Visualizing Business Production Performance

Real-Time Dashboard

Bachelor thesis

Industrial Engineering & Management

University of Twente

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medspray

medspray

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Preface

Dear reader,

This bachelor thesis is written in the context of completing my bachelor's in Industrial Engineering and Management at the University of Twente. I started with this research in April 2019 and I positively look back to the last three months I have been working on this research which is carried out for the company Medspray. During this assignment, I did research on visualizing the production performance within the manufacturing department of the company. In these months, I have gained many new experiences, learned a lot and gained knowledge about the activities within Medspray.

I would like to use the opportunity in this preface to thank my supervisor and colleagues of Medspray. I worked on my research with great pleasure, especially due to the pleasant and open atmosphere within the company.

In particular, I want to thank Jacob Pieffers, my company's supervisor, for his time and support during the research. I also would like to thank Wietze Nijdam for making this opportunity possible and helping me to gain knowledge about the company.

From the University of Twente, I want to thank my first supervisor Aldina Aldea for the constructive feedback and guidance during my whole thesis process which improved the quality of this research. I also want to thank Maria Iacob, my second supervisor, for her suggestions and feedback which has taken this research to a higher level. I learned a lot from critical remarks.

Finally, I want to thank my family and friends for providing support and giving advice. The interest of many gave me a pleasant feeling.

I hope you enjoy reading my report!

Kind regards,

Sandra Motamedi Nia

June 2019

Management summary

This management summary discusses the reason and approach of the research with the corresponding results.

Context

This research takes place in the manufacturing department of Medspray. Medspray designs and develops aerosol and spray devices and is active in three locations all located in Enschede. Throughout the years, the company has been dynamic and fast-growing towards being a high-tech business. Medspray aims to triple the speed of production by the end of 2019. To do so, the production line will expand. In order to keep track of the performance within the production line, the company needs a visualization of the production performance based on real-time data.

Problem description and purpose

Currently, the company monitors the performance of the production line in Excel-sheets and in the database of the company. This means there is no quick display of the performance within the production line of the manufacturing department. The end-users, which are the manufacturing manager, as well as the employees of the production line, want to have an insight into the performance based on real-time data. This will help them in making decisions and keeping track of production performance. Therefore, the main research question of the research is:

"How to visualize the production performance of Medspray?"

Approach

The first step to answer this main research question is to map the current situation within the production line of the company. The manufacturing manager and the employees within the production line are interviewed and observed to gain knowledge about the current situation.

Mapping the current situation of the manufacturing department within Medspray identifies the content of the visualization. The Systematic Literature Review identifies the Key Performance Indicators (KPIs) which are used to visualize the performance of the production process. The identified KPIs determine the content of the visualization on the criteria set up by the end-users. The end-users also requested other valuable information besides the KPIs. **Table 1** lists the selected content, both the KPIs and non-KPIs

Table 1: *Content of the dashboard*

KPI content	Non-KPI content
Productivity	Inventory level
Yield	Average production speed
On-Time Delivery	Schedule of the orders
	Summary production status

The next step is to find a visualization technique to visualize the chosen content. Various well-known visualization techniques are compared. To be able to determine which technique is most suitable for the company, criteria are set up based on the needs of the end-users. With these criteria, a technique is chosen that best meets the needs of Medspray, namely a dashboard.

Thereafter, the software to develop the dashboard is chosen based on the needs of the company. The next step discusses the data architecture of the required data. Finally, the design of the chosen technique is chosen by conducting a literature review.

Conclusion

All in all, the real-time dashboard which is developed for the manufacturing department of Medspray reached the norm of the company. The core problem is solved:

"There is no performance visualization of the production process within Medspray"

Meaning the dashboard gives a quick display of the performance within the production process of Medspray. So, the dashboard gives the company possibilities to monitor the performance within the production process of the company and based on that, make quick appropriate decisions to further improve.

Recommendations

Since the company is growing fast, the dashboard will play an essential role in keeping track of the performance. The dashboard which visualizes the content is based on the currently available data. Of course, when the company is expanding the production line through investing in more machines and outsourcing particular tasks, the information visualized on the dashboard increases. Therefore, managing and changing the dashboard over time is required.

Recommendations for KPIs to visualize in the future are performed when the company has expanded. These KPIs are listed in **Table 2**.

Table 2: *Recommended KPIs*

Recommended KPIs
Utilization rate
Breakdown frequency
Production cycle time
Order to delivery lead time
Overall equipment efficiency

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Terms and definitions

Canvas	A screen background for graphic representations and images.
Cleanroom	A cleanroom is a working environment with high purity and is designed to reduce or even exclude contamination of the product within that space. Within Medspray, it is a production hall where the production of the end product takes place.
Database	A database is a digital place where data can be stored in a structured and organized way.
Dashboard	A dashboard is a clear and insightful visual representation of information.
DAX	Data Analysis Expressions is a library of functions that can be combined to build formulas and expressions in Power BI Desktop.
Downtime	Downtime is the time that a system or resource is unavailable due to maintenance or repair.
ERP	An Enterprise Resource Planning system automates and connects business processes within an organization.
Flow chart	A flowchart is a schematic, graphical representation used to depict a business process.
KPI	A Key Performance Indicator is a variable to analyze the performance of a company.
OEE	Overall Equipment Effectiveness is a KPI which shows the actual production time as a percentage.
Operator	An operator is an employee who operates a machine in a factory. Within Medspray, an operator is an employee in the cleanroom.
SLR	A Systematic Literature Review is a method in which available evidence is collected systematically. The found literature is selected according to predetermined criteria. Finally, the literature is summarized.
Spray nozzle	A spray nozzle is a device that facilitates dispersion of liquid into a spray.
SQL	Structured Query Language is the world's most popular language for controlling relational databases. SQL can do several tasks such as perform queries within a data, extract data from a database and update data within a database.

1. Introduction

This report describes the completed research at Medspray in Enschede. The first chapter introduces the research. Within this chapter, section 1.1 provides a brief description of the company and section 1.2 contains the reason for the investigation. Therefore, section 1.3 describes the problem identification and section 1.4 discusses the research design. Finally, section 1.5 describes the intended deliverables.

1.1 Company information

The research is performed for the company Medspray which consists of three locations in Enschede. **Figure 1** visualizes these three locations.

- Headquarter (HQ) at Colosseum 23, Enschede. Here the offices and the research lab are located.
- High Tech Factory (HTF) at De Veldmaat 17, Enschede, the location of the production.
- MESA+ NanoLab at Hallenweg 23, Enschede which is for research and development.

Figure 1: *Locations of Medspray*

Medspray Enschede produces different spray nozzles for inhalers, body sprays, and air fresheners. The spray nozzles at Medspray consist of a processed silicon chip with a plastic shell. The design of the chip and the plastic shell are patented by Medspray. The processed chip is placed in the plastic shell and fused together. **Figure 2** illustrates the production of the Spray Nozzle Unit (SNU) at Medspray. The result is the end product: an SNU. The design and functionality of the chip are tested by Medspray in its own test lab.

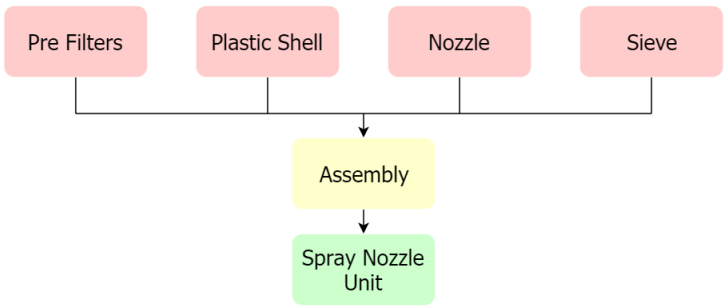

Figure 2: *Spray Nozzle Unit Production at Medspray*

Development of the company

The company Medspray was founded in 2002 and includes around 40 employees. Throughout the years the company has grown a lot towards being a high-tech business and has been constantly developing their products. Their employees are highly educated people who are working in diverse fields including lab, finance, manufacturing, and marketing and sales. During the research, the focus is on the manufacturing department of Medspray.

Because the research is for the manufacturing department of Medspray, data is used and gathered from the production line within the cleanroom in the High-Tech Factory, which is the location where the production takes place. In the High-Tech Factory, there are many cleanrooms, including one cleanroom for Medspray. In the cleanroom, the subassemblies are assembled, tested and finally packaged. Within the research, the focus is on the Spray Nozzle Units, which the company produces for a year from now.

1.2 Research objective

Medspray produces SNUs which are medical device components designed and manufactured by the company itself. **Figure 3** illustrates the use of an SNU. Currently, the goal of Medspray is to scale up the production three times the current size because of the increased demand of customers.

Figure 3: *The use of an SNU from Medspray*

Since the company is growing at such a high speed, the processes within the company get complicated and the chance of losing insight into the production process increases. To stay manageable after the expansion of the production line, the performance of the production process needs to be visualized. The visualization gives management information about the current situation within the production process to help them make appropriate decisions at the right time.

Moreover, the employees of the production line, which are operators, also need to have a structure in their work and need to have a visualization of their performance in order to perform specific tasks in the right order. Also, visualizing the performance creates a more transparent work environment and a clear understanding of the expectations which in return leads to a less stressful workplace.

The performance of the production process should be mainly expressed in Key Performance Indicators (KPIs) which are variables or measures to analyze the performance within an organization. The used KPIs need to be based on real-time data of the production process to give insight into the current situation.

Currently, there is no visualization within the production line of Medspray. The employees can keep track of the performance in Excel sheets. Within these sheets, the performance is not expressed in KPIs but the data is presented in tables. Therefore, there is no visualization of the current performance within the production line of Medspray in order to get a quick overview and determine improvements.

All in all, Medspray needs to get insight into the performance of the production process expressed in KPIs based on real-time data. This visualization helps the company to focus on the key drivers of the business and to manage the progress within the production process. The visualization of the performance is not a one-time activity, it has to be managed regularly. The visualization helps in recognizing improvements and making appropriate decisions by the management as well as the employees of the production line.

1.3 Problem Context

This section identifies the observed problems in Medspray. Subsequently, the problem cluster shows the relationship between these problems and motivation is given of the chosen core problem. The last part explains the current difference between the norm and reality.

1.3.1 Problem cluster

The manufacturing manager and the operators are interviewed to get a deep understanding of the problems within the manufacturing department.

In order to gain insight into the process and the problems associated, a problem cluster is made of the problems which can be influenced and are related to the start problem (Heerkens & van Winden, 2012). This problem cluster, which is visualized in **Figure 4**, shows the identified problems, the action problem, and the core problem.

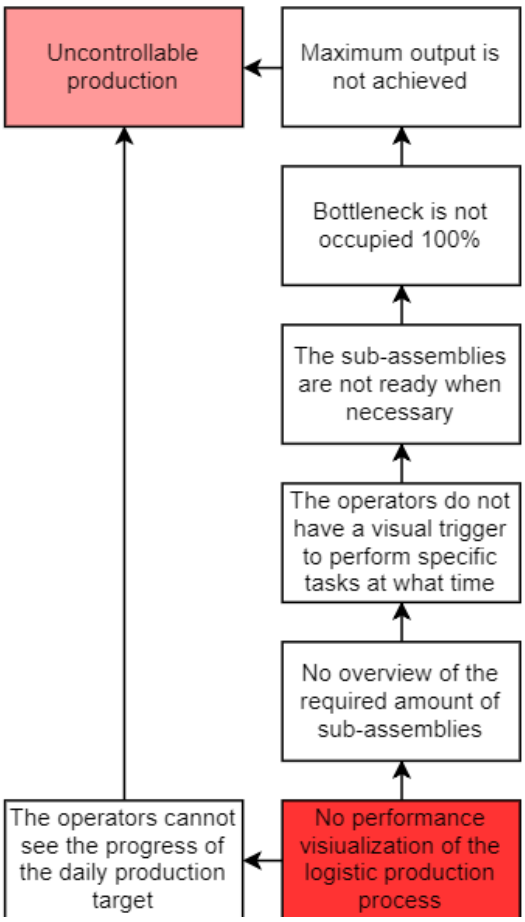

Figure 4: *Problem cluster to identify the core problem*

The starting problem is that Medspray has an uncontrollable production, the light red problem within the problem cluster. The causes of this problem are mainly that the employees of the production line cannot see the progress of the daily production target and have no overview of the required amount of sub-assemblies. The determined root of these causes is the core problem:

> *"There is no performance visualization of the production process within Medspray. "*

This core problem is chosen based on the four rules of thumbs of Heerkens and van Winden (2012):

1. A problem will only be in the problem cluster if it is sufficiently sure that the problem actually occurs. Therefore, leave out what is not known.
2. In the chain of problems, go back to the problems which no longer have a cause. These could be core problems. So, go back in the causal chain.
3. What cannot be influenced, cannot be a core problem.
4. If problems remain in the problem cluster, choose the most important problem as the core problem.

First of all, only problems which can be influenced and actually occur are included in the problem cluster. Secondly, the core problem *"There is no performance visualization of the production process within Medspray*" has no cause itself and can be influenced by developing a visualization.
Solving this core problem provides Medspray with a controllable production and solves all the subproblems in the problem cluster. Therefore, the assignment is to visualize the performance of the production process within Medspray.

1.3.2 Norm and Reality

When there is a difference between the norm and the reality, there is often a problem. Currently, this is the case within the manufacturing department of Medspray. The norm within Medspray is to have a controllable production. In other terms, the company wants to have a production line with visualizations of the real-time performance in order to make the right decisions at the right time and to manage the production to be more effective.

Instead, the performance is manually filled in and managed within Excel spreadsheets. **Figure 5** illustrates an example of the current visualization of the performance. Therefore, there is no quick display of the current performance within the production process. Moreover, due to the lack of a quick real-time performance visualization, it is hard for the management and the operators to determine improvements and have an insight into the current progress within the production process.

All in all, the norm is to provide the company with a quick display of the current performance within the production process. **Figure 6** visualizes an example of the norm for the company**.** The reality is that there is no visualization of the performance within the production process of the company. There is only visualization available through analyzing the manual input in Excel spreadsheets by the employees of the manufacturing department. Therefore, the manager and the operators do not have the right information at the right time in order to make appropriate decisions and reach the company's goals. The assignment, visualizing the performance of the production line, removes this discrepancy between the norm and reality.

Current situation	Preferred situation
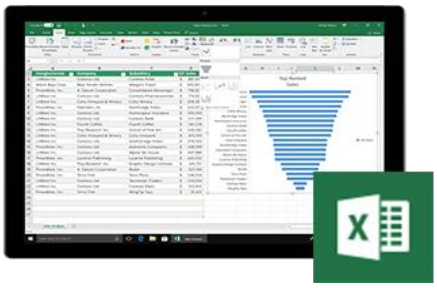	
Figure 5: *Reality – Manual input and Analysis of Excel sheets*	***Figure 6:*** *Norm – Quick display of the performance*

1.4 Research design

This section describes the steps of scientific research which are carried out. Section 1.4.1 first describes the problem-solving approach with the corresponding research questions. Section 1.4.2 discusses the type of research. Section 1.4.3 analyzes the reliability and validity of the research. Finally, section 1.4.4 discusses the limitations of the research.

1.4.1 Research method

In order to solve the core problem, *"Medspray has no visualization of the performance of the production process",* the Managerial Problem-Solving Method (MPSM) is used. The MPSM is a systematic approach to solve business problems which are handled in their organizational context (Heerkens & van Winden, 2017). Furthermore, the MPSM is a general method that can be used in various situations for different problems in all fields This makes it beneficial compared to other problem-solving methods.

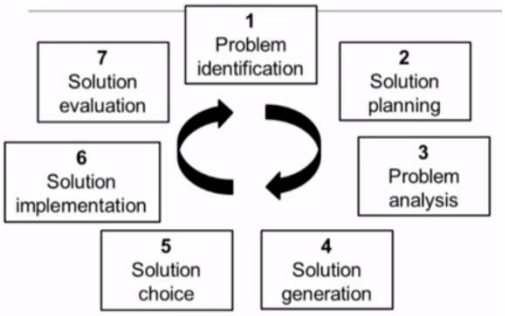

Figure 7: *Phases of the MPSM*

Moreover, the MPSM focuses on the context of an organization in order to come to a solution which is best suitable for a specific organization. **Figure 7** visualizes the seven phases within this problem-solving method. **Appendix A** shows the exact steps which are performed during this research within all phases.

The MPSM encounters research questions in almost all the phases. This section describes the research questions which are answered during each phase of the MPSM in order to solve the *main research question* of the research:

"How to visualize the performance of the production process of Medspray?"

Phase 1: Defining the problem and Phase 2: Formulating the approach

Research question 1: *What does the current production process of Medspray look like?*
First, the current situation within the production process of the company is analyzed. This is necessary in order to get a deep understanding of the core problem and to be able to compare the starting value with the end value after the solution is implemented. Moreover, mapping the current situation helps in finding the causes of the problem. Literature research is done to map the production process and choose the best suitable technique. After that, the production process of the company is mapped based on the chosen technique.

Research question 2*: What is performance management?*
This research question needs to be answered to get an idea about the core of the problem. Currently, Medspray does not have any visualization within the production line. Therefore, this research question helps in understanding the importance of visualization and the manner of

measurement. In order to get an answer to this research question, a literature review is needed to find out the characteristics of performance management. After this, the most used performance management methodologies are discussed.

Phase 3: Analyzing the problem

Research question 3: *Which KPIs can be used to measure the performance of the production process? (Systematic Literature Review)*
KPIs have to be found which can be used to visualize the performance of a production process. These KPIs are found through performing a Systematic Literature Review.

Phase 4: Formulating solutions and Phase 5: Choosing a solution

Research question 4**:** *Which KPIs are most suitable for the company?*
After the KPIs are found with the Systematic Literature Review, existing data is searched which is available within the company and based on that, KPIs are selected which are best suitable and have the most value for the company. Based on specific requirements of the manufacturing manager and the operators, the key KPIs are selected for the company with the use of a KPI selection.

Research question 5: *Which techniques can be used to visualize the performance of the production process within Medspray?*
Now, the focus is on finding visualization techniques to solve the core problem. First of all, existing techniques have to be found which visualize the performance of the production process, this is done through a literature review. After that, one technique has to be chosen which is most applicable for Medspray.

Phase 6: Implementing the solution

Research question 6: *Which software to make a dashboard is best suitable for Medspray?*
There is a lot of software to choose from to create a dashboard. The most used software are compared and the most applicable one for the company is used to develop the dashboard.

Research question 7: *How to prepare and structure the required data in the software?*
The content of the dashboard is based on real-time data which needs to be updated on a daily basis. Therefore, a data model architecture is required to ensure the right data is collected as required. This research question is answered through a literature review about data architecture and the way to model it.

Research question 8: *How to design the dashboard with the chosen software?*
After the visualization technique and the software are chosen, the design of the dashboard needs to be determined. This is done through a literature review and interviews with the end-users, which are the manufacturing manager and the operators. The design needs to fit the needs of the company. Furthermore, the interface and functionality of the software are discussed.

Phase 7: Evaluating the solution

In phase 7 of the MPSM, the evaluation is checked through measuring the improvement, ensuring further management and implementing possible improvements.
Table 3 gives an overview of the chapters where each research question is answered.

Table 3: *Overview of the research questions*

Research questions:	Chapter/Section:
Research question 1:	Section 2.1 & Chapter 3
Research question 2:	*Section 2.3*
Research question 3:	*Section 2.2 & Appendix B*
Research question 4:	*Chapter 4*
Research question 5:	*Section 2.4*
Research question 6:	*Section 2.5*
Research question 7:	*Section 2.6, Section 4.3 & Appendix C*
Research question 8:	*Section 2.7 & Chapter 5*

1.4.2 Type of research

This subsection discusses the type of research which is carried out for each of the research questions. The answer to research question 1, which is about the current situation of the company, is given by interviewing employees of the manufacturing department within Medspray. These interviews are semi-structured which means open questions are predetermined but are not fixed. The questions which are prepared beforehand are used as a kind of checklist to make sure all the subjects are covered. This way, there is room for the respondents to come up with personal views and experiences.

Moreover, this results in a deeper understanding of the activities within the company because the interview is not only focused on questions which are predetermined but also have space to come up with important information to better understand the activities of the company. Based on the information of these questions, a flow chart is created which gives an overview of the global activities within the manufacturing department of Medspray.

Due to the fact the focus of this research is on the manufacturing department, an in-depth understanding of the production process within the company is needed. To get an insight into the current situation within the manufacturing department, observations are done within the production line to map all the specific activities. During these observations, questions are asked to the employees within the production line to get a clear overview. These employees will use the visualization to see the performance and progress of the production line and therefore their preferences also need to be considered.

Also, a final interview is done with the manufacturing manager to check whether the information which is obtained from the observations and employees are correct. The manufacturing manager also uses the visualization to see the performance of the production process and make appropriate decisions to reach the company's goals. **Table 4** visualizes the type of research to answer the other research questions.

Table 4: *Research questions: Type of research*

Research question	Type of research
2	Literature review performance management and methodologies
3	Systematic Literature Review
4	Answer research question 3 and interview with end-users
5	Literature review visualization techniques
6	Literature review existing software
7	Literature review data architecture
8	Literature review dashboard design

1.4.3 Reliability and validity

Validity and reliability determine the quality of the research data and the conclusions which are drawn from it. Therefore, this subsection discusses the internal and external validity within the research and subsequently the reliability.
Valid research means that the research results are correct. Also, whether the measurements are done with what was intended to be measured (Golafshani, 2003). Validity can be categorized into two main types, external and internal validity:

1 *External validity* is the ability to generalize the data about people, situations and periods. During the research, the focus is on designing a way to visualize the performance of the production process. To be able to do this, first, an analysis of the current production process is made. Subsequently, the specific information which needs to be visualized is determined. Within the research, data is used from the company, which therefore means that the visualizations are specific for the company itself. However, the outcome of the research might be generalizable for a company which has a comparable production process and growth. Moreover, the visualization can be used for inspiration or as an example for other comparable companies. So, the research is in some way externally valid.
Also, within the company, there are about ten operators in total, which are selected randomly when doing observations in order to increase the external validity of the observations.

2 *Internal validity* is the extent to which the conclusions of the research are valid for the research group. Therefore, during the observations which are performed, the reality is observed. Of course, when the presence during those observations is known, it is likely that the operators behave differently. Therefore, observations are done as unobtrusively as possible to ensure the internal validity within the outcome of the observations.

Reliability is the accuracy and precision of a measurement procedure. Reliability does not guarantee the validity of the measurement, but it is a condition (Golafshani, 2003). When considering reliability within the research, constantly the question is asked: Would someone else get the same results if he or she carried out the observation again under the same conditions? A big part of the research is based on data which are gathered from observations. In order to make sure these data are reliable, observations are performed during different periods in time and on

different days. This reduces the chance of accidental events. Moreover, at the end of the research, the effect of the chosen visualization technique is tested. In order to check whether there are any improvements, observations are performed. To make sure the results are reliable, observations are performed in the exact same manner and timeframe.

1.6 Intended deliverables

This last section of the introduction discusses the deliverables of the research. First of all, a flow chart is given in order to map the supply chain of the manufacturing department of the company.

Moreover, the most suitable KPIs for Medspray are given based on the result of the systematic literature review and the needs of the company. Thereafter, advice will be given on which visualization technique is most suitable for Medspray to visualize and monitor the production performance. With the use of the recommended visualization techniques, the selected KPIs are visualized in a functional and attractive way. This solution visualizes the performance of the production process within the production process of the company.

Not only KPIs are visualized on the chosen visualization technique, but also inventory levels, production speed and the orders of customers. This helps the operators to get a structure in their work especially when the production process is scaling up.

Furthermore, a report is given with recommendations of the future visualization content to Medspray in order to optimize the performance of the production process.

1.7 Structure of the report

Table 5 gives an overview of the chapters within this research.

Table 5: *Overview chapters*

Overview chapters:	
Chapter 1:	Introduction
Chapter 2:	*Theoretical framework*
Chapter 3:	*Current situation*
Chapter 4:	*Content of the dashboard*
Chapter 5:	*Design of the visualization*
Chapter 6:	*Evaluation*
Chapter 7:	*Conclusions, Recommendations & Limitations*

2. Theoretical framework

This chapter discusses the theoretical framework which is needed to answer the main research question "How to visualize the performance of the production process of Medspray?". First, the techniques to map the current production process of the company are described. Thereafter, the existing KPIs to measure the performance of a production process are defined. Then the concept of performance management and the theory of visualization techniques are described. The last section is about the software to create the chosen visualization technique.

2.1 Current situation

This section is about mapping the current production process of the company. In order to do so, a literature review is done in existing methods to map business processes. "A business process is the combination of a set of activities within an enterprise with a structure describing their logical order and dependence whose objective is to produce the desired result." (Aguilar-Saven, 2004). Therefore, to get a deep understanding of the current business process, it should be visualized in a model. There are several modelling techniques possible depending on the purpose of the analysis (Aguilar-Saven, 2004). The article of Aguilar-Saven (2004) includes a list of the main process modelling techniques.

Flowchart

The purpose of mapping the business process within Medspray is to visualize the flow of the actions. Moreover, to get a graphic representation of the current production process of the company. Therefore, the process modelling technique which is used for mapping the current situation of the manufacturing department of the company is a flow chart. A flow chart gives a graphic representation of the flow of the actions within the production process. So, having mapped the business process within a flowchart gives a visualization of the high-level steps within the production process of the company.

Generally, a flow chart can be used to provide insight into the content of various sub-processes and process steps. The schematic representation of a (sub)process offers the user the opportunity to visualize findings. The simplicity of a flowchart ensures that it can be read and understood by almost everyone involved. This makes a flowchart a commonly used methodology in especially production and logistics flows.

A flowchart shows the steps within a process. All steps are linked with arrows which indicate the connections. The different symbols indicate whether it is a step or a decision. Flowcharts can be used for analyzing, documenting, improving and keeping track of a process. It helps in understanding the relationships between the steps, making decisions about important steps and eliminating less relevant steps.

Flowcharts use rectangles, ovals, diamonds, and many more shapes to indicate the type of step- and arrows to determine the flow and order. This can range from simple, manual diagrams to extensive, computer drawn diagrams with different steps. Considering all the different flow charts

together, this is one of the most used diagrams in the world, in both technical and non-technical fields. Flow charts often get more specialized names such as process flow diagram, process map, functional flow diagram, business process map and Business Process Modelling & Notation (BPMN). Flow charts are related to other popular charts, such as Data Flow Diagram (DFD) and the activity diagram in Unified Modelling Language (UML).

Business Process Modelling Notation

The flowchart will be developed using a Business Process Modelling Notation (BPMN), which is a formal notation for describing processes. BPMN is a universal modelling language that helps organizations to effectively model, optimize and execute processes. It is a tool for implementing Business Process Management. BPMN visualizes process flows, actors, process steps and actions (White, 2004).

For a company, it is essential to make business operations transparent and measurable. Each entrepreneur wants to improve the business. In order to improve, first, the current situation of working needs to be clear. Business processes are recorded to map the current situation within a company.

Once the business processes are established, improvements can be investigated. Improving a process can, for example, lead to the process of shortening by omitting steps. Another possibility is to recognize and remove duplicate steps in a process. Ultimately, improving processes can have many consequences for the company. Costs can be saved, the quality can be improved, the number of errors can be reduced and ultimately, customer satisfaction will increase.

2.2 KPIs to measure the performance of the production process

This section is about the existing Key Performance Indicators (KPIs) which express the performance of the production process. KPIs are a summarized set of key variables or measures which inform managers and employees about how well an organization is achieving its goals. A KPI is expressed in a number and is related to a norm or goal. By aligning the KPIs with the objectives of the organization, the objectives can be made measurable. A Systematic Literature Review is performed to identify the available performance KPIs. **Appendix B** shows the method of this systematic literature review and the table with the KPIs identified. This part discusses the concept matrix which is made based on the Systematic Literature Review. Furthermore, each of the review articles is discussed briefly. Finally, the answer to the research question is discussed.

2.2.1 Concept matrix

Table 6 shows a concept matrix which organizes the systematic research. This concept matrix presents connections between the chosen articles and the specific key concepts of the research question (Smale, 2015). Only in one of the articles, the key concept “logistic” has been discussed. If the topics “KPI”, “performance”, and “production process” are to be discussed, the articles from Jovan, Zorzut, and Žnidaršic (2006); Mousavi and Siervo (2017) could be used. However, if the discussion would be extended to the topic visualization, only the article of Mousavi and Siervo would be suitable. All in all, this concept matrix visualizes the key concepts discussed in each of the chosen articles.

Table 6: *Concept matrix*

		Key Concepts				
		KPI	Visualization	Performance	Production	Process
Articles	1. (Lai & Man, 2017)	X		X	X	
	2. (De Felice & Petrillo, 2015)	X		X	X	X
	3. (Mousavi and Siervo, 2017)	X	X	X	X	X
	4. (Tokola, Gröger, Järvenpää, & Niemi, 2016)	X	X	X	X	
	5. (Jovan et al., 2006)	X		X	X	X

2.2.2 Outcome of the Systematic Literature Review

In this subsection, the five chosen articles and their similarities are briefly discussed in order to summarize the answer of the research question "*Which KPIs exists that can express the performance of the production process?".*

Article 1 (Lai and Man, 2017)

This article is mainly about applicable KPIs for the performance of engineering facilities. Within the article, selection criteria for KPIs are discussed, such as being measurable and practical for data collection. Furthermore, the article divides KPIs into the five categories. Two of the five categories, "Financial" and "Task & equipment" , might be applicable for Medspray. Finally, the article highlights that the most essential indicators have to be chosen based on their weights of importance level.

Article 2 (De Felice & Petrillo, 2015)

This article is about the importance of an efficiency evaluation for the survival and growth of any firm (De Felice & Petrillo, 2015). Furthermore, the article describes the KPIs divided into the categories of each part of a scorecard. Also, the relationships between each part of the scorecard with the corresponding KPIs are discussed. Due to the fact that a scorecard is also a visualization technique, these KPIs might be applicable for Medspray.

Article 3 (Mousave and Siervo, 2016)

This article focusses on the translation of the real-time data into KPI transfer functions of the production process (Mousavi & Siervo, 2017). Two important KPIs, Overall Equipment Efficiency and Overall Line Effectiveness, are discussed in particular. These KPIs give the ability to visualize "the losses and gains more accurately and the cost of production can be reduced whilst resource utilization reaches a balance" (Mousavi & Siervo, 2017). Based on the fact that especially real-time data is used within the chosen visualization technique, these KPIs are definitely applicable.

Article 4 (Tokola et al., 2016)

Also, this article is focused on real-time data being an important success factor for manufacturing companies to facility agile and efficient manufacturing (Tokola et al., 2016). Furthermore, the article is mainly about the dashboard, which is a visualization technique. Finally, the article divides KPIs into "*Production" and "Quality*" categories, which are both applicable to this research. In the paper, research has been on the Interest of each KPI based on a 1-5 scale, therefore the importance of each KPI is tested.

Article 5 (Vladimir et al., 2016)

This article is about KPIs which visualize the efficiency of the production. The focus is on finding an appropriate set of KPIs that are specific to the observed production process (Lai & Man, 2017). Moreover, this article discusses that "a production manager is usually overloaded with current production process data with the main problem being how to extract the relevant information from this vast amount of data in order to make fast and correct decisions" (Lai & Man, 2017). This problem can be solved with the use of KPIs. Furthermore, the article gives requirements to output production process variables, like being easily measurable. This information is used in choosing the KPIs which are visualized within the company. The three main productions KPIs which are mentioned in the article are *"Productivity", "Mean Product Quality"* and "*Mean Production Costs"*, which are applicable to the company where the research is executed. These KPIs are focused on the existing production data.

Similarities and differences of the articles

Each of the articles expresses the importance of KPIs to cover performance aspects. Moreover, the identification of the KPIs is important for a company as is stated in all the articles. In this way, the current value of a KPI and the target of that KPI can be compared and decisions can be made to fill the possible gap. The interesting thing is that each of the 5 articles discuss KPIs which mainly visualize the performance of the production process, but none of them discuss the same KPIs.

2.3 Performance management

In order to make business decisions, usually, real-time data need to be used. There are several applications which users perform Business Intelligence tasks, performance management, among others, enables decision-makers to track key performance indicators of the business using visual dashboards (Chaudhuri, Dayal, & Narasayya, 2011). This section discusses first the difference between performance measurement and performance management. Thereafter, performance management methodologies are described. Finally, techniques are discussed which can visualize performance management.

2.3.1 Performance management Vs. Performance measurement

This subsection describes the concepts of performance management and performance measurement.

Performance measurement

Performance measurement is used within a multitude of organizations to, for example, keep track of the actual output of the various employees or components. Measuring performance can have both positive and negative effects. Deploying performance measurement can have various functions, all of which serve to improve the performance of the organization.

Performance management

Performance management is the systematic translation of the strategy, with the use of critical success factors and performance indicators, into business processes. The aim is to monitor and evaluate these processes in order to improve the strategy. In this way, the organization can respond faster and better to changes in the business environment and internal developments (Otley, 1999). The first step in the process of performance management is defining the

organization strategy. This creates a set of clear strategic goals and indicates which factors are essential for achieving the strategy. Key Performance Indicators (KPIs) need to be defined to measure success.

Therefore, the effectiveness of the measurements is largely dependent on the extent of managing the measurements. Organizations need to have a process of evaluating, responding to and aligning around measures in order to get anything out of them (Miyake, 2019). That is what performance management is about.
While performance measurement asks, "How do we *track* the progress of the strategy we've put in place?", performance *management* asks, "How do we *manage* the strategy we've put in place?"

All in all, performance measurements are critical in an organization to track the progress, but it is not a process for doing anything about the results. Performance management, on the other hand, offers a way to actually do something about the measures (Miyake, 2019). Therefore, a form of performance management in an organization is to assess whether an action is good, bad or indifferent. It would be impossible to maintain permanent control over an action or organization without performance management.

2.3.2 Performance management methodologies

A performance management methodology is a methodology which supports performance management. This section discusses the most commonly used performance management methodologies to continuously monitor the business performance based on the defined performance indicators.

Balanced Scorecard

The first method is the Balanced Scorecard (BSC). The BSC is a well-known strategic system of Kaplan & Norton which is the most commonly used model in both literature and practice (Garengo, Biazzo, & Bititci, 2005). The BSC attempts to provide important information that is necessary to adequately reflect the overall strategy of an organization in specific performance measures. The BSC can be used to define success factors and performance indicators.

This methodology clarifies the strategic goals and categorizes them into the perspectives financial, innovation, customer and internal. **Figure 8** visualizes these four perspectives.

- *The financial perspective:* shows how the company performs financially. The goal is to represent shareholder value. Measures can be related to profit, costs or income.
- *The internal perspective:* shows whether the company is doing the right things in the right way. Measures for this perspective can be, for example, productivity or machine downtime.
- *The innovation perspective:* shows how intangible resources, such as people and information, support the organization. Measures which fit this perspective are presence and data accuracy.
- *The customer perspective:* shows whether a customer gets what he or she wants. The goal is to ensure that the customer is satisfied with the product or service received.

Figure 8: *Perspectives of the BSC*

Six Sigma

Most companies use Six Sigma as a process improvement methodology to view processes critically and problems can be traced. Six Sigma offers the possibility to accelerate the improvement of the overall performance. Because Six Sigma focuses on business processes and process improvement, the methodology offers a simple way to address performance issues after they have been identified or detected ("What is Six Sigma? " 2004). In the statistics, the Greek letter sigma (σ) is used to express the variability. In terms of quality, variability is synonymous with the number of defects. The variability in business processes can be expressed in defects per million. To achieve the Six Sigma performance level, the company should reduce the number of defects. Six Sigma is, therefore, a performance methodology aimed at reducing the number of defects in a business process.

Lean

Lean is a business strategy and a way of working where everything and everyone in the company focuses on creating value for the customer in all processes. Therefore, lean is about creating value and eliminating waste. Through putting the customer first, a maximum added value can be created for the customer with minimal effort. This improves quality, reduces lead times and reduces costs. This has a positive effect on customer satisfaction, employee engagement, and on the profit.

Figure 9 visualizes the five important principles of lean management:

1. *Define value*: an organization needs to identify the customer's wishes and thereby identify the customer's perception of value.
2. *Map Value Stream:* An organization needs to map the value flow of processes and eliminate waste within these processes. The following questions are relevant:
    a. Which activities immediately add value for the customer?

   b. Which activities do not directly add value (but are necessary for business operations), and how can these activities be reduced to a minimum?
   c. Which activities add no value at all and can, therefore, be eliminated?
3. *Create Flow:* The organization needs to create a continuous flow of the product or service.
4. *Establish Pull*: The organization needs to prevent overproduction. This is done by ensuring that there is no production without the previous step in the process.
5. *Pursuit Perfection*: keep striving for perfection. The organization needs to create a continuous culture of improvement.

Figure 9: *Principles of Lean Management*

2.4 Techniques to visualize the performance of the production process

In the previous sections' performance management and the performance management methodologies: Balanced Scorecard, Six Sigma, and Lean are discussed. This section is about existing techniques which visualize performance management. In order to find the most suitable technique, a literature review is done.

The visualization of the performance can be done with various techniques. The two most commonly used techniques for companies to visualize KPIs are the Balanced Scorecard and the Dashboard (Brundage, Bernstein, Morris, & Horst, 2017; Pacific, Crest, & Group) "*Dashboard and Scorecard, both are automation tool represented graphically or as a structured report that provides "at-a-glance" information about the business performance by evaluating and measuring the crucial performance factors often termed as Key Performance Indicators (KPI) which helps management in taking an important decision." ("Dashboard and Scorecard," 2019).* **Table 7** shows the comparison between a dashboard and a scorecard.

Table 7: *Dashboard versus Scorecard (What is SixSigma.NET, 2018)*

Comparison based on	Dashboard	Scorecard
Purpose	Performance Monitoring	Performance Management
Parameters	Performance Metric	KPI (Metric + Target)
Measures	Performance	Progress (Current value versus the target)
Updates information	Real Time Basis	Periodically (Weekly/Monthly/Quarterly)
Focused On	Short Tem Goal	Long Term Goal
Decision Influences	Daily Operations	Companies Policies
Nature of Decisions	Tactical	Strategic
Supported By	Individual Managers	Top Management
Provides	Snapshot of Business Performance	Trends and changes in business activity over period of time.
Nature of Data	Real Time data obtained	Summarized/ Consolidated

Balanced Scorecard

The BSC is also discussed in section 2.3.2. “Using scorecards bridges gaps between short-term objectives, such as financial measures, and long-term strategies and planning” (Baker, 2015).

Due to the fact the company is interested in the daily strategies and planning and also not in financial measures, this visualization technique is not applicable for the research.

Dashboard

A popular way to dynamically display KPIs is to use a dashboard. A dashboard is a tool that is often used in combination with a Performance Management Methodology. Dashboards are used to display important information, including KPIs. Also, a dashboard offers an at-glance window into overall business performance, which is mainly the aim of the research (Baker, 2015). Another important purpose of a dashboard is that the data can be easily updated. The most distinctive feature of a dashboard is the three layers of information: monitoring, analysis, and management. Because of these layers, a dashboard is able to display a lot of information on a single screen.

Moreover, “A strategic dashboard focuses attention on analysis and reflection for quality decision making to improve performance” (Baker, 2015).

So, a dashboard displays the most important data at a glance. The dashboard brings the most important visualizations together in a consumable view. A dashboard is based on real-time data in order to give businesses the opportunity to make instant decisions.

Conclusion

The most suitable technique to visualize performance needs to be chosen based on the objectives and goals of the company. The most important requirements of the company are to have a visualization technique which handles real-time data, which measures performance, is interactive and maps the Business Performance.

Therefore, based on the comparison visualized in **Table 7** and the purposes of a scorecard and dashboard mentioned in the paper of Baker (2015), the best suitable visualization technique for Medspray is a dashboard.

2.5 Software to develop the dashboard

This section is about identifying the software which will be used to develop the dashboard. The selection is based on the requirements of the company and a comparison between existing software. Therefore, first, section 2.4.1 discusses the purpose of the dashboard based on observations and interviews with the manufacturing manager and the employees of the production line which are the end-users. Based on this information, section 2.4.2 compares three software to develop a dashboard and the most suitable one is chosen.

2.5.1 Purpose of the dashboard

First of all, the aim of the dashboard is to monitor and control the current situation within the manufacturing department of the company. The dashboard which is created for the company essentially gives a quick overview of the current performance of the production process. Therefore, the dashboard needs to be easily understood and modified by the end-users, especially because Medspray is fast growing and their demands will change over time.

The main end-users will be the operators who are working in the production line of the company. With the KPIs and information visualized on the dashboard, they will be able to make decisions to improve the performance and get motivated to do so. Of course, also the management will make use of the dashboard to see in a quick glance the current performance within the production line. Moreover, the management can, based on the dashboard, make decisions for the operators to improve the specific parts in the production line.

"Dashboards can now be the primary interface for measuring the success of an organization's strategy as part of a Business Performance Management (BPM) initiative" (Schiff, 2019). "Business performance management (BPM) is a key business initiative that enables companies to align strategic and operational objectives with business activities in order to fully manage performance through better-informed decision making and action" (Shi & Lu, 2010). Therefore, BPM is focussed on the constant improvement of an organization through connecting indicators such as KPIs with their performance. BPM is not only about objectives in KPIs, but also about the relationship between bosses and employees on the workplace.

Therefore, it is essential to create a dashboard which strengthens this relationship and let the staff feel responsible for their own results in order to be committed and motivated. Through activating and stimulating employees, they are more able to achieve both their own operational objectives and strategic objectives. To do so, the software can be used to create a dashboard in order to provide the employees with a good understanding of their duties and work performance. Therefore, the dashboard needs to visualize the most important KPIs and need to be interactive.

Since the company has high confidential data, the safety of the software has a critical role in choosing the appropriate software. Also, the flexibility of displaying the dashboard is important since the production line is in a different building as the headquarter of Medspray where the office of the manufacturing manager is located. Another point to consider is the possibility to customize the visualization and the variety of different visualization types.

So, the primary goal of the dashboard is to visualize the performance within the production line of the company based on a day-to-day basis. Therefore, the visualization of the data is essential. Also, the ease of use of the dashboard is a critical factor which needs to be considered. Since the company

is growing so fast, there is not much space for an employee to be trained for using and maintaining the dashboard. Of course, for each company costs are also an important factor.

2.5.2 Comparison of software

There are a lot of software to create a dashboard in, three of them, Tableau, Qlik Sense, and Microsoft Power BI, are compared in order to choose the most suitable one for Medspray. **Table 8** gives the advantages and disadvantages of each of the three software ranked by the importance of the criteria based on the interviews with the end-users.

Table 8: *Pros and Cons Dashboard Software*

Criteria	Tableau[1]	Qlik Sense[2]	Power BI[3]
Ease of use	–	–	✓
Costs	✗	✗	✓
Connectivity to a variety of data sources	✓	✓	✓
Technical support required	✗	✗	✓
Secure	✗	–	✓
Speed	✓	–	✓
Memory	–	✗	✓
Flexible use in different kind of screens	✓	✓	✓
Custom visualizations	✗	✓	✓
Innovation & Versioning	✗	–	✓

✓ Criteria available

– Criteria available in a limited way

✗ Criteria not available

Power BI is a Business Intelligence (BI) service from Microsoft. Data from a company can be simply exported to Power BI. The dashboards and reports make it possible to analyze and visualize data easily. Power BI has a cloud service (Power BI service) and a desktop interface (Power BI desktop), the use of these connections is explained in **Appendix C**.

[1] ("Tableau Software Review: Pros and Cons of a BI Solution for Data Visualization," 2017)

[2] ("Qlik Sense Advantages and Limitations – Explore the Pros & Cons," 2019)

[3] ("Microsoft Power BI Pros and Con," 2019)

Figure 10 visualizes the relation between Power BI Service and Power BI Desktop together with the other features of Power BI. In the Power BI Desktop, data can be imported from other programs. With this data, a report can be made. This report can be published to Power BI Service which can be attached to a dashboard. From the Power BI Service, users have the opportunity to open the dashboard or report on any device.

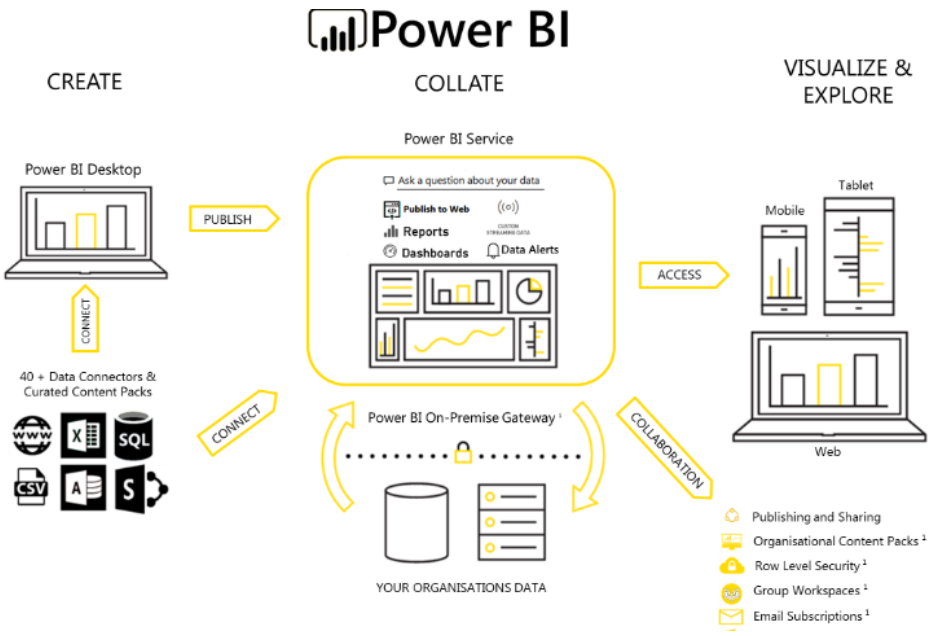

Figure 10: *Features of Power BI (Architecture)*

Moreover, Power BI is mainly an Excel-driven product which is a big advantage since Excel is an industry standard to store data. “Power BI is a data cleaning, data modelling and visualization tool which is capable of making a robust and complex data model composed of many different sources. This functionality is not present in Tableau Desktop, it requires the incorporation of another tool which essential drives up cost.” ("Tableau vs Power BI," 2019). Also, Power BI is an analytic tool that helps to create and share actionable and intuitive reports for business insights.

To summarize, the software Power BI is:

- Can eliminate repetitive work

- Can automate information provision
- Can combine all kind of data sources
- Low threshold for end users
- Low priced based on usage

Looking at the pros and cons of **Table 8**, the purposes and requirements from the company of the dashboard and the benefits discussed, the conclusion is that Power BI is the most suitable software the create a dashboard.

2.6 Data architecture

This section first introduces the concept of Data Management. Thereafter the concept of Data Architecture is discussed. Finally, ArchiMate is discussed as a tool to model the Data Architecture.

2.6.1 Concept of Data Management

After the content of the dashboard is determined, data need to be gathered and managed in order to visualize the chosen content (Huberman & Miles, 1994). For this, the data must be managed. Data management is about maintaining, updating, managing and securing data. Files are checked whether changes have occurred and adjusted if necessary. The files are enriched with new and additional data from external sources. Keeping the data up to date can be automated. Therefore, the purpose of data management is to ensure that the current data is complete, reliable and available on time for the execution of business processes and for taking the right management decisions.

2.6.2 Concept of Data Architecture

“The unambiguous specification and description of enterprise architecture’s components and especially of their relationships requires an architecture modelling language that addresses the issue of consistent alignment and facilitates coherent modelling of enterprise architectures.”(Group, 2013). Data architecture is part of the enterprise architecture and provides an overview of the present and required data in an organization. The data architecture is determined by analyzing the information needs of an organization and is represented using various models and techniques.

Data Architecture is about the agreements which are made about how data is stored and how an organization wants to deal with the possibilities to achieve optimal results with this data. Therefore, data architecture is a collection of models, processes, and rules which determine where data is stored and how they are integrated to be optimally utilized in systems and organizations.

Legislation and regulations are increasingly playing a greater role, which is why the foundation of a Data architecture is an essential condition for being able to continue to comply with laws and regulations.

2.6.3 Concept of ArchiMate model

ArchiMate originated from the desire to better align the architectural descriptions of different architectural approaches for different architectural disciplines. ArchiMate is used worldwide as the standard language within architecture.

ArchiMate makes it possible to provide insight into the structure and coherence of business processes, organizational structures, information flows, and technical infrastructure. ArchiMate offers a clearly defined set of concepts and relationships. Therefore, ArchiMate facilitates the discussion about architecture and the transfer of architectural knowledge to development teams.

ArchiMate is an integrated architectural language which describes and visualizes the relationship between different business and IT domains. With these integrated architectures, stakeholders can plan and communicate the impact of decisions and changes across the entire organization.

The focus of ArchiMate is on integrated modelling, visualization, and analysis. Integrated modelling means creating coherence between the models of other architecture languages and frameworks. Visualization or providing insight into architectural models means communicating within the own conceptual framework about the integrated architecture. Because the coherence between the domains can be made transparent, it can also be analyzed (Josey, Lankhorst, Band, Jonkers, & Quartel, 2016).

ArchiMate tries to model relationships at an abstract level between the domains which are described in more detail in other methods, such as UML and BPMN. ArchiMate differs from UML and BPMN because it is more conceptual and focuses less on the details. This makes it possible to provide insight into the structure and coherence of business process, organizational structures, information flows, and technical infrastructure. ArchiMate meets the need for more precise documentation in the field of enterprise architecture (Josey et al., 2016).

Because of the desire to gain insight into the coherence of the IT systems and the business, ArchiMate is chosen. ArchiMate makes information available to everyone, discover relationships between critical business processes, applications, data en creates a basis for analysis. ArchiMate is managed as an open standard by The Open Group. ArchiMate differentiates from other modelling languages such as UML and BPMN by focusing on modelling the entire organization and linking information from different architectural domains. ArchiMate is a program with an Enterprise architecture modelling language. In this program, architectures of processes, companies, and systems are made, this gives a clear representation of the process. ArchiMate makes it possible to model this in three layers, displayed in **Figure 11**. These three layers are the Business later, Application later and the Technology layer.

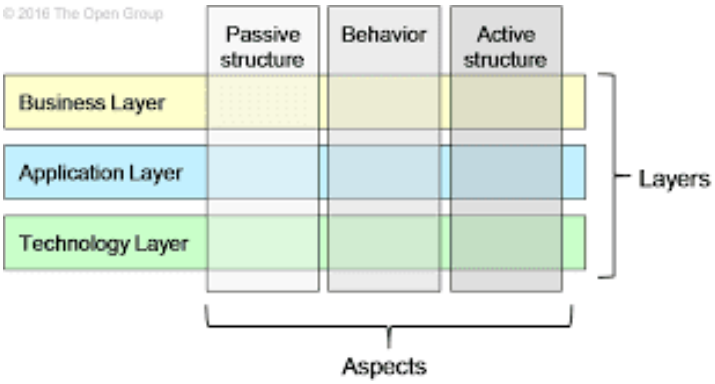

Figure 11: *General ArchiMate framework* (The Open Group, 2016)

- *The Business layer*: allows to model the business organization, business processes and products. This layer offers products and services to external customers.
- *The Application layer*: allows to document the application landscape and understand dependencies between these applications. This layer supports the business layer with application services.
- *The Technology layer*: allows cataloging an infrastructure over the hardware, software, and network. This layer offers infrastructure services need to run applications, realize by computer and communication: hardware and system software.

Each of these layers is further subdivided into passive structure, behaviour and active structure elements. This allows describing the enterprise.

- *Passive structure* (what): an object on which behaviour is performed.
- *Behaviour structure* (how): a unit of activity performed by one or more active structure elements.
- *Active structure* (who): an entity that is capable of performance behaviour (Group, 2013).

Appendix D explains the various elements of an ArchiMate Model with the layers and the relationship possibilities.

The modelling language ArchiMate connects concepts with which architectures can be modeled. There are clearly defined rules with which indirect relationships between concepts can be deduced. With the implementation, the connection between existing and desired situations can be made visible.

ArchiMate is about communication and is a visual modelling language for describing enterprise architecture. As the IT landscape of organizations becomes more and more complex and innovations and changes follow each other faster, it is important to create a joint picture of how IT is organized. To do this properly, a shared visualization language is needed (Josey et al., 2016).

All in all, ArchiMate provides:

- A **language** with concepts to describe architectures
- A **framework** to organize these concepts
- A **graphical notation** for these concepts
- An **open standard** maintained by the Open Group

2.7 Design of a dashboard

This section is about the design of the dashboard. After the software to create the dashboard and the content of the dashboard is chosen, a literature review is done about the design of this dashboard. First, general information about the design of the dashboard is discussed. Thereafter, the type of dashboard is described. Subsequently, the chart types and the layout of the dashboard are discussed.

2.7.1 General design

This subsection discusses the importance of the design and general features about the design of a dashboard.

"Dashboards can provide a unique and powerful means to present information, but they rarely live up to their potential. Most dashboards fail to communicate efficiently and effectively, not because of inadequate technology, but because of poorly designed implementations" (Few, 2006). Visualization makes data easier understandable. If there is a bad visualization, it does not give any meaningful information. Therefore, the way to use visualization is important. The design of a dashboard, therefore the visualization, is different from other visualization systems, it should be a single-screen display without scrollbars or multiple windows (Tokola et al., 2016). Since the data which will be visualized on the dashboard is based on real-time data, the visualization differs from a dashboard with historical data (Lockwood, 2016).

User-friendliness is key in determining the design of a dashboard. When designing the dashboard, it needs to be in line with specific objectives which need to be achieved. Another point of consideration is fitting the dashboard on a single computer screen (Few, 2006). The displayed information needs to be seen at a glance.

Furthermore, it is crucial to have a clear and consistent naming throughout the whole dashboard. Also, the alignment and layout are important for the readability of the dashboard. Moreover, it is important for the end-user to get a quick overview of the current situation within the production process, therefore this means the end-user does not have to perform many interactions to see the information which is needed. The end users need to understand the dashboard in order to act, therefore the visualizations on the dashboard need to be simple.

The dashboard needs to show data in a way that it can be acted upon immediately, for example visualizing whether the targets are being met of the current day or seeing opportunities for improvement (Lockwood, 2016). Another aspect to consider is the limited space available to display the data and the different display possibilities. For example, the dashboard can be visualized on a big screen but also on a tablet or a phone. Nowadays, there are more mobile users than desktop users, therefore it is essential to design the dashboard for mobile use. In each way, the dashboard needs to be clearly readable.

Putting data in a dashboard does not automatically mean that you add value to an organization. It may be that the visualization looks beautiful, but the information is misinterpreted and wrongly used by the end-users. The worst consequence is the end-users making wrong decisions because of the misinterpretation. On the other hand, it is also possible that the end-users are very enthusiastic about the dashboard during the development, but in the end, the dashboard is never used.

Simultaneous viewing of the pages at once is a crucial point to take into consideration when designing the dashboard. The operators within the company do not have their hands free to scroll and see what is not immediately visible, despite the fact that there is a change that this data is essential.

Another point of attention is the degree of detail. The level of detail displayed on the dashboard need to be high for a quick overview (Few, 2006). Too much detail distracts the end-users from then

information which really matters. Therefore, within the design of the dashboard, unnecessary detail must be avoided.

Of course, the goal is to make end-users happy and at the end embrace the developed dashboard. Moreover, end-users making better decisions with the insights obtained from the dashboard is the most valuable outcome of the dashboard. Therefore, the dashboard needs to be humanly centred instead of data centred. This means the users have to be at the centre when designing the dashboard. The developer of the dashboard needs to think about the way to best support the work of the end-users and the decisions which needs to be made. So human-centred does not mean asking the end-users what they want but to understand the work and needs and based on that come up with a dashboard which fits perfectly.

2.7.2 Type of dashboard

Before creating a dashboard, the type needs to be determined. Overall there are three types of dashboards, each differ in the level of detail is visualized, visualized in **Figure 12**. Each of the three types differs in visual design (Few, 2006).

Figure 12: *Level of detail in type of dashboards*

1. *Strategic*

These are "helicopter" dashboards which visualize only a few important KPIs for the management team of an organization. It provides a generic overview of the performance of the organization. This type of dashboard gives summarized information over time frames of a month, quarter or an even a year. Dashboards of this type focus on high-level measures of performance. This kind of dashboard is mainly used for managers to make strategic decisions.

2. Operational

An operational dashboard only contains operational KPIs which is based on real-time data. The focus of this type of dashboard is monitoring operations, focus on a specific department in a company in a short time horizon. The content visualized on this kind of dashboard changes constantly and requires a response as soon as possible. An operational dashboard is more detailed than a strategic dashboard. The information which is visualized is updated based on a daily basis. The users of this type of dashboard need to see the information visualized in a glance without drilling down into the dashboard. The data visualized need to be very simple (Few,2006). This kind of dashboards is mainly used in manufacturing companies.

3. Tactical

The focus of this type of dashboards is to analyze and optimize processes. The information visualized in a tactical dashboard is very detailed and the end-users need to drill down into the dashboard in order to find the information needed. These kinds of dashboards are often used when the information is complex and broad.

Comparing the three kinds of dashboards discussed above, the type of dashboard which is used for Medspray is an *operational dashboard*. The main reasons are the information visualized needs to be based on the manufacturing department, therefore not too general. On the other hand, a minimal interaction of the end-users needs to be required. The characteristic of an operational dashboard is

its dynamic and immediate nature (Few, 2006). These characteristics are essential within the dashboard which is developed for the company. Also, the dashboard is only based on real-time data which is essential for making decisions on the right time.

2.7.3 Chart types

The content of the dashboard consists mainly of KPIs which are selected for the company. Due to the fact that there are different types of KPIs visualized, therefore different types of information, attention must be paid to the type of charts used for the data visualization in order to prevent data misinterpretation. Therefore, the visualization of the content in the dashboard needs to be in line with the required information of the end-users.

The type of charts used in the visualization is also dependent on the software where the dashboard is created. Within Power BI there are two typical different chart types: line charts and column or bar chart. Line charts are mainly for trend analysis. Therefore, when the purpose is to display a trend, a line chart is the right type of chart. Column or bar charts show information in categories. Therefore, when categories need to be compared, this kind of charts are preferred.

Within Power BI, data can also be displayed in pie charts. The downside of the use of a pie chart is that no information is given when the value labels are not visualized. A horizontal bar graph is much more efficiently and accurately compared to a pie chart (Few, 2006). Therefore, when part-to-whole data needs to be displayed, a horizontal bar graph is recommended.

Radar graphs are rarely appropriate media for displaying business data due to the limited axes (Few, 2006). The information visualized in a radar graph is much clearer when visualizing it in a linear display, such as a bar graph (Few, 2006).

2.6.4 Layout

After having determined which kind of charts fits the purposes of the visualization, the layout of the dashboard needs to be considered. The space available within a dashboard is limited. Therefore, the content needs to be organized well.

Firstly, the position of the charts needs to be determined. The position of the information visualized need to be based on importance (Few, 2006). Therefore, the importance of the information visualized on the dashboard has to be ranked based on the positions which are first looked at, which is the position top left and centre (Tokola et al., 2016). **Figure 13** visualizes the extent of emphasis within each location of the dashboard (Few, 2006).

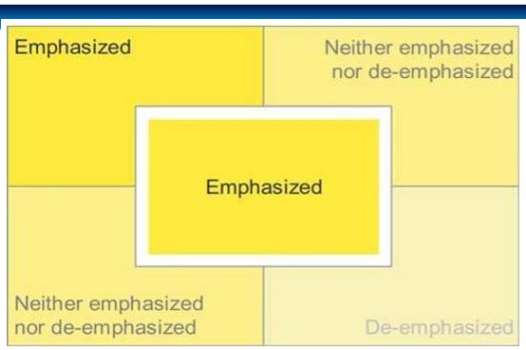

Figure 13: *Location of Emphasis*

Data that require attention need to stand out and data which need to be compared, need to be arranged (Few, 2006). Another point is the gridlines which only distract the end-users from the data. Therefore, when designing the dashboard, grid lines need to be used in graphs only when it is necessary to read the graph effectively (Few, 2006).

The colour use is another crucial point in determining the layout of the dashboard. Misused or overused colour use can distract the end-users or even cause misinterpretation of the data. Therefore, colour choices should be made thoughtfully and the difference between colours need to be understood before using it. For example, when colours are the same at the places within the dashboard, the data of these two places need to be related to each other. Also, the use of colours to visualize important data differs from the less important data. **Figure 14** displays the different colours (Few, 2006).

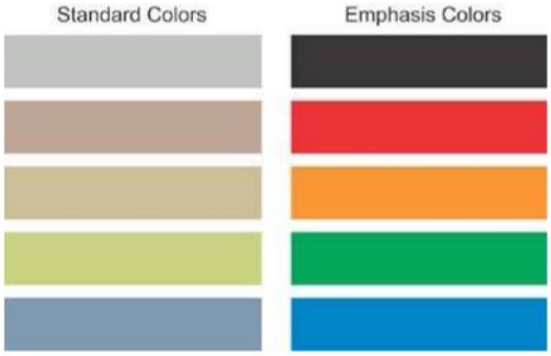

Figure 14*: Use of colours in Dashboard*

Using borders to delineate sections of data is very useful for the overview of the dashboard (Few, 2006). Especially because dashboard needs to visualize a lot of data and therefore do not have much spare space, subtle borders are the best way to separate a different kind of data.

3. Current situation

This chapter discusses the current situation within the manufacturing department of Medspray based on a flowchart. The purpose of the flowchart is to visualize the steps taken in the production process where the focus is on in this research.

3.1 Flowchart

Figure 15 displays the flowchart which shows all the subassemblies of the SNU production. Bizagi Modeler is used to create the flowchart which is a Business Process Modelling Software (BPMN) that facilitates the creation and implementation of flowcharts and workflows ("Bizagi Modeler Business Process Modelling Software," 2019).

The flowchart of the manufacturing department of Medspray provides insight into the current situation of the production process within Medspray to get a deep understanding. The flowchart visualizes the high-level activities of producing the SNUs. First of all, a customer orders a quantity of SNUs. When the order is received by the Manufacturing department of Medspray, first the inventory level of SNUs is checked.

When enough SNUs are in stock, the order is packaged and send to the customer. When there are not enough SNUs in stock, the inventory level of the subassemblies is checked. When all the subassemblies are in stock, the cleanroom of Medspray produces the ordered quantity of SNUs. On the other hand, when there are not enough subassemblies in stock, the suppliers of Medspray get an order and the cleanroom of Medspray needs to wait for the order to start with the production.

During the observations, the subassemblies where always in stock. This is the responsibility of the manufacturing manager. Creating this flowchart made is doable to communicate about the processes in clear and easy-to-understand diagrams.
All in all, the flow chart helped in getting insight into the various high-level actions which must be taken within the manufacturing department of Medspray. Furthermore, it made communicating about the production process clearer.

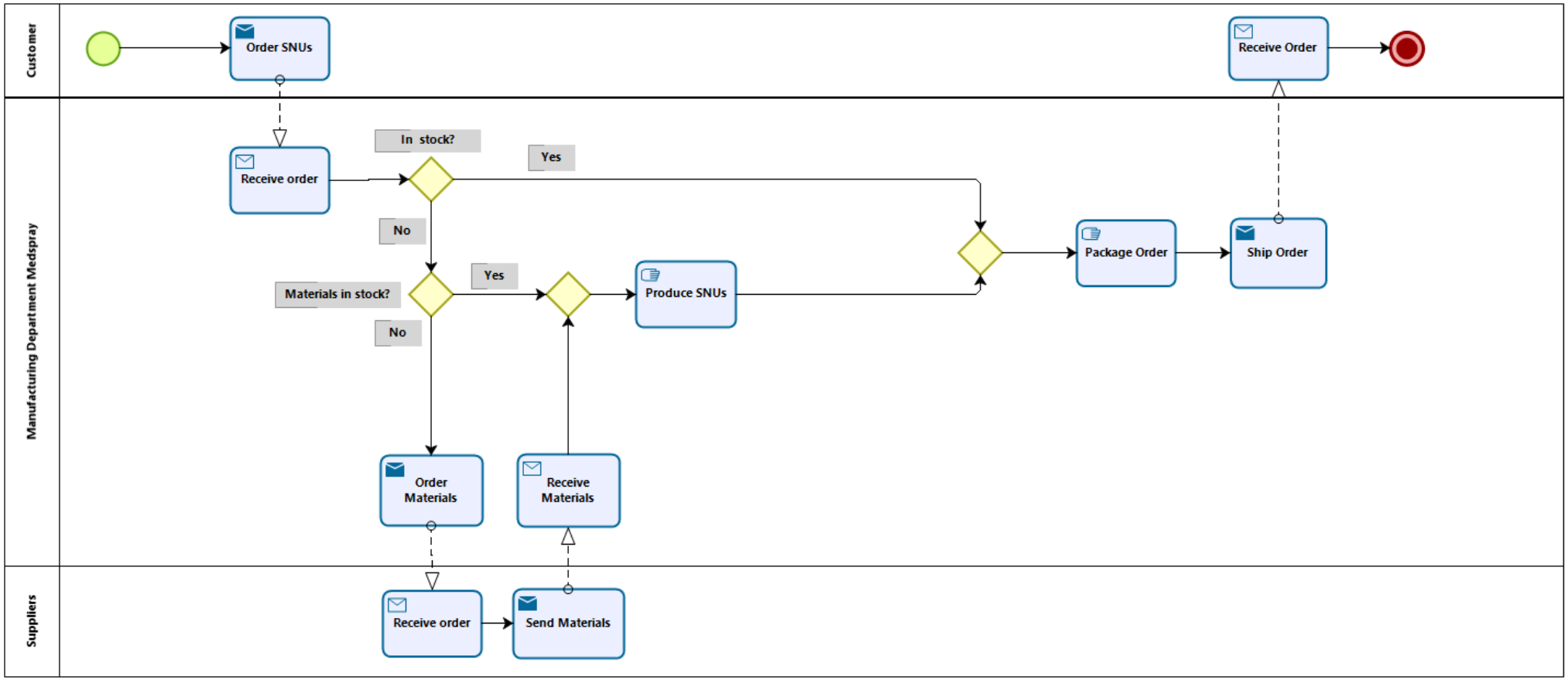

Figure 15: *Current Flowchart of the Supply Chain Medspray Manufacturing Department headquarter*

4. Content of the dashboard

This chapter is about defining and collecting the content of the dashboard. First, section 4.1 performs a KPI selection to identify the KPIs to visualize on the dashboard. Section 4.2 is about the content of the dashboard beside the selected KPIs. Section 4.3 discusses the collection of the required data for the content of the dashboard.

4.1 KPI selection

This section discusses a selection of the KPIs of Medspray based on the found KPIs from the Systematic Literature Review in section 2.2 and interviews with the end-users of the dashboard.

Therefore, now that it is known which KPIs exist that express the performance of the production process, the exact KPIs are determined through a KPI selection. A critical step is to determine which KPIs have the most value for the company. Due to the fact the company is not that big yet and therefore the available data is limited, the possible KPIs are limited.

Interviews have been prepared for the end-users of the dashboard to indicate the most important KPIs for Medspray. The selection will then be compared to the core values of the company so that it can be determined whether the KPIs are compatible with Medspray. Finally, it is examined whether the different perspectives of the Balanced Scorecard support the selection.

4.1.1 Interviews end-users

Interviews are used to select suitable KPIs for Medspray. These interviews have been prepared for the end-users of the dashboard, so the manufacturing manager and the operators of the production line. The method is ultimately intended for them and they know best what is relevant to the company. The interviews were semi-structured. The end-users where asked which performance they find important for the company and how they want to measure it.

First of all, the company wants to scale up the output. Therefore, the KPI “Quantity Produced” is an essential KPI which visualizes the number of products produced per time unit, also called “Productivity”.

Another KPI is the First Pass “Yield” which is a measure of the operational efficiency. It is defined as the number of units coming out of a process divided by the number of units going into that process over a specified period of time.

Another important KPI for the company is to keep track of the number of shipped orders and their corresponding reliability which is based on the number of orders delivered on time. This information is expressed in the “Delivery reliability”, also known as “On Time Delivery”. This KPI is essential for customer satisfaction.

Therefore, based on the KPI selection, interviews with the end-users and the available data the KPIs “Productivity”, “Yield” and “On Time Delivery” are visualized on the dashboard.

The KPIs resulted from the interviews are colored green and orange in **Table 9** depending on the availability of the required data. The KPIs which are colored green are used for the content of the

dashboard. The KPIs which are colored orange have a valuable meaning for the company but cannot be visualized yet due to lack of data. These KPIs are discussed as recommendations in chapter 7. The interviews resulted also in addressing important information, which is not KPIs, to visualize within the production line of Medspray. This valuable information is discussed in section 4.2.

Table 9: *Production Performance KPIs*

Article	(Lai & Man, 2017)	(De Felice & Petrillo, 2015)	(Mousavi and Siervo, 2017)	(Tokola et al., 2016)	(Jovan et al., 2006)
KPIs ⬇					
Breakdown severity		Return on Equipment	Overall Equipment Efficiency	Delivery reliability	Productivity
Work request response rate		Return on Investment	Overall Line Effectiveness	Production cycle time	Yield
Manpower utilization rate		Waste reduction		Order to delivery lead time	Mean Products Costs
Availability		Customer satisfaction		Resource utilization rate	
Utilization rate		Product recovery		Overall equipment effectiveness index	
Utilization index		Process Innovation		Capacity utilization rate	
Schedule realization rate		Time to market		Yield	
Work order turnover		Staff satisfaction		First Pass Yield	
Response rate for maintenance		Productivity		Suppliers' quality	
Failure/breakdown frequency				Line efficiency	

	KPI is applicable and preferred by the company
	Not applicable for the company
	Duplicates
	Preferred by the company

4.1.2 Perspectives Balanced Scorecard

As mentioned in section 2.3.2, the BSC consists of the perspectives financial, internal, innovation and customer. This section discusses whether the KPIs selected include each of the four perspectives.

First of all, the KPI “On Time Delivery” is a KPI in the customer perspective of the BSC. This KPI is essential for the customers because it visualizes how many orders are delivered on time to the customers. Therefore, this KPI is essential for customer satisfaction.

Second, the KPI “Productivity” is a typical KPI which fits the perspective internal perspective. This KPI shows how many products are produced per hour. Therefore, comparing the actual production speed with the intended production speed gives a good indication of whether the company is doing the right things in the right way.

Also, the KPI “Yield” fits the internal perspective since it measures how many products of the total products are rejected the first time.

There are no KPIs which fit the financial and innovation perspective. The financial perspective shows how the company performs financially. Since the research is focussed in visualizing the performance within the production line, financial KPIs are not relevant to keep track of. Of course, for the other departments of the company financial KPIs are essential. Because the most important end-users will be the operators, visualizing KPIs like the profit and costs does not help in improving their performance.

For the innovation perspective, there are not KPIs available yet for the company. KPIs such as the Overall Equipment Efficiency could be implemented since this KPI indicates how well the company is performing. Therefore, this KPI helps the company in monitoring the growth in a dynamic environment with growing competition. This KPI consists of the Performance, Availability, and Quality. Only data of the Availability is missing and therefore the KPI OEE cannot be implemented yet.

4.2 Key content of the dashboard

Besides the KPIs which are visualized on the dashboard, other information about the production process of the company is valuable which is discussed in this section.

For the operators, as well as the manufacturing manager it is essential to have a real-time update about the progress of the production amount. Therefore, the current amount and the planned amount of production is a valuable visualization. This data can be separated between the shifts and summarized the whole day in order to see whether the target of the current day is met.

In order to keep track of the performance, the average speed is also a value-added visualization. For example, when the production speed in a particular hour was low and in another hour, it was above average, these hours compensate with each other and therefore the target average speed will be met.

Also, the current inventory of the semi-finished products is preferred by the company in order to decide which task has the priority. This means that the current inventory level of the prefilters, wafers, and chips are visualized on the dashboard.

Finally, for the operators, an overview of the orders from customers with the corresponding deadlines helps them in having structure and motivation in their daily tasks. It gives them an idea of what they are working for. Therefore, but visualizing the orders, the operators have more insight into when the orders need to be finished.

4.3 ArchiMate Model

In this section, the Data Architecture of the production line within Medspray is described in an ArchiMate Model. For Medspray, the purpose of an ArchiMate model is to visualize where the required data of the dashboard is extracted from.

Medspray stores data in a PostgreSQL database and in Excel sheets. Therefore, when developing the dashboard, data needs to be extracted on a daily basis from these sources. **Table 10** shows where the required data need to be extracted from each part of the content within the dashboard.

Table 10: *Overview location of the extracted data*

Database: PostgreSQL	Excel sheet: Delivery dates	Excel sheet: Inventory level
Productivity	On-Time Delivery	Inventory level
Yield	Schedule of the orders	
Average production speed		
Summary production amount		

Data of the whole company Medspray is stored in a PostgreSQL database. PostgreSQL is an open source relational database which is freely available. It is an alternative to other open-source databases, such as MySQL. PostgreSQL is not managed or controlled by a single company but relies on a global community of developers and companies ("What is PostgreSQL? " 2019).

The company stores a lot of data in Excel sheets, among which the orders of the customers and whether the orders have met the deadline. These data are stored in the Excel sheet: “Delivery dates” which are managed by the manufacturing manager. Also, these Excel sheets are connected with Power BI to visualize the content on the dashboard.

All the connections of the dashboard are visualized in the ArchiMate model. This model is not visualized in the public version due to confidentiality. **Appendix C** describes the data preparation and structure of the software Power BI.

5. Design of the dashboard

After discussing the literature about the design of the dashboard in section 2.6, this chapter focusses on the design of the dashboard based on implementations within Medspray. Section 5.1 discusses the design based on the purpose of the dashboard for the company. Section 5.2 discusses the design based on the KPIs and information selected for the content of the dashboard.

5.1 Design based on the purpose of the dashboard

A good start is mapping the function of the end-users and the overall purpose of the dashboard. As mentioned in section 2.4.1, the end-users of the dashboard are the manufacturing manager and the employees of the production line in Medspray. After having interviews and observations within these end-users, the needs of the dashboard are identified.

The manufacturing manager is responsible for the performance within the production line of the company. Therefore, keeping track of the performance within the production line is essential for this end-user. The information needs to be real-time in order to make appropriate decisions and reach the target of the company. For the operators, it is essential to keep being motivated and know which tasks need to be performed at what time.

So, the main purpose of the dashboard is to provide the manufacturing department with real-time information about the performance within the production process of Medspray. Therefore, the dashboard needs to give an at a glance view of crucial data important for the end-user to analyze and make decisions. The end-users can only benefit from the dashboard if they are provided with visualizations of the data in a flexible and efficient way (Mazumdar, Varga, Lanfranchi, Petrelli, & Ciravegna, 2011).

Furthermore, the visualization on the dashboard has to be based on user needs (Mazumdar et al., 2011). Since the end-users of the dashboard will be the manufacturing manager as well as the employees within the production line, their needs have to be combined within the visualization. Another point to consider is that the decision maker, in this case, the end-users of the dashboard, are suffering from too much data which gives too little information and not on time to make effective decisions (Eckerson, 2010).

Moreover, when the dashboard is developed, the design should be accessible for other devices than a computer, such as a mobile phone or a table. Currently, there are more mobile users than desktop users. Therefore, since everyone nowadays has a mobile phone, it is essential to design the dashboard for mobile use.

5.2 The dashboard

After having determined the visualization techniques of the dashboard, the dashboard is developed. In this section, first, the final dashboard is visualized in section 5.2.1. Thereafter, each visualization is discussed based on the KPIs and data which is displayed on the dashboard in section 5.2.2.

5.2.1 Final dashboard

Figure 18 and
Figure 17 are screenshots of the developed dashboard for the production line with the company Medspray. Due to confidentiality, the data within the dashboard is covered in this public version.

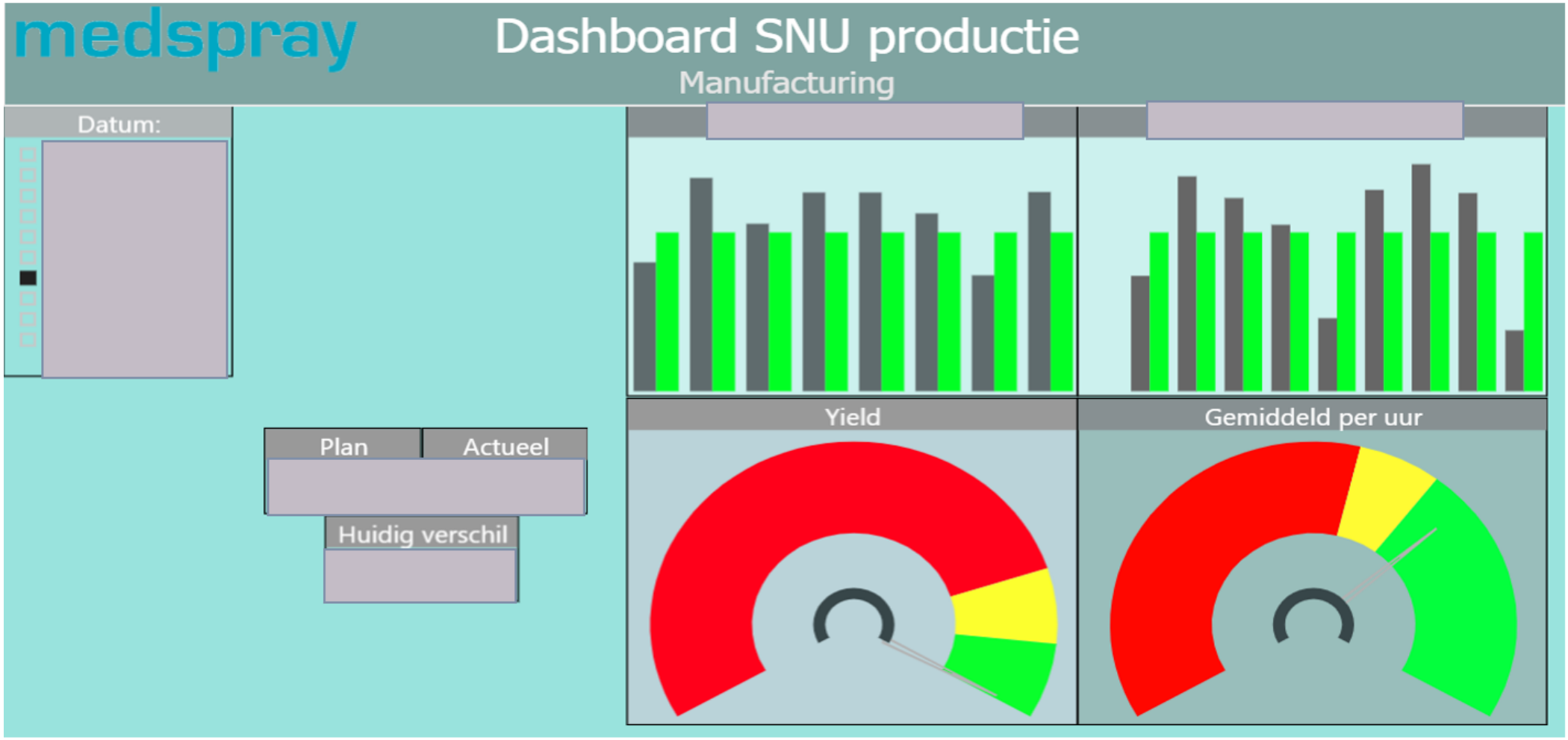

Figure 16: *Screenshot dashboard page 1*

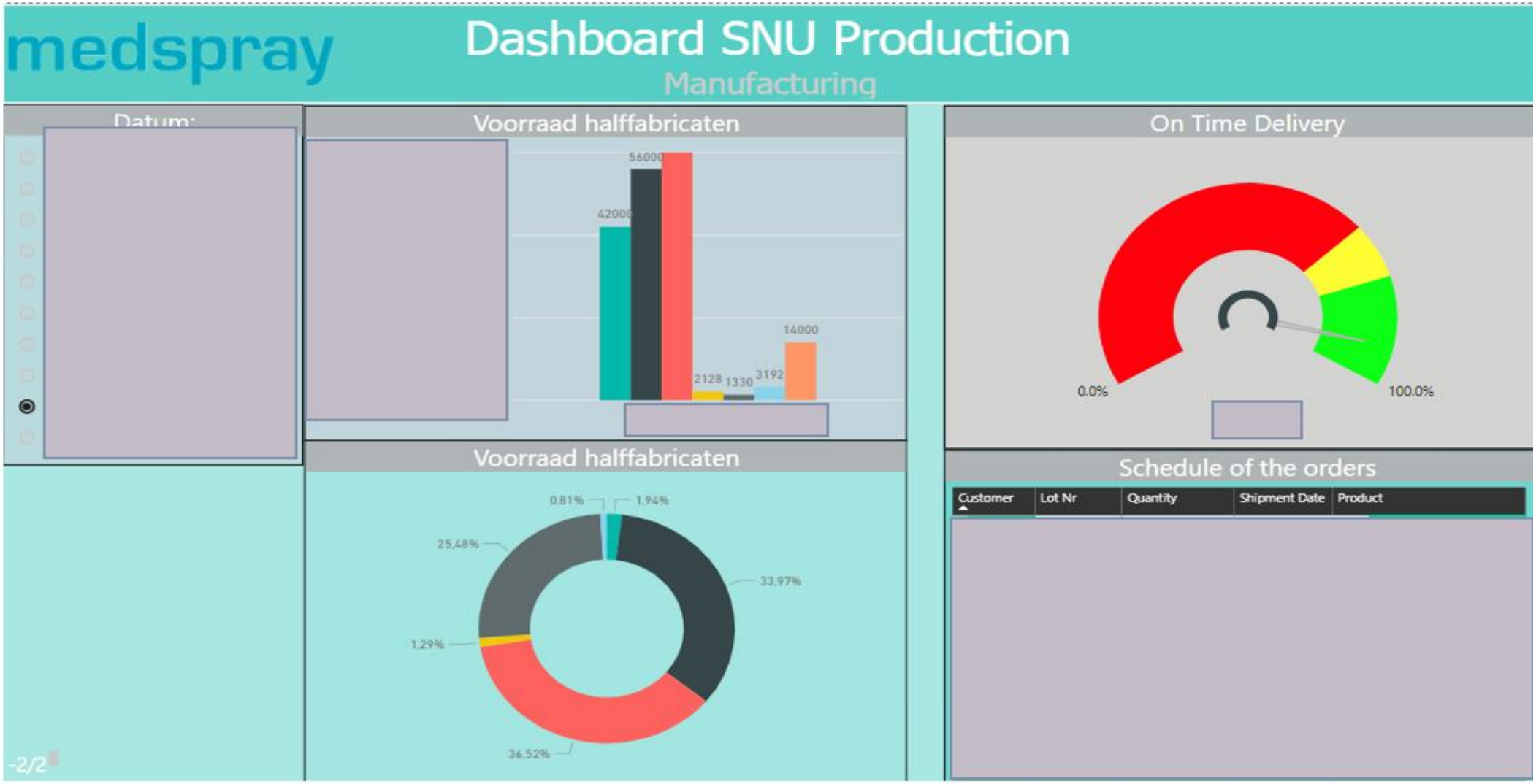

Figure 17: *Screenshot dashboard page 2*

5.2.2 Visualization of the KPIs and required data

The data which is visualized on the dashboard contains KPIs and valuable data for the company. **Table 11** shows the content of the dashboard. The design and use of each page and part of the content are discussed in this subsection.

Table 11: *Content of the dashboard*

KPIs:	Non-KPIs
Productivity	Average production speed
Yield	Inventory level
On-Time Delivery	Schedule of the orders
	Summary of the current status

Dashboard page 1

The first page of the dashboard contains the KPIs “Productivity” and “Yield”. Also, this page contains the “Average production speed” and the “Summary of the current status”. The components are visualized on the first page because the end-users want to see the content continuously. These data are updated every fifteen minutes. With these visualizations, the operators within the production line can see whether they are producing as planned. Therefore, on the first page, all the visualization relation to the amount of production per hour is displayed. The required data for these visualizations is extracted from the database of Medspray.

Dashboard page 2

The second page of the dashboard contains the KPI “On Time Delivery”. The inventory level of the subassemblies and the schedule of the orders is also displayed on this page. The data required for these visualizations are two excel sheets. The information on these components is not updated continuously. The operators just want to keep track of the orders in order to see where the produced SNUs are going to. Also, when the KPI “On Time Delivery” is low, actions need to be taken in order to improve it. Therefore, the reason that this information is displayed on the second page is that it is not needed continuously.

Summary production amount

With a summary of the current versus the planned production amount, visualized in **Figure 20**, every employee at Medspray can see at what stage the production process is. The summary displays the current number of produced products and the difference between the amount produce. Also, the total amount produced for the whole day is displayed together with the target amount of production. With this visualization, the employees and the manager can see in one glance how the performance within the production line is. If the production has been fallen behind, the manager can decide to take actions in order to reach the goal of the day despite the backlog.

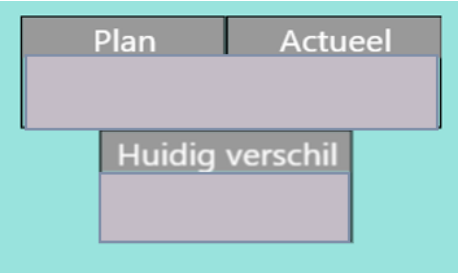

Figure 18: *Summary production current day*

KPI: Productivity

This KPI visualizes the production per hour. With a drill down function, the employees can select which day they want to see the performance, but usually, the current day is displayed.
Within the visualization of this KPI, the target is also displayed in a green bar next to the actual production amount. The use of this KPI is, for example, when the production amount in an hour is very low, the manager can discuss with the employees what happened in that hour. Therefore, this KPIs increases the overview of production performance. **Figure 21** visualizes a screenshot of this KPI from a random day.

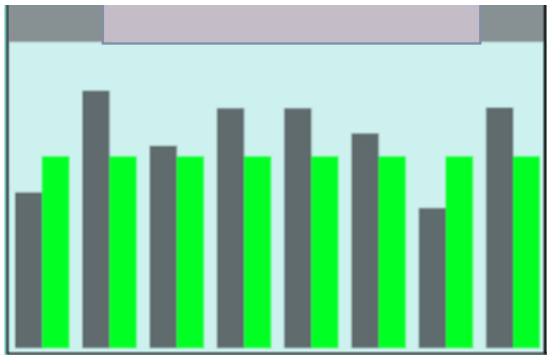

Figure 19*: KPI "Amount produced"*

KPI: Yield

This KPI visualizes the percentage of products which are of good yield compared to products which are rejected. Therefore, yield is dependent on the number of good products in relation to the number of goods produced. The KPI visualized the yield efficiency, therefore the fraction of approved products. **Figure 22** visualizes the yield in a gauge chart within the dashboard.

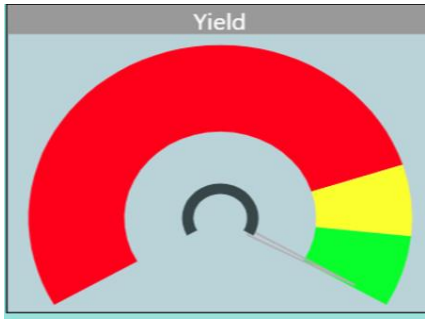

Figure 20: *KPI Yield*

KPI: On Time Delivery

Delivering the order of customers on time is an important aspect of logistics operations. Customers demand that their products are delivered as soon as possible. The KPI On Time Delivery indicates how many delivered orders were delivered on time which is essential in customer satisfaction. This KPI is also displayed in a gauge chart and the boundaries are identical with the KPI "Yield" as discussed with the end-users of the dashboard. **Figure 23** visualizes the KPI "On Time Delivery" as is displayed in the dashboard. When it is established that this KPI has a low score, action must be taken to improve it. Examples of actions are avoiding promises to customers which cannot be kept or making a forecast based on the required customer demand. These actions will decrease the chance of having an order delivered too late.

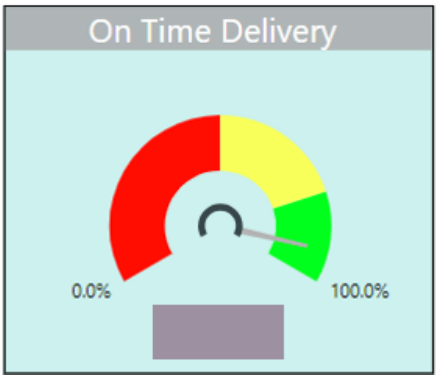

Figure 21: *KPI "On Time Delivery"*

Average production speed

This data visualized the actual speed of the whole day. **Figure 24** visualizes this content. Therefore, through visualizing the average speed, the operators get motivated to work harder and reach the target speed. Especially, because the progress is visualized on the dashboard immediately.

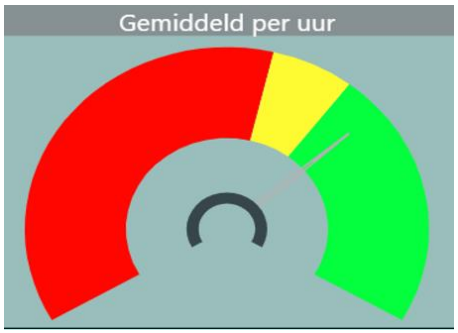

Figure 22: *Average speed*

Inventory level

Currently, there is no fixed order of the tasks within the production line. Of course, the bottleneck, which is the test machine, needs to be occupied as much as possible. The assembly machine needs to have inventory in order to assemble the product. For the inventory, the subassemblies which are delivered by the suppliers need to be processed. Therefore, the inventory level of each task within the production line is essential data for determining the priority of the tasks. **Figure 25** visualizes the inventory level of semi-finished products on Wednesday 22 May 2019

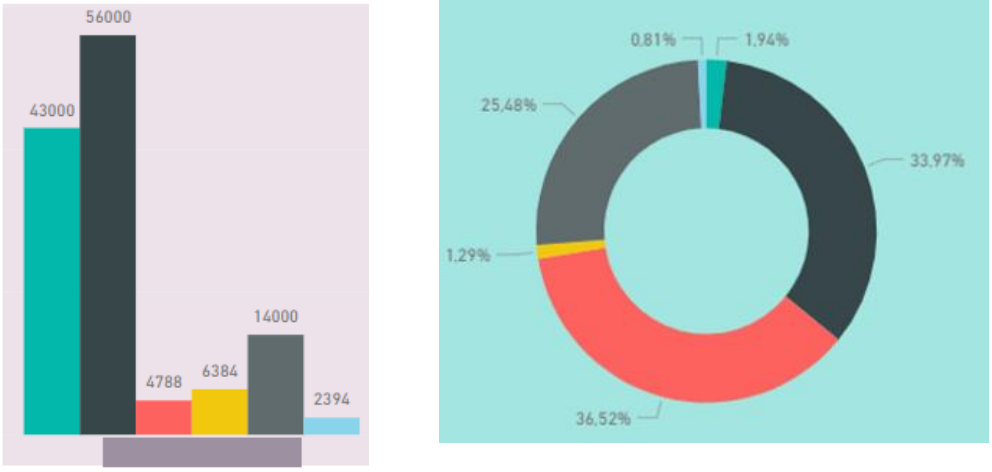

Figure 23: *Inventory level semi-finished products*

Schedule of the orders

This information is visualized in a table on the dashboard in order to increase the structure for the operators. **Table 13** shows the table which includes the deadline, customer and the quantity of the orders.

Table 12: *Schedule of the orders*

Slicers

Within the dashboard, a slicer is added which shows the past days till four weeks. This slicer is interactive, which means the end-users of the dashboard can manually select which day they want to see the performance of. Mainly the end-users are interested in the current day. **Figure 26** visualizes a part of the slicer.

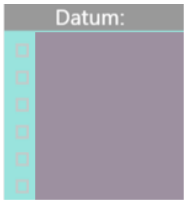

Figure 24: *Slicer per day*

6. Evaluation and validation of the dashboard

This chapter discusses the evaluation and validation of the dashboard. The evaluation and validation are determined by visualizing the prototypes which are made and changed after testing the prototype and conducting semi-structured interviews with the end-users of the dashboard.

6.1 Prototype 1

Since the company is working a lot with Excel sheets, the first dashboard is created in Excel, visualized in **Figure 25**. First, the setup of this dashboard was discussed with the manufacturing manager. The feedback was positive, but the hour and day target production were missing. Moreover, in Excel the visualization possibilities are limited. For the operators, the visualization is essential to get an at a glance overview of the performance. Therefore, another software was researched to create the dashboard in.

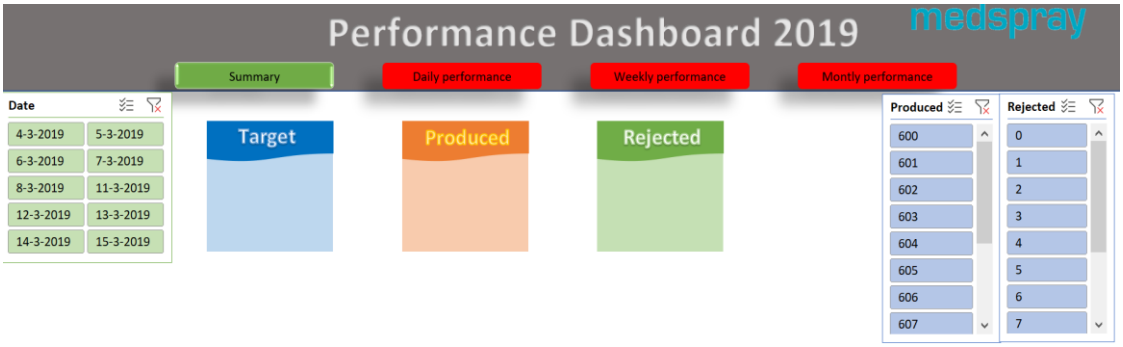

Figure 25: *Prototype 1: Dashboard in Excel*

6.2 Prototype 2

For the second prototype, the dashboard is created in the software Tableau. Tableau is a data visualization tool which is used for data science and business intelligence purposes. **Figure 28** visualizes the second prototype. After interviewing the end-users, the feedback was to also visualize the average speed in a gauge chart. Unfortunately, there was no possibility to include a gauge chart in Tableau. In **Table 8** it appeared that Tableau does not have custom visualizations. Therefore, not only there is no gauge chart, the visualizations are limited. Especially for the operators, it is necessary to have custom visualizations to make the information clear at a glance.

From **Table 8**, Tableau did not have an advantage regarding the ease of use. Because Medspray is growing at a fast speed, there is not much space to spend much time in understand and working with the dashboard. Therefore, this is also a disadvantage of using Tableau as the software to develop the dashboard.

Currently, not much data is available to implement in the dashboard. Since the company is expanded, the amount of data will increase rapidly. This means the software, which is used, needs to have a lot of memory. Also, from **Table 8**, it appears that Tableau does not provide a lot of memory.

All in all, Tableau does not meet the requirements of the company and will not be used as the software to develop the dashboard in.

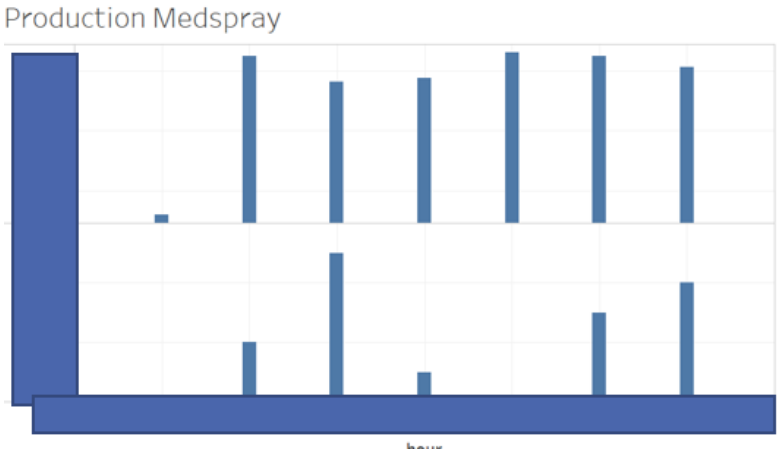

***Figure 26**: Prototype 2: Dashboard in Tableau*

6.3 Prototype 3

After performing a literature review, which is shown in section 2.4, Power BI appeared to be the most suitable software to create a dashboard based on the purposes and needs of the company. Power BI is a business analysis software which allows visualizing data and sharing insights throughout an organization. The software connects to hundreds of data sources and visualizes data within live dashboards and reports ("Power BI," 2019).

Error! Reference source not found. visualizes the first version of the dashboard developed in Power BI, due to confidentiality, this figure is not visualized in this public version. This version is the first dashboard which was actually used in the production line of the company. After using this dashboard for a couple of days within the production line, the main feedback of the operators was that they did not like the gauge charts of the production per hour. The reason is that at the beginning of each hour the gauge chart will be in red which is not motivating the operators. The gauge chart is in red despite the fact it is not something that the operators could have prevented. Since at the beginning of each hour, of course zero products are produced.

6.4 Final dashboard

In this last version of the dashboard, the production per hour is changed by the average speed per hour based on the current day. This ensures that the gauge chart is not being in red at the start of every hour. Furthermore, a second page is created with the inventory levels of the semi-finished products and the order schedule of the customers, which was requested by the operators. The two pages of the final dashboards are visualized in **Figure 18** and
Figure 17.

Evaluation final dashboard

In this part, the final dashboard is evaluated based on the functionality, user-friendliness and cognitive power according to the implementation of two weeks. The evaluation is based on interviews conducted with the end-users of the dashboard. These interviews were semi-structured. Therefore, during the implementation of the dashboard, first these questions were asked:

- Do you as an end-user see any improvements?
- Would you like to add more information to the dashboard?

- In what way is the dashboard useful to you?
- Is the dashboard motivating you?
- Do you work differently due to the dashboard?
- Do you have any feedback or comments for the dashboard?

Therefore, only open questions were asked in order to let the end-users give their own opinion and to prevent them from going to a certain answer.

The results of the interviews are discussed after the implementation of the final dashboard.

First of all, a legend is missing to indicate what the colours mean of the bars within the KPI "Productivity". Therefore, it was not clear for the operators, without any explanation, what the bars mean in the bar graph.

The functionality of each part of the dashboard is discussed in section 5.5. Overall, this dashboard is especially useful during the shift transfer. In this transfer, the operators together with the manufacturing manager discuss the progress within the production line. This dashboard gives an at a glance overview of the current performance within the production line.

Another point for improvement of the dashboard is to add the target of the production for each shift on the summary of the production status. Currently, only the difference between the target and the actual production amount is displayed together with the production amount itself. This would be easier for the operators to see how many products need to be finished at the end of each shift.

The end-users are positive about the user-friendliness of the dashboard because the interaction is minimal. The only interaction is clicking on the day where the information is needed and switching between the two pages of the dashboard.

The cognitive power of the operator and the manufacturing manager regarding production performance is increased. With the use of the dashboard ability to learn and exchange knowledge has been made more accessible. There is no need to look into the database or to analyze Excel sheets in order to see the progress of the production. This is concluded based on the comments received from both the operators and manufacturing manager. The manufacturing manager can see at a glance the current performance of the production line. The operators are able to see, especially during the shift transfer, in which extent the target of the day is reached. Moreover, because of the inventory level, the operators know exactly which tasks they have to perform in which order to prevent the bottleneck from being not occupied.

Another point which was requested of the operators is to visualize the orders of each customer separated instead of a list with all the customers. In this way also the KPI "On Time Delivery" could be calculated of each customer separately.

All in all, the dashboard ensures that the performance within the production process of Medspray is visualized in a quick display.

7. Conclusion, Limitations & Recommendations

In this chapter, section 7.1 discusses the answer to the research question and whether the norm is reached with the research which is carried out for Medspray. Section 7.2 gives some recommendations which the company could use for the future when the production process is expanded. Finally, section 7.3 considers the limitations of this research. Section 7.4 is about the contribution of the research.

7.1 Conclusion

During the research, several research questions are answered to answer the main research question:

"How to visualize the production performance of Medspray?"

This section discusses the research questions within this research. These research questions are divided into the phases of the MPSM. Thereafter, the problems within the problem cluster in **Figure 4** are discussed. Finally, the solution to the main research question is discussed.

7.1.1 Research questions

Phase 1: Defining the problem and Phase 2: Formulating the approach

Research question 1: *What does the current production process of Medspray look like?*

It is important to gather facts about the current situation to get a deeper understanding of the problem. To answer this question, first, literature research is done in existing methods to map business processes. Based on the literature and the purposes of mapping the business process within Medspray, the conclusion was to use a flowchart. The flowchart is used to display the current high-level activities within the manufacturing department of Medspray. This flowchart visualizes the steps which need to be taken by the headquarter of Medspray to make the production of SNUs possible. Moreover, the flowchart showed that the responsibility of having the subassemblies in stock is the responsibility of the manufacturing manager.

All in all, investigating the current situation within the production line of Medspray showed there is no visualization within the cleanroom and gave a deeper insight into the current way of working.

Research question 2*: What is performance management?*

This research question first discussed the difference between performance management and performance measurement. The main difference is that performance measurement is the first step in performance management. Therefore, to continuously keep track and control the performance, performance management is necessary. So, the effectiveness of measurements is dependent on the extent of managing the measurements.

Thereafter, the performance management methodologies “Balanced Scorecard”, “Six Sigma” and “Lean” are discussed to understand how performance management works in practice and to be able to implement it for Medspray.

Phase 3: Analyzing the problem

Research question 3: *Which KPIs can be used to measure the performance of the production process? (Systematic Literature Review)*

This research question gave a list of performance KPIs which could be implemented to visualize the performance of a production process. **Table 20** visualizes the list with the performance KPIs.

Phase 4: Formulating solutions and Phase 5: Choosing a solution

***Research question 4*:** Which KPIs are most suitable for the company?

To visualize the performance within the production process, KPIs are needed. In order to have an overview of the existing performance KPIs, first, a Systematic Literature Review is done to answer research question 3. From the KPIs found, KPIs are selected based on interviews with the end-users and based on the available data within Medspray. The selected KPIs are listed in Table **13**, which is the answer to research question 4. The number of selected KPIs are low due to the limited data available. During the interviews, also other content or information appeared to be important to visualize for the end-users. The content is listed in **Table 13** as non-KPIs.

Table 13: *Selected KPIs and non-KPIs*

KPI content	Non-KPI content
Productivity	Inventory level
Yield	Average production speed
On-Time Delivery	Schedule of the orders
	Summary production status

Research question 5: *Which techniques can be used to visualize the performance of the production process within Medspray?*

After the content of the visualization is set, the technique to visualize this content need to be chosen. Through a literature study, existing visualization techniques are compared. The most often used techniques are “the Balanced Scorecard” and “a Dashboard”. After comparing these two with each other, a dashboard turned out to be the most valuable technique to implement for Medspray based on the purposes of the visualization and the comparison from the literature.

Phase 6: Implementing the solution

Research question 6: Which software to make a dashboard is best suitable for Medspray?

After the content and the technique is set, the software to develop a dashboard needs to be chosen. This is done through comparing the most used dashboard software, Tableau, Power BI and Qlik Sense. After mapping the criteria of the company for the visualization and comparing the

disadvantages and advantages of each of the software, Power BI is chosen as the most valuable software to develop the dashboard in.

Research question 7 How to prepare and structure the required data in the software?

To develop the dashboard, data needs to be connected to the software. To make a clear overview of the required data and the use of this data, an ArchiMate model is developed. **Error! Reference source not found.** visualizes the ArchiMate model.

Research question 8: How to design the dashboard with the chosen software?

The design of the dashboard is an essential part of the development of the dashboard. Therefore, a literature review is performed to map the most important points of attention concerning the design of the dashboard. Also, the design needs to fit the needs of the company. Therefore, interviews are performed to map the needs of the dashboard to decide the location of each part of the content within the dashboard and the manner of visualization.

Phase 7: Evaluating the solution

In this last phase, the dashboard is implemented within the cleanroom of Medspray. Two prototypes are implemented and changed according to the feedback received from the end users. Thereafter, the final dashboard is implemented and used.

Therefore, the research questions of each step of the MPSM, discussed in chapter 1, are answered within this research. Answering the research question was needed to solve the main research question of the research.

7.1.2 Problems in problem cluster

Not only answering the research questions were needed to solve the core problem. **Figure 4** showed the problem cluster. Solving the problems within the problem cluster is also part of solving the core problem: "*There is no performance visualization of the production process within Medspray*". Solving this core problem should also mean the corresponding problems within the problem cluster in **Figure 4** are solved. Therefore, based on the created dashboard:

- The progress of the daily production target should be visible.
- An overview of the required amount of sub-assemblies should be visualized.
- The operators should have a visual trigger to perform specific tasks at a specific time.
- The sub-assemblies should be ready when necessary.
- The bottleneck should be occupied as much as possible.
- And as a consequence, the maximum output should be achieved.

When all these problems are solved, the end-users, which are the manufacturing manager and the employees at the production line of Medspray are able to make the right decisions at the right time in order to optimize the production process.

7.1.3 Main research question

This research is determined to be successful when the discrepancy between the norm and reality set by the company is removed. In this case, when the company has a production line with visualizations

of the real-time performance in order to make the right decisions at the right time and to manage the production instead of monitoring the performance through Excel spreadsheets.
First of all, after the implementation of the dashboard in the production line of the company, the company has a quick display of the current performance within the production process. Now, the manager has the right information at the right time to make appropriate decisions and reach the company's goals.

Table 14 gives an overview of the changes occurred, with the corresponding content, after the dashboard is developed and used within the production line of Medspray.

Table 14: *Situation after the implementation of a dashboard*

Content dashboard	Situation after implementing the dashboard
KPI: Productivity	The daily production target is visible within the cleanroom
KPI: Yield	Real-time indication of the yield.
KPI: On Time Delivery	Keep track of the orders delivered on time and act if the orders which are too late increase
Inventory level	Real-time update of the inventory of semi-finished products which gives the operators a visual trigger to perform and determine the priority of the tasks at a specific time. Therefore, based on the inventory levels, the workload of the operators is distributed more efficiently
Average production speed	Visual trigger to speed up the production
Schedule of the orders	Increase of the structure for the operators
Summary current status	Visual trigger to achieve the target production of the current day

All in all, the real-time dashboard which is developed for the manufacturing department of Medspray reached the norm of the company. The core problem "*There is no performance visualization of the production process within Medspray*" is solved. Meaning the dashboard gives a quick display of the performance within the production process of Medspray. The display consists of key content which is valuable for decisions within the production line by the manufacturing manager and the employees within the production line.
So, the dashboard gives the company the possibility to monitor the performance within the production process of the company and based on that, make quick appropriate decisions to further improve.

7.2 Limitations

There are several limitations that influenced the results of the research. These limitations are discussed in this section.

7.2.1 Lack of data

First of all, data need to be available to visualize certain indications of the performance within the production process on a dashboard. As mentioned before, the company is just ramping up production. With Medspray being a staring and growing company, available KPI data was limited. The

number of KPIs to visualize is thus low but in line with the needs of Medspray's manufacturing department.

More, due to lack of data, the availability could not be calculated which is a part of the KPI "Overall Equipment Effectiveness". Therefore, the other factors of this KPI, "Performance" and "Yield" are visualized on the dashboard, but the "Availability" is missing. It is not known exactly how much of the available time is actually being produced.

Furthermore, several interviews have been performed with the end-users. Since the company is scaling up production, there are not many operators available to conduct an interview on. Therefore, the results of the interviews and the received feedback are limited. When the sample size consisted of more end-users, there would be more options to improve the dashboard.

7.2.2 Lack of knowledge

Another limitation is the safety stock not being determined exactly. With this data, the operators know exactly when a specific task needs to be performed. Currently, the operators have an insight on what the status is of each inventory of the semi-finished products, but the minimum is not known yet.

Another limitation of the lack of prior knowledge on the application software Power BI and the development of dashboards. The limitation of background knowledge made it necessary to first follow a Power BI training and conduct research into KPIs and dashboard design.

Moreover, since Medspray is changing a lot every day, the recommendations which are given are based on the current information. This means the future situation is not known exactly and therefore the chances are that the recommendations do not fit exactly the future situation of Medspray.

7.2.3 Time limitation

Since the total time was limited to 10 weeks, it was not possible to become a professional in developing and designing a dashboard. Therefore, all the knowledge which is implemented on the dashboard is from the literature search done.

Also, the final dashboard is tested for a week within the cleanroom of Medspray. When there was more time, the dashboard could be implemented for a couple of weeks and could be adapted based on the achieved feedback from the end-users. Therefore, the dashboard is a Minimal Viable Product MVP) and serves as an advice of visualizing the performance within the production process. An MVP is the first version of a product which is given to the customer as early as possible. The aim is to achieve feedback as quickly as possible.

During the research, only one company is examined due to time limitation. If there was more time available, observations would be performed in more companies and findings would be implemented and compared to other companies in order to get the best possible outcome for the company Medspray. Furthermore, the extent of details is dependent on the time which is spent on developing the visualization.

7.3 Recommendations and further research

This section discusses recommendations which are made for further development and expanding the dashboard. Also, the possibilities are discussed for potential further research.

7.3.1 Recommended KPIs

Since the company is growing fast, the dashboard will play an essential role in keeping track of the performance. The content which is visualized on the dashboard is based on the data available currently. Of course, when the company is expanding the production line through investing in more machines and outsource particular tasks, the information visualized on the dashboard expands. Therefore, the dashboard needs to be managed and changed over time regarding the content which is visualized

From the key performance indicators in **Table 9** which resulted of the systematic literature review discussed in section 2.2, KPIs are selected which are recommended to the company to add to the dashboard when the company has grown and therefore more data is available.

Utilization rate

First of all, the utilization rate is a useful KPI within a production organization which is one of the most important KPIs in logistics. This KPI indicates to what extent the production capacity is used. Because companies are dealing with disruptions, breakdowns of machines and so on, a utilization rate of 100% is never feasible. Nevertheless, the higher the utilization rate, the more efficient the production is. The utilization rate is calculated by dividing the actual production by the production capacity.

Order to delivery lead time

The lead time is the time between a customer places the order and delivering the product. The lead time included all the steps required to produce the requested products. When the customer places an order, materials must be ordered, and machines and staff need to be scheduled. Thereafter, the products must be produced. The lead time, therefore, depends on the processing time. Nowadays customers expect the company to deliver their order as soon as possible. It is therefore important to gain insight into the lead time. In this way, the company can deliver and implement reliable planning.

Overall equipment efficiency

A key measurement is the productivity of the production line. In order to measure this productivity, the OEE (Overall Equipment Effectiveness) is often used which identifies the percentage of manufacturing time that is truly productive (Vorne, 2019). The calculation of the KPI OEE is based on three different metrics:

1. Availability (based on time): the percentage of the planned time in relation to the actual time produced. Often called uptime
2. Performance (based on speed): the optimal speed of the production in relation to the actual speed.
3. Yield is defined as the number of units coming out of a process divided by the number of units going into that process over a specified period of time.

7.3.2 Recommended non-KPIs

Besides the recommended KPIs, this section discusses the known- KPI content of the dashboard in the future for Medspray.

Safety stock

In the future, Medspray will produce more kind of products. Therefore, the type of subassemblies within the production line will increase. To continuously produce, the subassemblies need to be in stock. Through determining and visualizing the safety stock of each subassembly, the production can continue undisturbed. Within the dashboard, which is developed in this research, the stock level of the subassemblies of one product is visualized. Within this visualization, the safety stock should be displayed. Therefore, the operators know exactly when a certain subassembly is below the safety stock.

Not only the safety stock of the subassemblies within the production line should be visualized, but also the safety stock of the assemblies delivered by the suppliers with the corresponding inventory level. In this way, the manager has a quick overview when there is not enough stock level of a certain sub-product. The cause needs to be determined which could be that the order of that specific sub-product was too late, or the suppliers did not deliver on time.

Logbook

Another key information to visualize is a logbook of the events which happen during the production. In this way, the hours where the production speed was low, can be justified to look in the logbook and see what happened in that hour. Another advantages of having a logbook is for the communication between the shifts. With the use of a logbook not everything needs to be discussed during the shift transfer. The other shift can see what happened during specific times in the first shift. Planned and unplanned activities need to be kept up to date. Currently, the operators are working with a logbook, but that is not consistent. Not every specific activity is being noted within that logbook. Therefore, for the future, having a consistent and up to date logbook makes the communication between the shifts transparent, but also the communication between the manufacturing manager and the operators. Because the manufacturing manager can take a look into the logbook instead of calling the operators and asking them what is happening or what has happened in a specific moment. Another advantage of using a logbook is that the activities which provide the most breakdowns within the production or errors which often occur could be traced. In this way, actions could be taken to prevent such activities and errors happening again by resolving the cause.

7.3.3 Additional dashboards

Currently, the dashboard which is developed for the company is operational. In the future, there will be more cleanrooms within Medspray. Therefore, also a tactical dashboard is needed to see the overall performance and the level factory view of all the cleanrooms and an operational dashboard for each separate cleanroom.

The tactical dashboard is very detailed and required the interaction of end-users. Therefore, for each cleanroom, an operational dashboard should be designed which shows the performance of that specific cleanroom, such as the developed dashboard within this research. Also, a general tactical dashboard needs to be designed which visualizes the performance of all the cleanrooms together.

Specific information needs to be visualized and should be analyzed through a drill-down function. This information should be general KPIs such as 'On Time Delivery' and the 'OEE'.

Also, currently the focus was on the manufacturing department of Medspray. As discussed in chapter 1, the company consists of the departments: lab, finance, manufacturing, and marketing and sales. The communicating between these departments is open and therefore keeping track of the performance of each department is doable.

When the company expands, the communication between these departments can be difficult to approach. Therefore, developing a dashboard for each department which specific content and a general dashboard which visualizes all the department with the most essential information will help in the communication between the departments. With these dashboards, each department can keep track of the other departments. When necessary, one department can take actions to prevent another department from being unattended.

Since the company will produce a different kind of SNUs in the future, an overview of the products with the corresponding sales and amount of orders is a valuable visualization. In this way, the company can get a quick display of which type of product is most wanted by the customers. An example of the visualization is displayed in **Table 15**.

Table 15: *Example of visualization overview products*

Product name	Sold Items	Revenue
SNU type 1	100.000	€100.000

7.3.4 Speed of updating

Currently, the connected data with the dashboard is limited. Therefore, the speed of refreshing the dashboard is not time-consuming. When more data available and connected in the future, it may take a while to update the dashboard. Therefore, only direct data needs to be connected to the dashboard instead of connected unnecessary tables to prevent the updating speed being low.

7.3.5 Future work

The dashboard which is developed for the manufacturing department of Medspray serves as a prototype and shows the usefulness of visualizing the performance. When the company expands, the complexity of developing a dashboard increases. Therefore, in the future, the company could hire someone who focuses on the development of dashboards.

This research narrowed down the scope to one department. For future research, it would be interesting to review all the departments of the company. Not only developing the dashboard for the manufacturing department, but also for the other departments within Medspray is valuable. Therefore, the developed dashboard serves as a basis for the dashboards in the future for Medspray and further research should be conducted in order to implement the use of visualization within the company.

Another aspect which should be researched in the future is visualizing the performance in a time period of a month or year instead of only focussing on the current day. In this way, trends can be seen more easily, and appropriate actions can be taken to improve any negative trend.

All in all, the next step of this research could be investigating other departments of Medspray based on visualizing the performance. Furthermore, the Systematic Literature Review which is performed was based on production performance KPIs. Therefore, an overview can be made for each department with the corresponding KPIs. This overview will be beneficial for each company since usually, each company exists of at least the departments “finance”, “manufacturing”, “marketing” and “sales”. Within this research, an overview is made for the KPIs for the department “manufacturing”.

Dashboard screen

Currently the dashboard is visualized on one of the computers within the cleanroom. For the operators, it is more user-friendly to have one big screen where they can see the dashboard at a glance. During their work they could see the dashboard instead of having to stand up and walking to the computer where the dashboard is visualized. Therefore, a recommendation for the company is to visualize the dashboard on a big screen instead of on a computer.

7.5 Contribution to the theory

This section discusses in what way the solution of this research contributes to the theory. First of all, the Systematic Literature Review which is performed to map existing KPIs which measure the performance in a production process. The found KPIs are not specific for Medspray. Therefore, **Table 20** gives an overview of the performance KPIs which could be used for any company which wants to measure the production performance.

Furthermore, a method is developed in **Appendix E** which described the general steps which need to be taken to develop a performance dashboard in any kind of company. Therefore, each company which wants to develop a dashboard from any domain can use this method. With this method, companies have an overview of the sequence of tasks which need to be performed in order to develop a dashboard. So, it makes it easier for any company to implement a dashboard.

7.6 Contributions to practice

This section discusses in what way the solution of this research could contribute to practice. The dashboard created within this research is specifically made for Medspray. The main focus was to visualize the performance within the production line of the cleanroom. The steps which are taken to have a visualization which is most valuable for the company is:

1. Determining the purpose and objective of the visualization
2. Selecting KPIs
3. Selecting the visualization technique
4. Selecting the software
5. Determining the design of the dashboard

These steps are general steps which need to be taken for every company which does not have a visualization method yet.

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Appendices

Appendix A: Table with the corresponding tasks within each phase of the MPSM

Table 16 shows the specific tasks within the steps of the MPSM.

Table 16: *Tasks within phases MPSM*

	Phases MPSM	Tasks within the phases
1.	Defining the problem	• Understand the needs and focus of the company. • Performing observations and interviews to map all the problems. • Make a problem cluster which visualizes the causes and consequences (figure 4). • Define the core problem based on the problem cluster. • Define the problem statement. • Define the scope of the problem. • Define the objective of the research.
2.	Formulating the approach	• Collect data of the current situation within the production process of the company. • Map the current situation of the whole company in a Flow Chart. • Determine who is involved with the problem. • Determine the limitations of the research.
3.	Analyzing the problem	• Fill in missing details about the problem. • Brainstorm about potential root causes.
4.	Formulating solutions	• Perform literature research on techniques to visualize performance. • Set up criteria which have to be met. • Compare the visualization techniques.
5.	Choosing a solution	• Choose the best applicable technique for Medspray. • Performance a Systematic Literature Review to find existing performance KPIs. • Determining the best suitable KPIs for the company. • Determine how these KPIs have to be visualized.
6.	Implementing the solution	• Use the possible solutions to implement in the chosen technique. • Develop the chosen technique.
7.	Evaluating the solution	• Evaluate each step of the MPSM. • Measure the improvement of the implementation of the chosen technique. • Create a monitoring plan to continue measuring success. • Ensure the chosen technique is continually managed. • Apply possible improvements of the chosen technique.

Appendix B: Systematic literature review

A Systematic Literature Review has the intent to compare different studies and therefore find useful papers, the method of this review is discussed in this Appendix. Currently, Medspray does not have a visualization of the performance of the production process. Therefore, it is first important to find existing KPI's in the literature which visualize performance. Due to the fact that this is an essential part of the research, a Systematic Literature Review is done to answer the question: *Which KPIs exists that can express the performance of the production process.*

The steps within the Systematic Literature Review are:

- B.1 Defining the key concepts within the research question.
- B.2 Documenting the research.
- B.3 Determining the exclusion and inclusion criteria.
- B.4 Determining the articles for review.
- B.5 Overview of the answer

B.1 Definition of the key concepts

First of all, the key concepts of the core problem are defined in **Table 17**.

Table 17: *Definition key concepts*

	Key concept	Definition
1	Key performance indicator (KPI)	Variables to analyze the performance of organizations. A KPI is expressed in a number or is related to a norm or target ("Uitleg over KPI's! " 2019).
2	Visualization	The conversion of something into a visible image.
3	Performance	The fulfillment of a stated goal or obligation.
4	Logistic	The operations which need to be performed to process goods from raw material to end product.
5	Production	Converting resources into end products.
6	Process	Organization of the work within a company or organization.

B.2 Documentation

The database which is used for the Systematic Literature Review is Scopus. This database is a multidisciplinary focus with mainly peer-reviewed articles and conference papers. In **Table 18** the documentation of the Systematic Literature Review is shown.

Table 18: *Systematic Literature Review*

Search string	Scope	Data of search	Data range	# Entries
Search protocol for Scopus				
"KPI" AND "Performance"	Title, keywords and abstract	1 April 2019	2015 - present	20
"KPI" AND "Logistic"	Title, keywords and abstract	1 April 2019	2015 – present	24
"KPI" AND "production"	Title, keywords and abstract	2 April 2019	2015 - present	68

"KPI" AND "Manufacturing"	Title, keywords and abstract	2 April 2019	2015 - present	43
"KPI" AND "Lean"	Title, keywords and abstract	3 April 2019	2015 – present	10
"Visualization" AND "Performance"	Title, keywords and abstract	8 April 2019	2015 - present	21
"Production" AND "Key Performance"	Title, keywords and abstract	8 April 2019	2015 - present	70
Total in Endnote				256
Removing duplicates				-59
Selecting based on exclusion criteria				-43
Removing after reading the title				-54
Removing after reading abstract				-64
Removing after reading the whole article				-31
Total selected for review				5

B.3 Exclusion and Inclusion

Table 19 shows the exclusion and inclusion criteria with the corresponding criteria.

Table 19: *Exclusion and Inclusion criteria*

Number	Exclusion criteria	Reason for exclusion
1	Restricted access	No ability to read and analyze it.
2	Articles which do not refer to KPI's	Not relevant for the company
3	Non-English and non-Dutch articles	No ability to read and analyze it.
4	Firms larger than 250 employees	Does not include the company, which is an SME
5	Subject areas in Scopus: *Computer Science, Energy, and Decision Sciences* and *Engineering*	Not relevant for the company

Number	Inclusion criteria	Reason for inclusion
1	• Key Performance Indicators, KPI • Performance • Production, Manufacturing • Logistic	These keywords are relevant to the company.
2	Articles for SMEs	The company is an SME
3	Subject areas in Scopus: *Business, Management, and Accounting*	Relevant for the company
4	Publication data 2015-present	The company is producing for a year, so the KPIs have to be recent.

B.4 Review

In this part, the articles for review are shown.

B.4.1 Articles selected for review

The articles selected for review and used in the concept matrix are:

1. (Lai & Man, 2017)
2. (De Felice & Petrillo, 2015)
3. (Mousavi & Siervo, 2017)
4. (Tokola et al., 2016)
5. (Jovan et al., 2006)

B.5 Overview answer

Table 20 shows the KPIs which are found in each of the review articles.

Table 20: *Overview performance KPIs*

(Lai & Man, 2017)	(De Felice & Petrillo, 2015)	(Mousavi and Siervo, 2017)	(Tokola et al., 2016)	(Jovan et al., 2006)
KPIs ⬇				
Breakdown severity	Return on Equipment	Overall Equipment Efficiency	Delivery reliability	Productivity
Work request response rate	Return on Investment	Overall Line Effectiveness	Production cycle time	Yield
Availability	Customer satisfaction		Resource utilization rate	
Utilization rate	Product recovery		Overall equipment effectiveness index	
Utilization index	Process Innovation		Capacity utilization rate	
Schedule realization rate	Time to market		Yield	
Work order turnover	Staff satisfaction		First pass yield	
Response rate for maintenance	Productivity		Suppliers' quality	
Failure/breakdown frequency			Line efficiency	

Appendix C: Preparation and structure of the required data in Power BI

This Appendix is about the data architecture which "describes how data is collected, stored, transformed, distributed and consumed. IT includes rules governing structured formats, such as databases and file systems, and the systems for connecting data with the business process that consume it." (DalleMule & Davenport, 2017). There are numerous ways to architecture a dashboard, and the choices dictate what the dashboard can and cannot do (Eckerson, 2010). Therefore, in this Appendix, the manner of collecting and structuring data is discussed based on the selected software and the type of dashboard which is developed.

C.1 Software

The manner of data preparation and structuring is dependent on the software being used. Therefore, the first Power BI is discussed to get an overview of how the data needs to be gathered and managed. Power BI exists of Power BI desktop where the data model is created in the dashboard. In order to develop the dashboard, the tools displayed in **Figure 30** are available.

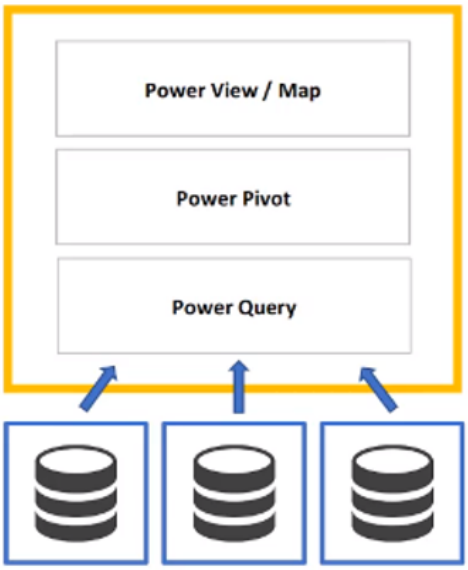


Figure 27: *Power BI Desktop structure*

With Power Query, data gets extracted out of data sources. There are a lot of data sources available such as Excel, CSV, SQL, Azure, Web Services, and so on. With the extracted data, all kinds of transformations can be done, such as deleting columns or rows, cleaning and grouping data and so on. Therefore, Power Query is the place where data is structured and formatted.
With Power Pivot, relationships can be established between the tables which are read. These relationships are necessary to combine data from different tables in a dashboard.

Thereafter, with Data Analysis Expressions (DAX) calculations and analysis can be added to the data. So, when data is read, cleaned and structured in Power Query and relations have been established and calculations are added in Power Pivot, the data model is ready.

Now, the presentation layer is discussed which exists of Power View and Power Map. Power View is functionality with ready-made graphs which can be dragged into a canvas and with which the data

can be inserted with drag and drop. Power Map is functionality with which data can be plotted geographically.

So, when the steps of the Power BI Desktop visualized in **Figure 30** are completed, a data model and a report are created. The created report is still locally on the computer or laptop. From this place, it is possible to share the report with Power BI Online. In Power BI Online an account needs to be created which is linked to the Office 365 license. The model which is created in Power BI Desktop can be published in the Power BI Online account. When published the data model, the whole model with the corresponding data is included.

From Power BI Online, the report which is created in Power BI Desktop can be shared with people who have a Power BI Online account. In this way, the person who has created the report in Power BI Desktop stays the owner of the report. So, with Power BI Online, there is always access to the reports. This needs to be done through logging via the internet. To make this even easier, Power BI has developed an app, the Power BI App, which can be downloaded on Mobile devices, laptops, iPads, and so on. The reports and dashboard which are online will synchronize with this app. This means at any place real-time insight in the dashboards and reports are available.

Software – data architecture layers

The architecture of any software, therefore also Power BI, involves three layers of functionality: (1) user interface, (2) application logic, and (3) data processing which are comparable with the layers discussed in section 2.5.1. The similarities with the corresponding visualizations are displayed in **Table 21**. It is essential to know where and how these layers are processed in the dashboard architecture to understand whether the system will meet the requirements of the organization (Eckerson, 2010). Layers are a way to separate responsibilities and manage dependencies. Each layer has a specific responsibility. A higher layer can use services from a lower layer, but not the other way around.

Table 21: *Data architecture vs. Power BI*

Data architecture layer:	Power BI layer:	Purpose:	Visualization:
User interface	Power View	Presentation	
Application logic	Power Pivot	Business	
Data processing	Power Query	Data	 PostgreSQL

User interface

This layer is the "top layer", also known as the front end of an application. This layer contains all the things that the user can see on the "outside" of the system, such as screen layout and navigation. The user interface is the interface between the user and the device which is composed of components such as buttons, selection lists, text fields, and images. Therefore, the user interface is the control panel of a product. So, the user interface is depended on the design of the dashboard which is discussed in section 2.6 and in chapter 5.

Application logic

This is the connection link between the layers "user interface" and "data processing". This later created and manipulated the components of a report.

Data processing

This layer consists of things like database, connection, table, and SQL. This layer retrieves information from a data source. Within the production line of Medspray, data is stored in a PostgreSQL database.

D.2 Type of dashboard – data architecture

The type of dashboard is another point which needs to be considered within the data architecture. Different types of dashboard require different types of architectures. As is discussed in chapter 5, the dashboard which is developed for this research is an operational dashboard. Therefore, the dashboard tends to query source systems directly and apply minimal transformations (Eckerson, 2010). Within an operational dashboard, users want to view real-time data from multiple systems in one place without drilling down (Eckerson, 2010).

"In the "direct query" architecture, the performance dashboard issues SQL queries to source systems and displays the result set with minimal to moderate transformation." (Eckerson, 2010). The purpose of these dashboards is to let the users view the current data without much interaction. The Direct Query Architecture is visualized in **Figure 32**.

This kind of architecture offers flexible data access and it is easy to extract data from multiple sources to display it in one place.

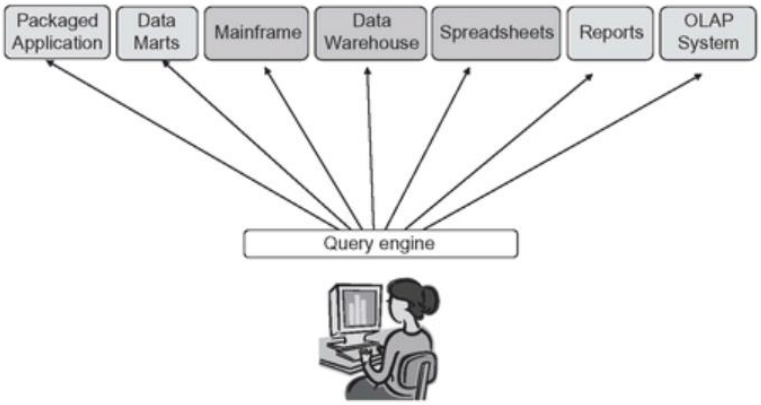


Figure 28: *Direct Query Architecture*

Appendix D: ArchiMate model Symbols

In this Appendix, the relationships and symbols of an ArchiMate Model with their definitions are described in **Table 24**, **Table 25**, **Table 26**, **Table 27**, **Table 28**, **Table 29** and **Table 30**.

Table 22: *Overview ArchiMate Structural Relationships {Josey et al., 2016}*

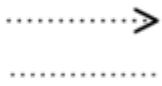
Structural Relationships		**Notation**
Association	Association models a relationship between objects that is not covered by another, more specific relationship.	
Access	The access relationship models the access of behavioral concepts to business or data objects.	
Used by	The used by relationship models the use of services by processes, functions, or interactions and the access to interfaces by roles, components, or collaborations.	
Realization	The realization relationship links a logical entity with a more concrete entity that realizes it.	
Assignment	The assignment relationship links units of behavior with active elements (e.g., roles, components) that perform them, or roles with actors that fulfill them.	
Aggregation	The aggregation relationship indicates that an object groups a number of other objects.	
Composition	The composition relationship indicates that an object is composed of one or more other objects.	

Table 24: *Overview ArchiMate Structural Relationships {Josey et al., 2016}*

Dynamic Relationships		**Notation**
Flow	The flow relationship describes the exchange or transfer of, for example, information or value between processes, function, interactions, and events.	
Triggering	The triggering relationship describes the temporal or causal relationships between processes, functions, interactions, and events.	

Table 23: *Overview ArchiMate Other Relationships {Josey et al., 2016}*

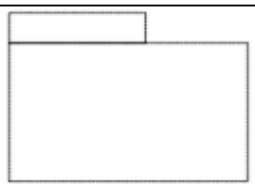
Other Relationships		**Notation**
Grouping	The grouping relationship indicates that objects, of the same type or different types, belong together based on some common characteristic.	
Junction	A junction is used to connect relationships of the same type.	
Specialization	The specialization relationship indicates that an object is a specialization of another object.	

Table 25: *ArchiMate Bussiness Layer Elements part 1 {Josey et al., 2016}*

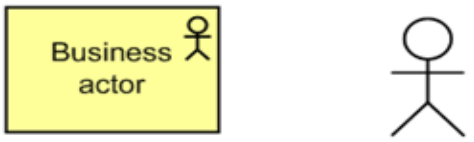
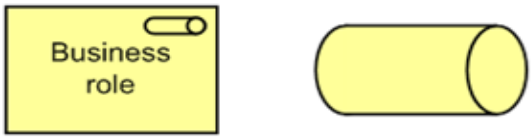
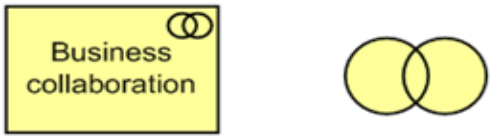
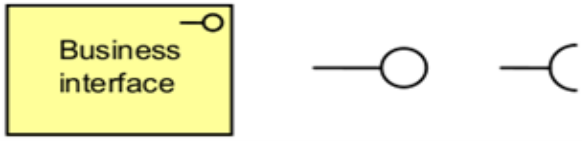
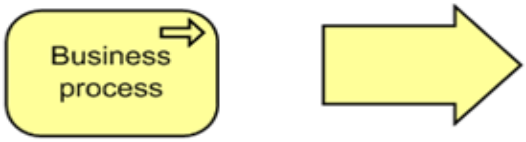
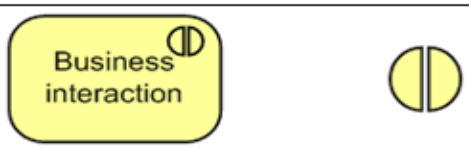
Concept	Description	Notation
Business actor	An organizational entity that is capable of performing behavior.	
Business role	The responsibility for performing specific behavior, to which an actor can be assigned.	
Business collaboration	An aggregate of two or more business roles that work together to perform collective behavior.	
Business interface	A point of access where a business service is made available to the environment.	
Location	A conceptual point or extent in space.	
Business process	A behavior element that groups behavior based on an ordering of activities. It is intended to produce a defined set of products or business services.	
Business function	A behavior element that groups behavior based on a chosen set of criteria (typically required business resources and/or competences).	
Business interaction	A behavior element that describes the behavior of a business collaboration.	

Table 26: *ArchiMate Business Layer Elements part 2 {Josey et al., 2016}*

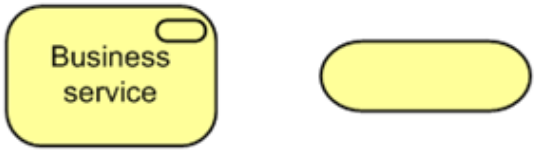
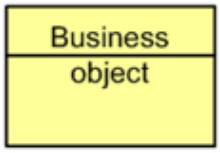
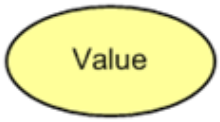
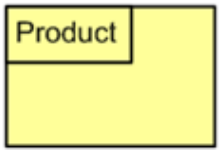
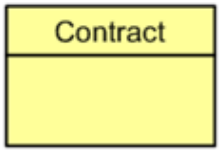
Concept	Description	Notation
Business event	Something that happens (internally or externally) and influences behavior.	
Business service	A service that fulfills a business need for a customer (internal or external to the organization).	
Business object	A passive element that has relevance from a business perspective.	
Representation	A perceptible form of the information carried by a business object.	
Meaning	The knowledge or expertise present in a business object or its representation, given a particular context.	
Value	The relative worth, utility, or importance of a business service or product.	
Product	A coherent collection of services, accompanied by a contract/set of agreements, which is offered as a whole to (internal or external) customers.	
Contract	A formal or informal specification of agreement that specifies the rights and obligations associated with a product.	

Table 27: *ArchiMate Application Layer Elements {Josey et al., 2016}*

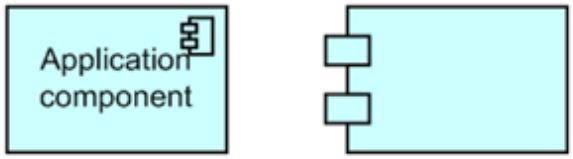
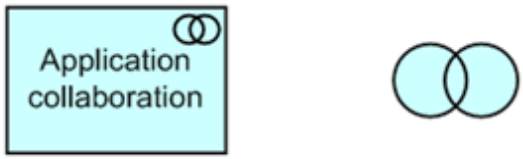
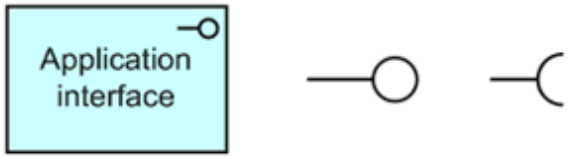
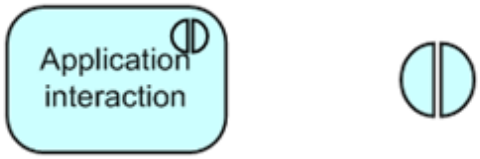
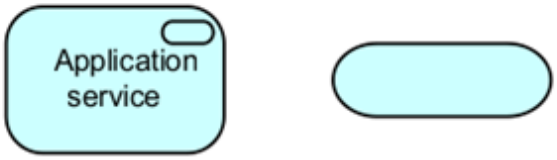
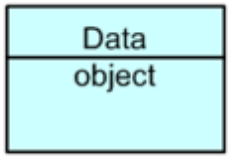
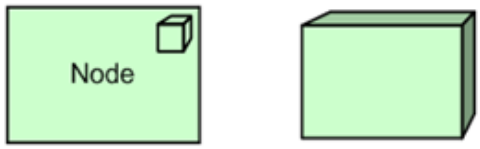
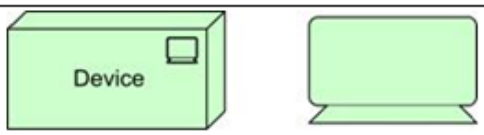
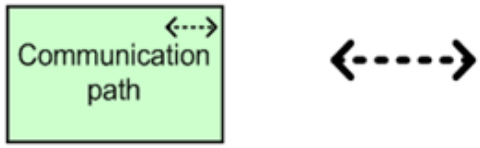
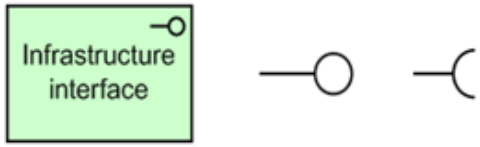
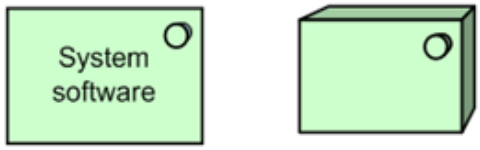
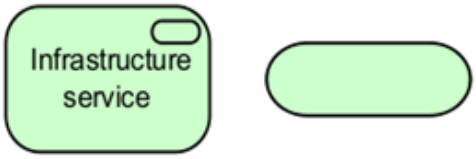
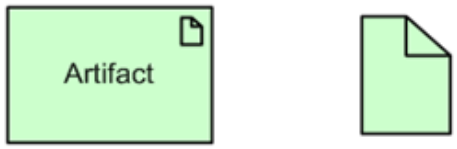
Concept	Definition	Notation
Application component	A modular, deployable, and replaceable part of a software system that encapsulates its behavior and data and exposes these through a set of interfaces.	
Application collaboration	An aggregate of two or more application components that work together to perform collective behavior.	
Application interface	A point of access where an application service is made available to a user or another application component.	
Application function	A behavior element that groups automated behavior that can be performed by an application component.	
Application interaction	A behavior element that describes the behavior of an application collaboration.	
Application service	A service that exposes automated behavior.	
Data object	A passive element suitable for automated processing.	

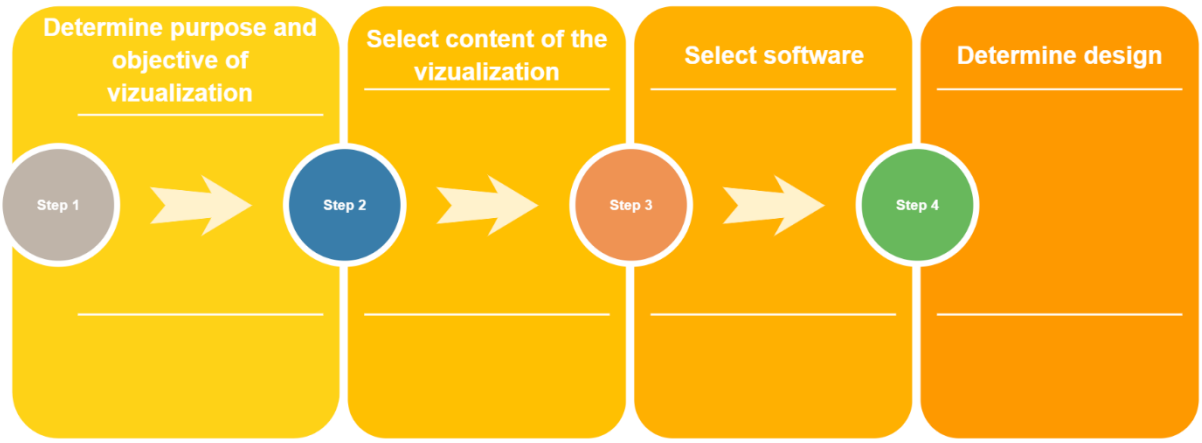
Table 28: *ArchiMate Technology Layer Elements {Josey et. al, 2016}*

Concept	Definition	Notation
Node	A computational resource upon which artifacts may be stored or deployed for execution.	
Device	A hardware resource upon which artifacts may be stored or deployed for execution.	
Network	A communication medium between two or more devices.	
Communication path	A link between two or more nodes, through which these nodes can exchange data.	
Infrastructure interface	A point of access where infrastructure services offered by a node can be accessed by other nodes and application components.	
System software	A software environment for specific types of components and objects that are deployed on it in the form of artifacts.	
Infrastructure function	A behavior element that groups infrastructural behavior that can be performed by a node.	
Infrastructure service	An externally visible unit of functionality, provided by one or more nodes, exposed through well-defined interfaces, and meaningful to the environment.	
Artifact	A physical piece of data that is used or produced in a software development process, or by deployment and operation of a system.	

Appendix E: General manual for developing a performance dashboard

In this Appendix, a method is described for the visualization of the performance within a company with the use of a manual. The general steps which are discussed in this Appendix are visualized in **Figure 34**. In the method, general steps are discussed which need to be taken before developing a dashboard to visualize the performance within a company.

Figure 30: *Steps of developing a performance dashboard*



F.1 Step 1: Purpose and objective

The first step, before developing a performance dashboard, is to determine the purpose and objective of the visualization. The goal of the visualization is essential since dashboards can be categorized in several ways. **Table 31** lists several variables that can be used to categorize dashboards.

Role

The first variable is the classification by role. Therefore, the business activity which it supports needs to be clarified. There are three types of roles of a dashboard: strategic, analytical, and operational (Few, 2006). These types of the dashboard are discussed in subsection 2.7.2.

Type of data

There are two types of data: quantitative and non-quantitative. In almost all cases dashboards primarily display quantitative measures of what is currently going on (Few, 2006).
"This type of data is common across almost all dashboards because they are used to monitor the critical information needed to do a job or meet one or more particular objectives, and of the information that does this best is quantitative" (Few, 2006).

Data Domain

Usually, a company has four different domains: Sales, Finance, Marketing, and Manufacturing. Before selecting the content of the dashboard, it needs to be clarified for which domain it will be used. Each domain has specific valuable information and KPIs. For example, the data domain "Manufacturing" could use "Number of units manufactured" or "Number of defects" as measurements.

Type of measures

Before developing the dashboard, the type of measures also needs to be clarified. Generally, there are three types of measures: Balanced Scorecard (for example, KPIs), Six Sigma and Non-performance measures (Few, 2006). These concepts are discussed in subsection 2.3.2 as performance management methodologies.

Span of data

The focus point of the dashboard determines the extent of the detail of the content. The dashboard could be enterprise-wide, departmental or individual. When a dashboard is only for a specific department, the content should be for that particular department.

Update frequently

The usage of the dashboard determines the frequency of updating the dashboard. If the visualization is for visualizing the performance over the past weeks, the dashboards need to be updated weekly or even monthly. If the dashboard will be used each quarter of an hour, it needs to be updated with real-time data.

Interactivity

The interaction of the end-users with the dashboard determines the structure. When the end-users just want to look at it without performing tasks, a static display is recommended. If the end-users want to really analyze the data, the display needs to be interactive with the use of drill-down functions and filters.

For example, Excel is a perfect tool to develop a static dashboard. Because Medspray wanted a dynamic dashboard, research is done in a more proper tool.

Display

The manner of displaying the content of the dashboard is another point which needs to be considered before developing the dashboard. The main decision is to visualize the content graphically, with text or a combination.

All these variables need to be determined before starting with the selection of the content which is performed in step 2 of the method. These decisions will help in determining the scope and detail of the content.

Table 29: Categorizing Dashboards (Few, 2006)

Variable	Values
Role	Strategic Analytical Operational
Type of data	Quantitative Non-quantitative
Data domain	Sales Finance Marketing Manufacturing Human Resources
Type of measures	Balanced Scorecard (for example, KPIs) Six Sigma Non-performance
Span of data	Enterprise-wide Departmental Individual
Update frequency	Monthly Weekly Daily Hourly Real time or near real time
Interactivity	Static display Interactive display (drill-down, filters, etc
Mechanisms of display	Primarily graphical Primarily text Integration of graphics and text
Portal functionality	Conduit to additional data No portal functionality

F.2 Step 2: Content of the dashboard

The second step is the determination of the content within the dashboard is described. The content of a dashboard consists usually of KPIs and non-KPIs.

KPIs

For the selection of KPIs, the decisions made in step 1 are crucial. If for example, the data domain is "Manufacturing" and the span of data is "Departmental", the selection of KPIs is specified on the data of this department. Therefore, based on all the choices made in step 1, KPIs should be found. This can be done by performing a Systematic Literature Review to get an overview of all the relevant KPIs.

In this research, the focus was on the manufacturing department and the span of data was departmental. Moreover, the visualization needed to be based on real-time. Based on these determinations, a Systematic Literature Review is done to get an overview of the existing performance KPIs within a manufacturing department. The overview is displayed in **Table 9**.

After generating an overview of the existing KPIs, the available data within the company need to be tracked. This data is mostly stored in the database of the company. Based on the available data for the KPIs, end-users need to be interviewed to find out which specific KPIs are most valuable for the company to visualize. In this way, a list of KPIs is left which could be used for the content of the dashboard. The final KPIs which need to be visualized on the dashboard need to be based on the importance the end-users give to the KPI.

Non-KPIs

Selecting non-KPI content is especially dependent on the needs of the end-users of the dashboard. Interviewing the end-users about their needs is a crucial step to determine the non-KPI content. Therefore, the end-users, for example, need to answer the questions:

- What kind of information is valuable to visualize?
- What is essential to keep track of?
- Would you like to visualize it on a monthly, weekly or daily basis?

Based on the results of the interview, available data need to be tracked. After comparing the required data with the information requested, a list of non-KPI content will be left which could be used for the content of the dashboard.

F.3 Step 3: Select software

Developing a dashboard can be done in several software. Some examples of dashboard software are Excel, Tableau, Power BI and Qlik Sense. The software needs to be chosen based on the criteria set by the end-users. Examples of criteria are listed in **Table 30**.

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In this research, the software "Power BI" is chosen based on the criteria set by the end-users. The comparison and the reasoning for selection "Power BI" are described in section 2.5. Also selecting the software has a huge influence on the results of Step 1: purpose and objective of the dashboard.

The required data of the dashboard needs to be connected to the selected software. Each software has a different approach to connecting data for the visualization. Within this research, the data is connected with the software “Power BI”. The exact steps will be described later on in this Appendix.

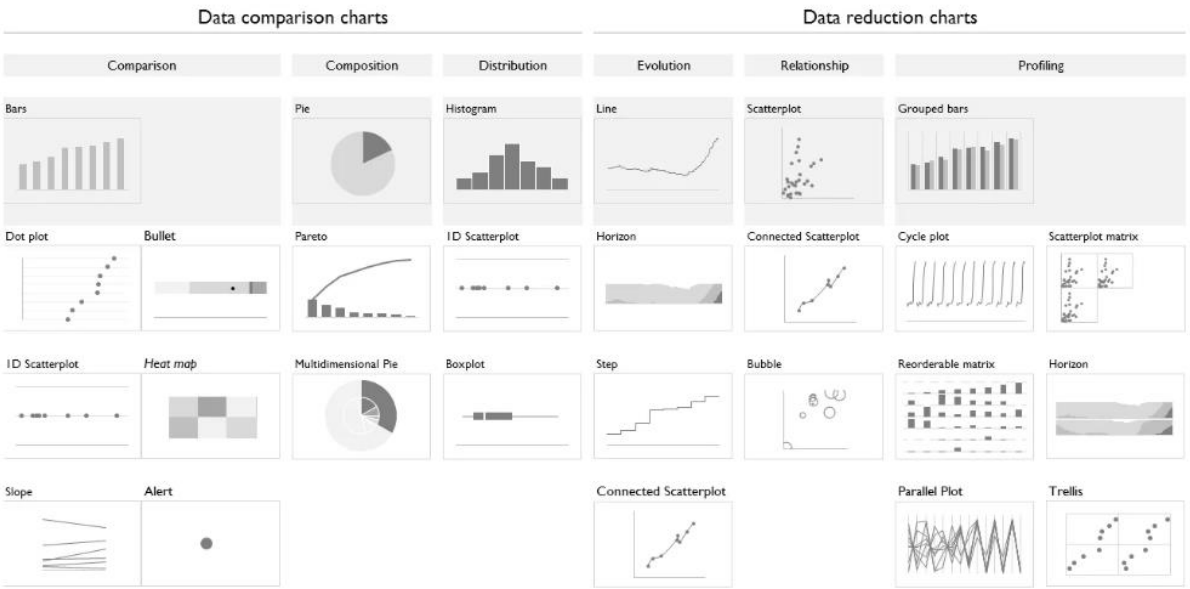
Table 30: *Criteria Dashboard Software*

Criteria
Ease of use
Costs
Connectivity to a variety of data sources
Technical support required
Secure
Speed
Memory
Flexible use in different kind of screens
Custom visualizations
Innovation & Versioning

F.4 Step 4: Design of the dashboard

After the content of the dashboard and the software to develop the dashboard is determined, the design needs to be determined. The general design of a dashboard is discussed in section 2.6 of this research. For example, the layout and the colour used are discussed in this part of the literature review. Based on the purpose of the dashboard, the visualizations method of the KPI and non-KPI content need to be determined. Each chart type has specific purposes, the most used chart types and purposes and visualized in **Figure 31**.

Figure 31: *Classification of chart types*



The chart types should be selected based on the purpose and needs of the end-users.

The general steps are discussed which need to be taken to develop a performance dashboard in any kind of company for any kind of data domain. The steps are summarized in a flow chart with the use of Bizagi Modeler in **Figure 32** ("Bizagi Modeler Business Process Modelling Software," 2019).

Figure 32: *General steps of developing a performance dashboard*