Visualizing incoming goods and suppliers

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AFMI
verspanende industrie

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Contents

1 – Introduction

"Research is what I'm doing when I do not know what I'm doing" – Werner von Braun

In this research I have delved into a problem of AFMI, a company located in Hengelo, The Netherlands. I start by introducing the company, the motivation for doing the research and the actual problem statement of AFMI. After that, I analyse the process, where the problem lies, and identify the issue. Lastly, I recommend a solution and set goals for the solution to be implemented.

1.1 Introduction

1.1.1 Background information

AFMI is a small-medium sized enterprise based in Hengelo. The company was created from a merger in 1989. The tool-making department of Stork Mufac and the mechanical departments of both Stork Pumps Hengelo and Stork Services were combined into AFMI Verspanende Industrie. The merger resulted in a company that is highly specialized in machine castings. Because of all the different machines in operation in the company they can produce castings in many different sizes and shapes. This creates a huge variability in products and clients.

Because of this high variability of products in the company, it is extremely difficult to plan the operations. For example, it is difficult to build inventory (create a buffer) or plan the routes through the different machines. To make the planning of routes through the company easier than manual planning AFMI makes use of an Advanced Planning and Scheduling (APS) program from Limis. This program allows the inputs for the manufacturing of a product to be filled in. Examples of such inputs are the date the product needs to be ready, the time needed in the different machines, and the times spent outsourcing the product etc. When these inputs are filled in, the APS system from Limis plans the optimal route for the product through the factory.

1.1.2 Motivation for research

Planning software systems like Enterprise Resource Planner, Supply Chain Management and Advances Planning Software get more advanced and get more widely adapted within small and big companies. (Robert Jacobs, F., & 'Ted' Weston, F. C., 2006) These software systems let companies optimize processes but in return create low flexibility in changing the processes. This low flexibility can create problems. For example, one day delay incoming goods can cause a major delay in outgoing goods because the systems need to reschedule everything which means the planning is no longer optimal. These outgoing goods, that are already delayed, from one company are the incoming goods of another. Zooming out you can see that a short delay at one company can cause a huge delay in the whole supply chain and can therefore cause high and unnecessary inventories.

One of the most basic solutions for dealing with the impact of delayed deliveries is stocking raw materials. Unfortunately, AFMI has a huge variability of products and therefore it is not possible to ensure sufficient stock as cover for possible delays. Hence AFMI needs to look at other possibilities to allow for delivery uncertainty and to minimize output delays. From the researcher's point of view it is interesting to investigate how to handle the incoming raw materials at a company with high variability and an APS system. What does literature have to say about it, how do other companies tackle the problem?

1.1.3 Problem statement

Planning with an APS, compared to manual planning, is much better for day-to-day planning purposes because it can calculate a lot of possibilities and thereby achieve optimal planning. However, in practice there are some shortcomings to the program from Limis. Where the APS system from Limis excels in planning operations, it lacks in clarity. Although the program has some graphs to show various KPI's, these not always give the information AFMI wants to see. Some information that is not clearly shown is an overview of all the materials that need to be purchased or which have already been purchased with the corresponding dates. Without this information it is very hard to control the deliveries of goods and to ensure they are on time. This leads to the main concern of AFMI: delays in the day-to-day planning and low delivery reliability for customers.

At the moment this problem causes a lot of irritation/annoyance among employees as well as clients. It is difficult to meet commitments. This only causes frustration at the moment, but will cause problems in the future. Competitors who handle this problem better will obviously have the upper hand.

1.2 Problem identification

1.2.1 Purchasing Process

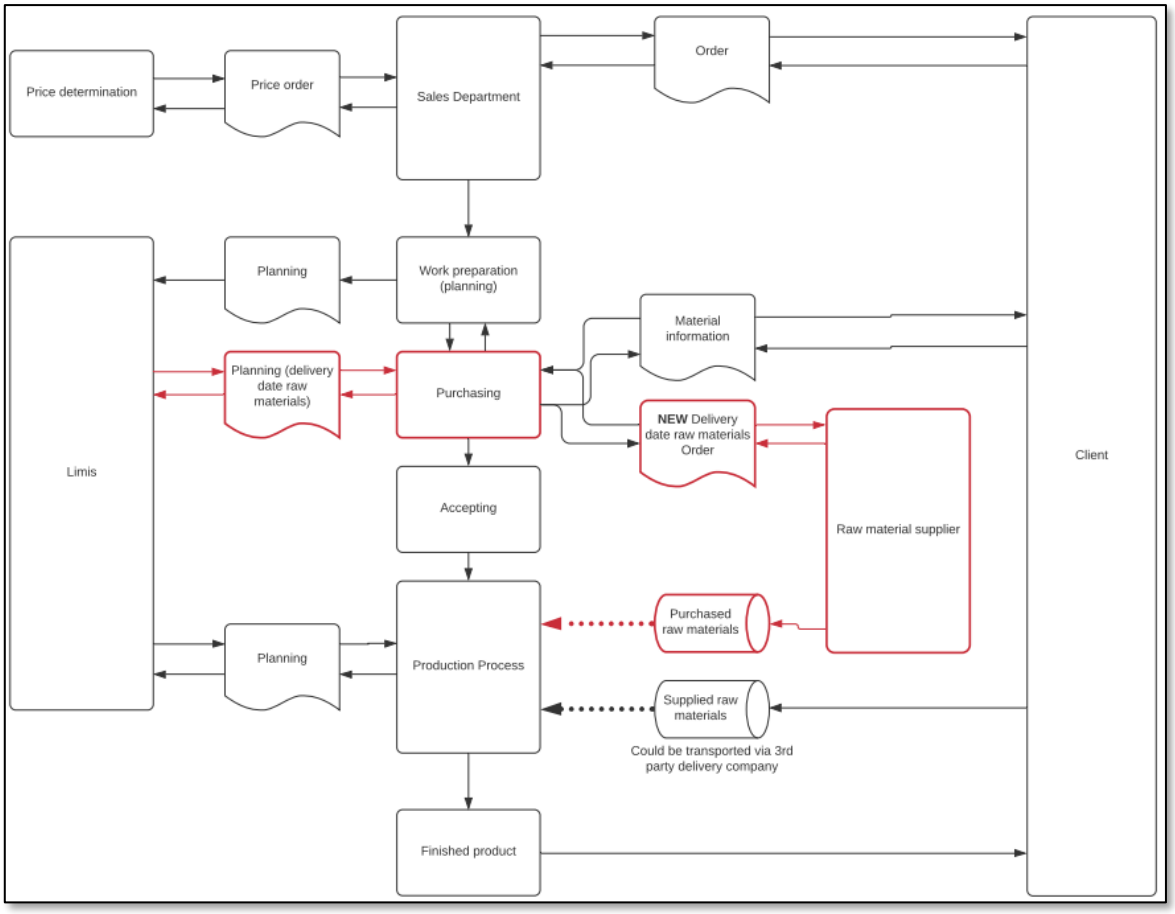


Figure 1 - Global overview of the purchasing process. In the process there are two streams, the buying of raw materials and the supplying of raw materials. In red the actions regarding the purchasing of raw materials are given.

To better understand the process that will be improved, Figure 1 gives an overview. This overview shows the steps regarding the purchasing process from getting a new order until the raw materials arrive at production process. Raw materials can be supplied by existing suppliers or bought from other suppliers. Everything that is outlined in red are actions relating to raw material purchase.

Firstly, contact with the client is made. The sales and finance department make an offer with an expected delivery date and a price. In the case of buying the raw materials, the expected delivery date and price are based on information gathered from the raw materials supplier.

The client accepts or declines this, which can take several weeks. When accepted, the information regarding the production is put into Limis by an employee from work preparation. The order then goes to purchasing which will input the expected delivery date into Limis and after that the order will be checked for production time and feasibility.

Once checked, the order goes either to purchasing or straight into production. When the raw materials are in stock it goes directly to production. When products/materials need to be bought or supplied, the order goes to the purchasing department. At this point the raw materials will be ordered and *could* give a completely different delivery date than the first date given to the sales department. This is then updated in Limis and the order will go to production.

1.2.2 Problem cluster

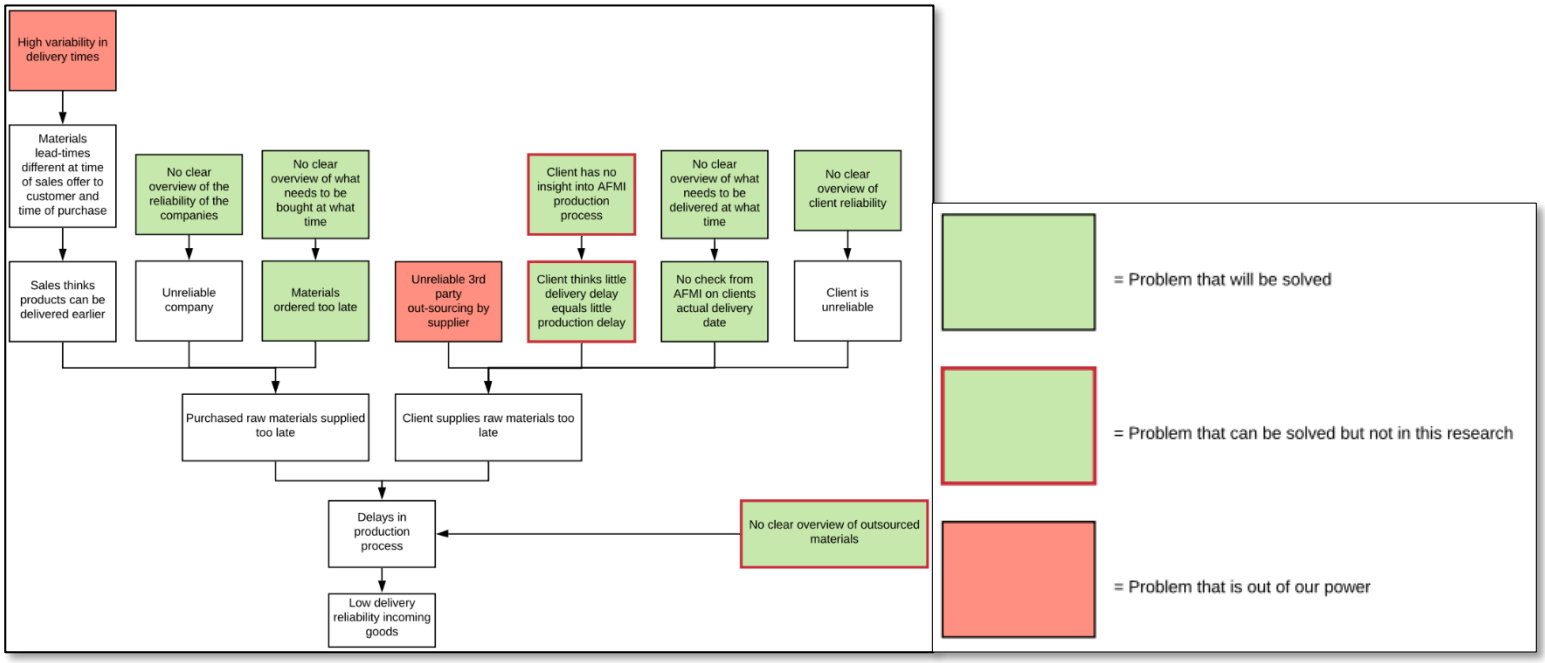


Figure 2 - Problem cluster with at the bottom the problem statement and to the right a legend.

With regard to the problem statement from Chapter 1.1.3: 'delays in the day-to-day planning and low delivery reliability', the problem cluster, shown in Figure 2, was drawn up. To do this I held interviews and short meetings with employees at AFMI. Together with my supervisor at AFMI we concluded that this problem cluster is an accurate visualization of the problem.

The problem cluster in Figure 2 shows the causes are of the various problems. Starting at the very bottom we have a low deliver reliability. This is caused by delays in the production process

followed by delayed deliveries of raw materials or delays in outsourcing. As can be seen the raw materials are delivered in two different ways. Either AFMI buys the raw materials themselves (called 'purchase of materials') or the client delivers it directly to AFMI (called 'supply of materials'). From interviews it was made clear that no clear overview in outsourcing also causes delays in the production processes. We have added this for completeness of the problem cluster but has no priority in our research.

The purchasing and the supply of materials create the same problem, but they have different causes. The delays in 'purchasing the materials' can be seen as caused by AFMI. Two causes are miscommunication between departments within AFMI and ordering the materials too late. The delays in 'supply of materials' are mainly caused by the suppliers themselves. Causes can be a third-party delivery company and the supplier's lack of understanding of AFMI's planning.

As can be seen in Figure 2, we will try to solve 4 problems. The four problems have one thing in common, the lack of a clear overview. Information on incoming goods, the supplied goods as well as the purchased goods, is spread over different screens and programs. Concerning the reliability of the suppliers and the clients, there is no easy way to reach the overview and to analyse them quickly. Because these problems are closely related we will try to solve all the problems and consider the solutions in this research.

1.2.3 Problem stakeholder analysis

By analysing the flow diagram in Figure 1 I tried to create a complete picture of the stakeholders in the purchasing process. In this analysis I found several stakeholders and will elaborate on who they are and what they do in this section.

Firstly, key stakeholders are the Commercial Manager and Sales representatives as they win the orders and create the need for the goods. After they have found a customer, the raw materials can either be supplied by the client or be bought by AFMI. When they are supplied by the client, the Commercial Manager and Process Engineer make sure they are delivered on time. Currently they make use of an Excel sheet to monitor whether action needs to be taken. After an order is accepted the planning department will plan/prepare the work. He does this by entering the production steps into Limis, this also contains the information on which materials are needed and when. As soon as all the information is put into Limis, the order goes to the Supply Chain Department. Employees in this department make sure that the incoming goods are ordered and check delivery schedules. In addition the Supply Chain staff input into Limis if orders have arrived. Currently they use several screens in Limis and sheets of actual paper to monitor what is ordered and what still needs to be done.

The personnel mentioned in the previous paragraph are all actively involved in influencing the incoming goods. As the goal of the dashboard will be to monitor the incoming goods and analyse the suppliers, the Commercial manager, the Process Engineer and the Supply Chain staff will mostly make use of it. Therefore, their opinion of the dashboard is particularly important.

1.2.4 Core problem

As stated in Chapter 1.2.2, we will try to solve the following 4 issues: no clear overview of (1) the incoming supplied materials, (2) the incoming purchased materials, (3) the reliability of a supplier and (4) the reliability of a client. The core problem of these four different issues can be described by the lack of overview. Information necessary to solve these problems is divided

over several programs and several screens within the programs. With this in mind the core problem is formulated as follows:

"It is difficult or impossible to find the information necessary to analyse the incoming goods and their suppliers quickly and accurately."

1.3 Research goal

The goal of this research will be to solve the core problem stated in Chapter 1.2.4 in order to reduce the delays it causes.. The overall goal of AFMI, however, is to create a base with/of business intelligence which they can further develop and use eventually to do more complex analysis. As a researcher my goal for this research will be to solve the core problem and to create a sustainable solution for the long term.. As an objective researcher, I will explore all the solutions mentioned in 1.4 and advise AFMI on the options available.

1.4 Research solutions

Recalling the core problem: "It is difficult or impossible to find the information necessary to analyse the incoming goods and their suppliers quickly and accurately." We can use several methods to work out a solution. The three foremost solutions are summarized in Table 1.

Solution	Advantages	Disadvantages
Implement new planning software	- New start, everything is possible - Builds on existing needs - Solves all problems at once	- Big investment - Costs a lot of time - Could cause other problems
Improve current planning system	- Relatively low investment - Quick to implement	- Data limited to one program - Dependence on external skills
Use business intelligence to create overview	- Low investment - Quick to implement - Use of data from multiple sources - Not limited by external company - Can be applied to other cases	- Solves problem partially - Adds a new program to the currently implemented programs

Table 1 - Advantages and disadvantages of proposed solutions for the core problem.

Implementing a whole new system to plan the operational tasks would be the most comprehensive solution. Everything could be built from scratch and all problems that are experienced currently could be solved. However, this would come at a big cost in terms of time and money. Furthermore, implementing a new system could cause problems not currently foreseeable.

Improving the current system could also work. If done properly it could solve a problem with relatively low investment costs. Furthermore, it could be a quick solution as the company behind the current planning system is very responsive and helpful. The downside of this solution are the program limits as well as the dependence on the external company.

Lastly a business intelligence program could be used to show data needed. This has low investment costs, is quick to implement, can use data from multiple sources, is not limited by

external company and can be applied in many ways. The disadvantages will be that it only solves the problem partially because the planning software still falls short of what is wanted. Furthermore, an extra program will have to be added and employees will need to learn how to use it.

My recommendation would either be (1) to further research the current system and evaluate which aspects of the current program are good and which could be improved and subsequently decide on either implementing a new system or improving the current system with yet more research, or (2) to create a business intelligence dashboard to solve the problems. Eventually AFMI chooses for the solution of implementing a business intelligence system. This solution is chosen as it will create a base for further research with the other data they have and because of the low investment costs. The program to be used to create the overview is Microsoft Power BI.

1.5 Methodology

With the solution of creating a business intelligence system chosen, the next step can be taken: selecting the research methodology. In this research the Design Science Research Methodology (DSRM) will be used because DSRM focusses on an artifact as the solution. An artifact is a physical tool/product specifically made to solve a problem. As described in Chapter 1.4 I will make an artifact/product to solve the problem, which makes DSRM very suitable.

DSRM has 6 steps (Peffers, Tuunamen, Rothenberger, & Chatterjee, 2007) which can be seen as guidelines and will help to build the artifact. The first two steps, (1) identifying the problem and motivating its solution and (2) defining the objectives of the solution are shown in Chapter 1.2 and Chapter 1.7 respectively. After a clear definition of the solution's objectives the next steps can be initiated: designing and developing the artifact, followed by demonstration, evaluation and communication. As indicated by the arrows in Figure 3 the steps can be iterated from evaluation and communication creating a more suitable product over time. A more elaborate description of the DSRM is given in Chapter 3.1.

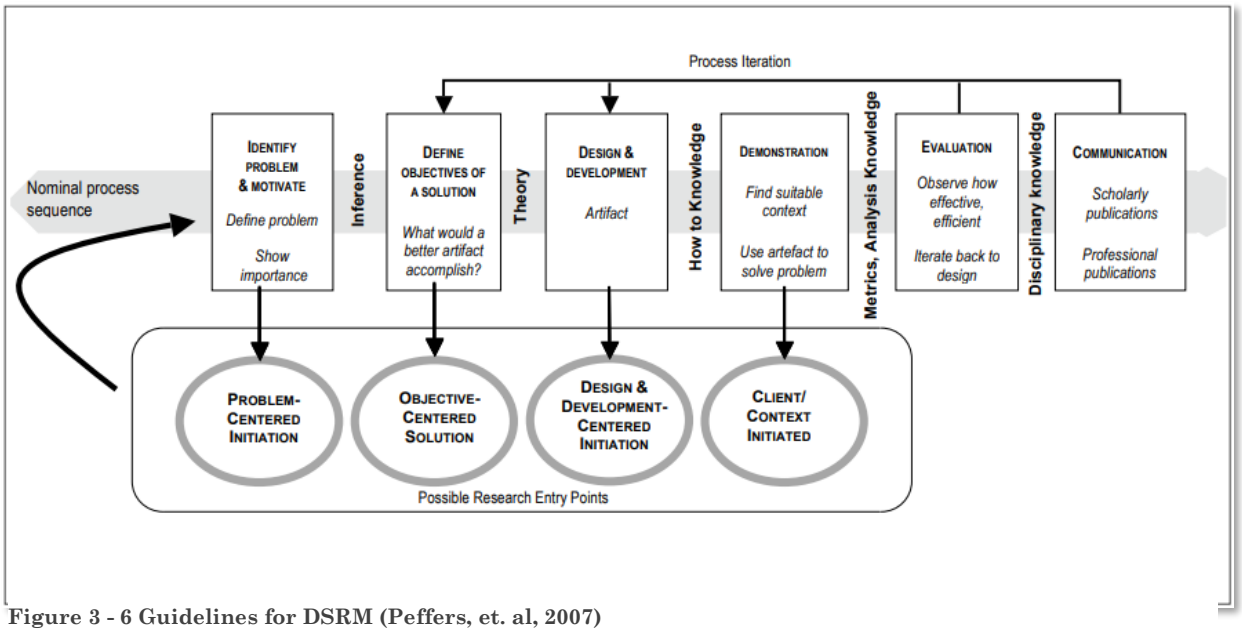


Figure 3 - 6 Guidelines for DSRM (Peffers, et. al, 2007)

1.6 Research questions

As well as the research methodology, discussed in Chapter 1.5 and Chapter 3.1, the research question gives guidance for the research. Whereas the research methodology is more about the broader structure of the research, the research question gives structure specifically for finding the solution. With an eye on the core problem, mentioned in Chapter 1.2.4, the main research question will be:

"How to create a real-time dashboard such that AMFI can monitor the incoming goods quickly and accurately and analyse their suppliers thereby preventing delays in incoming goods?"

This question is difficult to address at once because there are currently so many unknowns. To counter the unknowns, I formulated six research questions.. Through finding answers to these smaller questions I can give a considered and convincing answer to the main research question.

1. **What is the current situation at AFMI regarding the incoming goods and their suppliers?** **[C 1]**
   a. *What does the purchasing process look like?* **[C1.2.1]**
   b. *Who are the stakeholders in the purchasing process?* **[C1.2.3]**

   First a good context analysis is essential in finding and assessing the core-problem. It will give a good view on how big the problem is, who is responsible for the problem and what the best approach is to solve the problem. Furthermore, a good context analysis creates the basis for the ultimate solution created and will ensure that the rest of the research is a lot more efficient.

2. **What is the goal of the dashboard?** **[C 1.3]**
   a. *Who will be the end-user(s)?* **[C 1.2.3]**
   b. *What are the needs of the(se) end-user(s)?* **[C 1.7]**

   As seen in Chapter 1.4, the solution will be provided by means of a dashboard. A dashboard has a broad meaning and can be used for a great variety of applications. To understand which application this problem needs it is necessary to go deeper into the subject. Moreover the needs of the end-users need to be mapped. Answering this research question partly ensures that the dashboard can analyse incoming goods and their suppliers quickly and accurately.

3. **What KPIs/info needs to be shown in the dashboard?** **[C 2.2, C 4.1]**
   a. *How to monitor all the incoming goods?* **[C 4.1.1]**
   b. *How to analyse the suppliers of incoming goods?* **[C 2.2, C4.1.2]**

   Before obtaining a convincing answer to the main research question I will need more information on what KPIs/info will be used in the dashboard. This needs to be done for the monitoring of the incoming goods as well as for analysing their suppliers. Literature on the monitoring of the incoming goods, or on the monitoring of operational

planning as a whole, is not widely available. Therefore I will do this through interviews. As literature about this subject is limited, especially in the procurement department, it will be interesting to see what the conclusions of these interviews are and if this contributes to the literature. I will analyse the suppliers by conducting a systematic literature review.

4. **How to prepare the data to use it in the dashboard? [C 2.3, C 4.2]**
    a. *What data architecture is best?* **[C 2.3.2, C 4.2.1]**
    b. *How to connect the data?* **[C 2.3.3, C 4.2.2]**
    c. *How to clean the data?* **[C 2.3.4, C 4.2.3]**

    With the right KPIs and info found in research question 3, the info needs to be translated to the actual information in the dashboard. In order to create this, I will need to research what needs to be done to prepare the raw data. Preparing data has a lot of different aspects that influence the outcome. With the three sub-questions I will research different aspects of preparing data. The research will partly be done via a systematic literature review and partly via information provided with the dashboard application.

5. **How to visualize the prepared data to show the information? [C 2.4, 4.3]**
    a. *What charts and graphs to use?* **[C 2.4.1, C 4.3.1]**
    b. *What is a good layout for a dashboard?* **[C 2.4.2, C 4.3.2]**

    The last step in making a dashboard, and therefore answering the main research question, is visualizing the prepared data. Visualizing the information and laying the information out on the dashboard can be done in several ways. With this question in mind I will try to find the best way of visualizing information.

6. **How to validate if the implied solution improved the process? [C 3.3, C 5.1]**

    After making the dashboard it is important to know if we have improved the process or not.

1.7 Research design

To answer the research questions in Chapter 1.6 I will make use of two different methods: systematic literature reviews and interviews with the stakeholders in the process. The interviews are to investigate the subjects that cannot be looked up. Take for example the preferences of employees, or criticisms about the current process. In all other cases a systematic literature review will be conducted.

The interviews will be qualitative and semi-structured in nature for several reasons. Firstly, qualitative interviews are necessary for this research. The insight of the stakeholders is really important, as they will eventually need to work with the solution. Without a good knowledge of their preferences and criticisms the solution has a low chance of succeeding. Nevertheless, as the research group (the stakeholders in the purchasing process) is really small, with around 5 people, conducting quantitative interviews will not give accurate results. In addition the interviews will be semi-structured. Given the little knowledge there is about the whole process

at the company a really structured interview will give answers to the questions that already exist, but they will not address the matters there was no knowledge about at all. Using a semi-structured approach questions can be asked about new issues that come up during the interview without losing focus. The drawback of this method is that everybody has their own opinion. They can get very subjective and lead to wrong conclusions. This problem is countered by doing interviews with multiple people.

For the secondary data that cannot be collected through interviews at the company I will make use of the Systematic Literature Review (SLR) method. The data that is collected during the SLR will be peer-reviewed based as this gives a higher validity and reliability. In Chapter 2.1 we explain how the SLRs are conducted.

1.8 Norm and reality

Chapter 1.2.1 describes what the incoming goods process looks like, where the problems lie and who influences it all. Subsequently, the solution to the problem is discussed in Chapter 1.4. Furthermore, following step 2 of the DSRM, in this section I will quantify the core-problem and define the objectives for the solution. I look at the current measures (reality) and set objectives for what we want them to be (norm).

In order to reach a desired norm, we need to measure the problem. Because the problem in itself, the lack of overview, is not measurable we will measure the problem using four factors that are related to the problem. The four factors that are related to the problem are measurable and a norm for these factors can be set.

1. **Programs used to retrieve and visualize data.**
   There are a several ways to get and show data at the moment. The switching between these programs is a hassle and makes working complicated. With this measurement we want to reduce the number of programs used in order to create a clearer overview and make working easier.
   Reality: Several programs are used to retrieve data, these are Limis, Crystal reports and Excel. Next to that physical paper is used to check whether products are bought or not.
   Norm: One program that provides the information for the overview of the purchasing process.

2. **Info available**
   At the moment there is a lot of information that can be viewed but not all of it is necessary. With this measurement we want to eliminate the redundant data and only show the data that is important for the goal.
   Reality: There is too much info that is retrieved via all the different programs to cover. The info ranges from production steps to product drawings to names of clients.
   Norm:
   The info that is shown to the user will be the info that is actually needed. This needs to be just what the end user will benefit from. Globally the following is necessary:
   - Checklist, if necessary, to ensure steps are performed
   - Overview of upcoming deliveries
   - Deliver reliability of clients
   - Delivery reliability of suppliers

The specifics on what information is needed to present this in an efficient manner is explained in Chapter 2.2, the actual selected KPIs are chosen in Chapter 4.1.

3. **Time needed to retrieve data**

   Retrieving data costs time. Time that could be spent on other activities thereby improving work efficiency. Through this measurement we want to decrease the time an employee has to spend on retrieving data.
   Reality: Info is retrieved through the various programs and papers. This currently takes up to around an hour a day.
   Norm: The time needed should not take more than a few minutes a day.

4. **Update frequency**

   The more updated the data, the more accurate the decisions which are based on them. Our aim is to use this measurement to increase the accuracy of the data.
   Reality: Data in the spreadsheets and on papers is only updated when someone changes it, which ranges from once a week to twice a day. Limis is updated every hour.
   Norm: The information should be updated every hour.

2 – Background information

In order to design a good artifact and go on to the next step in the DSRM more knowledge is needed on some research questions. All the relevant knowledge that I have discovered on research questions 3, 4 and 5 is summarized in this chapter. Subsequently I will have knowledge on selecting KPIs, data preparation and data visualization for business intelligence. In Chapter 4 we will use this knowledge for the actual design and development of the artifact.

The knowledge in this chapter is based on two literature reviews, an online course and information provided by the program Microsoft Power BI. The literature reviews conducted for the KPI selection (C2.2) and parts of the data preparation (C2.3.1, C2.3.2, C2.3.4) and are indicated. The way the literature reviews are conducted is shown in Chapter 2.1.

2.1 Systematic Literature Review

Within the research four knowledge related questions need to be answered to solve the core problem. I have answered some of these questions by conducting a systematic literature review (SLR) and when a SLR has been conducted this has been indicated. I conducted the SLRs according to the steps given in the lecture by P.D. Noort at the University of Twente on 23-10-2020. Before following the steps, I also carried out a small piece of research on related issues by searching the internet on related issues. Gaining a broad knowledge on the subject creates a better understanding and results in a more thorough review.

Steps when conducting a literature review:

1. **Define knowledge problem and research question**
2. **Identify scope on requirements and plan**
3. **Conduct the search**
4. **Review the literature**
5. **Compose the review**

In this chapter the compositions of the reviews (step 5) can be found. To give a good view on how I executed these systematic literature reviews the first four steps of the SLR on Key Performance Indicators have been elaborated in Appendix A.

2.2 KPI selection

Based on a systematic literature review.

I adopted the following definition for Key Performance Indicators: KPIs represent a set of measures focusing on those aspects of organizational performance which are the most critical for the current and future success of the organization. (D. Parmenter, 2014) Within this definition KPIs play an important role in turning organizational goals into reality and helping organizations to understand how well they are performing in relation to their strategic goals (Baker & AusIndustry, 2002)

12 step model:

D. Parmenter (2014) suggests the 12-step model for in his book Developing, Implementing, and Using Winning KPIs. D. Parmenter (2014) This 12-step model is based on four building stones for implementing KPIs:
1. Partnership with the staff, unions, key suppliers, and key customers,
2. Transfer of power to the front line,
3. Measuring and Reporting only what happens,
4. Linkage of performance measures to strategy through the CSFs. (Baker & AusIndustry, 2002)

In Parmenter's 12 step model, originally published in 2007, the first 5 steps are designed to convince the employers and employees about using KPIs. These steps are not interesting for this research as all the people I talked to were already convinced of KPI's. The steps subsequent to getting people "on board" are about finding the right KPIs and implementing them. These are shown in Figure 4.

Step 6: Identifying Organization-Wide Critical Success Factors
Step 7: Recording Performance Measures in a Database
Step 8: Selecting Team-Level Performance Measures
Step 9: Selecting Organizational Winning KPIs
Step 10: Developing the Reporting Framework at All Levels
Step 11: Facilitating the Use of Winning KPIs
Step 12: Refining KPIs to Maintain Their Relevance

Figure 4 – The last 6 steps in identifying winning KPIs (D. Parmenter, 2014)

Balanced scorecard:

Another way of selecting KPIs is the balanced scorecard – a set of measures that gives top managers a fast but comprehensive view of the business. (Baker & AusIndustry, 2002) Kaplan and Norton describe the balanced scorecard as an airplane cockpit. For flying the airplane, the pilot needs a lot of detailed information such as speed, altitude, direction and amount of fuel. Managing a business can be compared to flying an airplane, the cockpit then would be the KPIs set to measure the business.

The balanced scorecard looks at a business from 4 perspectives, (1) the financial perspective, (2) the customer perspective, (3) the internal business perspective, and (4) the innovation and learning perspective. For each of these perspectives goals, and measures how to monitor these goals are created. In this way a complete picture of the current situation of the business is formed.

KPI's found in literature:

In addition to selecting KPIs I took a look at the existing KPIs for the purchasing function in literature. KPIs can be used to measure many different functions of a company. Increasingly, managers view the operations and purchasing functions as intimately linked parts of the supply chain, each with the ability to contribute strategically to the firm. (Daniel R. Krause, 2001) To serve this purpose of using the purchasing function strategically the function needs to be measured. Therefore we have listed the KPIs I found for purchasing. We based the categories on the paper of Fedrico Contiato, 2012 and duplicate KPIs have been removed. All KPIs found are shown in Appendix B.

Quality	Cost	Time	Innovation	Flexibility	Other
Product reliability	Total cost	Just In Time	Product Innovation	Volume Flexibility	Purchases in Time and Budget
Product durability	Procurement Cost Reduction	Delivery Speed	Technological capabilities	Mix Flexibility	Spend by Management
Supplier Defect Rate	Procurement Cost Avoidance	Delivery reliability	Technology sharing	Modification Flexibility	Number of suppliers
Compliance rate (contract/specifications)	Procurement ROI	Distance		Emergency Purchase Ratio	Number of orders placed
	Cost effectiveness	Purchase order cycle time		Supplier Availability	
		Lead Time		Willingness to take back product	
		Delivery Schedule			

Table 2 - List of KPIs found in literature for evaluating suppliers divided in six categories.

Most of the sources I used described more about the basics of KPIs. The most useful sources were the books that described the 12-step model [4] and the balanced scorecard (AusIndustries, 1999) as they combined a lot of sources in them and took, in my opinion, the best practices from them. They give good guidance in selecting the right KPIs. Furthermore, a lot of KPIs were found in literature. With this complete list of KPIs the most suitable can be selected to analyse the suppliers.

2.3.1 Business Intelligence

Based on a systematic literature review.

In its broadest sense business intelligence (BI) can be described as a term which includes the strategies, processes, applications, data, products, technologies and technical architecture used to support the collection, analysis, presentation and dissemination of business information (Azeroual, 2020). In this thesis I will use data from one or more databases to present business information by means of a dashboard.

2.3.2 Architecture

Based on a systematic literature review.

A typical architecture for supporting BI in an enterprise is shown in Figure 5. (Chaudhuri, 2011)

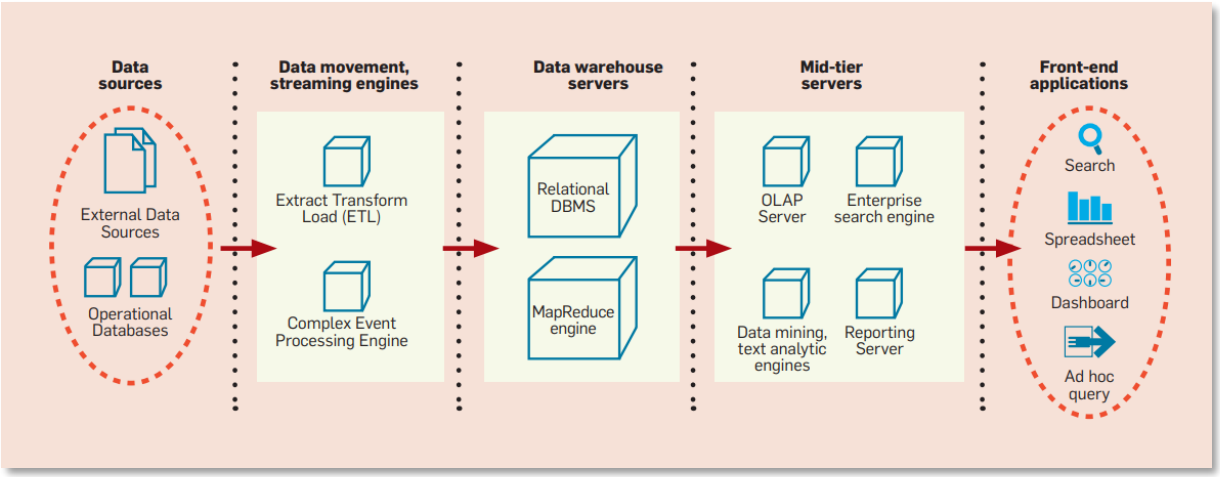


Figure 5 - Typical architecture supporting BI tasks. (Chaudhuri, 2011)

Data comes from different data sources. This data is extracted from these sources, transformed and loaded into data warehouse servers. Transforming and cleaning the data is necessary to make it ready to use in dashboards. This process is elaborated under the header 'data cleaning'. After all the data is stored in the data warehouses, the mid-tier servers will come to use. These servers are designed to serve specialized functionality for different BI scenarios.

Online analytic processing (OLAP) servers expose the multidimensional view of data to applications or users efficiently and enable further BI operations such as filtering, aggregation, drill-down and pivoting. Reporting servers enable the definition, efficient execution and rendering of reports. Enterprise search engines support the keyword search paradigm about text and structured data in the warehouse. Data mining engines enable in-depth analysis of data that goes well beyond what is offered by OLAP or reporting servers and provides the ability to build predictive models. (Chaudhuri, 2011) Once data is processed by a server, the data can be used in a front-end application, Microsoft Power BI, in our research.

2.3.3 Data connection

As far as data connection is concerned I mean the connection that the front-end application Microsoft Power BI makes to the actual data. Microsoft Power BI has numerous ways to connect data to the program. All these ways have different options and different choices need to be made as a result. As researching all these options would be a lot of work, we first explored the connection that AFMI will make use of. The result of this small piece of research is that the data that I need is stored locally in the operational database on the SQL server. This means that I will need the SQL connection from Microsoft Power BI to connect to the operational database.

Extracting the data immediately from the Operational Database (ODB) means the ODB will have an extra connection. This extra connection will also take up extra processing power and memory and can result in slowing down the other processes connected to the ODB. (Chaudhuri, 2011) Taking up extra processing power and memory is something to consider when making the connection.

When connecting to an SQL server with Microsoft Power BI, the program will give the choice to 'import' the data or to use 'DirectQuery'. These options affect the way Microsoft Power BI loads the data. The differences between the two options are given in the next two paragraphs.

Import: The selected tables and columns are imported into Microsoft Power BI Desktop. As you create or interact with a visualization, Microsoft Power BI Desktop uses the imported data. To see underlying data changes since the initial import or the most recent refresh, you must refresh the data, which imports the full dataset again. (Microsoft, 2020)

DirectQuery: No data is imported or copied into the Microsoft Power BI Desktop. For relational sources, the selected tables and columns appear in the Fields list. For multi-dimensional sources, the dimensions and measures of the selected cube appear in the Fields list. As you create or interact with a visualization, Microsoft Power BI Desktop queries the underlying data source, so you are always viewing current data. (Microsoft, 2020) The benefits and limitations of DirectQuery over Import are shown in Table 3.

Benefits	Limitations
- DirectQuery lets you build visualizations over very large datasets, where it would otherwise be unfeasible to first import all the data with pre-aggregation. - Underlying data changes can require a refresh of data. For some reports, the need to display current data can require large data transfers, making reimporting data unfeasible. By contrast, DirectQuery reports always use current data. - Import has a 1GB of data limitation. This 1-GB dataset limitation does not apply to DirectQuery.	- If the Query Editor query is overly complex, an error occurs. To remedy the error, either delete the problematic step in Query Editor, or import the data instead of using DirectQuery. For multi-dimensional sources, there is no Query Editor. - Calculated tables and calculated columns that reference a DirectQuery table from a data source with Single Sign-on (SSO) authentication are not supported in the Microsoft Power BI Service. - Auto date/time is unavailable in DirectQuery. For example, special treatment of date columns (drill down by using year, quarter, month, or day) is not supported in DirectQuery mode.

Table 3 - Benefits and limitations of DirectQuery over Import (Microsoft, 2020)

2.3.4 Data cleaning

Based on a systematic literature review.

In order to create correct KPIs the data that is used for the KPIs must be 'clean' and this can be done via data cleaning. Data cleansing or data cleaning is the process of detecting and correcting (or removing) corrupt or inaccurate records from a record set, table, or database and refers to identifying incomplete, incorrect, inaccurate, or irrelevant parts of the data and then replacing, modifying, or deleting the dirty or coarse data. (Wang, R. Y., & Strong, D. M., 1996) Examples of quality problems are not maintained attributes, abuse of attributes for additional information, incorrect data caused by incorrect input, typing error, inaccurate data, missing data, redundant and inconsistent data and numerous others. (Wu, S., 2013) This can be done by hand, or by scripts executed on a computer. As the system at AFMI is rather small, employees can be instructed on how to clean the data, or better, be instructed to prevent the necessity of cleaning data.

2.3.5 Data transformation

After clean data is produced new data can be added and data can be filtered to create suitable information for the KPIs. In Microsoft Power BI data can be added by the means of measures, calculated columns and hierarchies. Additionally filters can be placed over the data to show filtered information.

Data Analysis Expression

Creating new data in Microsoft Power BI is done by Data Analysis Expressions (DAX). DAX is a formula expression language used in Analysis Services, Power BI, and Power Pivot in Excel. DAX formulas include functions, operators, and values to perform advanced calculations and queries on data in related tables and columns in tabular data models. DAX formulas are used in measures, calculated columns, calculated tables, and row-level security. (Microsoft, 2021)

Measures

Measures are dynamic calculation formulas where the results change depending on context. Measures are used in reporting that support combining and filtering model data by using multiple attributes such as a Microsoft Power BI report or Excel PivotTable or PivotChart. Measures are created by using the DAX formula bar in the model designer. Measures are used in some of the most common data analyses. Simple summarizations such as sums, averages, minimum, maximum and counts can be set through the Fields well. The calculated results of measures are always changing in response to interaction with reports, allowing for fast and dynamic ad-hoc data exploration.

Small example:

The sum of the 'Last year's sales' is shown in a bar chart. The expectations are that the sales will grow by 6%. To show this in the bar chart a measure can be added. This measure will look as follows:

```
Projected sales = SUM('Sales'[Last years sales]) * 1,06
```

This measure 'projected sales' can be added to the bar chart and can be seen in black in Figure 6.

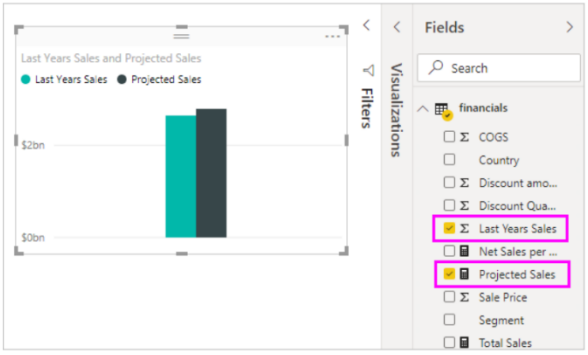


Figure 6 – An example for using measures in Power BI (Microsoft, 2021)

Calculated columns

A calculated column is a column that you add to an existing table and then create a DAX formula that defines the column's values. When a calculated column contains a valid DAX formula, values are calculated for each row as soon as the formula is entered. Values are then stored in the in-memory data model. (Microsoft, 2021)

Calculated tables

A calculated table is a computed object, based on a formula expression, derived from all or part of other tables in the same model. Instead of querying and loading values into your new table's columns from a data source, a DAX formula defines the table's values. (Microsoft, 2021)

Filters

Within Microsoft Power BI filters can be added to the whole report, to the current page or to a single chart or graph. A filter strips down the info that is necessary for showing a visual. In some cases, you only want to see orders placed in the last year. Or you want to filter on the sales of a certain product. Filtering can be done via DAX or via intuitive options within Microsoft Power BI

2.4 Data visualization

There are numerous ways to show data and the layout of all these visualizations can differ. First is elaborated in what charts and graphs data can be shown and later what the layout of these charts and graphs should be in order to effectively communicate the information to the viewer.

2.4.1 Charts and graphs

A lot of charts and graphs are available to show KPIs. As described in Chapter 1.4 I will use the program called Microsoft Power BI for the visualization of the information. First of all, in Microsoft Power BI the standard graphs can be found, these are elaborated in Table 4. Next to these standard charts there is a huge database with personalized charts available. These will not be analysed as most of them are variations on the standard ones.

Visualization	**Explanation**
Table and Matrix	- The Table is a grid that contains related data in a logical series of rows and columns. The table supports two dimensions and the data is flat, which means that duplicate values are displayed and not aggregated. It can also contain headers and a row for totals. - The Matrix visualization looks like the table visualization; however, it allows you selection of one or more elements (rows, columns, values) in the matrix to cross-highlight other visuals on the report page.
Bar and column chart	Shows bars for dimensions. The hight of the bar/column depends on the measured value. Bars can be stacked.
Line and Area charts	The basic area chart is based on the line chart with the area between the axis and line filled in. Area charts emphasize the magnitude of change over time and can be used to draw attention to the total value across a trend.
Pie charts, donut charts	Pie charts and donut charts show the relationship of parts to a whole. The size of the piece represents the value.
Tree maps	Tree maps are charts of coloured rectangles, with size representing value. They can be hierarchical, with rectangles nested within the main rectangles. The space inside each rectangle is allocated based on the value being measured. And the rectangles are arranged in size from top left (largest) to bottom right (smallest).
Combo charts	A combo chart combines a column chart and a line chart. Combining the two charts into one lets you make a quicker comparison of the data. Combo charts can have one or two Y axes, so be sure to look closely.
Card (single number, multi row	Single number cards display a single fact, a single data point. Multi row cards display one or more data points, one per row.
Funnel	Funnels help visualize a process that has stages, and items flow sequentially from one stage to the next.
Gauge	A radial gauge chart has a circular arc and displays a single value that measures progress toward a goal/KPI. The goal, or target value, is represented by the line (needle). Progress toward that goal is represented by the shading. And the value that represents that progress is shown in bold inside the arc. All possible values are spread evenly along the arc, from the minimum (left-most value) to the maximum (right-most value).
Waterfall	A waterfall chart shows a running total as values are added or subtracted. It is useful for understanding how an initial value (for example, net income) is affected by a series of positive and negative changes.
Scatter chart	A scatter chart always has two value axes to show one set of numerical data along a horizontal axis and another set of numerical values along a vertical axis. The chart displays points at the intersection of an x and y numerical value, combining these values into single data points. These data points may be distributed evenly or unevenly across the horizontal axis, depending on the data.

Maps	Use a basic map to associate both categorical and quantitative information with spatial locations. Values are shown in bubbles with the size depending on their measured value
Slicer	A slicer is a stand-alone chart that can be used to filter the other visuals on the page. Slicers come in many different formats (category, range, date, etc.) and can be formatted to allow selection of only one, many, or all the available values.

Table 4 - Summarization of the available charts and graphs in Microsoft Power BI (Microsoft, 2020)

2.4.2 Layout dashboard

After selecting the right visuals for the selected KPIs the visualizations need to be shown on one or more pages in Microsoft Power BI. The layout of these visualizations can differ and a KPI can be placed in the top or the bottom of the screen. On the information pages of Microsoft Power BI, a lot of tips and guidelines are given for the layout of the dashboard. Most important is the opinion of the end users and their feedback on the layout. To get a good start on a dashboard server, 13 guidelines are summarized in Table 5. These guidelines will be used when designing the dashboard. How I did this is stated in Chapter 4.3.1.

nr	Guideline
1	Limit content to fit entirely on one screen.
2	Be cognizant of audience natural textual reading tendency. Starting with the highest level of detail in the upper corner of the screen and show more detail you move down in the direction the audience is used to reading.
3	Keep your dashboard simple with only a 3 to 5 key values, charts, or tables. Avoid putting too much information on a dashboard.
4	Remember to provide adequate context and keep related items near each other.
5	Avoid displaying "singular numbers" without any other context. Show degrees of change for quick comparisons.
6	Avoid data visualization variety for the sake of variety.
7	If detail tables are needed, place them on the bottom of the dashboard
8	Choose appropriate data visualizations. Do not use charts that distort reality i.e., 3-D charts. Keep in mind that it is difficult for the human brain to interpret circular shapes. Pie charts, donut charts, gauges and other circular chart types may look pretty but they
9	Be consistent with chart scales on axes, chart dimension ordering and the colours used for dimension values within charts.
10	Be sure to encode quantitative data nicely. Do not exceed three or four numerals when displaying numbers. Display measures to one or two numerals left of the decimal point and scale for thousands or millions i.e., 3.4 million not 3,400,000.
11	Do not mix levels of precision and time. Make sure that time frames are well understood. Do not have one chart that has last month next to filtered charts from a specific month of the year.
12	Do not mix big and small measures on the same scale, such as on a line or bar chart. For example one measure can be in the millions and the other measure in the thousands. With such a large scale, it would be difficult to see the differences of the measure that is in the thousands.
13	Do not clutter your charts with data labels that are not needed. The values in bar charts are usually well understood without displaying the actual number.

Table 5 – 13 guidelines for designing a layout. (Microsoft, 2020)

3 – Methodology

The first steps of the design science research methodology of Peffer, et. al, (2007) have been taken. In Chapter 1 I discussed step 1: the problem identification and motivation and step 2: defining the objectives of a solution. In Chapter 2 I created a knowledge base for the design and the development. In this chapter I evaluate the use of the methodology, create a research design and investigate how the result will be validated in Chapter 5.

3.1 Research methodology

In Chapter 1.5, the Design Science Research Methodology (DSRM) is chosen for this research. Design science is a discipline that applies knowledge to solve practical problems, in this case by creating a dashboard. Research methodology consists of a six-step framework that will take the researcher from identifying the problem to solving the problem. The six steps are shown in Figure 7. The reason for choosing the DSRM is explained in Chapter 1.5, in this section I will elaborate on the steps, how they are executed and where they are executed.

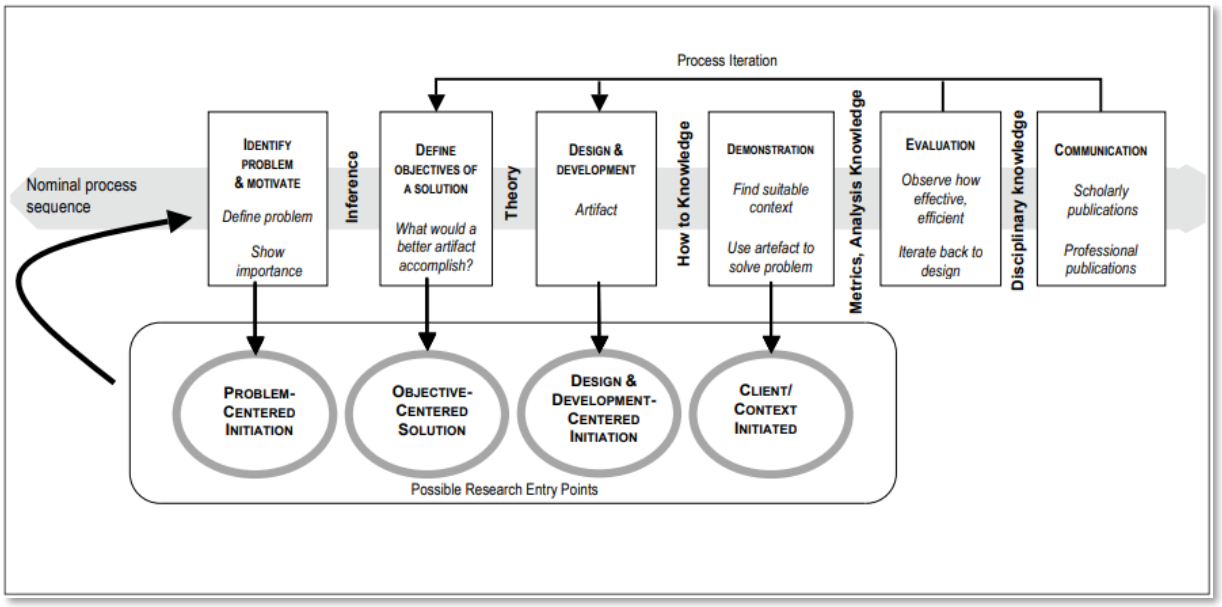


Figure 7 - 6 Steps for DSRM (Peffers, et. al, 2007)

First of all, Figure 7 shows that there are four entry points. (1) Problem centred initiation, (2) Objective centred solution, (3) Design & development centred initiation and (4) Client/context initiated. In the case of this research, I started at (2) Objective centred solution as the client of this researcher already had a solution in mind. From this entry point I go to the first step of the DSRM: identifying the problem and motivation.

In the first step, identify problem & motivation, the specific research problem is defined and the value of a solution is justified. (Peffers, et. al, 2007) In Chapter 1 the process is analysed and a problem definition is created. The problem definition is translated to a research question and this research question is atomized in smaller sub-research questions to capture its complexity – Chapter 1.6. In addition to defining the problem I also justified the value of the solution by showing the benefits and the possibilities in Chapter 1.4.

In the second step I use the problem definition of step one to determine objectives. The objectives can be quantitative, e.g., terms in which a desirable solution would be better than

current ones, or qualitative, e.g., a description of how a new artifact is expected to support solutions to problems not hitherto addressed. (Peffers, et. al, 2007) I chose for a quantitative objective. In Chapter 1.8 the reality of the problem is measured with four indicators and the norm four these four indicators have been set; the norm of these indicators are the objectives of the solution.

In the third step the artifact is created. This activity includes determining the artifact's desired functionality and its architecture and then creating the actual artifact. (Peffers, et. al, 2007) Gaining knowledge and a substantiation for creating the artifact is done in Chapter 2. This knowledge is used for the creation of the artifact which will be illustrated in Chapter 4.

In the fourth step the artifact is demonstrated. Demonstrated is the use of the artifact to solve one or more instances of the problem. This is done by giving the end-users the artifact and letting them use the artifact in their work.

In the fifth step the use of the artifact is evaluated. In this step I observe and measure how well the artifact supports a solution to the problem. This activity involves comparing the objectives of a solution to actual observed results from the use of the artifact in the demonstration. (Peffers, et. al, 2007) Within the evaluation is the specific validation of the artifact. How the artifact is validated will be explained in Chapter 3.2, the actual validation of the artifact is done in Chapter 5. With the validation I can evaluate the artifact, this is done in Chapter 6.

In the last step, step 6 – communication, I communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences, such as practicing professionals, if/when appropriate. (Peffers, et. al, 2007) With this research I communicate to the audience via this research paper.

3.2 Research validation

The core problem is found and will be improved from the reality to the norm. These are measured by four variables mentioned in Chapter 1 and it can be said that the core problem is solved if the norms are reached. However, I want to validate that the solution had an impact on the problems that were caused.

The best way to validate is to measure the problems that our core-problem caused. These are:

- Delays in delivery from supplier
- Delays in production process
- Delays in delivery to client

These three factors can be measured before implementing the solution and a period after the implementation. Unfortunately, the period of time available is limited for this thesis. The measurements at the end will not reflect the impact of the solution. Therefore other ways of validation are evaluated. I found two other viable methods for validation - validation via surveying and validation via a focus group.

Ways of surveying can differ. Searching through literature for surveying information technology I found two suitable papers: Dyczkowski et. al. (2014) and Venkatesh et. al. (2003). These two papers propose different ways of surveying. Dyczkowski et. al. (2014) focusses on the improvement on a dashboard and Venkatesh et. al. (2003) focusses on whether a dashboard

is efficient and effective for the user. As only one dashboard will be used, I will use the survey of Venkatesh et. al. (2003) to validate and evaluate the solution.

The paper of Venkatesh proposes the Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT measures if a new technology, in this case an artifact, is accepted and used. If the verdict of the UTAUT is positive, I can validate that the artifact works.

Validating via UTAUT is done by a series of question categorized in 5 constructs: (1) Performance expectancy, (2) Effort expectancy, (3) Social influence, (4) Facilitating conditions, (5) Attitude towards using technology. The constructs, their definition and their statements are shown below. A 5-point Likert scale is used to measure the extent of the agreement on the solution with 1 = "totally disagree" to 5 = "totally agree".

Constructs of the UTAUT:

1. ***Performance expectancy***
   Defined as the degree to which an individual believes that using the system will help him or her to improve job performance.

   Questions:
   - Using the system would enable me to accomplish tasks more quickly
   - Using the system would increase my productivity
   - Using the system would enhance my effectiveness to do my job
   - I would find the system useful in my job

2. ***Effort expectancy***
   Defined as the degree of ease associated with the use of the system.

   Questions:
   - Learning to operate the system would be easy for me
   - I would find it easy to get the system to do what I want it to do
   - I would find the system flexible to interact with
   - It would be easy for me to become skilful at using the system
   - I would find the system easy to use

3. ***Social influence***

   Defined as the degree to which an individual perceives that it is important if others believe he or she should use the new system.

   Questions:

   - I use the system because of the proportion of co-workers who user the system
   - The senior management of this business have been helpful in the use of this system
   - My supervisor is very supportive of the use of the system for my job
   - In general, the organization has supported the use of the system

4. ***Facilitating conditions***
   Defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system.

Questions:

- Using the system is compatible with all aspects of my work
- I think that using the system fits well with the way I like to work
- Using the system fits into my workstyle

5. ***Attitude towards using technology***
   Defined as an individual's overall reaction to using a system.

   Questions:

   - Using the system is a good idea
   - Using the system is a wise idea
   - I dislike the idea of using the system
   - Using the system is unpleasant

Besides validating by surveying, validating can also be done via a focus group. A focus group is a group interview with a small number of people. In this focus group the researcher asks questions and discussions can be held on the question, either guided or open. This can also be used for validating the artifact by asking open questions about it. With positive results from the survey and from a focus group, it can be stated that the artifact is validated and will indeed improve the work processes.

I will start the validation process with the more quantitative way of validation, surveying. This is done because this can be done more quickly. The answers from the survey do not have a lot of depth but can give a direction for the focus group held after the survey. When both the validations of the survey and the focus group are done the results of the validation will be evaluated, which I do in Chapter 5.

3.3 Summary

In Chapter 3.1 I have reviewed and elaborated on the methodology that had been chosen in Chapter 1.5. I've looked at what steps have already been taken with this methodology and looked at the steps that are to come. Reviewing the steps that have been taken confirms that I've chosen the right research methodology and can continue this way. In the upcoming paragraphs I will design the artifact and validate it.

I shall conduct/carry out the validation process using two methods. This is validation by surveying and validating with the help of a focus group. The survey will be used as a guidance for the focus group and give the focus group more meaning.

4 – Design & Development

Up to this point, we know what the problem is, which solution we will use and I have created a knowledge base for creating such a solution. In this chapter we will apply the knowledge for the actual dashboard, as described in step 3 of the DSRM. Furthermore, this chapter will also give answers on research questions 3, 4 and 5.

4.1 KPI selection

In the quest to finding the right KPIs we recall research question 3 from Chapter 1.6: What KPIs/info needs to be shown on the dashboard? Subject to this question there are two smaller questions. 1) How to monitor all the incoming goods? 2) how to analyse the suppliers of incoming goods? The objectives of these questions are to create:

1. An overview to **monitor the incoming goods** in order to minimize the faults made.
2. A **supplier analysis** to get a view on how reliable a supplier is

4.1.1 Monitoring

Because the objective of monitoring the incoming goods is so specific to this one company no literature was found on the subject. Therefore a lot of qualitative interviews were held with the end-users to find out what KPIs were necessary for them. During the interviews it boiled down to two specific goals for the monitoring. These are (1) an overview of all the materials that still need to be ordered and (2) an overview of the upcoming deliveries. Therefore two separate tabs will be built in the dashboard for monitoring the incoming goods.

Monitoring materials to order

The first tab on the dashboard will be for monitoring the materials that still need to be ordered. For every order accepted at AFMI, a new project is started in the planning program software Limis. Within this project the materials that are needed are entered. Next to that it is stated if the materials are delivered by the customer or if AFMI needs to buy it themselves. Every material that needs to be ordered is called a 'purchasing line'. For each of these purchasing lines an order needs to be placed in the purchasing module of Limis. For now, there is only an overview in the form of a physical piece of paper. The goal of this overview is to digitalize the paper overview. Through interviews I gathered what info is used from the papers. The info needed is shown in Table 6.

Dutch	**English**
Klant naam	Client name
Inkoop/toelevering	Purchase / supply
Materiaal info	Material info
Materiaal omschrijving	Material description
Verdeling inkoop/toelevering	Distribution purchase/supply

Table 6 - Selected KPIs materials to order in Dutch and English.

Monitoring upcoming deliveries

The second tab that will be made in the dashboard is for the monitoring of the upcoming deliveries. All the incoming goods are shown in the table 'all orders' within Limis. This overview shows when every purchase line will be delivered. However, this is only a small portion of the info that is required. In interviews with the Process Engineer and the Commercial Manager it became clear that they want a reminder to call the suppliers in advance to make sure that the materials are delivered on time. They used to use a spreadsheet

to keep track of that in the past but because it was too much work to keep it up to date, they stopped using it. Using the spreadsheet and the interviews, the KPIs are selected, these are shown in Table 7.

Dutch	**English**
AFMI project nummer	AFMI project number
Klant project nummer	Client project number
Inkoop/toelevering/voorraad	Purchase/supply/stock
Dagen tot levering	Days till delivery
Leverdatum	Delivery date
Leverancier naam	Supplier name
Leverancier plaats	Supplier location
Leverancier telefoonnummer	Supplier telephone number
Bon nummer AFMI	Receipt number AFMI
# inkopen aankomende periode	# supplies upcoming periods

Table 7 - Selected KPIs upcoming deliveries in Dutch and English.

4.1.2 Supplier rating

Next to the two tabs for monitoring the incoming goods another tab will be created for the supplier analysis. To find KPIs for analysing suppliers I conducted a systematic literature review. In this literature review I found a list of KPIs that could be useful to access suppliers.

In this section I will select the 'winning KPI' to create one tab on the dashboard for the analysis of a supplier. The list that was created in the literature review contained a lot of KPIs not applicable for this research, therefore those KPIs are deleted. The deleted KPI's are shown in Table 8 in yellow. The reasons for removal can be found in the next paragraph.

Quality	Cost	Time	Innovation	Flexibility	Other
Product reliability	Total cost	Just In Time	Product Innovation	Volume Flexibility	Purchases in Time and Budget
Product durability	Procurement Cost Reduction	Delivery Speed	Technological capabilities	Mix Flexibility	Spend Under Management
Supplier Defect Rate	Procurement Cost Aviodance	Delivery reliability	Technology sharing	Modification Flexibility	Number of suppliers
Compliance rate (contract/specifications)	Procurement ROI	Distance		Emergency Purchase Ratio	Number of orders placed
	Cost effectiveness	Purchase order cycle time		Supplier Availability	
		Lead Time		Willingness to take back product	
		Delivery Schedule			

Table 8 - List of KPIs found in literature. The KPIs highlighted in yellow have been deleted because they are not applicable for this research.

Product durability: In this case the products that are bought are only machined and not used. The durability of the material is not seen. *Procurement cost reduction, Procurement cost avoidance*: As products are bought occasionally and have such low volume the cost reductions and cost avoidance are negligible. *Purchase order cycle, Delivery schedule*: Products are bought occasionally and have low volume. No order cycle or delivery schedule can be applied in this case. *Product innovation:* High variation of products are bought. Innovations on one product are therefore not interesting. *Purchases in time and budget:* No budget is set on purchases thus this KPI is invalid. *Spend under management:* Products are not bought strategically, therefore this KPI is not applicable.

The KPIs that are suitable for AFMI are selected and the next step is to select the 'winning KPIs' as stated by Baker & AusIndustry (2002). Four employees at AFMI are selected for a survey to 'rate' the KPIs. These four employees were selected because they all have knowledge on the purchasing process within AFMI but from different perspectives. Two of the employees are from management and the other two are employees from purchasing. In the survey the employees gave their assessment using a 5-point Likert scale (1 = "Really not important" to 5 = "Really important").

			Answers			
KPI	**Average**		**1**	**2**	**3**	**4**
Supplier Defect Rate	5,0		5	5	5	5
Compliance rate contract	4,5		5	5	4	4
Total cost	3,3		4	3	2	4
Cost effectiveness	3,5		3	4	2	5
Procurement ROI	3,5		3	3	4	4
Just In Time	4,8		5	5	5	4
Lead Time	3,3		3	3	3	4
Delivery reliability	4,8		5	5	5	4
Distance	2,3		2	3	2	2
Technological capabilities	3,8		4	4	3	4
Technology sharing	3,3		4	3	3	3
Volume Flexibility	2,5		3	3	2	2
Modification Flexibility	2,8		3	3	3	2
Mix Flexibility	3,3		4	4	3	2
Emergency Purchase Ratio	4,0		4	4	4	4
Supplier Availability	4,3		4	4	5	4
Willingness to take back product	3,5		5	3	3	3
Number of orders placed	2,8		2	4	3	2
Number of suppliers	2,3		1	3	2	3

Table 9 - Results of survey measuring how important KPIs are to four participants. Measured with a Likert-scale from 1 = "Really not important" to 5 = "Really important".

The results of the survey are shown in Table 9. From left to right the columns show: the KPI, the average score and the four answers from each of the employees. The average of the answers is taken and all the KPIs with an average of 4 or higher are green, between 3 and 3,9 is yellow and lower is red. For this research the KPIs with a 4 or higher were chosen as they are perceived as 'important' by the employees, and I can agree with the results. The selected KPIs are 'supplier defect rate', 'just in time', 'delivery reliability', 'compliance rate contract', 'supplier availability' and 'emergency purchase ratio'.

The 'supplier defect rate' and 'compliance rate contract' is managed in a separate spreadsheet. At the moment the information in the spreadsheet is not in the right format which means the information cannot be shown in Power BI. Furthermore, there is no data yet on 'supplier availability' and 'emergency purchase ratio'. AFMI is recommended t to put the information in the spreadsheets in the right format and in such a way that it can be imported in Power BI. In addition it is recommended that the data of the 'supplier availability' and 'emergency purchase

ratio' is kept track of. With the exclusion of 'supplier defect rate', 'compliance rate contract', 'supplier availability' and 'emergency purchase ratio' we will analyse the supplier with two KPIs: Just in Time and Delivery Reliability.

Interesting KPIs which stand out are the three 'cost-KPIs', (1) Total cost, (2) Cost effectiveness and (3) Procurement ROI. Most of the KPIs received more or less the same answers on how important a KPI it was. However, the KPIs for costs received very variable results. This can be explained by the differences between the regular employees and the management employees as they both have very different goals. As AFMI is a company that focusses on quality rather than costs I decided that these KPIs should not be included in the dashboard.

4.2 Data preparation

Before it is possible to implement the KPIs chosen in Chapter 4.1 the data needs to be prepared. This is done by creating the architecture for the data, connecting the data to the front-end application, in this case Power BI, and transforming the data in a way that it can be used. In this section I explain how the knowledge of Chapter 2.3 is applied.

4.2.1 Architecture

Firstly, the architecture of the data system at AFMI needs to be in order. The architecture described in Chapter 2.2 is made for big data sources with millions and millions of rows extracted from multiple data sources. Within this research only one data source is used which is, compared to other examples, rather small with only a few hundred thousand rows. Therefore the typical architecture described in Chapter 2.3 will not be used because the costs for implementation are huge and do not outweigh the main benefit which is speed. Since we, at AFMI, use one small operational database as a source the architecture described in Figure 8 is possible. In this case the data in the operational database is produced by LIMIS. This data is extracted, transformed and loaded (ETL), and presented by Microsoft Power BI.

The architecture described in Figure 8 can be used for a long time, around 10 years, if the use of the applications stays the same. This is because the number of rows added per year is very low and thus the total data will stay low. However, if new applications or systems are implemented, this could be different because they increase the data. In the case that the current architecture becomes slow and results in very high loading times into Microsoft Power BI, AFMI is recommended to implement a data-warehouse server designed for huge amounts of data.

4.2.2 Data connection

After designing the architecture, the data from the SQL database needs to be connected to Microsoft Power BI. There are two ways to connect Microsoft Power BI to a SQL database. These are 'Import' and 'DirectQuery'. Because of the small data size and the improved versatility that it brings, 'Import' is the logical choice. Power BI will import the data selected and copy that on a local file. This means that from the moment you import the data in Microsoft Power BI it is separated from the operational database and does not affect the speed of it.

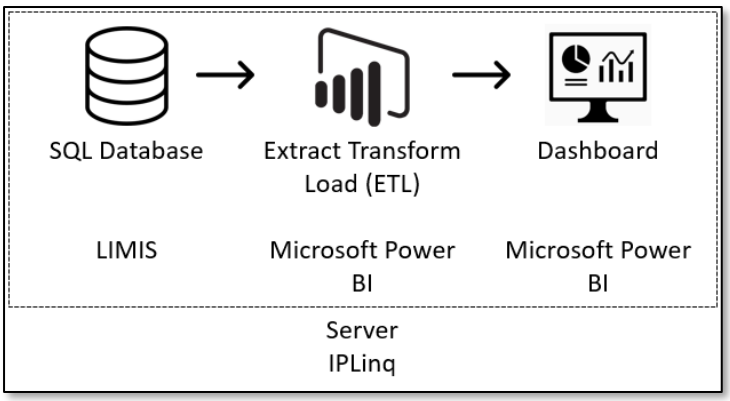


Figure 8 - The current data architecture of AFMI on the server managed by the company IPlinq. The process from raw data on a SQL database to visualizations on the program Microsoft Power BI.

Currently only LIMIS is connected to the database, but when Power BI is also connected to the operational database it means the database has two connections. As LIMIS handles the day-to-day planning of the factory it is of the utmost importance that this program keeps running smoothly. Therefore Power BI needs to make way for LIMIS. Fortunately, the amount of processing power and memory used by Power BI can be managed by selecting a refresh rate which can be set to one hour.

4.2.3 Data cleaning

To ensure that the data selected in Chapter 4.1 is visualized correctly, the data needs to be cleaned. Data that is not correct or of no use in showing the KPIs is removed from the database or simply not imported. Furthermore, the data tables that are imported into Power BI need to be connected to each other, because doing this in the wrong way can also give inaccurate values of KPIs. Lastly, data that is imported can be filtered, removing the values not useful or wrong for the KPIs. In this section the importation of data, the table connection and the filters are elaborated.

Imported data

First of all, only the necessary data is imported. The tables with the columns that are imported can be found in Table 10. The data that is imported is selected from the full database that is shown in Appendix C. Together with the columns that are imported, new columns are created and they are highlighted in yellow in Table 10. The reason why the new columns are added is explained in Chapter 4.2.4.

a_orders	a_projects	a_stapmat	io_inkord	io_inkordtekst	r_klant (leverancier)	r_klant (klant)	r_relatie
ord_aant_afkeur	pj_sch_levdatum	mat_aant_picked	io_besteld_telf	iot_lastmodified	klt_aanvraag_type	klt_aanvraag_type	r_email
ord_aant_gereed	pj_aant_afkeur	mat_artcode	io_bevdatum	Dagen tot levering	klt_active_yn	klt_active_yn	r_fax
ord_aant_plan	pj_aant_gereed	mat_eenheid	io_bonnr	geleverd-leverdatum	klt_adres	klt_adres	r_klantnr
ord_aant_real	pj_aant_totaal	mat_info	io_contpers	iot_aantal	klt_code	klt_code	r_naam
ord_artcode	pj_aanvraag_tijdstip	mat_lastmodified	io_crediteurnr	iot_aantal_terug	klt_dlvdatumbev_yn	klt_dlvdatumbev_yn	r_telefoon
ord_gereed_yn	pj_aanvraag_type	mat_leverdatum	io_datum	iot_afkeur_yn	klt_email	klt_email	r_volgnr
ord_invoerdatum	pj_calc_dlvdate	mat_omschr	io_invoerdatum	iot_artcode	klt_fax	klt_fax	
ord_omschr	pj_datum_geleverd	mat_ord	io_koptekst	iot_bonnr	klt_naam	klt_naam	
ord_ordnr	pj_gepland_yn	mat_pickstat	io_lastmodified	iot_compleet_yn	klt_nummer	klt_nummer	
ord_plan_eind	pj_gevraagde_leverdatum	mat_ppe_manual	io_leverdatum	iot_control_yn	klt_pc	klt_pc	
ord_plan_start	pj_invoerdatum	mat_prijs_per_eenh	io_leverdatum_bev	iot_datum_geleverd	klt_plaats	klt_plaats	
ord_prj	pj_klantnaam	mat_prijs_totaal	io_lvrdatum_wrklk	iot_goed_yn	klt_post_adres	klt_post_adres	
ord_real_eind	pj_klantnr	mat_prj	io_medewnr	iot_invoerdatum	klt_post_pc	klt_post_pc	
ord_revnr	pj_klantordnr	mat_refno	io_paraaf	iot_leverdatum	klt_post_plaats	klt_post_plaats	
ord_sch_levdatum	pj_lastmodified	mat_stapnr	io_postadres_yn	iot_leverdatum_bev	klt_telefoon	klt_telefoon	
ord_sim_levdatum	pj_lc	mat_stukaant_eenh	io_slottekst	iot_lvrdatum_wrklk	klt_transporteur_yn	klt_transporteur_yn	
ord_status	pj_levcond_tekst	mat_verbruik	io_vc_bedrag	iot_ordnr	klt_type	klt_type	
ord_vrije_tekst_1	pj_leverdatum	prj,ord,stp,rgl	io_verzenddatum	iot_pickstat			
ord_vrije_tekst_2	pj_leverdatum_bev	prj,ordnr		iot_prj			
ord_vrije_tekst_3	pj_leverdatum_by_lp	Regelnummer (stapmat)		iot_refno			
ord_vrije_tekst_4	pj_leveringsconditie			iot_regelnr			
prj,ordnr	pj_lt			iot_revnr			
	pj_omschr			iot_rubrieknr			
	pj_plan_einddatum			iot_stapnr			
	pj_plan_startdatum			iot_stukprijs			
	pj_prj			iot_tekst			
	pj_rework_yn			iot_totaalprijs			
	pj_sch_levdatum_1			iot_type			
	pj_sch_levdatum_2			iot_verzonden_dt			
	pj_sch_levdatum_3			prj,ordnr			
	pj_sch_levdatum_4			Te laat			
	pj_sch_levdatum_5						
	pj_sim_levdatum						
	pj_transporteur						
	pj_verwerkt_yn						

Table 10 - All the data imported from the database. Each column represents a table, and the rows of those columns represent the columns of those tables. Highlighted in yellow are the columns that are added afterwards, which is explained in Chapter 4.2.3.

Table connections

The columns that are imported into Power BI need to be connected to each other. The connection is needed because only when all the tables are connected, can information be extracted. For example, table 'a projects' contains a row for each project AFMI has started. In this row all the information related to that project, including the client number but not the client's email, is given. The table 'r_klant' does contain the client number and the client's email. By connecting the 'a_ projects' and 'r_klant' via the column client number Power BI knows what email you need to use if you, for example, have questions regarding a project.

All the tables that are stated in Table 10 are connected to each other. The way these are connected is visualized in Figure 9. In this figure the seven imported tables are shown with lines between them. These lines indicate that a connection has been made between the two tables. The connection that has been made is between two corresponding columns of tables. For example, r_klant and a_projects both have the column 'client number' and you can connect the tables with these two columns. In order to make connections between all the tables, some new columns are created. The explanation of these additional columns is given in Chapter 4.2.4.

As well as visualizing a connection, the lines between the tables also contain information about the kind of connection that is made between the corresponding columns in the tables. In the figure three different icons can be seen: '**1**', '*****', '**<>**'. When looking at r_klant (klant) and a_projects we see from left to right the '**1**', the '**<>**' and the '*****'. The '**1**' to '*****' means that one (1) row in r_ klant has multiple (*) rows in a_project which can be interpreted as that a client can start more than one projects at AFMI. The '**<>**' indicates the way the information flows. In this

research information flows to and from everywhere.. If a project is listed it is possible to ascertain the client's name/details or, conversely, with a client number it is possible to see which projects a particular client is involved in at AFMI.

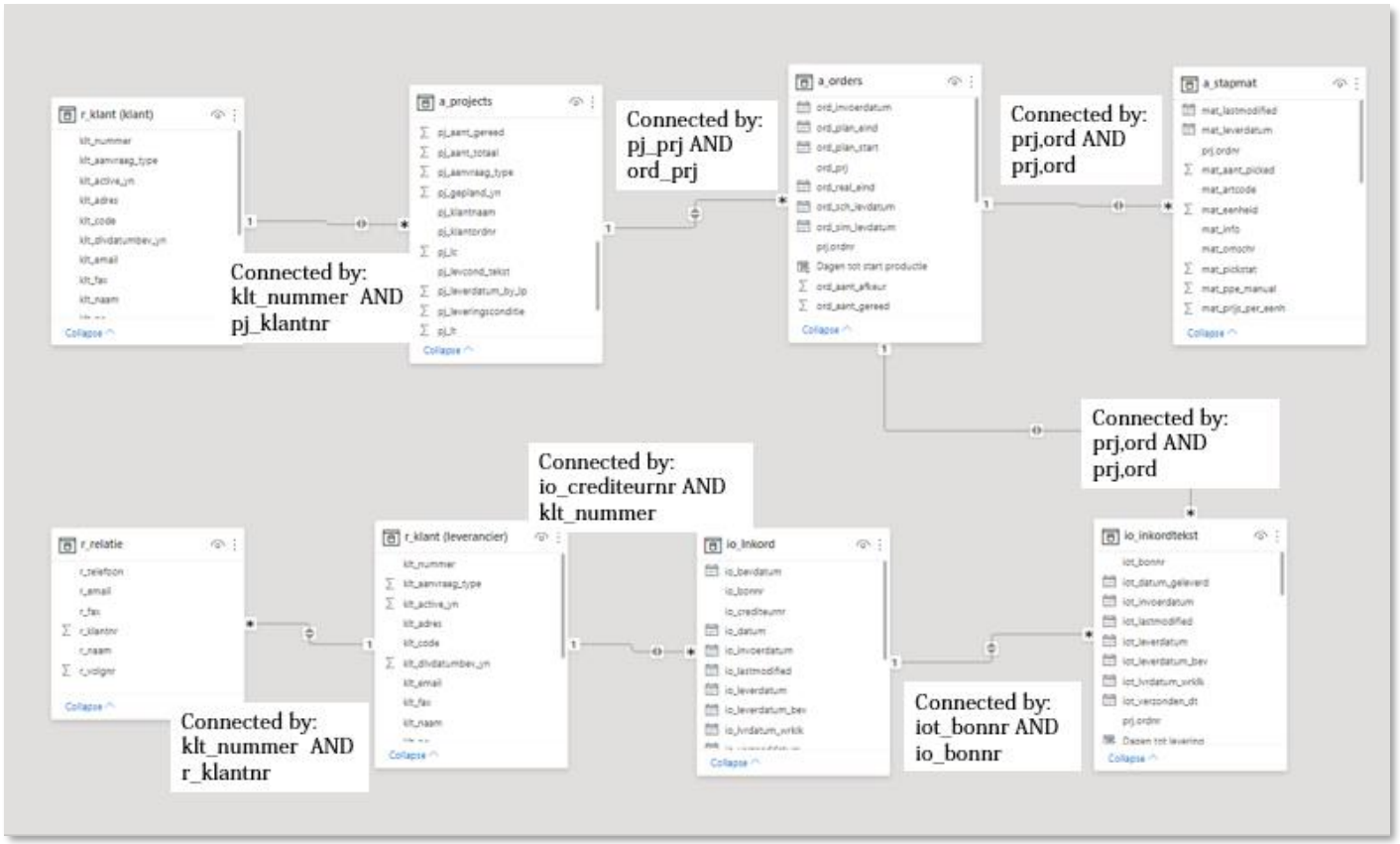


Figure 9 - Visualization on how the imported tables are connected to each other. The lines show the kind of connections, the white blocks give the columns on which the tables are connected.

Filters

For each of the three tabs within the dashboard that are made, filters are placed over the data. A filter is a step that is taken to skim the data to analyse specific rows. For example, if the orders not yet shipped to the client need to be analysed. In this case a filter can be added on the column 'finished' filtering out the number '0' meaning that it is not shipped yet. These filters can be added to all columns and Power BI has a lot of filter options. It is possible to filter out dates, numbers and text. When a filter is placed on a column it can be stipulated where the filter applies. In Power BI a filter can be applied to all tabs, to the current tab or just to a specific chart or graph.

For the tab 'in te kopen/in te voeren' three filters have been applied. Two of them are applicable on the whole dashboard: (1) filter out the items that are not already delivered as those are the only ones you want to see, (2) filter out only the orders that are entered in the last 2 years because the info before that period is irrelevant. The third filter was only applied to the matrix table and filtered out blanks to see if a product needed had already been purchased. In Table 11 an overview of these filters can be found.

Table	Column	Filter	applied to	Reason
a_stapmat	mat_pickstat	is 0	whole dashboard	Only the items that are not allready picked (delivered) need to be shown.
a_orders	ord_invoerdatum	Last 2 years	whole dashboard	Only the orders that are generated in the last two years are needed. Orders older than that are not relevant.
io_inkordtekst	iot_bonnr	is blank	matrix table	In this matrix we want to see the purchasing lines for which a 'bonnr' was not yet generated.

Table 11 – Filters placed in the tab 'in te kopen/in te voeren'. The table and column which the filter is filtering together with the filter and where the filter is applied to is shown.

For the tab 'Overzicht actuele orders' three filters are applied to the whole tab. (1) not yet delivered product, (2) an order entered in the last 2 years, (3) a not yet finished project . An overview of these filters is given in Table 12.

Table	Column	Filter	applied to	Reason
io_inkordtekst	iot_pickstat	is 0	whole dashboard	Checks if supplies are delivered. Needed to show only the orders that are not delivered yet
a_orders	ord_invoerdatum	Last 2 years	whole dashboard	Only the orders that are generated in the last two years are needed. Orders older than that are not relevant.
a_projects	pj_aant_gereed	is 0	whole dashboard	Checks if a project is still in progress. If a project is finished it is not shown on this page

Table 12 - Filters placed in the tab 'Overzicht actuele orders'. The table and column which the filter is filtering together with the filter and where the filter is applied to is shown.

For the tab 'Leveranciers analyse' three filters are applied. The first one is applicable to the whole tab in this dashboard and filters out client names that are not blank and are not AFMI. The second filters out a measure 'count bestelling' and makes sure that each of the clients shown on the tab have more than 0 orders placed at AFMI. The last filter makes sure that the order placed is 'Inkoop' (Purchase) or 'Toelevering' (Delivery). An overview of the filters is shown in Table 13.

Table	Column	Filter	applied to	Reason
r_klant (leverancier	klt_naam	is not BLANK or AFMI	whole dashboard	Some lines in the table don't contain values. These are filtered out. AFMI is in the suppliers table, but doesn't supply to AFMI.
MEASURE	Count bestellingen	Higher than 0	Slicer 'leverancier'	Only the supplier which actually have supplied are shown.
io_inkordtekst	iot_artcode	is 'INKOOP'or 'TOELEVERING'	Slicer 'leverancier'	Only the suppliers who have supplied 'inkoop' or 'toelevering' are selected as those are the only that are interesting.

Table 13 - Filters placed in the tab 'Leveranciers analyse'. The table and column on which the filter is filtering together with the actual filter and where the filter is applied to is shown.

4.2.4 Data transformation

Data that is imported can be transformed. Data transformation is the process of creating new columns or altering columns. In Power BI an extra kind of transformation is used in the form of 'measures'. The reason for creating new columns, altering columns or creating measures can vary. In this research I transformed the data to connect the tables to each other and to create the new information needed to visualize the KPIs selected in Chapter 4.1.

Connecting tables

To connect the tables correctly, transformations are made. In three tables an extra column is added to make the connection. Furthermore, the 'r_klant' table is copy pasted. This is explained in this section.

Firstly, extra columns are added for connections between tables. This was necessary to link rows within the tables. Currently the tables a_orders, a_stapmat and io_inkordtekst are related to each other via multiple columns. However, Power BI needs one single column to connect the tables. Therefore, for the tables a_orders, a_stapmat and io_inkordtekst a new column is created by merging the columns 'project number and 'order number'. Secondly, in the database there is only one table for the clients as well as for the suppliers. For Power BI it is not possible to retrieve information this way as it would create a 'circle' in the connections. To counter the problem the whole table is copied and renamed. One table is called 'r_klant (klant)' which represents the clients and the other 'r_klant (leverancier)' which represents the suppliers.

Data for KPIs

With the connections between the tables ready I can focus on creating the data for the KPIs. Creating this new data for the KPIs is done via transforming: making measures, columns and hierarchies. The actual transformations made are explained in this section.

First of all, six new measures are added. Measures are dynamic calculation formulas where the results change depending on context. For example a measure can be 'sum of sales', when you create a visualization, you can plot this 'sum of sales' over years and see what the sum of sales was each year, or over companies and see what the sum of sales was per company. The measures added in this are shown in Table 14. This table shows in which dashboard a measure is added, the name of the measure, the formula for the measure, the reason why the measure is added and which KPI the measure supports.

Dashboard	Measures	Formula	Reason	Supports
In te kopen	In te kopen (inkoop)	= CALCULATE(COUNT(a_stapmat[prj,ord,stp,rgl]), a_stapmat[mat_pickstat] = 0, io_inkordtekst[iot_pickstat] = BLANK(), a_stapmat[mat_artcode] = "inkoop")	Too show the distribution between the 'inkoop' and 'toelevering'	**KPI:** 'Distribution purchased/supplied'
In te kopen	In te kopen (toelevering)	= CALCULATE(COUNT(a_stapmat[prj,ord,stp,rgl]), a_stapmat[mat_pickstat] = 0, io_inkordtekst[iot_pickstat] = BLANK(), a_stapmat[mat_artcode] = "toelevering")	Too show the distribution between the 'inkoop' and 'toelevering'	**KPI:** 'Distribution purchased/supplied'
Leverancier analyse	Gemiddelde JIT (dagen)	= CALCULATE(AVERAGE(io_inkordtekst[geleverd-leverdatum]),io_inkordtekst[geleverd-leverdatum]>-1000, io_inkordtekst[geleverd-leverdatum]<2000)	Too show the average difference from the scheduled delivery date. If the average is 3, it means that a company delivers the supplies 3 days to early on average.	**KPI:** 'Just in Time'
Leverancier analyse	Count bestellingen	= COUNT(io_inkordtekst[iot_bonnr])	Counts the total orders based on the filters. Shows how reliable a KPI is. With a higher order count the KPI that calculates the JIT is more reliable.	**KPI:** 'Just in Time', **KPI:** 'Delivery reliability'
Leverancier analyse	Count te laat	= SUM(io_inkordtekst[Te laat])	Summates all the ones in the column 'te laat' based on the filters. The column 'te laat' gives a 1 when the column 'geleverd-leverdatum' is positive, meaning that the order is delivered to late.	**KPI:** 'Delivery reliability'
Leverancier analyse	Percentage te laat	= DIVIDE([Count te laat],[Count bestellingen],0)	Divides the measures 'Count te laat' over 'count bestellingen' to give a percentage of how many orders are delivered to late.	**KPI:** 'Delivery reliability'

Table 14 – An overview of the added measures to the database. For each measure it shows to on which dashboards it is used, the formula for the measure, the reason for adding the measure and what the measure supports.

As well as adding the measures new columns are added. New columns are added to support visuals, other columns and KPIs. The added columns are shown in Table 15. It shows which table this column is added to, the reason why this column is added and what the new column supports.

Table	Columns	Reason	Supports
Stapmat	prj, ord, stp, rgl	This column is created to give each row in the table a unique code to refer to. This enables some more features to create graphs.	**Visual:** Matrix table in 'Overzicht acutele orders', **Visual:** Matrix table in 'in te kopen/ in te voeren'
io_inkordtekst	Dagen tot levering	Calculates the difference in days from today to the scheduled deliverydate.	**KPI:** 'days until delivery'
io_inkordtekst	Geleverd - leverdatum	Calculates the difference in days the scheduled delivery date and the actual delivery.	**Column:** 'te laat', **KPI:** 'Just in time'
io_inkordtekst	Te laat	Checks if the column 'geleverd - leverdatum'is positive or negative. When it is positive it means that the order is delivered after the scheduled date, meaning that it is to late and returns a '1' otherwise it returns a '0' meaning it was on time.	**KPI:** ' delivery reliability

Table 15 - An overview of the added columns to the database. It shows on which table each column is added, the reason for adding the column and what the column supports.

Lastly a hierarchy is added to support two visuals in two dashboards. A hierarchy gives Power BI information about how certain columns are related to each other. In this case you have a Project which contains multiple Orders which in turn contain multiple Lines. This hierarchy is added in the a_stapmat table.

4.3 Data visualization

After the KPIs are selected, the data is connected, cleaned and transformed. The data is now ready to be visualized. In Chapter 4.1 I stated that I would create three tabs which have their own objective, two for the monitoring of the incoming goods and one for the analysis of the suppliers. In this chapter the dashboards are designed. In Chapter 4.3.1 the general layout of the tabs is discussed. After explaining the general layout each tab is described and discussed.

4.3.1 Layout

In Chapter 2.3 I researched what the best way is to layout a dashboard. I found that the best way to design a layout is to interview the users and visualize their preferences. Furthermore, I discovered 13 guidelines for designing the layout. When the dashboards were designed these guidelines were kept in mind. When the layout was finished the guidelines were used as a checklist and each dashboard design follows the 13 guidelines. I came to the conclusion that two guidelines are more important than others and I elaborate on these in the subsequent paragraphs

Firstly, and what I realized was very important was the way the viewer sees the dashboard. In so far as people read from left to right and top to bottom, the dashboards are designed in such a way that the general information is in the top-left and the more detailed information in the bottom-right. This way the viewer gets a more detailed idea about time when 'reading' the dashboard.

Secondly, I realized that it is also very important to have an easily readable dashboard. This was done by showing as few key-values as possible on the dashboard while still meeting the objective of the dashboard and by using the same colours over all the dashboards. By only showing the KPIs selected in Chapter 4.1 the reader only had the information he needed. Additional information that could have been added was not included and this resulted in a clean look for the dashboard. Next to that, for all the dashboards the colours black and yellow are used as AFMI uses these colours throughout the whole company. This resulted in a clear dashboard with a look that resembles AFMI.

4.3.2 Materials to order (in te kopen/ in te voeren)

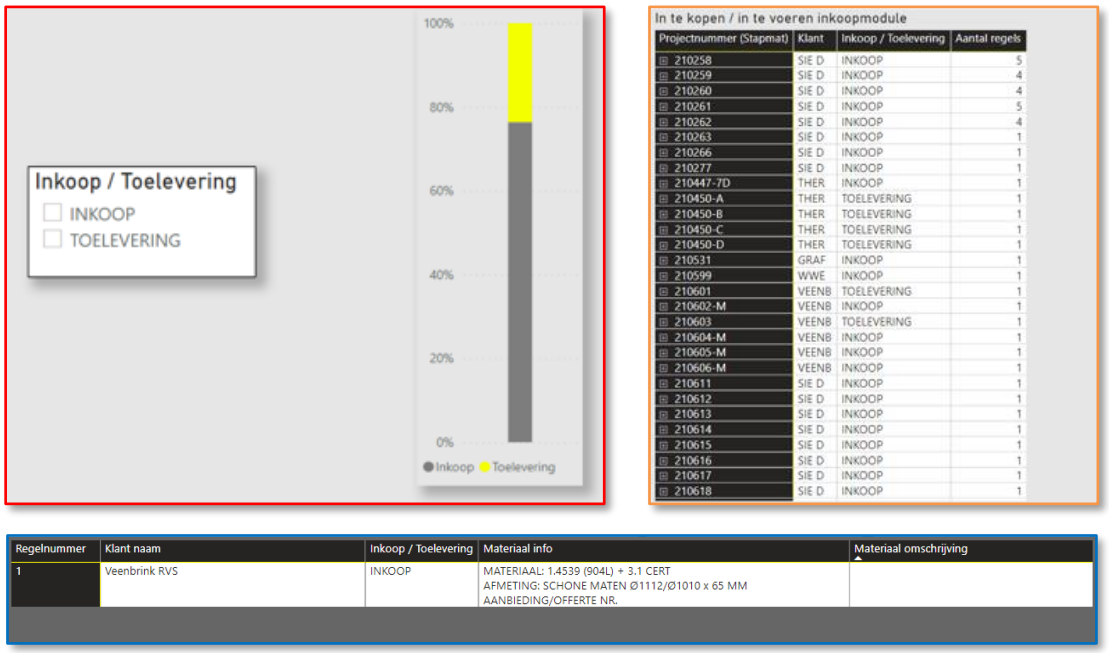


Figure 10 – The dashboard showing the materials that still need to be ordered divided into three sections.

The objective of this dashboard is to monitor the materials that need to be ordered. The info needed for this objective is shown in Table 16 and this is the only information added to the dashboard. The dashboard is divided into three sections and shown in Figure 10. The red section is the first thing you see. In this section you can select if you want to filter out 'inkoop' or 'toelevering'. Furthermore the division between 'inkoop' and 'toelevering 'can be seen. The second section the reader sees is the orange section. In this section an overview is given of all the materials that still need to be ordered, together with the name of the client, and the quantity of the materials which need to be ordered. The last section is the blue section, in which section the details of the materials that need to be ordered are shown.

Dutch	**English**
Klant naam	Client name
Inkoop/toelevering	Purchase / supplied
Materiaal info	Material info
Materiaal omschrijving	Material description
Verdeling inkoop/toelevering	Distribution purchased/supplied

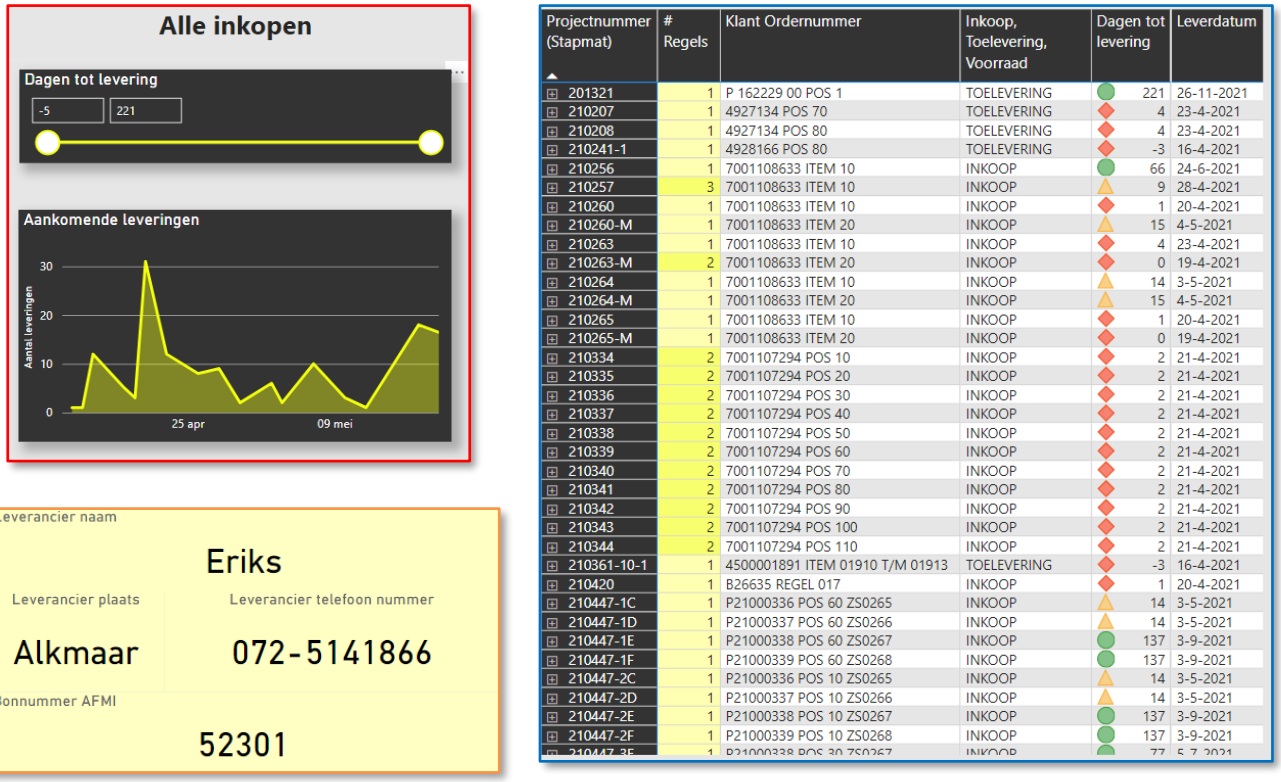
Table 16: Selected KPIs materials to order in Dutch and English

4.3.4 Upcoming deliveries

The objective of this dashboard is to monitor all the materials that are needed in the upcoming period. For the layout of this dashboard, it was decided to have three sections. One section with a big list that contains all the upcoming deliveries, a section with a slicer with an area chart to specify what you want to see and a section with the contact details of the supplier. The dashboard is shown in Figure 11.

The red section contains a slicer and an area chart, this is the first section the reader sees. The slicer lets the user filter the info that is shown. This slicer is connected to 'Dagen tot levering'. For example, it can be set from 0 to 7. The red table adapts to this and only shows the lines with 'Dagen tot levering' with a value between 0 and 7. The area chart gives information on

how many deliveries can be expected in the upcoming period. The second section the viewer sees is the blue section. This section contains the list of all the materials that need to be delivered. If the materials are already purchased the rows 'Dagen tot levering' and 'Leverdatum' are filled in. It shows AFMIs project number, the project number of the client, if it is purchased, from supplier by client or from stock, the days until delivery and the delivery date. The last section seen is the orange section. If a project needs to be delivered and AFMI wants to call them, you can select a line in the blue section. The info in the orange box adapts to this and shows the supplier's name, place and phone number, as well as the order number



Projectnummer (Stapmat)	# Regels	Klant Ordernummer	Inkoop, Toelevering, Voorraad	Dagen tot levering	Leverdatum
201321	1	P 162229 00 POS 1	TOELEVERING	221	26-11-2021
210207	1	4927134 POS 70	TOELEVERING	4	23-4-2021
210208	1	4927134 POS 80	TOELEVERING	4	23-4-2021
210241-1	1	4928166 POS 80	TOELEVERING	-3	16-4-2021
210256	1	7001108633 ITEM 10	INKOOP	66	24-6-2021
210257	3	7001108633 ITEM 10	INKOOP	9	28-4-2021
210260	1	7001108633 ITEM 10	INKOOP	1	20-4-2021
210260-M	1	7001108633 ITEM 20	INKOOP	15	4-5-2021
210263	1	7001108633 ITEM 10	INKOOP	4	23-4-2021
210263-M	2	7001108633 ITEM 20	INKOOP	0	19-4-2021
210264	1	7001108633 ITEM 10	INKOOP	14	3-5-2021
210264-M	1	7001108633 ITEM 20	INKOOP	15	4-5-2021
210265	1	7001108633 ITEM 10	INKOOP	1	20-4-2021
210265-M	1	7001108633 ITEM 20	INKOOP	0	19-4-2021
210334	2	7001107294 POS 10	INKOOP	2	21-4-2021
210335	2	7001107294 POS 20	INKOOP	2	21-4-2021
210336	2	7001107294 POS 30	INKOOP	2	21-4-2021
210337	2	7001107294 POS 40	INKOOP	2	21-4-2021
210338	2	7001107294 POS 50	INKOOP	2	21-4-2021
210339	2	7001107294 POS 60	INKOOP	2	21-4-2021
210340	2	7001107294 POS 70	INKOOP	2	21-4-2021
210341	2	7001107294 POS 80	INKOOP	2	21-4-2021
210342	2	7001107294 POS 90	INKOOP	2	21-4-2021
210343	2	7001107294 POS 100	INKOOP	2	21-4-2021
210344	2	7001107294 POS 110	INKOOP	2	21-4-2021
210361-10-1	1	4500001891 ITEM 01910 T/M 01913	TOELEVERING	-3	16-4-2021
210420	1	B26635 REGEL 017	INKOOP	1	20-4-2021
210447-1C	1	P21000336 POS 60 ZS0265	INKOOP	14	3-5-2021
210447-1D	1	P21000337 POS 60 ZS0266	INKOOP	14	3-5-2021
210447-1E	1	P21000338 POS 60 ZS0267	INKOOP	137	3-9-2021
210447-1F	1	P21000339 POS 60 ZS0268	INKOOP	137	3-9-2021
210447-2C	1	P21000336 POS 10 ZS0265	INKOOP	14	3-5-2021
210447-2D	1	P21000337 POS 10 ZS0266	INKOOP	14	3-5-2021
210447-2E	1	P21000338 POS 10 ZS0267	INKOOP	137	3-9-2021
210447-2F	1	P21000339 POS 10 ZS0268	INKOOP	137	3-9-2021

Figure 11 - The dashboard that shows the materials that will be delivered in the upcoming period divided into three sections.

of AFMI.

4.3.4 Supplier rating

The objective of this dashboard is to analyse a supplier. The layout of this dashboard is divided into three sections. The red section is for selecting the kind of supplier and one or more companies. The other two sections are for evaluating the selected companies with the specified supply. If one company is selected, the info is shown in the 'individueel' (individual) area (blue). If more companies are selected and you want to compare them, they are shown in the 'vergelijken' (comparison) area (orange). The dashboard is shown in Figure 12.

The first section seen by the reader is the red section. The red section contains two slicers that can filter the information that is shown on the other parts of the dashboard. The slicers filter out the companies that are shown and whether the products are purchased or supplied.

The second section seen is the blue section. It shows the delivery reliability and JIT relating to one specific company with a gauge and a number. That gauge is chosen because it needs to be as low as possible this is a useful chart for those purposes. The number is chosen because it can vary considerably and a graph would make it less readable. If two or more companies are selected it will show the average of all the companies.

Figure 12 - The dashboard that shows the analysis of the suppliers divided into three sections.

Lastly the orange section is seen. It shows the delivery reliability and JIT on two or more companies. Bar charts are chosen because we want to compare companies. On the 'percentage te laat' chart the bar needs to be as low as possible. On the 'JIT' chart the bar needs to be as small as possible, but not negative.

4.4 Summary

The artifact is designed and developed in this section. This has been done following three major steps, (1) selecting the KPIs, (2) preparing the data and (3) visualizing the data. These steps eventually result in one Microsoft Power BI file with three dashboards that conform to the objectives we set in Chapter 1.

In the first step, selecting the KPIs, as detailed in Chapter 4.1, I discovered that for the two objectives we had, we needed three different dashboards. Two for the monitoring of incoming goods and one for the analyses of the suppliers. The information that was needed for monitoring was selected via interviews and for analysing suppliers via an SLR. In the second step the data was prepared for use in Microsoft Power BI. A data architecture was designed, and data connection, cleaning and transforming was executed. This led to the last step, the visualization of the data to show the information needed to meet the objectives. A general layout was chosen for this and graphs and charts were selected via the list made in Chapter 2.

Selecting the KPIs for the monitoring of the incoming goods was very interesting as it is a subject which there is little to no literature on. Because of that reason, a lot of meetings

 and interviews were held with the end-users. As a result of these I concluded that every department has very different needs relating to the same topic: instead of creating one dashboard for the incoming goods I ended up with designing two for monitoring with both mostly containing some information but visualized in different ways. This is because the monitoring is a process which can be looked at from very different perspectives, each generating the need for another dashboard.

Applying this in other cases, the first step would be to analyse the subject of interest, for example outsourcing. Via interviews with the employees who deal with the relevant subject the information that is needed can be gathered in addition to gaining insight into the different perspectives relating to the subject of interest.. This data can be imported and prepared in Power BI before taking the next step. With the data ready and the perspectives in mind, the visualization of the information can begin giving each perspective a different dashboard.

5 – Validation

The 4th step of the DSRM is the demonstration of the artifact to the user and the 5th step stipulates that the dashboard is evaluated. The artifact is demonstrated by letting the end-users use the dashboard in their day-to-day work. After this demonstration the artifact is validated in the first instance via a survey and a then a focus group which is described in this chapter as part of the evaluation.

5.1 Survey

As explained in Chapter 3.2 the way of surveying as proposed by Venkatesh (2003) is used for validating. The survey follows the Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT uses five key constructs for validation. These key constructs, the questions and the answers are shown in Table 17. For the answers the 5-point Likert scale is used with 1 = "totally disagree" to 5 = "totally agree". Because the main language at AFMI is Dutch it is more efficient and more effective if the questions are in Dutch. Therefore the questions stated in Chapter 3.2 are translated from English to Dutch.

The survey was sent to the three people involved in using the dashboard. This was done because they are the only ones that know enough about the process that the artifact was supposed to improve. It can be argued that more people have the knowledge of the overall process and can validate the solution. However, these people will not use the dashboard themselves and do not therefore know enough about the details making their evaluation worthless..

	Questions	Answers		
	Performance Expectancy	1	2	3
1	Met dit dashboard zal ik mijn taken sneller uitvoeren	3	4	5
2	Met dit dashboard zal ik mijn productiviteit verhogen	3	5	4
3	Met dit dashboard zal ik mijn taken effectiever uitvoeren	5	5	4
4	Ik vind dit dashboard handig om te hebben	5	5	4
	Effort expectancy			
5	Leren om het dashboard te gebruiken is makkelijk voor mij	3	4	5
6	Ik vind het makkelijk om het dashboard te laten doen wat ik wil	3	4	4
7	Ik vind het dashboard flexibel om mee te werken	3	4	3
8	Het is makkelijk om dit dashboard te leren gebruiken	3	4	4
9	Het is makkelijk om dit dashboard te gebruiken	3	4	4
	Social influence			
10	Ik gebruik het dashboard omdat heel veel collega's het gebruiken	2	2	2
11	Het management is behulpzaam bij het gebruik	2	3	4
12	Het management is ondersteunend bij het gebruik van het dashboard	2	4	4
13	In het algemeen wordt het dashboard ondersteund binnen het bedrijf	2	4	4
	Facilitating conditions			
14	Het dashboard ondersteund mij in al mijn taken	2	2	2
15	Het dashboard werkt goed met mijn manier van werken	4	4	4

16	Het dashboard past bij mijn werkstijl	4	4	4
	Attitude towards using the technology			
17	Het gebruik van het dashboard is een goed idee	4	5	5
18	Het gebruik van het dashboard een wijs besluit	2	4	4
19	Ik zou het dashboard graag willen gebruiken	4	4	4
20	Het gebruik van het dashboard is fijn	3	4	3

Table 17 – The results of the validation survey send to three participants. Numbers represent a five-point Likert-scale with 1 = "totally disagree" to 5 = "totally agree".

Discussion

The survey is sent and the answers are gathered. This gives us the possibility to reflect on the answers. The answers are discussed per key construct and the survey has three respondents, of which 2 are in management

Performance expectancy: Overall the answers are positive. It is expected that the tasks will be executed more effectively. However, it is arguable whether the tasks will be executed more efficiently and more quickly.

Effort expectancy: Respondent 1 is very neutral on this subject, respondents 2 and 3 are more positive. It is possible that the dashboard hasn't been used enough to get a good view on whether it is easy to use or not. Furthermore, respondent 2 could be more positive on the ease of use because she has been more involved with the dashboards therefore having more knowledge on the subject. Overall the effort expectancy looks good.

Social influence: This is a subject by enlarge negatively reflected on by respondent 1 and rather positively by respondents 2 and 3. This discrepancy probably has to do with the positions the respondents are in: respondent 1 is an employee whereas respondents 2 and 3 are from management. From these contrasting reactions we can conclude that the perceptions of employees and management are different. From a management perspective they see that they are supportive on using the dashboard, whereas, from the employees perspective they see that management is not supportive.

The number of respondents is low and does not therefore give a true reflection of the whole company. However, I would recommend that the company takes up the subject of support in the use of a dashboard with management and employees. This way both employees and management should have the same goals in mind, which could result in more compliance from both sides.

Facilitating conditions: Overall the facilitating conditions are good. The dashboard as it is does not support all the tasks the employees have. However, dashboards can be modified, improved and even perfected in time to support more tasks.

Attitude towards using the technology: The attitude towards using the technology is good overall. There is nonetheless some discussion between the respondents whether the dashboard is a wise idea or not. Just as in the case of social influence, I think it is a good idea to discuss these answers to get everyone on board.

5.2 Focus group

In addition to the survey an independent evaluation-meeting (focus group) was held with the three end-users, the same three people as the three respondents from the survey. From this meeting it was concluded that the dashboard was very useful and definitely would be used. It was concluded that it did create a better overview of the products that needed to be purchased and in the products that will be delivered in the near future. Also, the fact that suppliers are analysed helps them in selecting better suppliers and creates proof for their ISO quality certificate.

In addition, minor l feedback was given on the dashboard: (1) It was not clear how to use some parts of the dashboard. This was primarily caused by a lack of knowledge of the part of the user. More instructions on use could be provided. Furthermore, (2) a column with the name of the client should be added on the 'actuele orders' matrix. In addition, (3) the name of the client should also be visible on the 'leveranciers analyse'. Lastly, (4) a slicer needs to be added to the 'leveranciers analyse' to change the filter on the time.

5.3 Concluding validation

Looking at the survey and the focus group it can be validated that the dashboard will have a positive influence on the purchasing process and therefore making a huge practical contribution to the company. Mainly positive results are evident in the validation: the dashboards will increase performance and make work easier to do, the expected effort is neutral as it is not yet known how it works precisely, the facilitating conditions look good and the attitude towards using the dashboard is also positive. Furthermore, the dashboard will be beneficial for more than it was intended by providing proof for the ISO quality certificate.

In validating the artifact, this research will also have contributed to theory on business intelligence. The theory on using business intelligence for the application of analysing sales or suppliers, for example, for medium to long term planning is easy to find and widely written about. However, finding literature for using business intelligence for operational planning is much more difficult as not much research has been done on this topic. The research shows that monitoring operational planning is perfectly possible by using business intelligence but takes a lot of time. Monitoring an operational task, such as incoming goods, can be looked at from different perspectives each with their own dashboard. Creating one dashboard alone for all the perspectives is possible but this would have to include a lot of adjustable filters making it thereby really user-unfriendly.

6 – Conclusion & Recommendation

In Chapter 5 I started on step 5 of the DSRM, the evaluation. In this Chapter the rest of the evaluation will be discussed. The research is at an end and recommendations need to be given to the company. This will be done by evaluating the overall research, the individual research questions and the norm and reality. After the evaluation, the recommendations for the company can be made.

6.1 Conclusion

In short, the research was started because problems in the purchasing process were signalized. From there the situation was analysed and a problem cluster was made. With the analysis of the purchasing process and the problem cluster, the core problem was created: "The information necessary to analyse the incoming goods and their suppliers quickly and accurately is hard to find or cannot be found."

With the core problem formulated, the work on the solution could be started by formulating the main research question and by using the Design Science Research Methodology (DSRM). The main research question - "How to create a real-time dashboard such that AMFI can quickly and correctly monitor the incoming goods and analyse their suppliers quickly and accurately thus preventing delays in incoming goods?" - on its own is hard to answer simply, therefore six smaller research questions were created. Both the DSRM and the research questions give guidance for the research. In addition to the smaller research questions and the research methodology, a solution together with the corresponding goals were chosen. These goals are stated in the section on 'norm and reality' in Chapter 1.7. In this section I will give a conclusion on each research question and on each goal after the limitations have been discussed.

6.1.1 Research limitations

As in every research, limitations are encountered. Some are more significant than others and some only apply to specific parts of the research. First I will discuss the more significant limitations which had an influence on the whole research. The smaller, more specific, limitations are mentioned in Chapter 6.1.2 or Chapter 6.1.3 if they had influence on the outcome.

Unfortunately the cause of most of the limitations encountered was Covid-19. Starting a research project at a company as yet unknown to the researcher means that a lot of information needs to be gathered from the company. This information can be found in part on the internet, but most of the information needs to be gathered from the employers and employees. Covid-19 put a constraint on the contact that could be made. Interviews and conversations needed to be done via video conferencing and calling. Although we are lucky enough to be living in the current time and being able to videocall, this technology will not give all the information. For example, even though it is possible to ask what an employee does during a day, only by observing is it possible to see what he/she actually does. Conversely too I there are similar limitations. As I was not visible as the researcher and was working from home it was hard to contact me. This caused annoyance and frustration on both sides. In addition to the limited contact, Covid-19 also meant that everyone had to adapt to working from home. Home is generally a place that is not designed for working, and this caused major distractions and required everyone concerned to adapt to a whole new work sphere and lifestyle. The distractions and challenging adjustment to the new style of work takes time, a resource which is already limited.

Most of the Covid-19 related limitations mentioned were encountered at the beginning of the research period. After a few weeks the contact didn't need to be as intensive as before and some of the regulations in The Netherlands were lifted, making it easier to make contact. Moreover, standard meetings could be planned. Furthermore, adapting to the new workstyle became easier by improving the workplace. Reflecting on these limitations, it would have been better to have had more regular meetings with employees, even without having any specific questions and just talking about the work they perform. Additionally the creation of a better workplace really improved the work efficiency.

Another limitation besides Covid-19 was the involvement of two external companies. Throughout the research, commissioned by AFMI, two other companies had influence on the research. These two companies are (1) the administrator of the servers of AFMI called IPlinq and (2) the administrator of the planning software called Limis. The external companies mainly limited the research by causing time delays and by being hard to reach. Reflecting on this limitation perhaps it could have been countered by creating even more thorough planning and more efficient meetings with the external companies.

6.1.1 Research questions

In this section each research question formulated in Chapter 1.6 is evaluated. For each research question the methodology on answering is explained. Furthermore, the results of the answers and the limitations are discussed.

1. **What is current situation at AFMI regarding the incoming goods and their suppliers?** **[C 1]**
    a. *What does the purchasing process look like?* **[C1.2.1]**
    b. *Who are the stakeholders in the purchasing process?* **[C1.2.3]**

First of all, I made a context analysis for the incoming goods process. From the problem statement given by the company, the procurement process and its stakeholders were analysed. These analyses gave a good overview of the causes and effects of the problem and were summarized in a problem cluster. From the problem cluster a core problem was chosen to research and to create a solution for.

Methodology:

Finding answers to the questions was done via an unregistered amount of semi-structured interviews and short conversations with employees of AFMI that were both related and unrelated to the purchasing process. The first interviews and conversations were held with the supervisor from AFMI. Later on, the more detailed information was gathered from other employees who were closer to the specific subjects or associated work processes.

Results:

I found that the purchasing process was not a simple 'build on stock' situation. A high variation of products are purchased of which no stock can be generated. A lack of building supplies on stock makes managing the incoming goods more difficult because everything needs to be bought separately. Furthermore, not all the materials needed for production are bought, some materials are supplied by the client which complicates it even more.

Besides the complicated purchasing process as many as three departments with their own personnel influence the purchasing process. The purchasing process starts with the sales department which creates the need for materials, followed by the planning department who prepares the work in Limis and lastly the actual purchasing department.

We made a problem cluster based on the information gathered and a core problem was selected from this problem cluster. Based on this problem three possible solutions were evaluated and we chose to solve the problem using business intelligence software connected to the operational database.

Limitations:
No new limitations were encountered next to the limitations mentioned in Chapter 6.1.1.

2. **What will be the goal of the dashboard?** **[C 1.3]**
    a. *Who will be the end-user(s)?* **[C 1.2.3]**
    b. *What are the needs of the(se) end-user(s)?* **[C 1.6.1]**

The solution of a dashboard was chosen in RQ1. In this question the goals and the users of the dashboard are researched. This information is necessary to create a base for what the dashboard needed to do.

Methodology:
Based on the information gathered in RQ1, more semi-structured interviews were held with the stakeholders influencing the core problem. After the 2 end-users were found, more interviews and brainstorming sessions were held to discuss the needs and the possibilities.

Results:
Two end-users were found, the Commercial Manager and the employee responsible for the Supply Chain from sales and purchasing respectively. These two people had very different needs. The Commercial Manager was more focussed on what deliveries would arrive in the upcoming weeks. The person responsible for the Supply Chain was more focussed on making sure he purchased the materials he needed to and making sure he put all the information into Limis. The overall goal of both was that the materials needed to be on time with minimal effort.

Because of the different needs to achieve the same ultimate goal: at this stage it was chosen to create several dashboards with their own purposes to realize the common goal. The needs of the end-users were divided into two parts: monitoring incoming materials and analysing suppliers.

To measure the core problem four performance indicators were chosen. The current state of those indicators was measured and the desired measurements were defined together with the end-users. Those defined measurements are the goal of the dashboards combined.

Limitations:
No new limitations were encountered besides the limitations mentioned in Chapter 6.1.1.

3. **What KPI's/info needs to be shown on the dashboard?** **[C 2.2, C 4.1]**

a. *How to monitor all the incoming goods?* **[C 4.1.1]**
b. *How to analyse the suppliers of incoming goods?* **[C 2.2, C4.1.2]**

In RQ2 the goal of the dashboard was researched. In this question I researched what specific information is needed to reach that goal. Because RQ2 gave two sub-goals, these are specifically mentioned in RQ3.a and RQ3.b.

Methodology:
In RQ2 it was decided to divide the needs into two parts: monitoring incoming goods and the analysis of suppliers. Investigative searches were done on the internet to get a broader picture of the subject of monitoring incoming goods and the analysis of suppliers. As the monitoring of incoming goods is so specific little information could be found on it. However, a lot of literature could be found on the analysis of suppliers. Therefore it was decided that the KPIs and information for the monitoring incoming goods had to come from structured interviews and brainstorming with the end-users.

For the KPI's and information on the analysis of the suppliers a systematic literature research was conducted. After the literature review a survey with the KPIs from literature were sent to 4 employees with knowledge about purchasing. In this survey a five-point Likert scale was used to see how important the KPIs were perceived. KPIs that scored a four or higher were selected for the dashboard as they were seen as important for the company.

Results:
For the monitoring of incoming materials it was found that the monitoring could be divided into two types of monitoring. (1) The monitoring of the materials that would be delivered in the upcoming period and (2) the monitoring of all the materials that needed to be purchased.

For the monitoring of the upcoming materials an Excel file was already being used. The KPIs used in this excel were selected for the dashboard. For the monitoring of materials that need to be purchased several screens were used. The essential information was filtered together with the end-user and this information was put onto the dashboard.

From the survey for the KPIs for the analysis of the suppliers, six KPIs were chosen. No data was available on two of those. However for two other KPIs the data was available in Excel files and for the last two KPIs the data was available. Therefore the dashboard currently has two KPIs for the analysis of a supplier.

The KPIs which scored lower than a four were discarded due to the perceived unimportance. However, with the benefit of hindsight, it could be argued that some of the discarded KPIs actually should have been chosen.

Limitations: Besides the limitations mentioned in Chapter 6.1.1, some other limitations were encountered by finding an answer to this research question. First of all, little to no literature could be found on monitoring operational planning (RQ3.a), especially with regard to the purchasing department. This meant I had to start from the beginning and no theory could be applied for answering the question. Reflecting on this, a more systematic approach on finding the answer could have been taken, giving a better chance of finding a good answer.

Furthermore, the data available was limited or not in the right format for implementing some KPIs. Two KPIs could not be implemented because the data simply was not available at that moment. Furthermore two KPIs were not in the right format and as a result could not be implemented. Missing data could be available in the future if required. Putting the other KPIs in another format would also be possible if more time were available.

4. **How to prepare the data for use in the dashboard?** **[C 2.3, C 4.2]**
    a. *What data architecture is best?* **[C 2.3.2, C 4.2.1]**
    b. *How to connect the data?* **[C 2.3.3, C 4.2.2]**
    c. *How to clean the data?* **[C 2.3.4, C 4.2.3]**

In RQ1, the current situation, RQ2, the goal of the dashboard, and RQ3, the information needed, the next step could be taken. This is the creation of the data necessary to show the information in the dashboard. By answering these questions, the information needed can be created and imported into the visualization program.

Methodology:
Systematic literature reviews were conducted on RQ4a,b and c. This provided the basic knowledge on data preparation. Because Microsoft Power BI was chosen as the front-end application an additional course was bought at udemy.com. The general information on data preparation was gathered by literature reviews, the information specific for Microsoft Power BI was gathered via the course.

Results:
AFMI has a rather small database that made it easy for the data architecture and data connection. No additional servers had to be installed to transform data to the front-end application. A simple connection from Microsoft Power BI to the operational database was enough.

With the data architecture and connection in place, the data could be cleaned. This proved to be a very difficult task as the database was not designed for the application of creating dashboards. It had more than 400 tables, mostly without primary keys, and did not have a scheme of the connections between the tables.

Through transformation of the data the connections between tables were made and the necessary information for the KPIs was created.

Limitations:
Several limitations were experienced besides the limitations mentioned in Chapter 6.1.1. The access to the data was not always there because the database refreshed every week, which took a lot of time. Furthermore, a lot of tables and columns had the same information with slight differences, which made finding the right data take a lot of time. Lastly, the owner of the database was hard to contact, which further limited the information on the design of the database and the data it contained.

5. **How to visualize the data to show the information?** **[C 2.4, 4.3]**
    a. *What charts and graphs to use?* **[C 2.4.1, C 4.3.1]**

b. What is a good layout for a dashboard? **[C 2.4.2, C 4.3.2]**

In RQ4 the information was prepared and loaded into the visualization program and this question, researched how this information could be visualized. This was necessary as despite the fact that many charts and graphs were available not all of them were suitable for the purpose we had in mind. Furthermore, it was necessary to create a good layout for these charts and graphs so it could easily be understood what the information meant.

Methodology:
The same methodology as RQ4 was used: General information was gathered via literature and Microsoft Power BI specific information was gathered via the Microsoft Power BI course on udemy.com.

Results:
Data is shown through graphs and charts and these graphs and charts belong to the layout. For the visualization of the KPIs the list of charts and graphs was analysed and the most appropriate was selected based on the experience of the researcher. More than one options were available per KPI. Intuitively the best one was selected

On the layout a checklist with dos and don'ts was applied.

Limitations:
Besides the limitations mentioned in Chapter 6.1.1 some other limitations were encountered. The foremost limitation with respect to the visualization of a dashboard is the researcher as designing something is very subjective. Only some basic rules apply to making a visualization and therefore, the dashboards can be good or bad according to the base rules, but it can never be perfect. To counter this limitation I tried to get as much feedback on the dashboard as possible.

6. How to validate if the implied solution improved the process? [C 3.3, C 5.1]

After all the work is done the solution must be validated. The ways of validating a solution can differ so a research on how to validate this is also needed. The validation shows if the solution has a good impact on the problem. With this question I found out what the best way for validating the dashboard was.

Methodology:
Answering the research question was done by the literature review as explained in Chapter 3.3. The actual validation is done in Chapter 5.1.

Results:
Looking for the best validation methods three commonly used methods were found in literature. The most reliable measures the process before and after the solution. However, time was limited and the actual results of the solution, the dashboard, couldn't be measured. The second method is to validate through a survey. The core benefit is that the dashboard can be validated before it is even used. The downside is that the validation is based on the opinions of people rather than numbers. The last way is validating via a focus group, an interview with

a group. This has the benefit that is can be an in-depth discussion and a lot of information can be gathered. The downside is that it is very time consuming. Validating via surveying and validating via a focus group were chosen.

Among the literature two papers were found on validating artifacts, the dashboard in this case, through surveys: Dyczkowski et. al. (2014) and Venkatesh et. al. (2003). The paper of Dyczkowski et. al. (2014) focussed more on the improvement of artifacts by comparing them to scales. This is very useful if new artifacts are made and the improvements need to be validated. Venkatesh et. al. (2003) focusses more on if an artifact is useful and if it will be used by people. This can be used for validating new artifacts. Because the artifact created did not have something to compare with the method of Venkatesh et. al. (2003) was chosen.

Overall, the actual validation of the dashboard went very well. The surveys were filled in and a focus group was formed. From this validation we can conclude that the dashboard will improve the purchasing process of AFMI. Furthermore, it was concluded that the dashboard could also be used for the ISO quality label by analysing the suppliers.

Limitations:
No new limitations were encountered besides the limitations mentioned in Chapter 6.1.1.

6.1.2 Norm and reality

After the current situation was analysed in research question 1 and a core problem was found the next step was taken to solve this. In research question 2 the goals were investigated and four performance indicators which measured the core problem were chosen. The current situation - reality - was analysed and the goal – norm – was set. In this section the new situation and the reflection on the new situation is elaborated .

1. **Programs used to retrieve and visualize data.**
   Old reality: Several programs are used to retrieve data, these are Limis, Crystal reports and Excel. In addition physical paper is used to check whether products are bought or not.
   Norm: One program that provides everything, Microsoft Power BI.

   New reality: Three programs are used: Microsoft Power BI, Excel and Limis.

   Reflection: The norm was not reached, setting the norm to one program only was somewhat too ambitious in this timeframe. However, Microsoft Power BI has taken over a lot of information providing tasks from Limis and excel which are still used to retrieve some data. This could be eliminated in the future by implementing more dashboards in Microsoft Power BI

2. **Info available**
   Old reality: There is too much info retrieved via all the different programs to cover. The info ranges from production steps to the drawing to the client's name. Still not everything shown is used.
   Norm:
   The info shown to the user will be the info which is actually needed. This needs to be precisely what will benefit the end user.
   Generally the following is necessary:

- Checklist if appropriate of steps to be performed
- Overview of upcoming deliveries
- Deliver reliability of clients
- Deliver reliability of suppliers

New reality: The info that is used is stated in C4.1 – KPI selection.

Reflection: This norm 'The info that is shown to the user will be the info that is actually needed' is reached. The norm is not easily measurable because of the 'generally necessary goals' but in Chapter 4.1 – KPI selection can be seen how the KPIs are selected and why this is the only information that is necessary.

3. **Time needed to retrieve data**

   Old reality: Info is retrieved through the several programs and papers. This currently takes up to around an hour a day.
   Norm: Time needed should not take more than a few minutes a day.

   New reality: A few minutes per day is needed

   Reflection: The norm has been reached. Almost all information needed can be found on Microsoft Power BI and information required can be interpreted at a glance. Detailed information about an order and some of the supplier analyses KPIs are shown via Limis and Excel respectively. However, they are easily found and therefore no longer takes a lot of time.

4. **Number of times updated**

   Old reality: Data in the Excel sheets and on paper is updated instantly if changed. Data in Limis is updated every hour.
   Norm: Ideally, but not necessarily, all the information is changed every hour, just as in Limis. If this is not possible it is enough to update the information once a day.

   New reality: Data can be refreshed by the click of a button.

   Reflection: The norm has been reached. Data can be refreshed every hour due to the small size of the database.

6.2 Recommendations

The purchasing process has been improved with the three dashboards that have been built for (1) monitoring the incoming goods, (2) monitoring the goods that need to be bought and (3) analysing the suppliers. However, processes, technology and goals change over time. Therefore it is important to maintain the current dashboards and look at further improvements.

Maintaining

Maintaining a dashboard is important. A lot of alterations can occur that will make the visualizations invalid. The database behind the dashboard could change, the data in the database could change and new systems could be adopted which replace data. Therefore it is recommended that someone with knowledge of Microsoft Power BI is hired to maintain the system behind the dashboard.

Improving

A connection between Microsoft Power BI and the database of Limis has been made and a lot of data can be analysed. This data can benefit the company in several ways. Firstly, improvements can be made within the purchasing department which is researched in this paper. Secondly there can be improvements in other departments of the company because more information is readily available.

In this research the data on the incoming goods is analysed for the purchasing department with a focus on the raw materials delivered. Due to lack of time and data some KPIs which were found interesting were not included in the dashboard. It is recommended to have another look at the KPIs: 'supplier defect' and 'contract compliance' because the data is available, but the connection has not yet been made. Furthermore, a fresh look can be given to the KPIs 'supplier availability' and 'emergency purchase ratio' as data was not available for them but could be implemented if deemed necessary.

Lastly, business intelligence can be applicable in a lot of departments at AFMI as there is a lot of data to work with. It is recommended to look into other departments to check if visualizations could have a positive influence on the processes. This can be done by showing the current dashboard to employees in other departments to show the possibilities a dashboard can create. Fundamentally I think that creating an overview for the projects that are being outsourced as well as doing an analysis of the companies which do the outsourcing can have a positive influence on the production process too.

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Appendix A – Systematic literature review

Conducting a systematic literature review

The Systematic Literature Review was conducted following the steps given in the lecture by P.D. Noort at the University of Twente on 23-10-2020. Before following the steps, a little research was done by searching the internet for related issues. Gaining basic knowledge of the issues leads to a better understanding and results in being able to formulate better search strategies.

1. **Define: knowledge problem and research question**

Many key performance indicators are available to monitor processes. It was not known if there were optimal KPI's to monitor the incoming goods. Therefore the following research question was composed: 'Which KPIs could be used to analyse the suppliers of incoming goods?'

2. **Scope: requirements and plan**

When searching for the answer I include and exclude the following.

Included	**Reason**
Keywords: Analyze, KPI, Key performance indicator, performance measurement, purchasing, incoming, raw materials, import	These are words related to the research question.
Subjects: 'business, management and accounting' AND 'Economics, econometrics and finance'	These are the areas that are relevant to writing the research.

Excluded	**Reason**
Non-Dutch or non-English literature	Difficult/impossible to read
Keywords: Trade, sustainability, biology	Has nothing to do with the research

The following databases will be used to search.

Database	**Reason**
Scopus	Multidisciplinary, peer-reviewed
Web of Science	Multidisciplinary, peer-reviewed
Business Source Elite	Multidisciplinary, peer-reviewed, focused on business related articles

3. **Conduct the search**

Search string	**Scope**	**Database**	**Entries**
"KPI" AND ("incoming" OR "import")	Title, abstract, keywords	Scopus	13
'KPI' AND ('raw' AND 'materials' OR 'import')	Title, abstract, keywords	Scopus	27
'KPI'AND 'Purchasing'	Title, abstract, keywords	Scopus	29

“KPI” AND (“incoming” OR “import”)	Topic	Web of Science	6
'KPI' AND (‘raw AND ‘materials’ OR ‘import’)	Topic	Web of Science	15
‘KPI’AND ‘Purchasing’	Topic	Web of Science	15
“KPI” AND (“incoming” OR “import”)	Topic	Business Source Elite	12
'KPI' AND (‘raw AND materials’ OR ‘import’)	Topic	BSE	22
‘KPI’AND ‘Purchasing’	Topic	BSE	104

4. Review the literature

In total 243 articles were found. After applying the inclusion and exclusion criteria and removing the duplicates I selected and used a total is 9 which are listed below.

1) D. Parmenter, Key performance indicators: developing, implementing, and using winning KPIs, John Wiley & Sons, Inc., New York, NY, USA, 2007.
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4) Parmenter, D. (2010). Key Performance Indicators (KPI): Developing, Implementing, and Using Winning KPIs (2nd ed.). Wiley.
5) “Key Performance Indicators Manual: A Practical Guide for the Best Practice Development, Implementation and Use of KPIs” (Baker & AusIndustry, 2002)
6) R.S. Kaplan, D.P. Norton, the balanced scorecard: measures that drive performance, Harvard Business School Publishing, 2005
7) Caniato, F., Luzzini, D., & Ronchi, S. (2012). Purchasing performance management systems: an empirical investigation. *Production Planning & Control*, *25*(7), 616–635. https://doi.org/10.1080/09537287.2012.743686
8) Rehman Khan, S. A., & Yu, Z. (2019). Performance Measurement and Evaluation. *Strategic Supply Chain Management*, 207–232. https://doi.org/10.1007/978-3-030-15058-7_9
9) Krause, D. R., Pagell, M., & Curkovic, S. (2001). Toward a measure of competitive priorities for purchasing. *Journal of Operations Management*, *19*(4), 497–512. https://doi.org/10.1016/s0272-6963(01)00047-x

5. Compose the review

As described in Chapter 2.2.

Appendix B – KPI list

Daniel R Kraus	DataPine	Rehman Khan	Federico Caniato	Oxford
QUALITY	Compliance rate	Price effectiveness	*INTERNAL*	Defect Rate
product reliability	Number of suppliers	Cost effctiveness	Cost	Procurement Cycle Time
Product durability	Purchase order cycle time	Quality	Quality	Delivery Schedule
Conformance to specifications	Supplier Quality Rating	Time	Innovation	Compliance with original contract
DEVILVERY	Supplier Availability	Technology	Time	Cost savings
Expediting	Supplier Defect Rate	Assets	Flecibility	Cost Avoidance
New product development	Vendor Rejection Rate & Costs	Efficiency	Sustainability	Managed vs total spend
JIT	Lead Time			Procurement ROI
Delivery Speed	Emergency Purchase Ratio		*SUPPLIERS*	
Delivery reliability	Purchases in Time and Budget		Cost	
Distance	Cost of purchase order		Quality	
FLEXIBILITY	procurement Cost Reduction		Innovation	
Volume Flexibility	Procuement Cost Aviodance		Time	
Mix Flexibility	Spend Under Managhement		Flecibility	
Modification Flexibility	Procurement ROI		Sustainability	
COST				
Total cost				
cost information				
competitive pricing				
INNOVATION				
Product onnivation				
Technological capabilities				
Technology sharing				

Appendix C – Whole database

- spar.a_aantmut
- spar.a_afdeling
- spar.a_artgroep
- spar.a_bulletin
- spar.a_bulletin_ontv
- spar.a_cal_slots
- spar.a_cap_correctie
- spar.a_cap_flexcapadmin
- spar.a_capgroep
- spar.a_capgroep_ext
- spar.a_cluster
- spar.a_crprinter
- spar.a_db
- spar.a_deellever
- spar.a_dfl_slots
- spar.a_dlvmut
- spar.a_exceptie
- spar.a_ext_planmut
- spar.a_feestdagen
- spar.a_iface_cap_uitsl
- spar.a_instellingen
- spar.a_kalender
- spar.a_kenmerk
- spar.a_kleuren
- spar.a_labels
- spar.a_labels_vt
- spar.a_lisa_log
- spar.a_lpi_class
- spar.a_lpi_groups
- spar.a_lpi_range
- spar.a_mach_av
- spar.a_machgrp
- spar.a_man_av
- spar.a_mansoort
- spar.a_materiaal
- spar.a_materiaaltype
- spar.a_medew
- spar.a_medew_av
- spar.a_medew_klt
- spar.a_milestone
- spar.a_milestonesymbool
- spar.a_multiplant
- spar.a_mw_inzetmatrix
- spar.a_mwgroep
- spar.a_nieuws
- spar.a_offerte
- spar.a_offkosten
- spar.a_offorders
- spar.a_offstap
- spar.a_oldkalender
- spar.a_omstellen
- spar.a_opdrbev
- spar.a_opdrbevtekst
- spar.a_options
- spar.a_ord_bezetting
- spar.a_ord_link
- spar.a_ord_mutatie
- spar.a_ord_verwijderd
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- spar.a_order_clsrel
- spar.a_orderentry
- spar.a_orderentryrecept
- spar.a_orderentryregels
- spar.a_orders
- spar.a_orders_mut
- spar.a_orders_opv
- spar.a_orders_vt
- spar.a_ordervarianten
- spar.a_ordetik
- spar.a_pauzes
- spar.a_percentages
- spar.a_prjdata
- spar.a_prodstap
- spar.a_prodstap_mut
- spar.a_prodstap_opv
- spar.a_produktgroep
- spar.a_projecteninfo
- spar.a_projects
- spar.a_projects_vt
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- spar.a_sch_cluster
- spar.a_sch_mach
- spar.a_sch_measurements
- spar.a_sch_mngmt_mach
- spar.a_sch_mngmt_man
- spar.a_sch_opt
- spar.a_sch_rules
- spar.a_sch_settings
- spar.a_sch_setup_condition
- spar.a_sch_setup_config
- spar.a_sch_setup_rules
- spar.a_sch_statistics
- spar.a_sch_tankcfg
- spar.a_sch_tankcfgregel
- spar.a_sch_tanks
- spar.a_sch_tankvulling
- spar.a_sch_unplanned
- spar.a_sch_vt
- spar.a_sch_wicam
- spar.a_sch_xvt
- spar.a_schedule
- spar.a_schedule_sim
- spar.a_servicerap
- spar.a_servicerapact
- spar.a_servicerappnt
- spar.a_serviceraptype
- spar.a_settings
- spar.a_settings_lpr
- spar.a_slotblocks
- spar.a_sortcodes
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- spar.a_specificatienrs
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- spar.a_stapmat
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- spar.a_stapmat_uitsl
- spar.a_stapmedew
- spar.a_staptool
- spar.a_stapwerkplek
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- spar.a_stdtekst_vt
- spar.a_stelmatrix
- spar.a_stortparams
- spar.a_stortschema
- spar.a_stortschema_per
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- spar.a_tariefcodegrprel
- spar.a_tariefcodekltgrp
- spar.a_tekorten
- spar.a_toeslag
- spar.a_tool
- spar.a_tool_av
- spar.a_tool_inzetmatrix
- spar.a_toolgrp
- spar.a_tools
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- spar.a_transportplanning
- spar.a_transportschema
- spar.a_uitbest
- spar.a_uursoort
- spar.a_uursoort_regels
- spar.a_vakantie
- spar.a_valuta
- spar.a_verplichtevelden
- spar.a_volgstaat
- spar.a_volgstaatinfo
- spar.a_volgstaatregel
- spar.a_vrijgave
- spar.a_wbso
- spar.a_werkplek
- spar.a_werkplek_alt
- spar.a_werkplek_alt_rules
- spar.a_werkplek_lijn
- spar.a_werkplek_stations
- spar.a_werkplek_tarief
- spar.a_werkplektype
- spar.a_werkzaamheid
- spar.adm_logboek
- spar.api_log
- spar.api_RestConfig
- spar.dp_db
- spar.e_jonkeriface
- spar.ex_debiteur
- spar.ex_project
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- spar.f_fakaanm
- spar.f_fakgroep
- spar.f_fakkop
- spar.f_fakoptions
- spar.f_fakregels
- spar.f_finovz_ohw
- spar.g_orders
- spar.g_prodstap
- spar.g_stapinfo
- spar.g_stapmat
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- spar.h_logboek
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- spar.h_mach_thisyear
- spar.h_man_prevyear
- spar.h_man_thisyear
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- spar.h_prodstap_opv
- spar.h_prodstap_tijd

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- spar.h_tijdvw_eb
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- spar.h_wknfo_wlwp
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- spar.ha_inst
- spar.ha_medew
- spar.ha_overuren
- spar.ha_pauzeschema
- spar.ha_ploeg
- spar.ha_ploegschema
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- spar.ha_schema
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- spar.hd_helpdesk
- spar.hd_modules
- spar.hd_prioriteit
- spar.hd_prjrelease
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- spar.hd_status
- spar.hd_verstuurd
- spar.i_capgroep
- spar.i_db
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- spar.i_erp2lms
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- spar.io_inkordtekst
- spar.io_ontvangst
- spar.io_ontvangstregi
- spar.io_rubriek
- spar.io_sjabloon
- spar.io_stdtekst
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- spar.k_inkfactuur
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- spar.k_kostsoort
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- spar.lp_mrp_lvd_analyse
- spar.lp_mrp_scenario
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- spar.lw_menuitems
- spar.lw_prodstap
- spar.lw_user
- spar.lw_user_mgwp
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- spar.m_lpi
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- spar.m_portefeuille
- spar.m_prjdetail
- spar.m_saldo
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- spar.mo_orddata
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- spar.mo_refanswer
- spar.mo_refconc
- spar.mo_vormplaat
- spar.old_k_materiaal
- spar.old_ks_materiaal
- spar.p_categorie
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- spar.pb_wpman
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- spar.q_foutregi
- spar.q_foutsoort
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- spar.q_pbsjabloon
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- spar.q_verzadvtekst
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- spar.r_klantgrp
- spar.r_klanttekst
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- spar.r_prognose
- spar.r_relatie
- spar.s_archief
- spar.s_artdata
- spar.s_buildblock
- spar.s_buildblockvrrd
- spar.s_cluster
- spar.s_db
- spar.s_eenheid
- spar.s_materiaal
- spar.s_meth_masker
- spar.s_methode
- spar.s_methode_opv
- spar.s_methrel
- spar.s_omstellen
- spar.s_prodstap
- spar.s_prodstap_opv
- spar.s_produkt
- spar.s_recept
- spar.s_receptbb
- spar.s_receptrel
- spar.s_relatie
- spar.s_stapmat
- spar.s_stapmat_sav
- spar.s_stapwerkplek
- spar.s_tools
- spar.s_verpakking
- spar.s_voorraad
- spar.s_voorraad_hfdloc
- spar.s_voorraad_logboek
- spar.s_voorraad_lokatie
- spar.s_voorraad_picking
- spar.s_voorraad_subloc
- spar.sfc_logboek
- spar.sm_db
- spar.sm_session
- spar.u_extsyst
- spar.vko_db
- spar.vko_econvr
- spar.vko_forecasts
- spar.vko_forecasts_lt
- spar.vko_orders
- spar.vko_projects
- spar.vko_settings
- spar.w_benaming
- spar.w_cl_info
- spar.w_cluster
- spar.w_db
- spar.w_directories
- spar.w_materiaal
- spar.w_off_cap
- spar.w_off_set
- spar.w_serfact
- spar.w_settings
- spar.w_stpdfl
- spar.w_tenlist

Columns of used tables

A_orders

- ord_prj (PK, varchar(20), not null)
- ord_ordnr (PK, smallint, not null)
- ord_artcode (varchar(40), null)
- ord_omschr (text, null)
- ord_status (smallint, not null)
- ord_aant_plan (float, not null)
- ord_aant_real (int, null)
- ord_aant_gereed (float, not null)
- ord_aant_afkeur (int, null)
- ord_plan_start (datetime, null)
- ord_plan_eind (datetime, null)
- ord_release_date (datetime, null)
- ord_real_start (datetime, null)
- ord_real_eind (datetime, null)
- ord_afdnr (int, null)
- ord_opvolger (smallint, null)
- ord_release_yn (smallint, null)
- ord_voorgang_yn (smallint, null)
- ord_material_yn (smallint, null)
- ord_gereed_yn (smallint, null)
- ord_geblokkeerd_yn (smallint, null)
- ord_kenmerknr (int, null)
- ord_kritisch_yn (smallint, null)
- ord_info (text, null)
- ord_compr_factor (float, null)
- ord_wl_per_dag (float, null)
- ord_achterstand (float, null)
- ord_inp_delay (float, null)
- ord_outp_delay (float, null)
- ord_freezed_yn (smallint, null)
- ord_wevo_by (varchar(80), null)
- ord_mulnr (int, null)
- ord_geoptim_yn (smallint, null)
- ord_uit_stamb_yn (smallint, null)
- ord_prio (smallint, null)
- ord_revnr (varchar(10), null)
- ord_spares (int, null)
- ord_dt_geleverd (datetime, null)
- ord_grofcalc_yn (smallint, null)
- ord_wie_begint (smallint, null)
- ord_leverdatum (datetime, null)
- ord_methode (varchar(40), null)
- ord_whatif_yn (smallint, null)
- ord_sch_levdatum (datetime, null)
- ord_aant_deellever (int, null)
- ord_aant_geleverd (int, null)
- ord_vrije_tekst_1 (varchar(80), null)
- ord_vrije_tekst_2 (varchar(80), null)
- ord_vrije_tekst_3 (varchar(80), null)
- ord_vrije_tekst_4 (varchar(80), null)
- ord_vrije_tekst_5 (varchar(80), null)
- ord_planstatus (smallint, null)
- ord_nxt_stapnr (smallint, null)
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- ord_ext_opv_ordnr (varchar(40), null)
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- ord_nieuw_yn (smallint, null)
- ord_niveau (smallint, null)
- ord_mat_avail_yn (smallint, null)
- ord_cluster_yn (smallint, null)
- ord_cluster (smallint, null)
- ord_stort_start (datetime, null)
- ord_stort_eind (datetime, null)
- ord_if_timestamp (datetime, null)
- ord_verkoopgroep (varchar(10), null)
- ord_iface_yn (smallint, null)
- ord_type (smallint, null)
- ord_opbouwen_yn (smallint, null)
- ord_aant_verzonden (int, null)
- ord_uren_fabrikage (float, null)
- ord_uren_bouwen (float, null)
- ord_orig_ext_ordnr (varchar(20), null)
- ord_aant_picked (float, null)
- ord_pickstat (smallint, null)
- ord_slaagperc (float, null)
- ord_afgeleidvan (smallint, null)
- ord_artgrpnr (int, null)
- ord_prodgrpnr (int, null)
- ord_specnr (int, null)
- ord_batchsize (int, null)
- ord_factuurbedrag (float, null)
- ord_factuurksttype (smallint, null)
- ord_volgnr (smallint, null)
- ord_vrije_checkbox_1 (smallint, null)
- ord_vrije_checkbox_2 (smallint, null)
- ord_vrije_checkbox_3 (smallint, null)
- ord_vrije_checkbox_4 (smallint, null)
- ord_vrije_checkbox_5 (smallint, null)
- ord_aant_afdruk (smallint, null)
- ord_planmethode (smallint, null)
- ord_gepland_yn (smallint, null)
- ord_tekening (varchar(40), null)
- ord_referentienr (varchar(40), null)
- ord_houdbaar_days (smallint, null)
- ord_art_batchcontr_yn (smallint, null)
- ord_orig_start_dt (datetime, null)
- ord_orig_eind_dt (datetime, null)
- ord_dt_levertijd (datetime, null)
- ord_dt_bevlevertijd (datetime, null)
- ord_dt_schlevertijd (datetime, null)
- ord_transport_status (smallint, null)
- ord_transport_refnr (int, null)
- ord_meerwerk_yn (smallint, null)
- ord_vervallen_yn (smallint, null)
- ord_halffabr_yn (smallint, null)
- ord_perc_winst (float, null)
- ord_perc_risico_ord (float, null)
- ord_perc_risico_mat (float, null)
- ord_perc_risico_stpi (float, null)
- ord_perc_risico_stpe (float, null)
- ord_aant_plan_orig (int, null)
- ord_opv_gewzgd_yn (smallint, null)
- ord_stock_late_yn (smallint, null)
- ord_probleem_yn (smallint, null)
- ord_manualchange_yn (smallint, null)
- ord_minstartdte (datetime, null)
- ord_bedrag_winst (float, null)
- ord_bedrag_risico_ord (float, null)
- ord_bedrag_risico_mat (float, null)
- ord_bedrag_risico_stpi (float, null)
- ord_bedrag_risico_stpe (float, null)
- ord_type_winst (smallint, null)
- ord_type_risico_ord (smallint, null)
- ord_type_risico_mat (smallint, null)
- ord_type_risico_stpi (smallint, null)
- ord_type_risico_stpe (smallint, null)
- ord_gewicht (float, null)
- ord_afm_hoogte (float, null)
- ord_afm_breedte (float, null)
- ord_afm_lengte (float, null)
- ord_leveringsconditie (smallint, null)
- ord_levcond_tekst (varchar(80), null)
- ord_yield (float, null)
- ord_orig_ordnr (smallint, null)
- ord_transp_dlt (float, null)
- ord_status_if (smallint, null)
- ord_plan_seq_fwd (int, null)
- ord_plan_seq_bwd (int, null)
- ord_has_step_loop (smallint, null)
- ord_loop_info (varchar(255), null)
- ord_sim_levdatum (datetime, null)
- ord_tmp_plantimestamp (datetime, null)
- ord_importcontrole_yn (smallint, null)
- ord_progn_grofpl (datetime, null)
- ord_art_erp_guid (varchar(128), null)
- ord_bedrag_btw (float, null)
- ord_prijs_per_stuk (float, null)
- ord_bedrag_korting (float, null)
- ord_invoerdatum (datetime, null)
- ord_valuta (varchar(3), null)
- ord_shipready_yn (smallint, null)
- ord_status_offerte (smallint, null)
- ord_leverdatum_by_lp (smallint, null)
- ord_ddmrp_leverdatum (date, null)
- ord_block_ddmrp_yn (smallint, null)
- ord_ddmrp_timestamp (datetime, null)
- ord_ddmrp_orig_leverdatum (date, null)
- ord_voorrang_yn (smallint, null)
- ord_leverdatum_krit (datetime, null)
- ord_ddmrp_leverdatum_krit (date, null)
- ord_skip_from_krit_yn (smallint, null)
- ord_erp_guid (varchar(128), null)
- ord_eenheid_txt (varchar(10), null)
- ord_leverdatum_bev_by_lp (smallint, null)
- ord_leverdatum_bev (datetime, null)
- ord_info_erp (varchar(max), null)
- ord_splitted_yn (smallint, null)

A_projects:

- pj_prj (PK, varchar(20), not null)
- pj_gemaskeerd_yn (smallint, null)
- pj_type (smallint, null)
- pj_klantord_yn (smallint, null)
- pj_klantnr (int, null)
- pj_klantnaam (varchar(80), null)
- pj_klantordnr (varchar(40), null)
- pj_klantbestelnr (varchar(40), null)
- pj_besteldatum (datetime, null)
- pj_leverdatum (datetime, null)
- pj_afgegeven_door (smallint, null)
- pj_opm_leverdatum (text, null)
- pj_artcode (varchar(40), null)
- pj_artgrpnr (int, null)
- pj_omschr (text, null)
- pj_aant_totaal (int, null)
- pj_aant_gereed (int, null)
- pj_aant_afkeur (int, null)
- pj_rework_yn (smallint, null)
- pj_invoerdatum (datetime, null)
- pj_plan_startdatum (datetime, null)
- pj_real_startdatum (datetime, null)
- pj_plan_einddatum (datetime, null)
- pj_real_einddatum (datetime, null)
- pj_datum_geleverd (datetime, null)
- pj_geblokkeerd_yn (smallint, null)
- pj_was_blok_yn (smallint, null)
- pj_blok_startdatum (datetime, null)
- pj_blok_einddatum (datetime, null)
- pj_blok_omschr (varchar(80), null)
- pj_type_calculatie (smallint, null)
- pj_info (text, null)
- pj_compr_factor (float, null)
- pj_achterstand (float, null)
- pj_planmethode (smallint, null)
- pj_calc_dlvdate (datetime, null)
- pj_plantimestamp (datetime, null)
- pj_gepland_yn (smallint, null)
- pj_lt (float, null)
- pj_lc (float, null)
- pj_verwerkt_yn (smallint, null)
- pj_vc_totman (float, null)
- pj_vc_totmach (float, null)
- pj_nc_totman (float, null)
- pj_nc_totmach (float, null)
- pj_inp_delay (float, null)
- pj_outp_delay (float, null)
- pj_leverdatum_bev (datetime, null)
- pj_rush_yn (smallint, null)
- pj_lpi (float, null)
- pj_mag_lokatie (varchar(80), null)
- pj_sch_levdatum (datetime, null)
- pj_projectleider (int, null)
- pj_vrije_tekst_1 (varchar(80), null)
- pj_vrije_tekst_2 (varchar(80), null)
- pj_vrije_tekst_3 (varchar(80), null)
- pj_vrije_tekst_4 (varchar(80), null)
- pj_vrije_tekst_5 (varchar(80), null)
- pj_whatif_yn (smallint, null)
- pj_klant_cp (int, null)
- pj_lastmodified (datetime, null)
- pj_webshow_yn (smallint, null)
- pj_tariefcode (varchar(20), null)
- pj_afgeleidvan (varchar(20), null)
- pj_dt_levertijd (datetime, null)
- pj_dt_bevlevertijd (datetime, null)
- pj_dt_schlevertijd (datetime, null)
- pj_ext_prj (varchar(20), null)
- pj_kgnr (int, null)
- pj_calcnr (varchar(20), null)
- pj_aflvr_adres (varchar(80), null)
- pj_aflvr_pc (varchar(7), null)
- pj_aflvr_plaats (varchar(80), null)
- pj_aflvr_land (varchar(80), null)
- pj_if_timestamp (datetime, null)
- pj_ordervariant (int, null)
- pj_infoid (int, null)
- pj_vrije_checkbox_1 (smallint, null)
- pj_vrije_checkbox_2 (smallint, null)
- pj_vrije_checkbox_3 (smallint, null)
- pj_vrije_checkbox_4 (smallint, null)
- pj_vrije_checkbox_5 (smallint, null)
- pj_sch_levdatum_1 (datetime, null)
- pj_sch_levdatum_2 (datetime, null)
- pj_sch_levdatum_3 (datetime, null)
- pj_sch_levdatum_4 (datetime, null)
- pj_sch_levdatum_5 (datetime, null)
- pj_offerte_uitgewerkt_yn (smallint, null)
- pj_bevestigd_yn (smallint, null)
- pj_req_leverdatum (datetime, null)
- pj_aanvraag_type (smallint, null)
- pj_bevestigd_door (smallint, null)
- pj_dt_transport (datetime, null)
- pj_gevraagde_leverdatum (datetime, null)
- pj_plan_volgorde (varchar(20), null)
- pj_aanvraag_tijdstip (datetime, null)
- pj_bevestiging_tijdstip (datetime, null)
- pj_aanvraag_einddatum (datetime, null)
- pj_berekende_leverdatum (datetime, null)
- pj_transporteur (int, null)
- pj_minstartdte (datetime, null)
- pj_gewicht (float, null)
- pj_afm_hoogte (float, null)
- pj_afm_breedte (float, null)
- pj_afm_lengte (float, null)
- pj_leveringsconditie (smallint, null)
- pj_levcond_tekst (varchar(80), null)
- pj_blok_if_yn (smallint, null)
- pj_transp_dlt (float, null)
- pj_start_leverdatum (datetime, null)
- pj_has_ord_loop (smallint, null)
- pj_loop_info (varchar(255), null)
- pj_sim_levdatum (datetime, null)
- pj_lockdlv_yn (smallint, null)
- pj_aflvr_naam (varchar(256), null)
- pj_dosim_yn (smallint, null)
- pj_importcontrole_yn (smallint, null)
- pj_terms_of_delivery (varchar(80), null)
- pj_terms_of_payment1 (varchar(80), null)
- pj_terms_of_payment2 (varchar(80), null)
- pj_btw_code (varchar(10), null)
- pj_btw_perc (float, null)
- pj_fakt_adres (varchar(80), null)
- pj_fakt_pc (varchar(7), null)
- pj_fakt_plaats (varchar(80), null)
- pj_fakt_land (varchar(80), null)
- pj_factuurkorting (float, null)
- pj_leverdatum_by_lp (smallint, null)
- pj_ddmrp_leverdatum (date, null)
- pj_ddmrp_timestamp (datetime, null)
- pj_erp_guid (varchar(128), null)
- pj_leverdatum_bev_by_lp (smallint, null)

A_stapmat

- mat_prj (PK, varchar(20), not null)
- mat_ordnr (PK, smallint, not null)
- mat_stapnr (PK, smallint, not null)
- mat_artcode (varchar(40), null)
- mat_omschr (varchar(80), null)
- mat_verbruik (float, null)
- mat_eenheid (int, null)
- mat_prijs_per_eenh (float, null)
- mat_prijs_totaal (float, null)
- mat_kostcode (int, null)
- mat_type (smallint, null)
- mat_breedte (float, null)
- mat_hoogte (float, null)
- mat_lengte (float, null)
- mat_walsricht_yn (smallint, null)
- mat_codering (varchar(255), null)
- mat_beschikbaar_yn (smallint, null)
- mat_opmerking (varchar(80), null)
- mat_peuklengte (float, null)
- mat_aan_staaf_yn (smallint, null)
- mat_plaatdikte (float, null)
- mat_vrije_tekst_1 (varchar(80), null)
- mat_vrije_tekst_2 (varchar(80), null)
- mat_vrije_tekst_3 (varchar(80), null)
- mat_vrije_tekst_4 (varchar(80), null)
- mat_vrije_tekst_5 (varchar(80), null)
- mat_lastmodified (datetime, null)
- mat_regelnr (PK, int, not null)
- mat_status (smallint, null)
- mat_aant_picked (float, null)
- mat_pickstat (smallint, null)
- mat_leverdatum (datetime, null)
- mat_diameter (float, null)
- mat_gereserveerd_yn (smallint, null)
- mat_leverancier (int, null)
- mat_besteld_yn (smallint, null)
- mat_ppe_manual (smallint, null)
- mat_art_batchcontr_yn (smallint, null)
- mat_aant_decimaal_yn (smallint, null)
- mat_toeslagperc (float, null)
- mat_info (text, null)
- mat_stukaant_eenh (int, null)
- mat_meerwerk_yn (smallint, null)
- mat_vervallen_yn (smallint, null)
- mat_if_timestamp (datetime, null)
- mat_ord_whatif_yn (smallint, null)
- mat_probleem_yn (smallint, null)
- mat_iot_bonnr (int, null)
- mat_iot_regelnr (int, null)
- mat_erp_deleted_yn (smallint, null)
- mat_importcontrole_yn (smallint, null)
- mat_erp_guid (varchar(128), null)
- mat_aant_scrap (float, null)
- mat_eenheid_txt (varchar(10), null)
- mat_refno (int, not null)

Io_inkord

- io_bonnr (PK, int, not null)
- io_datum (datetime, null)
- io_medewnr (int, not null)
- io_crediteurnr (int, null)
- io_contpers (varchar(80), null)
- io_paraaf (varchar(80), null)
- io_postadres_yn (smallint, null)
- io_leverdatum (datetime, null)
- io_besteld_telf (smallint, null)
- io_koptekst (text, null)
- io_slottekst (text, null)
- io_bevdatum (datetime, null)
- io_leverdatum_bev (datetime, null)
- io_vc_bedrag (float, null)
- io_vrije_tekst_1 (varchar(80), null)
- io_vrije_tekst_2 (varchar(80), null)
- io_vrije_tekst_3 (varchar(80), null)
- io_vrije_tekst_4 (varchar(80), null)
- io_vrije_tekst_5 (varchar(80), null)
- io_opmerking (text, null)
- io_lastmodified (datetime, null)
- io_lvrdatum_wrklk (datetime, null)
- io_transporteur (int, null)
- io_referentie (varchar(80), null)
- io_doorkiesnr (varchar(10), null)
- io_leverconditie (varchar(80), null)
- io_betaalconditie (varchar(80), null)
- io_besteller_cntr (smallint, null)
- io_bonnr_extern (varchar(20), null)
- io_bonnr_mag (varchar(20), null)
- io_valuta_teken (varchar(3), null)
- io_valuta_faktor (float, null)
- io_if_timestamp (datetime, null)
- io_verzenddatum (datetime, null)
- io_importcontrole_yn (smallint, null)
- io_invoerdatum (datetime, null)

Io_inkordtekst

- iot_bonnr (int, null)
- iot_prj (varchar(20), null)
- iot_ordnr (smallint, null)
- iot_stapnr (smallint, null)
- iot_aantal (float, not null)
- iot_aantal_terug (float, not null)
- iot_artcode (varchar(40), null)
- iot_tekst (text, null)
- iot_stukprijs (float, null)
- iot_totaalprijs (float, null)
- iot_leverdatum (datetime, null)
- iot_datum_geleverd (datetime, null)
- iot_type (smallint, null)
- iot_compleet_yn (smallint, null)
- iot_goed_yn (smallint, null)
- iot_control_yn (smallint, null)
- iot_afkeur_yn (smallint, null)
- iot_leverdatum_bev (datetime, null)
- iot_revnr (varchar(10), null)
- iot_rubrieknr (int, null)
- iot_vrije_tekst_1 (varchar(80), null)
- iot_vrije_tekst_2 (varchar(80), null)
- iot_vrije_tekst_3 (varchar(80), null)
- iot_vrije_tekst_4 (varchar(80), null)
- iot_vrije_tekst_5 (varchar(80), null)
- iot_lastmodified (datetime, null)
- iot_lvrdatum_wrklk (datetime, null)
- iot_korting (float, null)
- iot_eenheid (int, null)
- iot_regelnr (int, null)
- iot_pickstat (smallint, null)
- iot_aant_picked (float, null)
- iot_status (smallint, null)
- iot_verzonden_dt (datetime, null)
- iot_supl_ontv_dt (datetime, null)
- iot_supl_start_dt (datetime, null)
- iot_supl_gereed_dt (datetime, null)
- iot_supl_verz_dt (datetime, null)
- iot_opmerking (text, null)
- iot_bonnr_mag (varchar(20), null)
- iot_toeslagperc (float, null)
- iot_if_timestamp (datetime, null)
- iot_refno_old (int, null)
- iot_importcontrole_yn (smallint, null)
- iot_refno (PK, int, not null)
- iot_invoerdatum (datetime, null)
- iot_geblokkeerd_yn (smallint, null)
- iot_manual_lnk_stp_yn (smallint, null)
- iot_leverdatum_by_lp (smallint, null)
- iot_leverdatum_orig (datetime, null)
- iot_erp_guid (varchar(128), null)
- iot_eenheid_txt (varchar(10), null)

R_klant

- klt_nummer (PK, int, not null)
- klt_naam (varchar(80), null)
- klt_code (varchar(5), null)
- klt_type (smallint, null)
- klt_adres (varchar(80), null)
- klt_pc (varchar(7), null)
- klt_plaats (varchar(80), null)
- klt_post_adres (varchar(80), null)
- klt_post_pc (varchar(7), null)
- klt_post_plaats (varchar(80), null)
- klt_telefoon (varchar(30), null)
- klt_fax (varchar(30), null)
- klt_email (varchar(80), null)
- klt_dlvdatumbev_yn (smallint, null)
- klt_dfl_off_tarief (float, null)
- klt_dfl_off_marge (float, null)
- klt_kgnr (int, null)
- klt_progn_budget (float, null)
- klt_info (text, null)
- klt_land (int, null)
- klt_post_land (int, null)
- klt_fact_adres (varchar(80), null)
- klt_fact_pc (varchar(7), null)
- klt_fact_plaats (varchar(80), null)
- klt_fact_land (int, null)
- klt_fact_tav (varchar(80), null)
- klt_website_url (varchar(80), null)
- klt_dfl_prio (smallint, null)
- klt_betaaltermijn (smallint, null)
- klt_vrije_tekst_1 (varchar(80), null)
- klt_vrije_tekst_2 (varchar(80), null)
- klt_vrije_tekst_3 (varchar(80), null)
- klt_vrije_tekst_4 (varchar(80), null)
- klt_vrije_tekst_5 (varchar(80), null)
- klt_medewnr (int, null)
- klt_mijnrecord_yn (smallint, null)
- klt_lastmodified (datetime, null)
- klt_terms_of_delivery (int, null)
- klt_terms_of_payment (int, null)
- klt_terms_of_payment_faktuur (int, null)
- klt_vatnr (varchar(30), null)
- klt_btw_yn (smallint, null)
- klt_active_yn (smallint, null)
- klt_fact_debnr (varchar(20), null)
- klt_fact_naam (varchar(80), null)
- klt_grootboekrek (int, null)
- klt_dfl_valuta (int, null)
- klt_aanvraag_type (smallint, null)
- klt_vendorrating_yn (smallint, null)
- klt_transporteur_yn (smallint, null)
- klt_lpi_yn (smallint, null)
- klt_importcontrole_yn (smallint, null)
- klt_created (datetime, null)
- klt_ext_nummer (varchar(40), null)
- klt_ext_dfl_mg (varchar(10), null)
- klt_ext_dfl_wp (varchar(10), null)
- klt_erp_guid (varchar(128), null)
- klt_voorrang_yn (smallint, null)
- klt_skip_from_krit_yn (smallint, null)

R_relatie

- r_klantnr (PK, int, not null)
- r_volgnr (PK, smallint, not null)
- r_naam (varchar(80), null)
- r_fax (varchar(20), null)
- r_email (varchar(80), null)
- r_telefoon (varchar(30), null)
- r_lastmodified (datetime, null)
- r_gender (smallint, null)
- r_active_yn (smallint, null)
- r_vrije_tekst_1 (varchar(80), null)
- r_vrije_tekst_2 (varchar(80), null)
- r_vrije_tekst_3 (varchar(80), null)
- r_vrije_tekst_4 (varchar(80), null)
- r_vrije_tekst_5 (varchar(80), null)
- r_functie (varchar(80), null)
- r_ext_relnr (varchar(40), null)
- r_importcontrole_yn (smallint, null)
- r_created (datetime, null)