, the throughput of the warehouse is also visible, one of the transactions translates directly to the throughput. This transaction is Weigh oLPN.

Distribution Carriers = "Verdeling Vervoerders"

This KPI is shown in a table, again because of the amount of information this KPI contains. The table shows the order distribution of the carriers that are used for outbound orders, meaning that exact numbers are shown for how many orders each carrier transports each day. In this case, distribution means the distribution of outbound orders. There are three main transactions for which the logistics manager thinks the distribution is interesting. These are for the transactions "Laden Trailer," "Pick Carton" and "Weigh LPN." For each order, the carrier is noted. Then the totals for each day are put

into a table. This way, the KPI shows the distribution of the carriers. The table gives a quick overview of how many outbound orders are transported via each carrier.

Distribution Countries = "Verdeling Landen"

This KPI is exactly the same as the Distribution for carriers, only now the destination country is noted instead of the used carrier. There are again three tables for the same transactions. These tables thus give a quick overview of how many outbound orders go to what country.

Picking and Receiving Productivity = "Productiviteit"

This KPI shows the average number of scans per person during the day for the selected settings. There are four main activities for which the logistics manager would like to know the productivity. The first is the transaction Pick Carton. The logistics manager already had some information about this, as he had an overview of the total number of picks per day. This KPI is more detailed. The other transactions are the receiving of LPNs, the weighing of LPNs and loading orders into the truck. This KPI is calculated by dividing the total number of scans for that transaction in that hour by the number of individuals that did at least one scan for that transaction in that hour. This means that it shows the average number of scans for one person in that hour for that specific transaction. The KPI is visualized with a line graph, with the specific numbers underneath. This is to easily portray the progression of productivity over a day. The productivity is calculated for each selected day and the average of these is taken for the KPI.

Average number of pallets per day = "Gemiddeld Aantal Pallets Per Dag"

A pallet is created when an order is so large that it needs a pallet to support it. This happens several times per day. Each pallet is given a unique pallet ID. This KPI is calculated by counting the total number of different pallet IDs per day. The totals for each day are then written down. The KPI is shown on the dashboard as the average of the selected days. Again, the KPI value is shown in bright red.

Average pallet creation time = "Gemiddelde Tijd Nodig Om Een Pallet Te Maken"

This KPI shows the time it takes from when the first item is put on the pallet to the last item. As each scan is timed precisely, the time difference between the first and last scan of the transaction "Palletize cartons" for a unique pallet ID is taken as the pallet creation time. For each single pallet ID, the pallet creation time is written down. On the dashboard, the KPI value is shown in bright red as the average of the creation times.

Order Picking time, Dock to Stock time and Queueing time

When selecting the KPIs, the perception was that these three KPIs were able to be calculated with the data available at that time. However, this turned out to not be the case. Therefore, the recommendation to the company is to add these KPIs at a later stage. The data is already being stored but is not yet available for the dashboard. For this to be the case, the correct columns have to be put in the correct table. To do this, contact has to be sought with the French department. They also helped with extracting data for this dashboard and have exceptional knowledge of Microsoft's SQL server.

5.4 Dashboard Design

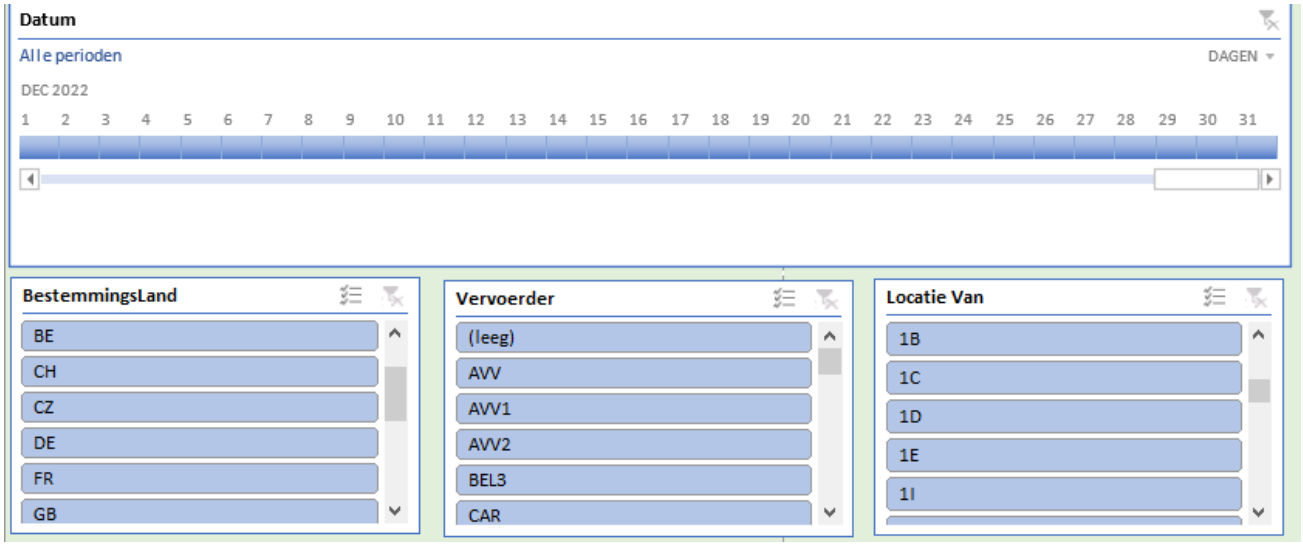


Figure 9: The settings of the dashboard

There are a few settings in the top left of the dashboard that influence the outcome of the KPIs. Changing these settings changes what data is used to calculate KPIs. The settings are therefore the most important and are thus put in the top right, the most prominent place in a dashboard. The settings can be found in Figure 9.

The first setting is the date. In this timeline, dates can be selected for which the KPIs in the dashboard will be calculated. The next setting is the selection of destination countries. The user can select which destination countries for outbound orders he wants to view the results. For example, if the user only selects “BE,” the KPI shown for the outbounds orders will have been calculated solely with orders that have Belgium as the destination. The setting for carriers does the same, only for the carriers. For these two settings, only the KPIs that have to do with outbound orders are affected.

The next setting is the location in the warehouse in the Netherlands. There are three main locations: station 1, station 2 and the plateau. Each of these locations have subsections. In this setting, the locations can be selected, so that only data from certain locations is included.

The main part of the dashboard is all in one sheet. This is the main sheet and can be found in Figure 10. The graphs are easy to interpret and the colours used ensure that the most important data stands out. The background colour is calm and does not distract the user. There is no need for scrolling as everything can be viewed at once. There is some room left in the bottom right, which contradicts the idea that non-data pixels should be minimized. However, there is an idea behind this left-over space. Room is left over so that KPIs can be added easily without having to change up the whole dashboard. As there are already plans to add more KPIs once the data is there, this seems like the best idea. Otherwise, the whole dashboard setup would have to change when a new KPI is introduced, and an introduction of a KPI in the coming months seems inevitable.

The carrier and country distribution are in separate sheets, as well as the overview of the number of transactions. They are found in Figures 11, 12 and 13. For the carrier and country distribution, just one example of a table is given. The table for the overview of the number of transactions is cut off but the idea of the table is still clear. These KPIs could not be visualized in any other way as the whole table is needed for context.

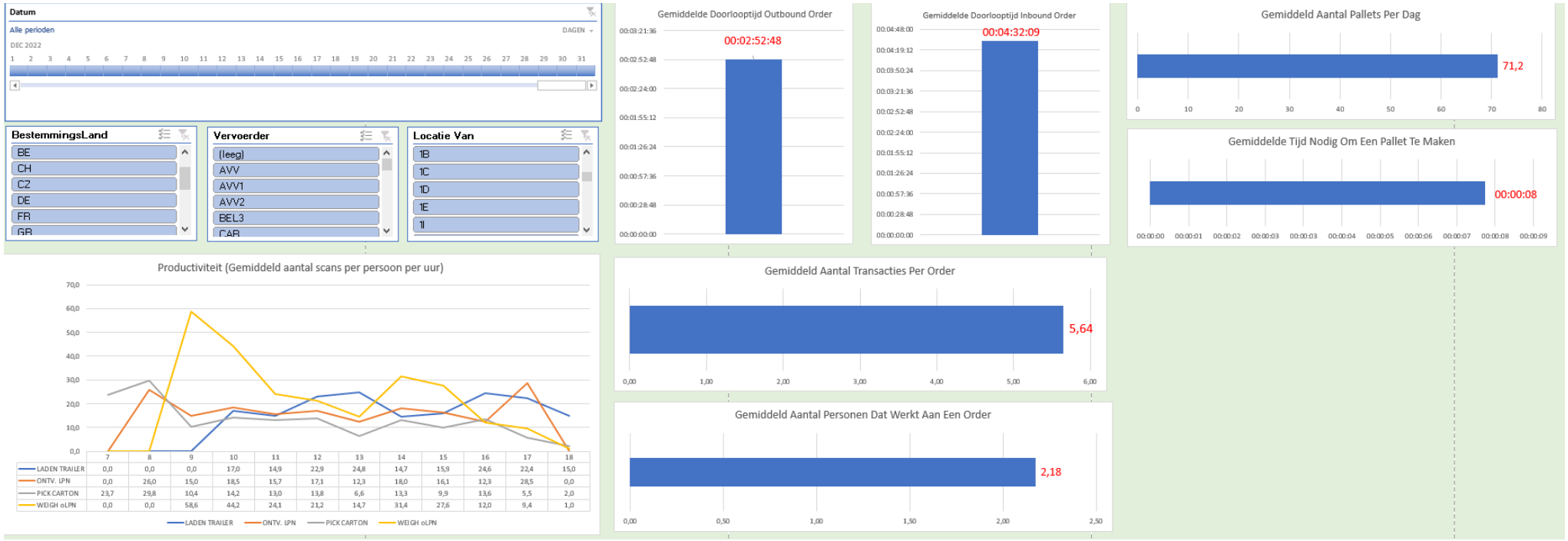


Figure 10: Main Dashboard Sheet

Telling van vervoerders	Vervoerder																					
Datum	AVV	AVV1	AVV2	CAR	CAR1	CAR2	CARV	DACH	DPD	FABR	GEF	GEF1	GEF2	GEFV	HEP2	KEYD	KEYS	MAFS	TSJE	VASN	WITR	WITS	Eindtotaal
3-8-2022		64	10		69	8	70	6	2	165		96			10	6			71					577
4-8-2022		81	15		163	7	27	49	5	375	21	169		16	61				99					1088
5-8-2022		53	12		204	3	21	50	17	342	7	178	3	24	21		2	46	69	32	2	32	28	1146
8-8-2022		93	24	4	140	3	33	73	6	296		207		17	33				199					1128
9-8-2022		82	22		228	1	57	94	3	324	16	140	11	18	21				76					1093
Eindtotaal		**373**	**83**	**4**	**804**	**22**	**208**	**272**	**33**	**1502**	**44**	**790**	**14**	**75**	**146**	**6**	**2**	**46**	**514**	**32**	**2**	**32**	**28**	**5032**

Figure 11: Carrier distribution

Transactie	PICK CARTON													
Telling van landen	**Landen**													
Datum	**AT**	**BE**	**CH**	**CZ**	**DE**	**FR**	**GB**	**IT**	**LU**	**MC**	**NL**	**PL**	**SE**	**Eindtotaal**
3-8-2022		78	9	2	10	210		4	1		254		3	571
4-8-2022		242	3	8	27	789	17				596		2	1684
5-8-2022	2	282	76		129	668	1		3	14	485		1	1661
8-8-2022	71	323	5	72	79	812			5		625	69	63	2124
9-8-2022		305	2	22	51	554	29		2		850	139	55	2009
Eindtotaal	**73**	**1230**	**95**	**104**	**296**	**3033**	**47**	**4**	**11**	**14**	**2810**	**208**	**124**	**8049**

Figure 12: Country Distribution

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
2	Transactie		6	7	8	9	10	11	12	13	14	15	16	17	18		
3	**ONTV. LPN**		**160**	**270**	**172**	**291**	**275**	**288**	**181**	**359**	**154**	**82**	**114**				
4	3-8-2022										20	10	64				
5	4-8-2022		74	82	20	24	97	119	38	134	20		18				
6	5-8-2022		32	76	51	82	43	78	28	28	38						
7	8-8-2022		24	2	22	62	66	50	35	65	34	58	22				
8	9-8-2022		30	110	79	123	69	41	80	132	42	14	10				
9																	
10	**Cancel OLPN**					**2**	**1**	**1**	**5**	**1**	**5**		**6**				
11	4-8-2022						1		2		1						
12	5-8-2022								3	1	2						
13	8-8-2022							1			2						
14	9-8-2022					2							6				
15																	
16	**Cancel Order**					**2**	**1**	**1**	**5**	**1**	**5**		**6**				
17	4-8-2022						1		2		1						
18	5-8-2022								3	1	2						
19	8-8-2022							1			2						
20	9-8-2022					2							6				
21																	
22	**CREEER LPN**			**1**		**4**	**2**		**2**	**1**	**1**	**2**	**1**				
23	4-8-2022					1	1		1			1	1				
24	5-8-2022								1		1	1					

Grafiekgebied

Transactie

- INSL PLATEAU
- LADEN TRAILER
- Lock Unlock
- Modify iLPN
- ONTV. LPN
- ONTV. XDK CROSSDO
- PALLETISEER CARTONS
- PICK CARTON
- PICK PER ZONE
- REA Fill Actv
- REA Fill Actv Dyn
- Replenish Active
- RF Close Trailer
- Shipments UI

Figure 13: Table with overview of transactions

Takeaway Chapter 5

In this chapter, the decisions for the dashboard and the final dashboard design are explained. Firstly, the chosen performance measurement system is indeed a dashboard as this fits the wishes of Company X better. A dashboard can focus on one sector while a balanced scorecard is meant to view the performance of multiple sectors within a company. Furthermore, a dashboard gives constant updates on the performance while a balanced scorecard only gives period updates. As the company desired a performance measurement system solely for the warehouse and wanted daily updates, the dashboard was the logical choice. The dashboard is built in Excel with the help of the Power-Pivot add-in. Every employee at Company X already has access to Excel and Excel is easy to understand. Therefore, Excel is chosen as the company then does not have to invest in specialized dashboard-building software. The KPIs that are included in the final dashboard are the following: order handling time, putaway time, distribution countries, picking and receiving productivity, the average number of pallets per day, the average pallet creation time, the average number of transactions per order, the average number of transactions per order, the average number of people working on the same order, number of transactions per hour for each transaction type and distribution carriers. The final dashboard design is explained in the pages above. The rules of thumb and tips from section 4.6 were followed when designing the dashboard.

Chapter 6: Implementation

Implementing a dashboard is no simple feat. Change in an organization is often complicated and it should not be assumed that the process goes smoothly if no effort is made to ensure that the dashboard is adopted appropriately. While the dashboard will only affect a small part of the company, it is good to consider the possible resistance to change. In this case, the change will be the newly introduced dashboard, which was not there before and the introduction of such a dashboard might influence the way of working for several employees. Next to the psychological side of change, there is also a technical side to implementing the dashboard. At Company X a Business Intelligence structure already exists and the newly created dashboard will have to be incorporated into this structure without affecting the present structure. This is because it is not feasible to change the whole structure to add a dashboard as this will be way too much work. In literature, several models for change management exist. The most prominent models are the 8-step model from Kotter and Lewin's change management model (Kotter, 2007). Both are pretty similar in the way of working, but Kotter's model goes more in-depth and is more guided toward change in an organization, while Lewin's model is more about general change. Both models state that change begins with making people realise there is a need for change and making them support the change. Instead of the eight steps from Kotter, Lewin's model only has three steps. These are 'unfreeze,' 'transition' and 'freeze.' As the model from Kotter is more detailed, recent and suited to this change, the 8-step model from Kotter will be used for implementing the dashboard, to ensure the change is supported and that the dashboard is adopted correctly. Below, the model will shortly be elaborated on how each step will be executed.

Step 1: Establishing a Sense of Urgency

Over 50% of companies fail in this step, according to Kotter (2007), so this is a vital step. Since, however, the company itself produced the idea of a dashboard, there is already a sense of urgency present. Moreover, from every conversation, it is clear that the change is welcome and that the logistics manager is enthusiastic about implementing the dashboard. He will become the main user of the dashboard.

Step 2: Forming a Powerful Guiding Coalition

In this step, a group must be formed that both have the power to change things and are committed to the cause. This dashboard will be created specifically for the warehouse. Therefore, the logistics manager and business intelligence manager are included in the coalition as both have enough power inside the company to realise change, are enthusiastic about the dashboard and have excellent knowledge about the warehouse and the data needed for the dashboard.

Step 3: Creating a Vision

The vision needs to be easy to communicate and appeal to the stakeholders. The goal of this research is an operational dashboard that adds something to the warehouse department. The idea is that the dashboard will be used to base decisions on and to improve forecasting. The stakeholders know what a dashboard is and what it can add. To create this dashboard, a research plan has been created. This plan is elaborated on in Chapter 1.

Step 4: Communicating the vision

Transformation is impossible without people willing to help. As every employee has only been positive about the introduction of a dashboard, this will not be a problem. Communicating the vision will be one with the stakeholders and employees that work on the warehouse floor. The higher-ups, already know of the dashboard, that it is being worked on, what the benefits and what it can add to the work floor. When the dashboard is complete, a presentation will be given to them to introduce the dashboard. The other employees will be notified when the dashboard is fully functional and will receive information on how it works. The current idea is that this will be done in the form of workshops.

Step 5: Empowering Others to Act on the Vision
In this step, the systems or structures that undermine the vision need to be removed. In this case, removing anything is unnecessary, as the dashboard is extra and is not replacing anything. If there is still any resistance from influential individuals this needs to be dealt with, but again the change is very much supported at Company X. Resistance is not expected as the employees do not need to change their way of working.

Step 6: Planning for and Creating Short-Term Wins
This step can only be done when the dashboard is fully functional and has been operational for a few months. This is out of the scope of this thesis. First, the managers have to notice the difference the dashboard makes. These are the short-term wins. Next, the improvements need to be visible to the employees.

Step 7: Consolidating Improvements and Producing Still More Change
If the change is proven to work and short-term wins have been achieved, more significant changes can be made with the credibility gathered.

Step 8: Institutionalizing New Approaches
The last step is integrating the new change into the company's structure. Using the dashboard should become a habit. An example of this could be to discuss the previous days' dashboard results at the beginning of each morning. Furthermore, the dashboard could be updated or changed over the years to accompany the ever-changing goals of the company.

Not only is there a psychological side to the change, but also a technical side. The first step is ensuring the right people have access to the dashboard. Giving them access can be done quickly as the Excel document can be shared with those people. However, for it to work for them, they also need to have Microsoft's SQL server on their computer, with access to the correct database. This will take a little bit of effort, but it is possible. When people have bot access to the document and database, they can use and update the dashboard. As they have access to the document and the database, it is possible to update the dashboard to their liking in the future. A dashboard manual is created, as part of this research, for the company to ensure successful integration of the dashboard. This manual is in Dutch. This manual explains how the dashboard and KPIs are set up and what parts do what in the dashboard. It also explains how the connection with the dashboard is made and how they can change what data is gathered from the database. Lastly, it also explains how the company can change the query to gather data from longer or shorter periods of time.

Takeaway Chapter 6

In this chapter, the possible challenges for the implementation are discussed. There is a technical side to the implementation as well as a psychological side. To ensure the implementation goes smoothly, a manual for the dashboard is provided. This manual carefully explains how the dashboard was created and how the KPIs are calculated. Also included in this manual are explanations of how data can be added to the database on how the dashboard can be changed. The dashboard was uploaded onto the OneDrive of the company, giving the correct people access. To ensure is accepted in the company, Kotter's 8-step model of change was followed and for each step, it was explained how this step was carried out. Steps 1 through 5 are already performed. These steps are, in order; establishing a sense of urgency, forming a powerful guiding coalition, creating a vision, communicating the vision and empowering others to act on the vision. Steps 6,7 and 8 can only be performed when the dashboard has been operational for some time. These steps are, in order; planning for and creating short-term wins, consolidating improvements and producing still more change and institutionalizing new approaches. If Company X follows the last three steps as well, the dashboard will be successfully implemented and integrated into the company.

Chapter 7: Evaluation

This chapter is the fifth step of the DSRM. In this step, the artefact is evaluated and together with the logistics manager the dashboard is assessed and it is determined whether the dashboard actually adds something to Company X and is an improvement from the previous situation. A semi-structured interview with the logistics manager was held after presenting him with the final version of the dashboard to evaluate the dashboard. Below, his answers and opinion are put into easily readable paragraphs.

7.1 Evaluation with Company X's logistics manager

The logistics manager is very content with the dashboard. He sees it as something that will be used in the company, as opposed to some other assignments by students that end up on the shelves without ever being used by the company. He is enthusiastic about the dashboard and the possibilities. He is also sure the dashboard is an improvement from the previous situation. The data for the dashboard was there for a long time, but there was never any time to create the dashboard, even though he would have liked to have it. Now that the dashboard is there, he finally has insight into the large data set.

Furthermore, he likes the usability of the dashboard. The data can be refreshed with one click, making it easy to use and easily accessible. He is pleased with both the technical and operational sides of the dashboard. So, he likes what the dashboard can do, but it is also a big plus that the dashboard is already operational and can immediately be used by him. This also makes the likelihood that the dashboard will be used higher. The dashboard will be used in his everyday work. It can help with insight into the software, as they now have access to exact numbers they had to guess before. This dashboard also helps argue any assumptions or estimations with actual data. It can also help with forecasting and he gave one example. For each instance of a "weigh oLPN" transaction, a sticker is used. With the help of this dashboard, he knows exactly how many scans of "weigh oLPN" there are on average in a week. Based on that, he can schedule when he needs to order new ones because it has happened before that the employees in the warehouse contact him too late for that.

He is happy with the KPIs on the dashboard, although he mentioned that now that he sees KPI "Pallet creation time" he does not think it is that relevant. Also, he is still interested in the KPI "Order warehouse time," but the data was not yet available. The same holds for Order Picking, Queueing and Dock to Stock time. These KPIs will be added in the future. More data needs to be added to the SQL table for this KPI, which will take some time. In the future, he would like to zoom in on the individual performance of employees and more specific instances that do not happen that often. The biggest impact will come when the dashboard has been in place for a few months. Then employees will know what is interesting and what is not. Of course, they will require some time to learn this and then they could set targets for KPIs, which will make the dashboard more insightful.

7.2 Discussion

One point of discussion is that the KPI selection is only made together with the logistics manager. The dashboard tells information about many employees, so it can be argued that they would also like to be involved in the KPI selection process. However, the logistics manager will be the one using the dashboard. Another point of discussion is that the assumption is made that the employees scan at the right time. This might not always be the case, but for the sake of the research, this had to be assumed.

Takeaway Chapter 7

In this chapter, the dashboard is evaluated. This is done with the help of a semi-structured interview with the logistics manager. The interview is held with him as he is the person who will be using the

dashboard the most at Company X. The manager was extremely content with the dashboard. He was enthusiastic during the whole conversation and was happy that the dashboard was already operational. This was a big plus according to him. He already had plans of using the dashboard and he was sure this wasn't going to end up on the shelves but will actually end up being used.

As for the KPIs present on the dashboard, he stated that he hoped that some more KPIs would be available that he was interested in, but the data needed to calculate these KPIs was not available. The KPIs currently present do already provide a much better insight than he had before and the manager confirmed that the new situation is much better than the old situation.

Chapter 8: Conclusion, limitations and recommendations

This chapter will conclude the research by answering the main research question as well as the sub-questions, explain how the research contributes to theory and practice and elaborate on limitations and recommendations. As a refresher, first, a summary of the problem is given.

8.1 Motivation

For this thesis, research was performed to combat a problem Company X faced. Company X is a B2B company that sells everything a business needs, which means that they have a lot of varying items in stock. The Dutch department of this international company has two warehouses. This company uses a Warehouse Management System. This system tracks everything that happens in the warehouse with the help of terminals. This is where the problem starts, as Company X does gather a lot of data about the warehouse processes but no system to analyse the data or it does not use the collected data to make decisions or use it to forecast. The data is being collected for quite some time now, but they simply have not had time to work on a dashboard. Because the data is not being analysed properly, they lacked insight into the performance of the warehouse. The idea was to introduce a performance measurement system that would help the Company analyse the large dataset and use it to predict and argue decisions. A performance measurement system would summarize the heaps of data they already collected and output it in telling KPIs that the logistics manager could use to make decisions. To structure the research and to structure the way the problem will be solved, a main research question was set up. This research question is the following:

The main research question was *How can a performance measurement system help improve the insight into the performance of the warehouse processes at Company X?*

8.2 Conclusion

To answer this research question, sub-questions were also set up. These questions are a bit smaller and the answers provide the knowledge necessary for the research question. Below, answers to the sub-questions can be found, explained as well is how the answers were found and where the fully detailed answers can be found in this thesis. The main research question will then be answered at the end of the section after all of the sub-questions have been answered, as they help answer the research question.

1. *What is the situation regarding the warehouse processes of Company X?*

The purpose of answering this question is to get a good overview of the way of working in Company X's warehouses. This would help in determining what is important to include in the performance measurement model. To answer this question, conversations were held with employees. Furthermore, a tour of the warehouse was given twice to explain in detail how everything worked. From the conversation and the tours, an accurate description of the current situation could be given. In short, the warehouse processes of Company X can be divided into six separate processes. The first is receiving, where inbound orders are checked and cleared. The following process is putting away, where items are moved to the correct place. The next process is storing, where inventory is counted and locations of items can be changed. The fourth process is the picking of outbound orders. The following process is the packing of the orders. The last step is shipping, where the products are loaded into the trucks. A more detailed version of the answer can be found in section 2.1.

2. *What is the company's current level of insight into the processes in its warehouse?*

This question exists to determine the current situation, which can later be compared to the new situation. To answer the second subquestion, a discussion was held with the logistics manager of

Company X. In this conversation, he showed exactly how the Warehouse Management System worked and how he could track exactly where an order was. From the conversation, it also became clear that he did not have a lot of insight into the performance as the insight of the logistic manager had consisted of one Excel document. In this document, he tracked the performance of the warehouse as well as the scheduling of employees. There was one KPI in the file which was picking productivity, is measured. This productivity is calculated by dividing the number of scheduled hours by the number of items picked. A database with a lot of data about the warehouse processes does already exist but is not used. The conclusion is thus that Company X does indeed lack insight into the performance of the warehouse processes. This question was answered in more detail in section 2.3.

3. *What tools for performance measurement exist?*

As a performance measurement tool will be introduced to increase insight, this question serves to find out what tools could be used for this. A literature review was used to answer the third subquestion. From this review, it became apparent that the most commonly used performance measurement tools are a balanced scorecard and a dashboard. A dashboard is a graphical user interface that shows the user an overview of selected key performance indicators. It helps the company measure the performance of processes and individuals over time. It consists of graphs and charts that communicate to the user the outcome of the data collected from the databases. (Smith, 2003). A balanced scorecard is a performance measurement system that uses a set of goals and specific measures to give managers a quick overview of the business and its progress. It was founded by Kaplan and Norton (1992) to present managers with a balanced presentation of both financial and operational measures. The idea is that the performance of different company parts is brought together into one report. After reviewing both options, the dashboard fits the wishes of Company X. Therefore, the decision was taken to build a dashboard to generate insight. The full answer to this question can be found in section 2.4.

4. *What are appropriate KPIs for Company X to gain insight into the productivity of the warehouse processes?*
    a. *How can these KPIs be measured and visualized?*

A vital step in building a performance measurement tool is to select relevant KPIs. The goal of this question is to find those KPIs. After performing a literature study and a brainstorming session with the logistics manager, a list of possible KPIs for the dashboard was lined up. This list consisted of two parts; the first one was the KPI from literature and the second part were the ones that the logistics manager would like to have included in the dashboard. However, from this list, the most relevant and impactful KPIs would have to be selected, as not every KPI could be included in the dashboard and it could be the case that the KPI could not be calculated with the available data. To decide on the final list of KPIs, a proper selection method had to be used. After a literature study, the Analytic Hierarchy Process method seemed the most fitting. With the help of the Analytic Hierarchy Process method, the most interesting KPIs from the list were selected. These are; Putaway Time, Order picking time, Queueing Time, Dock to Stock time, Throughput, Picking Productivity, Receiving Productivity, Order Handling Time, Number of Transactions per order, Number of people that work on the same order, Number of pallets created per day, Pallet creation time, Number of transactions per hour for each transaction type, Distribution of carriers and Distribution of destination countries. For part A of question four, again literature study was performed. This was done in order to learn more about all the options that exist when visualizing KPIs and what charts are useful when. These KPIs are visualized in graphs and charts. In the dashboard for Company X, the KPIs are visualized by bar and line graphs. The data for the KPIs comes from the SQL database of Company X. With the use of the Power Pivot add-in, the data

is loaded into Excel. With the use of pivot tables, the KPIs are calculated in Excel. The full elaboration of both answers can be found in sections 4.1 to section 4.5.

5. *How to design a data dashboard that monitors the performance of the warehouse processes of Company X?*
    a. *How should this dashboard be implemented within Company X?*

As the decision was taken to build a dashboard, the next step was to research the best way to do this. The goal of this question is therefore to gather knowledge about dashboard design. To answer this subquestion, a literature study was done to find out what literature said about dashboard design. For dashboard design, there are a few rules of thumb. For example, people look at the top left part of the screen first, out of habit. Therefore, the most crucial part of the dashboard should be put there. Furthermore, while the dashboard should look nice, the most important part is what it tells the user. Therefore, this should stand out in the dashboard. Also, the goal of dashboard building is to include as many data pixels as possible and make sure they stand out. Non-data pixels should be minimized. Next, the colours used should be calm and easy on the eye. For the implementation, Kotter's 8-step method was used. This is a model that helps with change within a company. In this case, the addition of the dashboard is the change. Furthermore, a detailed manual about the dashboard was created and a presentation was given as well. This is to help the employees understand the dashboard and what it can and cannot do so that it is implemented correctly. The answer to this subquestion can be found in section 4.6. The answer to subquestion 5a can be found in Chapter 6.

6. *To what degree did the dashboard meet the objectives of the research and thus improve the insight?*

The purpose of this question is to compare the new situation with the old situation and to investigate what the dashboard achieved. To help answer this subquestion an evaluative interview was held with the logistics manager together with the logistics manager. This was a semi-structured interview where some questions were prepared but the conversation could also flow freely. The answer to this question is that the dashboard did meet the objectives of the research. The logistics manager of Company X was very content with the dashboard and the fact that it can be implemented and used immediately. Almost all of the desired KPIs are also featured on the dashboard. The data for the other desired KPIs is there, but it needs to be connected in SQL, which will take some time. A more detailed evaluation can be found in Chapter 7.

Now that all of the sub-questions have been answered, the main research question can be answered.

Main research question: *How can a performance measurement system help improve the insight into the performance of the warehouse processes at Company X?*

The first thing that the dashboard adds to the insight is that it provides an overview of KPIs that were not available before. It wasn't clear how the warehouse was performing. The dashboard gives the logistics manager a handy oversight that was not available before. This overview is automatic and can be refreshed each morning, the KPIs will then update automatically. Before, the logistics manager had to update the only KPI they had manually in an Excel file. Now, the dashboard gives the manager the scores of each KPI automatically.

Next, this dashboard is adaptable. This helps with insight in the sense that it can be changed quickly to add a new KPI that gives the manager new insight. If a new form of data is collected, this can quickly be added to the database and the dashboard. A characteristic of a dashboard is that it improves constantly over time. Relevant KPIs are added to the dashboard and less relevant KPIs could be removed. In the old sheet, it was quite hard to introduce a new KPI that would give the manager more insight. Now it is possible to do it quite easily.

Another thing that the dashboard adds is comparability. As the date can be changed quickly in the dashboard, the performance of different months or years can quickly be compared. This not was possible before the introduction of the dashboard. Therefore, it is easier to track the performance and verify whether the performance is improving. This gives the manager more insight into the performance of the dashboard, as he can easily compare performance. Comparability also helps put the performance into perspective for the manager. The dashboard also introduces the possibility to add targets to KPIs. It is impossible to add target scores to KPIs with context and the dashboard provides this context. From the dashboard, average scores for KPIs can be determined and from these scores can be added. Target scores add massively to the insight, as it will be possible to view with one glance whether the warehouse is performing properly or not.

The increased insight that this dashboard gives can be used to back decisions or to forecast. An example of possible forecasting is that for each instance of a “weigh oLPN” transaction, a sticker is used. With the help of this dashboard, the logistics manager knows exactly how many scans of “weigh oLPN” there are on average in a week and thus how many stickers are needed Based on that, he can schedule when he needs to order new ones because it has happened before that the employees in the warehouse contact him too late for that. This kind of exact information was not available to him before. The dashboard can also be used to show other people exact numbers of the performance of the warehouse and use it to support decisions. If for example, the order handling times for one specific country are always longer than average, this will come up in the dashboard and based on this the decision can be taken to shift more workforce to that country.

The dashboard can also introduce a new daily routine. The KPIs provide a summary of the KPI scores of the previous day. In the schedule of the warehouse of Company X, there are already 15 minutes scheduled each morning to discuss the plan for that day and what parts to focus on. Reviewing and showing the dashboard results from the day before can be added to this meeting. This does not necessarily add to the insight but it is more something that can be done with the increased insight. It will add something to the general warehouse process. With the actual numbers from the KPIs, it is easier to prove what part needs in improvement in the warehouse.

8.2 Contribution to theory

This thesis uses a literature review study as a basis for the research. Literature is used to create a theoretical framework for dashboard creation. This study's theoretical framework is used to create a dashboard for Company X. This study can thus be seen as a case study where the theory is applied in practice to build an actual dashboard for an existing company. This dashboard was built specifically for the warehouse department, and it will be most useful for companies also looking to build a dashboard in that sector. This report can then act as a guideline for designing, creating and implementing the dashboard. However, companies in other sectors can also study the steps taken in this report and the way the dashboard was built.

8.3 Contribution to practice

The contribution to practice is that the logistics manager will use the dashboard to monitor the performance of the warehouse process. He and other employees will learn to understand the dashboard and learn what information it can and cannot tell. They might change the dashboard a bit to include data that they find relevant. The logistics manager will have a whole new range of possible insights. It will take time to discover all of the different views and insights the dashboard gives him. After learning this, it is up to the logistics manager to do something with newly generated insight. One specific example of what is possible is that the logistics manager uses the dashboard to view exactly how many stickers for orders he needs on average per week. Before he had to take an educated guess on when to order, now he can forecast with much more precision when to order. Furthermore, the

dashboard can be used to back decisions. If for example the conclusion from the dashboard always takes longer than average, the manager could decide to investigate why this is the case. Another possibility is to view the progress over time. These are all examples of what the manager can do with the insight the dashboard provides.

8.4 Limitations

The first limitation is the time restriction that is tied to this thesis. As it is not a project with unlimited time to deliver something perfect, the idea is to deliver something substantial within approximately ten weeks of work. If there had been more time for this research, the dashboard could have been developed further and more time could have been spent to make the dashboard look professional. Now the focus lay completely on the functionality of the dashboard and not so much on the looks.

Another limitation is the software used to create the dashboard. The decision was made to create the dashboard in Excel for time- and monetary reasons. Excel can be used to create dashboards, but it is far from optimal as certain functions do not exist. One example is that is not possible to view different settings at the same time. If you want to compare the average order handling time of orders destined for France and Belgium, the file needs to be opened twice as it cannot be done in the same document. This was already discussed with the employees and the idea was to create files specific for a country as a temporary solution. This option is available in for example in Power BI.

Furthermore, there was a data limitation. Company X gathers a lot of data which is spread out over different tables in different databases. Adding more data columns to a table could only be done by the French department. The process of asking them to add data and the French workers actually adding it was slow. Most of the data was available on time. However, it was decided to take the available data and build the dashboard because of time restrictions. This decision was taken because it would take too long to wait for more data to be added to the table.

8.5 Recommendations and future work

The first recommendation for Company X is to invest in specialized dashboard software. It was proven that Excel does not fit all of the desires. Therefore, the recommendation is for Company X to investigate what software would fit the goals the best, comparing both pros and cons.

Another recommendation is to add more data to the database and dashboard with the help of the French department. This will also take some time but will be worth the wait. As the data is already being stored, this is an easy decision. All that has to be done is to add the already existing data to the correct table so that it can be used for the dashboard.

Another recommendation is to add target scores to the KPIs. Because this dashboard is entirely new, it is unknown what average KPI scores are. After a while, the logistics manager will learn the average KPI scores. Then it is helpful to add a target or grading scale to quickly analyse whether a KPI is scoring above or under average.

The following recommendation is to keep evaluating the dashboard and KPIs. The dashboard was built in a relatively brief time, so some things are still missing in the dashboard. An example could be to connect costs to the dashboard or to add the Warehouse Outbound Order Time. Also, the KPIs present in the dashboard needs to be evaluated. There were chosen at one point, but the logistics manager could realize that there are other more relevant KPIs that could replace unnecessary KPIs. When presenting the dashboard, the logistics manager already realized that the “Pallet creation time” KPI is not as relevant as he had hoped, so he can decide to delete that KPI in the future.

If Company X is enthusiastic about the dashboard after the introduction period, a recommendation is to expand the dashboard to warehouses in other countries that Company X operates in. The introduction period is estimated to be around six months. This gives the employees enough time to master the dashboard and familiarize themselves with average KPI scores to be able to set target scores. An expansion can be realised quite easily, as the idea of the dashboard stays the same. Only the dataset itself will have to change. With the proof that the dashboard adds something to the Dutch warehouse, other countries will be keen to also adapt a dashboard.

Lastly, the current dashboard only looks at the overall performance. In the future, it will be interesting to see if individual performance can be portrayed on the dashboard. This is possible because the User_ID is also saved for each transaction. However, there are laws about managing personal data in the Netherlands and therefore, Company X should look at confidentiality issues and informed consent. It was briefly considered to include personal performance in this dashboard, but the supervisors from the company did not have any time left over to handle everything that would be included with being able to use the personal data. Therefore, it is left as a recommendation.

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Appendix

Appendix A. The Design Science Research Method

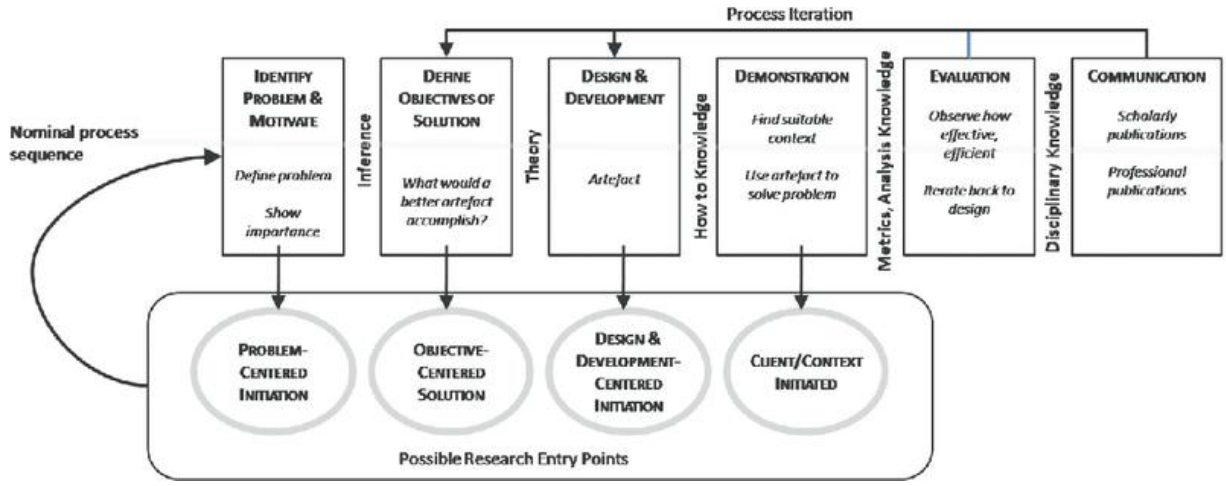

Figure 14: The steps of the Design Science Research Method

Appendix B. Different figures about dashboard design

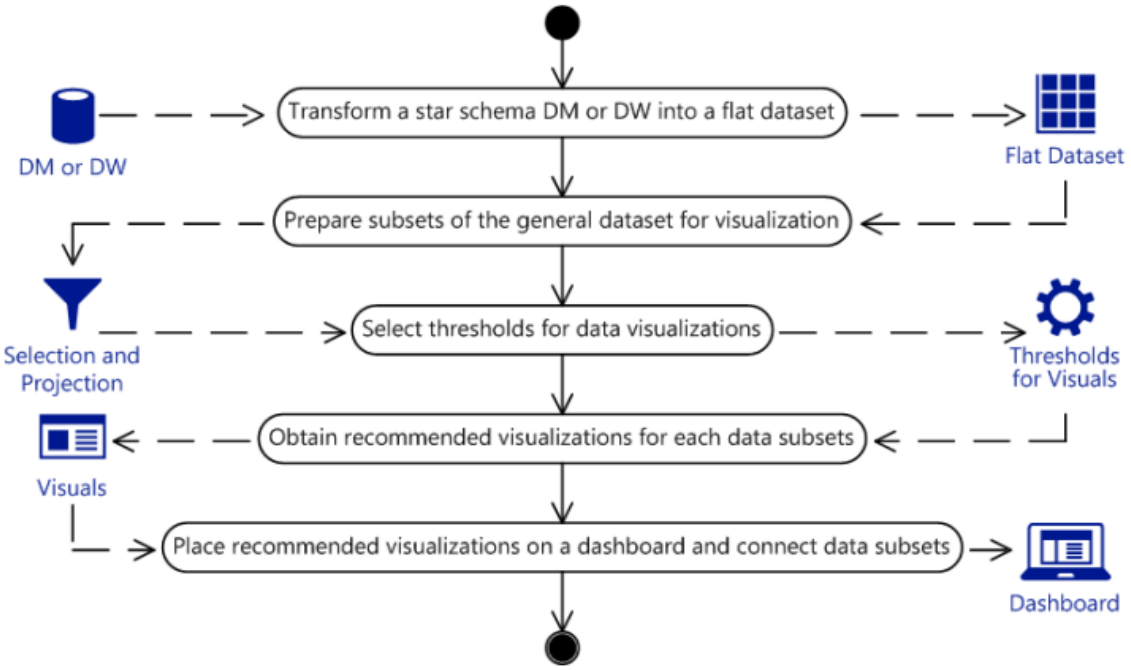

Figure 15: Six Steps of Dashboard Building

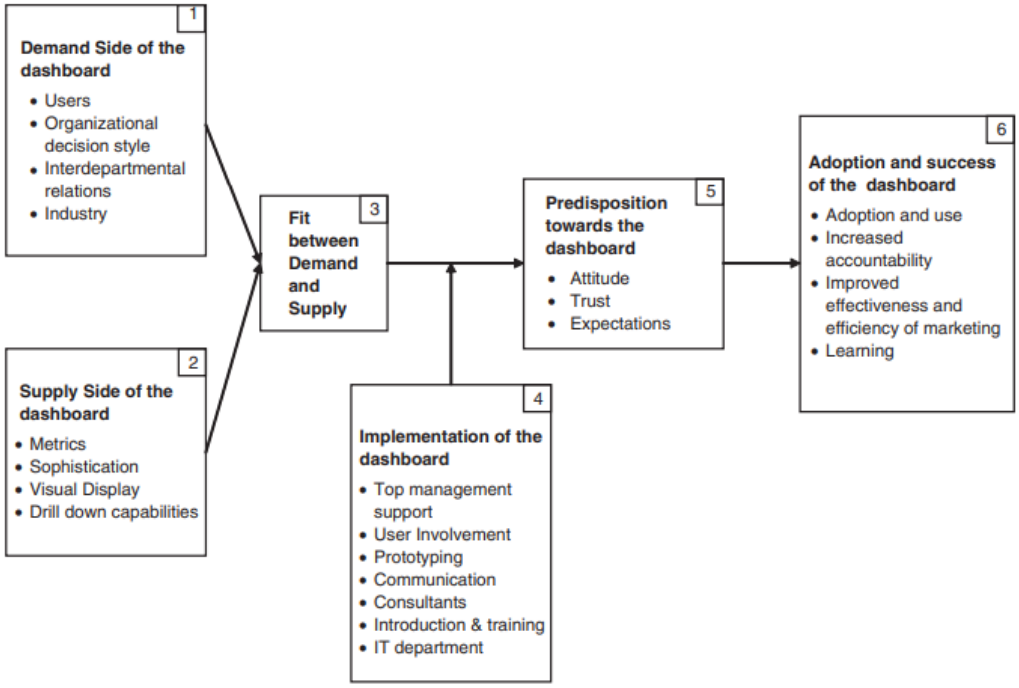

Figure 16: Framework for the Adoption and Success of Dashboards

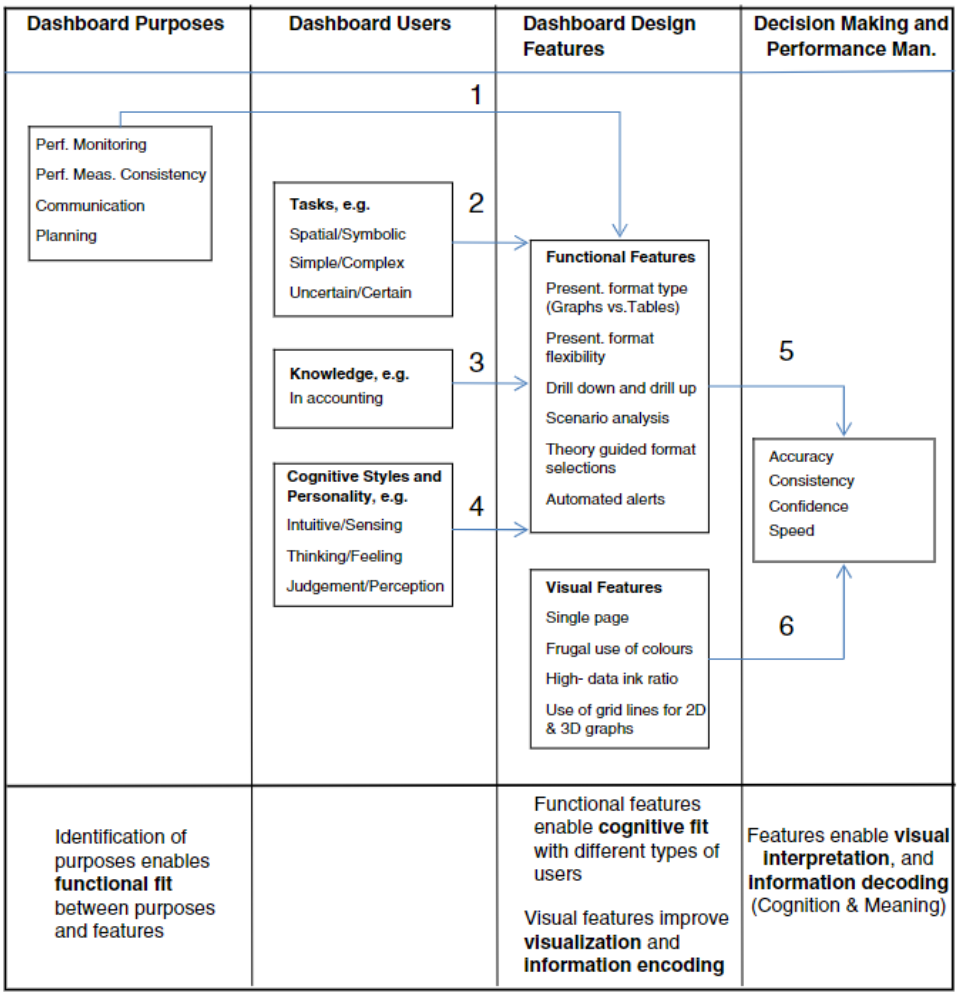

Figure 17: Relationships between parts of Dashboard Building

Appendix C: Lists of KPIs from literature

Dimension	KPI	Definition
Time	Receiving time	Unloading time
	Putaway time	Lead time since a product has been unloaded to when it is stored in the correct place
	Order picking time	Lead time to pick an order line
	Queuing time	The time that products wait on hold to be handled
	Dock to stock time	Lead time from supply arrival until the product is available for order picking
	Equipment downtime	The period in which a piece of equipment is not functional, downtime incurred for repairs
Cost	Inventory costs	Total storage costs per unit
	Order processing cost	The total processing cost of all orders per number of orders

	Labour costs	Cost of personnel involved in the warehouse operations
	Cost as a % of sales	Total warehousing cost as a per cent of total company sales
	Maintenance cost	Costs of building maintenance and equipment maintenance
Quality	Picking accuracy	Accuracy of the orders picking process where errors may be caught prior to shipment
	Storage accuracy	Storing products in proper locations
Productivity	Labour productivity	The ratio of the total number of items managed to the amount of item-handling working hours
	Throughput	The number of items per hour leaving the warehouse
	Warehouse utilization	Rate of warehouse capacity used
	Inventory space utilization	Rate of space occupied by storage
	Outbound space utilization	Utilization of the area inside the warehouse used for retrieving, order picking, packing and shipping
	Picking productivity	Total number of products picked per labour hours in picking activity
	Receiving productivity	The number of vehicles unloaded per labour hour.
	Turnover	The ratio between the cost of goods sold and the average inventory

Dimensions	KPI	Definition
Time	Receiving time	Unloading time
	Putaway time	Lead time since a product has been unloaded to when it is stored in the correct place
	Dock to stock time	Lead time from supply arrival until the product is available for order picking
	Order picking time	Lead time to pick an order line
Accuracy	Receiving accuracy	Pallets unloaded without incidents
	Storage accuracy	Storing products in proper locations
	Picking accuracy	Number of orders picked correctly per orders picked
Cost	Inventory costs	Holding costs and the stock-out penalty

	Order processing cost	The total processing cost of all orders per number of orders
	Cost as a % of sales	Total warehousing cost as a per cent of total company sales
	Labour cost	Cost of personnel involved in the warehouse operations
	Maintenance	Costs of building maintenance and equipment maintenance
Productivity	Labour productivity	The ratio of the total number of items managed to the amount of item-handling working hours
	Receiving productivity	The number of vehicles unloaded per labour hour.
	Storage productivity	Total number of products stored per labour hour in storage activity
	Picking productivity	Total number of products picked per labour hour in picking activity
	Inventory utilization	Rate of space occupied by storage
	Turnover	The ratio between the cost of goods sold and the average inventory
	Warehouse utilization	Rate of warehouse capacity used
	Equipment downtime	Percentage of hours that the equipment is not utilized
	Throughput	The number of items per hour leaving the warehouse

Table 4-1: Warehouse key performance indicators (Frazelle, 2002, 56)

	Financial	Productivity	Utilization	Quality	Cycle Time
Receiving	Receiving cost per line	Receipts per man-hour	% Dock door utilization	%Receipts processed accurately	Receipt processing time per receipts
Putaway	Putaway cost per line	Putaways per man-hour	% Utilization of putaway labor and equipment	% Perfect putaways	Putaways cycle time (per putaway)
Storage	Storage space cost per item	Inventory per square foot	% Locations and cube occupied	% Locations without inventory discrepancies	Inventory days on hand
Order picking	Picking cost per order line	Order lines picked per man-hour	% Utilization of picking labor and equipment	% Perfect picking lines	Order picking cycle time (per order)
Shipping	Shipping cost per customer order	Orders prepared for shipment per man-hour	% Utilization of shipping docks	% Perfect shipments	Warehouse order cycle time

Figure 18: Frazelle Model

Appendix D: Calculation of weights for the AHP method

The first step in the AHP method is to create a five-by-five matrix, where the criteria are compared with each other. The meaning of the numbers can be found in Table 3.

$$\begin{bmatrix} 1 & 1/7 & 1/4 & 1/7 & 2 \\ 7 & 1 & 4 & 1/2 & 5 \\ 4 & 1/4 & 1 & 1/5 & 3 \\ 7 & 2 & 5 & 1 & 4 \\ 1/2 & 1/5 & 1/3 & 1/4 & 1 \end{bmatrix}$$

The next step is to calculate the normalized matrix.

$$\begin{bmatrix} 0{,}051 & 0{,}04 & 0{,}024 & 0{,}068 & 0{,}133 \\ 0{,}359 & 0{,}278 & 0{,}378 & 0{,}239 & 0{,}333 \\ 0{,}205 & 0{,}07 & 0{,}094 & 0{,}096 & 0{,}2 \\ 0{,}357 & 0{,}557 & 0{,}472 & 0{,}478 & 0{,}267 \\ 0{,}026 & 0{,}056 & 0{,}031 & 0{,}119 & 0{,}067 \end{bmatrix}$$

In this matrix, the column vector can be calculated. This column vector consists of the weights for the criteria.

$$\begin{bmatrix} 6{,}33\% \\ 31{,}75\% \\ 13{,}30\% \\ 42{,}65\% \\ 5{,}98\% \end{bmatrix}$$

It has already been mentioned that a consistency check has to be performed in order to confirm that the pairwise comparison done in the first matrix is valid. In the next appendix, the consistency check will be performed

Appendix E: Consistency check AHP

The consistency index is calculated by the following steps:

1. Calculate the Aw
2. Calculate $\frac{1}{n}\sum_{i=1}^{i=n}\frac{i\ entry\ in\ Aw}{i\ entry\ in\ w}$
3. Compute the CI. $CI = \frac{(Result\ from\ step\ 2)-n}{n-1}$
4. Divide the CI by the RI for the appropriate value of n. If $\frac{CU}{RI} < 0{,}10$, the consistency level is valid. If not, the AHP will not yield meaningful results.

Step 1: Aw = $\begin{bmatrix} 0{,}32 \\ 1{,}805 \\ 0{,}73 \\ 2{,}409 \\ 0{,}305 \end{bmatrix}$

Step 2: $\frac{1}{n}\sum_{i=1}^{i=n}\frac{i\ entry\ in\ Aw}{i\ entry\ in\ w} = \left(\frac{1}{5}\right) * \left(\frac{0{,}32}{0{,}0633} + \frac{1{,}805}{0{,}3175} + \frac{0{,}73}{0{,}133} + \frac{2{,}409}{0{,}4265} + \frac{0{,}305}{0{,}0598}\right) = 5{,}40$

Step 3: $\frac{5{,}40-5}{4}$ = 0,099

Step 4: The CI is 0,099 and for an n of 5 RI is 1,12. Therefore the consistency level is $\frac{0{,}099}{1{,}12} = 0{,}089$

This is lower than 0,10 and therefore the pairwise comparison is valid and satisfactory.