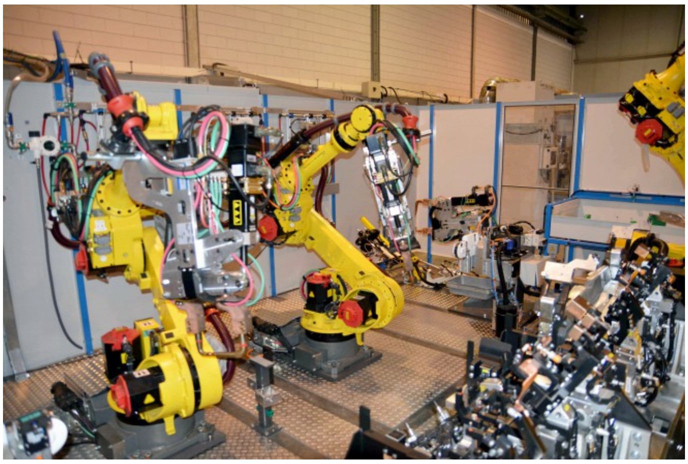

MONITOR KPI'S WITH A PERFORMANCE DASHBOARD

SIMULATION & ROBOTICS AT AWL-TECHNIEK

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ABSTRACT

Key Performance Indicators (KPIs) are important when organizations want to monitor their performance. To get insights into the performance of a team in a glance, a performance dashboard is used. This research elaborates on assessing, selecting and visualizing KPIs in such a dashboard. The Balanced Scorecard is used as the performance measurement model. The method of assessing, selecting and visualizing KPIs can be used in a team in an engineering and manufacturing environment.

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Chapter 1 Problem identification

This chapter introduces the company and the reason to start this research. Next, is the elaboration on the problems and how they are connected and who is involved in these problems. This chapter also includes the goal and scope of the research. This is followed by the research questions, the problem-solving approach, the deliverables, research method, reliability, validity, and limitations.

Chapter 2 Theoretical framework

The second chapter is the theoretical framework and consists of four parts. The first part is about process modelling languages and their characteristics. Followed by different methods about selecting key performance indicators. Thirdly, the performance measurement models are explained. Lastly, the theory of visualization is explained.

Chapter 3 Current situation of the processes in S&RE

In this chapter, a process modelling language is selected and used to model the processes of the Simulation & Robotics department.

Chapter 4 Select Key Performance Indicators for S&RE

In this chapter, a methodology is chosen to selected KPIs. Next, the methodology is applied to S&RE.

Chapter 5 Performance Measurement Model

This chapter starts with choosing an appropriate performance measurement model. Followed by structuring the selected KPIs from chapter 4 into the performance measurement model.

Chapter 6 Dashboard design

Chapter 6 explains the requirements for the dashboard. Next, the design choices and the dashboard itself is explained.

Chapter 7 Evaluation, conclusion & discussion

The evaluation and conclusion are part of chapter 7. Followed by recommendation to the company, contributions to theory and practice. The chapter ends with the discussion and future work.

Chapter 8 Bibliography

This chapter contains all the sources that are used for this research.

Chapter 9 Appendices

Chapter 9 contains the appendices.

In Figure 1 an overview is given of the main steps that are taken in this research.

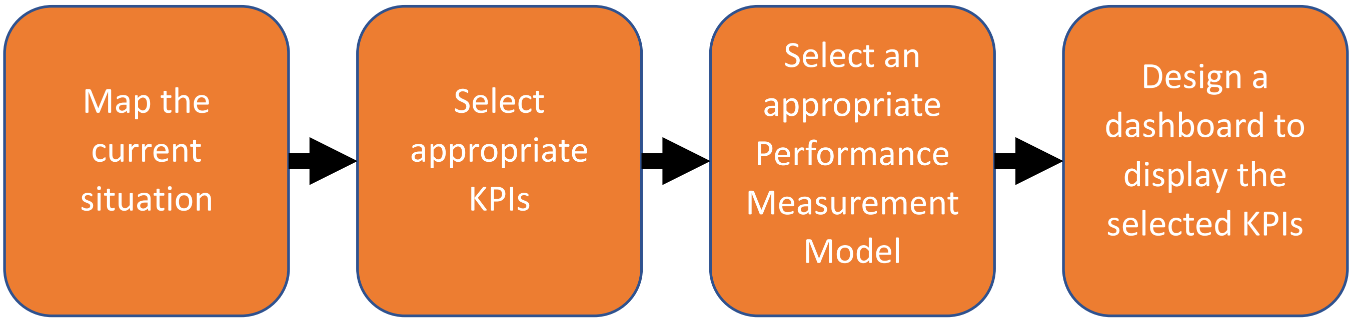

Figure 1 Research overview

1. Problem identification.

1.1. Introduction AWL-Techniek

AWL is a worldwide company for automated joining solutions. With branches in the Netherlands, the Czech Republic, China, Mexico, and the United States, AWL supports customers all over the world. This guarantees the customers' global productivity using smart and reliable solutions in the field of high-end automation, robotization, and jointing techniques. Today, AWL is a private company with more than 600 employees worldwide. When the company started, it specialized in spot and arc welding. Later, it started specializing in laser welding, and now other automation tasks such as glued joints, vision systems, product handling, quality control, and traceability are just as important. All disciplines are represented within the organization so that AWL can offer complete solutions. (AWL Techniek, sd)

1.2. Reason for research

Several months ago, the higher management of AWL decided to merge the departments; *Simulation* and *Robotics Engineering* into one new department: Simulation & Robotics. The manager of this new department has currently no insight on how the two parts of the team perform and collaborate. AWL is a fast-growing company, which causes troubles for the management to keep up with procedures. The goal of this research is to hand the manager of Simulation & Robotics tool to be prepared for the potential growth of AWL.

1.3. Problem statement

1.3.1. Problem cluster

The manager of the just merged departments Simulation & Robotics Engineering has troubles with monitoring the performance of the two parts of the team. There is a digital deliverable checklist developed within the simulation part of the team. This checklist is developed to make sure every step in the process is well-taken and no mistakes are made. There is also room on this checklist to give or ask for feedback. However, this checklist is not always filled in (completely). The other part of the team, Robotics Engineering, uses a so-called roadmap to check their work themselves.

Because there are no clear performance indicators set, it is unknown how the department Simulation & Robotics Engineering is performing. Since the budget per project for S&RE is relatively small compared to Mechanical Engineering or Controls Engineering.

When a project starts, several hours are budgeted for each part of the process. This means that each part of the Simulation & Robotics Engineering (S&RE) has its budget (hours) per project. The manager of S&RE has only the ability to check the number of hours worked after a project is finished. This makes it hard to get a signal when and how things go wrong within projects.

Sometimes it happens that a customer wants that a project that is already sold will be adjusted. This often means that the number of hours that are needed for the Simulation engineer and the Robotics Engineer is adjusted. However, the number of budgeted hours does not change. This results in an image of the performance which is not in line with reality.

At the moment it is not possible to see if the number of hours worked on each project are in line with the planning that was made. It is also not possible to see easily if the number of hours exceeds the budget for the project. This problem is chosen as the core problem for this research. With solving this problem the KPIs will be known and this will give insights into the performance of the different parts of the Simulation & Robotics department.

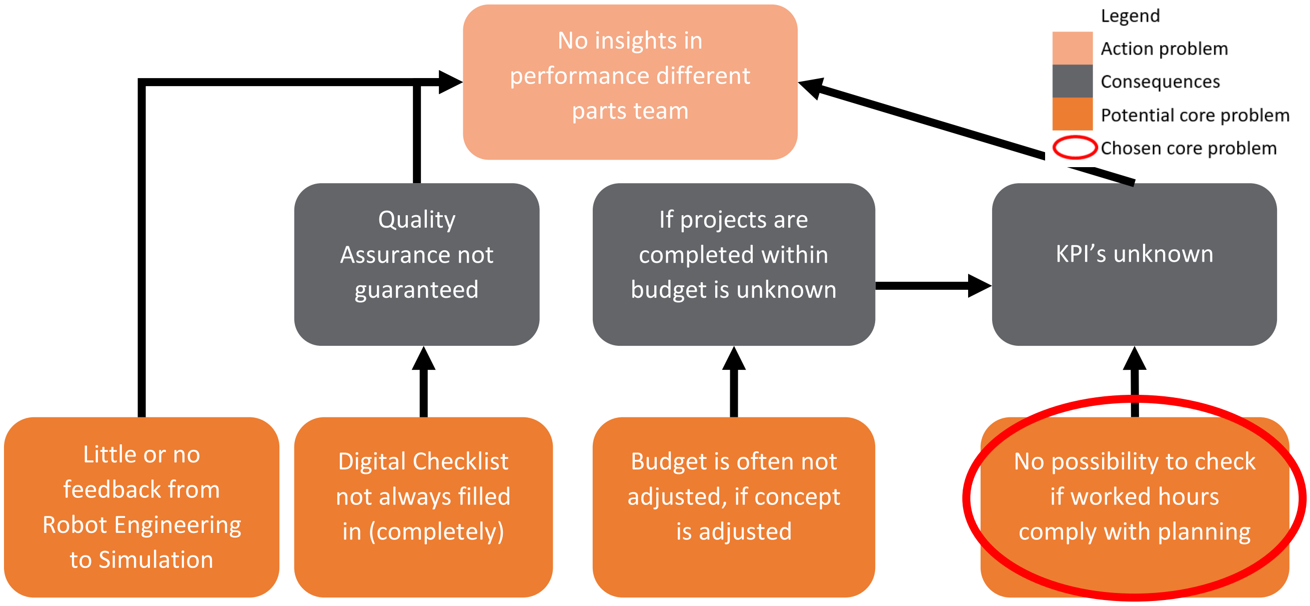

Figure 2 Problem cluster

1.3.2.Stakeholders

Table 1 Stakeholders displays the stakeholders, their role in this project and their score on *power and influence (P&I)* and *interest.*

Stakeholder	Role	Comment	Score (P&I)	Score interest
Researcher (me)	Author of report/researcher		9	10
Supervisor UT	Guide	She gives feedback on the conducted research	9	3
Supervisor AWL/ Manager S&RE	Information source/ Guide/ Receiver of solutions	He can give information about the current situation and point out what is important in his eyes. He gives feedback on the conducted research. He will be the person to implement the solutions found in the research	10	9
Simulation Engineers	Information source	They can give information about the current situation and point out what is important in their eyes.	2	6
Robotics Engineers	Information source	They can give information about the current situation and point out what is important in their eyes.	2	6

Table 1 Stakeholders

"The level of stakeholders' interests of the project was assessed on a scale of [0; 10]. The higher the index is, the stronger the impact on the project is observed. The level of power and influence (P&I) was assessed on a scale of [0; 10] according to a similar principle" (Kuzmin & Khilukha, 2016). The scores can be seen in Table 1 Stakeholders and the matrix itself is shown below in Figure 3 Stakeholders Matrix.

The researcher is the one with the most power and influence. The researcher has high interest and aspiration because he wants to conduct good and useful research. Also, the supervisor of AWL/manager S&RE has a strong influence and a high interest. He is the person who knows the current situation the best and will be helped a lot if the problems in the company can be solved because of this research. So, both the researcher and the supervisor AWL can be placed in the 'Keep close' quadrant. The supervisor UT also has a strong influence on the research. She is the person who will grade the whole research and has experience in doing research. But the supervisor UT lack interest in the direct results. The engineers from Simulation and Robotics have not so much power and influence, but their interest is high because it is likely that the research will affect their work. So, the engineers will be in the 'Keep informed' quadrant.

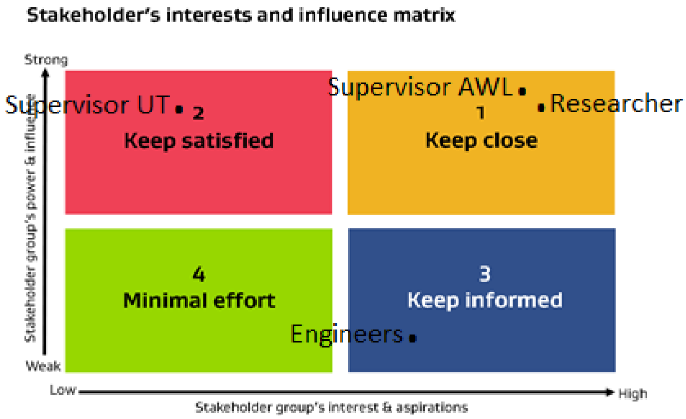

Figure 3 Stakeholders Matrix

1.4. Goal and Scope of research

Now it takes several hours to check how many hours the members of the team worked productively. This should not take more than a minute to load the data and visualize the productivity of the team. The goal of this research is to enable the manager of Simulation & Robotics to monitor the performance of the department.

To determine the scope of my project, I investigated different problems. Which of these problems lay within S&RE? Which problem is solvable within 10 weeks? To limit the scope of this research, there will only one problem solved. That problem is the problem of not having the possibility to check if worked hours comply with planning. This means that KPIs are unknown. Which will result in the fact that there is no insight into the performance of the team of Simulation & Robotics Engineering (S&RE). The problems about the digital checklist and the lack of adjustment of the budget will be left out of this research since these problems have less influence on not having insights into the performance.

1.5. Research Questions.

To solve the problem of having no insights into the performance of the department Simulation & Robotics, the following research question is formulated:

How can AWL monitor the performance of the department Simulation & Robotics?

To be able to answer the main research question, several sub-questions are formulated. The sub-question will cover the different aspects of the research.

1. What is the current situation of the processes in S&RE?
   First, it is necessary to understand the current situation and the way of working of Simulation & Robotics. With this understanding, it will become clear how projects flow through the

different departments of AWL and how they interact. With a clear overview of the business processes of S&RE, it will become clearer which aspects are more important for the performance of Simulation & Robotics.

2. How to select Key Performance Indicators for S&RE?
   To answer the question of how to select KPIs, literature research is conducted. Which KPI's are relevant for branch-specific companies like engineering companies? Selecting good KPI's is necessary to monitor performance and gain insights on how to improve it. The performance needs of S&RE combined with the literature research will result in the selection of the KPI's that can be visualized on the performance dashboard.

3. Which methods can be used for performance measurement?
   It is necessary to determine which methods exist for performance measurement. It is important to compare the qualities of the different methods to make sure to select the best fitting one for S&RE.

4. How to visualize the selected KPI's?
   Fourth, a correct analysis of the KPIs is necessary to make sure no mistakes are made with the interpretation of the data. To be able to make such a correct analysis, the visualizations need to be easy to read and use. The best way to visualize the KPIs needs to be determined.

1.6. Research Design

1.6.1. Problem Solving Approach: Design Science Research Methodology (DSRM)

"Design science creates and evaluates IT artefacts intended to solve identified organizational problems." (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) Within the DSRM, which is a methodology to research in the field of design science as the name suggests, there are certain *rules* which must be kept in mind or followed.

- the research must produce an "artefact created to address a problem"
- the research should be relevant to the solution of a "heretofore unsolved and important business problem"
- It's "utility, quality and efficacy" must be rigorously evaluated.
- The research should represent a verifiable contribution and rigour must be applied in both the development of the artefact and its evaluation.
- The development of the artefact should be a search process that draws from existing theories and knowledge to come up with a solution to a defined problem.
- The research must be effectively communicated to appropriate audiences

In my research, I will build a performance dashboard. This dashboard can be seen as an artefact that will help to solve the problem of having no insight into the performance of the team. The utility, quality, and efficacy of the created dashboard will be evaluated by the manager of Simulation & Robotics, the supervisor from the university and by myself. The development of the dashboard will be founded on theories that are already proven. The report of this research will be published on the website of the University of Twente.

To make sure research is conducted systematically, the DSRM says that six steps need to be followed. These steps are schematically pictured in Figure 4.

1. Problem identification and motivation
   The reason why this research is conducted in the first place is explained in section 1.2. Problem identification and motivation will be discussed in section 1.3 of the report.
2. Define the objectives for a solution
   There are certain goals for this research. These goals will be stated in section 1.4 of this report. In this section also the deliverables of the project will be stated.

3. Design and development
   This step consists of two parts. The first part is gathering the knowledge and theories of building such an artefact. This theoretical framework can be found in section 3. The second part is the building itself.
4. Demonstration
   The newly developed dashboard will be given to the manager of the Simulation & Robotics department. This will include a guideline on how-to-use the dashboard.
5. Evaluation
   During the evaluation, the artefact will be observed on how well it supports the solution of the problem and if this solution is in line with the objectives formulated in step 2 of this process.
6. Communication
   All the findings of this research, including the dashboard, will be presented at my colloquium. Besides that, the report will be published on the website of the University of Twente.

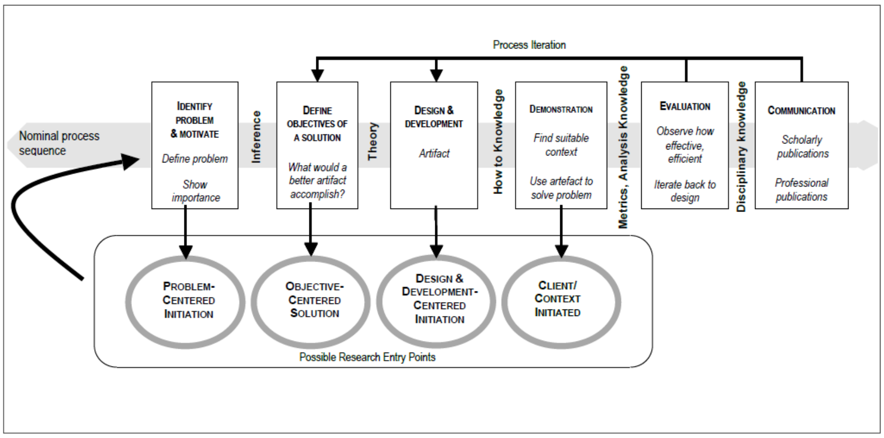

Figure 4 Design Science Research Methodology

1.6.2. Deliverables

When answering all the research questions, several *products* are created or produced. The first research question results in a Business Process Model of the department of Simulation & Robotics. The result of the second research question is a method of selecting KPIs and the selection itself. The third and fourth research questions combined make a business intelligence dashboard to measure the performance of Simulation & Robotics. The fifth question is about the application and implementation of the dashboard and how to conclude it. This results in recommendations on how to use the dashboard. Below is an overview of the deliverables of this research

1.6.3. Research method

Data collection

For this research data needs to be collected. Input data for the business process model is collected in two ways: the available structure on the internal file server of the company and the other part is collected through interviewing the engineers on how they do their jobs.

There is also data necessary on which the KPIs are based. The data need to be available within the company somehow or it needs to be generated. Most of the data on which the KPIs are based can be fetched from the ERP system of the company. But there are several KPIs that need to be provided with data that does not exist yet. This concerns the internal feedback on each project. To be able to use these KPIs, a feedback form needs to be created. This feedback form is something that is not included in the scope of this research.

Data analysis

After the data is collected, the data needs to be analysed. Most of the Key Performance indicator in the dashboard are quantitative, this can be seen in appendix 9.2. The type analysis is depending on the type of data. This means that the data need a quantitative way of processing and analysing: producing tables, graphs, and charts. Based on these visualizations' conclusions can be drawn.

1.6.4. Reliability and Validity

Reliability says something about the accuracy of the research. In other words, high reliability is when the same thing is measured again and again under the same conditions it should return the same result. Validity is about what is measured, is what needs to be measured actually measures. So, could be that the thing you measure is not the thing that you want to measure, but it gives every time the same result. In this case, it is reliable, but not valid. (Cooper & Schindler, 2011)

Data research is when carried out correctly, reliable. But this does not make it valid. Data research always seems accurate, reliable and valid. It needs to be considered that it could be that data is not interpreted correctly. The correct meaning needs to be allocated to the results of data research.

Construct validity is "the degree to which a test measures what it claims, or purports, to be measuring." (Brown, 2000). The main topic of this research is measuring performance. Performance is in this research measured by means of KPIs. To make sure the construct validity of measuring performance is high, the KPIs used must tell the performance of the team. To assure higher construct validity, that the KPIs communicate the performance of the team, an already validated method, the KPI Assessment Methodology (KAM), is used. A small remark is necessary, it is possible that the used KPI input list of the KAM is not sufficient and some aspects of performance are not addressed with the selected KPIs, this could lower the construct validity of this research.

Related to this research, the selection of the KPIs is subjected to a change of unreliability because which KPIs are selected for the performance measurement is mostly based on the opinion of the researcher and professionals within the company. If someone else would conduct the same research, the result will probably be slightly different.

External validity is the degree to which the results of a study also apply to other situations and can be generalised. The main result of this research, the performance dashboard, is specifically designed for the manager of the Simulation & Robotics department. So, it is plausible that the results do not apply to other situations, and therefore have low external validity.

In the evaluation of the performance dashboard an item list for estimating the Unified Theory of Acceptance and Use of Technology (UTAUT) was used (Venkatesh, Morris, Davis, & Davis, 2003). This item list is already validated in the research of Venkatesh et al. (2003).

1.6.5. Limitations

This research also has several limitations: time restrictions, data availability and resistance within the company, not enough respondents of the KPI selection, and only one case study.

The first limitation of this research concerns time restrictions. The research is conducted as a bachelor's assignment. This means that the research should be carried out within ten weeks. This limits the scope of the research, that is why the implementation of the dashboard is not included.

In addition to that, not all the necessary data was available. This limitation is intertwined with the third limitation. I experienced some resistance within the company for this research. The IT department of AWL was not willing to give access to all the necessary data.

Fourthly, the KPI Assessment Methodology (KAM) is usually carried out during a workshop with the management team or the board of the company. For this research, the criteria and the KPIs are scored only by the researcher. To achieve a higher If others would replicate this research in their company, I suggest organising a KAM workshop to make sure enough people assess the KPI selection.

Lastly, this research was conducted within only one department of only one company. This means that the results of the research are not necessarily applicable in other departments, other companies, or other branches.

2. Theoretical Framework.

2.1. Process Modelling Language

To make a selection for which process modelling language to use for modelling the processes in the current situation of the department of Simulation & Robotics, several of these languages are being investigated. In this research, the focus lies on conceptual modelling languages instead of executable languages. That is why the following languages are selected for comparison; Event-driven process chain (EPC), Coloured Petri nets extension (CPN), and Business Process Modelling Notation (BPMN).

Event-driven process chain (EPC) is an intuitive graphical business process description language, which will be used to describe different processes on a business level and is easy to use and understand by businesspeople. An EPC makes the distinction between three elements: events, functions, and logical connectors. (van der Aalst, 1998) The majority of the business process modelling techniques or methods that are used are program-specific, this means they can be used by only one tool. Event-driven process chain (EPC) can be used by multiple tools and is therefore in the minority group. EPC is used in for example SAP, ARIS, and Visio. SAP is the world-leading ERP-system, Aris is the world-leading Business Process Re-design (BRP) tool, and Visio is another BRP tool based on EPC. (van der Aalst, 1998)

A Petri net is a mathematical modelling language that is used to describe distributed systems. A Petri net is a graph with places, transitions, and arcs. The places are the conditions and the transitions are the events that may happen. The arcs are the arrows to describe what the flow is within a Petri net. A coloured Petri net is an extension of the classical Petri net. The difference between the coloured Petri nets (CPN) and the classical Petri nets is that the tokens in the coloured version have a data value connected to them, this data value is called the token colour. Unlike other business process modelling languages, Petri nets have well-defined mathematical definitions, execution semantics, and a mathematical theory for process analysis. (Jensen, 1997)

Business Process Model and Notation (BPMN) is a language used for business process modelling that enables a graphical notation. The goal of BPMN is to support technical users and business users by their business process management. The language is intuitive for business users and able to map complex processes for technical users. (Object Management Group, 2014) EPC and BPMN can be very similar, these models can be transformed into each other. A BPMN model needs approximately 40% fewer elements than its EPC counterpart, but the BPMN model needs a larger set of types of elements. (Kotsev, Stanev, & Grigorova, 2011) BPMN consists of a lot of elements; events, activities, gateways, sequence flows, message flows, associations, pools, lanes, data objects, groups, and annotations.

To select which business process modelling language is the most suitable for the Simulation & Robotics department of AWL, it is necessary to know who will make the model and who will use or read the model. In this case, the business process model will be made by the researcher and will be used by both the manager of S&RE and the researcher. The manager has a business background and the researcher has both a business and a technical background. The goal of this model is to discover and map all the processes within S&RE to be able to measure the performance of these processes. Therefore, it is not important to have clear mathematical definitions in the modelling language. It is convenient to be able to map the same processes with fewer elements. To conclude BPMN is selected as the business process modelling language to model the processes within the Simulation & Robotics department of AWL.

2.2. How to select KPI's

Selecting Key Performance Indicators is not an easy task. The people who do this need to understand the business deeply. (Meyers & Hester, 2011) People need to understand what each KPI contributes to the company's mission. Besides that, it is necessary to know in which Performance Measurement System (PMS) the KPI's are going to be monitored. (Lawsure, et al., 2015) Such a PMS can be Balanced Scorecard (BSC), Performance Measurement Matrix (PMM), DOE/NV, or Supply Chain Operations Reference (SCOR). Several methods to select the KPI's can be used, for example, the method from Horst and Weiss (2015), the Analytic Hierarchy Process (AHP), the method from Hester et al. (2017), or the model from Coppola et al. (2014)

The method form Horst and Weiss (2015) uses seven steps to come to the right KPI's for the stakeholders. The first step is the selection of effectiveness criteria and the feasibility of KPI's. Examples of effectiveness criteria are: aligned, quantifiable, relevant, predictive, standardized, verified, accurate, timely, traceable, independent, actionable, buy-in, understandable, documented, and inexpensive (ISO, 2014). The second step is the scoring of how important each effectiveness criterion is. The use of a 1 to 10 scale is advised. Since scoring each effectiveness criterion of each KPI takes a lot of time, it is advised to use a limited number of KPI's (Baumeister & Tierney, 2012). The third step is to score each KPI for how it fits each effectiveness criteria. Next, determine the overall scores for each KPI. The fifth step is to discuss if the KPI sets are balanced. Sixth is to compare the normalized scores for these KPI sets. Last, is the implementation of the KPI's with the highest scores. (Horst & Weiss, 2015)

The Analytic Hierarchy Process (AHP) is a method to systematically compare alternatives with weighted criteria. The AHP can also be used to determine which KPIs are more important than others. The AHP consists of six steps. The first step is to develop a model. In other words, make a hierarchy of the goals, criteria, and alternatives. In the process of selecting KPIs, the alternatives are the KPIs that are going to be compared. Step two is to compare the criteria pairwise to derive weights. Then the consistency is checked, to make sure all the criteria are proportionally consistent. In the third step, the alternatives are pairwise scored on each criterion. The fourth step is to combine the results of the second and third steps. The weights per criterion multiplied with the scores per criterion result in an overall priority. This is called the synthesis results. The alternative with the highest overall priority is the best choice. Next, a sensitivity analysis is carried out. This means changes the weights of the criteria and see how the results change to understand how robust the decision of the best choice is. The sixth and last step is the final decision. Based on the synthesis results and sensitivity analysis, a decision can be made. (Mu & Pereyra-Rojas, 2017)

The method from Hester et al. (2017) is an assessment of KPI's for manufacturing organizations. This assessment is called the KPI assessment methodology (KAM). The eleven steps from the KAM are depicted in Figure 5.

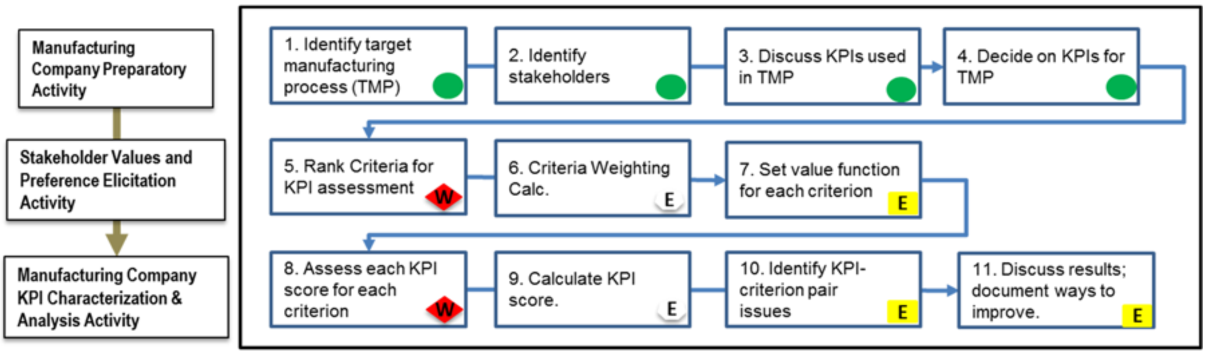

Figure 5 KPI Assessment Methodology

Steps 1 – 4 will result in a list of stakeholders, targets for a manufacturing process and KPIs which will be assessed in the steps that follow. Fifth, the criteria will be ranked from most important to least important by each of the stakeholders, in other words, the most important one gets one, the second gets two, etc. The criteria that are used for this assessment are from Horst and Weiss (2015) and are shown in Table 2.

Criterion	Definition
Quantifiable	The degree to which the KPI's value can be numerically specified.
Relevant	The degree to which the KPI enables performance improvement in the target operation.
Predictive	The degree to which the KPI can predict non-steady-state operations and is accompanied by a record of the past performance values for analysis and feedback control.
Standardized	The degree to which a standard for the KPI exists and that standard is correct, complete, and unambiguous; also, the broader the scope of the standard, the better, for example, plant-wide is good, corporate-wide is better, and industry-wide is best.
Verified	The degree to which the KPI can be shown to be true and correct concerning an accepted standard and has been correctly implemented
Accurate	The degree to which the measured value of the KPI is close to the true value.
Timely	The degree to which the KPI is computed and accessible in real-time, where real-time depends on the operational context, and real-time means the updated KPI is accessible close enough in time to the occurrence of the event triggering a change in any metric affecting the KPI.
Traceable	The degree to which the steps to fix a problem are known, documented, and accessible, where the particular problem is indicated by values or temporal trends of the KPI.
Independent	The degree to which the KPI collection, transfer, computation, implementation, and reporting are performed independently from process stakeholders.
Actionable	The degree to which a team responsible for the KPI has the ability and authority to improve the actual value of the KPI within their process.
Buy-in	The degree to which the team responsible for the target operation is willing to support the use of the KPI and perform the tasks necessary to achieve target values for the KPI.
Understandable	The degree to which the meaning of the KPI is comprehended by team members and management, particularly concerning corporate goals.
Documented	The degree to which the documented instructions for implementation of a KPI are up-to-date, correct, and complete, including instructions on how to compute the KPI, what measurements are necessary for its computation, and what actions to take for different KPI values.
Inexpensive	The degree to which the cost of measuring, computing, and reporting the KPI is low.

Table 2 KPI Criteria and Definitions adapted from (Horst & Weiss, 2015)

During the sixth step, the weights for the criteria are calculated by using the Rank Sum Method.

$$w_i = \frac{K + 1 - r_i}{\sum_{j=1}^{K} K + 1 - r_i}$$

Equation 1 Rank Sum Method

Where r_i is the rank of the i^{th} criterion, K is the total number of criteria, and w_i is the normalized ratio scale weight of the i^{th} criteria.

The seventh step, set value function for each criterion, is an optional step to develop value functions to account for measures with a natural or constructed scale. Next, each KPI will be scored for each criterion. The ninth step is to calculate the KPI scores using where M is the number of criteria, v_{ik} is the

i^{th} KPI score from the k^{th} stakeholder. v_{ijk} is the i^{th} KPI score, from the k^{th} stakeholder, for the jth effectiveness criterion. The stakeholder average weight of the j^{th} criterion is given by $\overline{w}_j$.

$$v_{ik} = \frac{\sum_{j=1}^{M} \overline{w}_j v_{ijk}}{\sum_{j=1}^{M} \overline{w}_j}$$

Equation 2 KPI Scores

The last two steps are assessing the KPI scores to see if certain pairs of criteria and KPI are problematic and discuss these issues including ways to improve these pairs.

The model from Coppola et al. (2014) is based on a two-step approach. During the first step, the criteria and KPIs for evaluating performance are identified by a systematic literature review. The initial set of indicators is grouped in the following way: KPI are grouped by criteria, criteria are grouped by key areas. In the second step, two methodologies are combined, the Redundancy Model (RM) and Analytical Hierarchy Process (AHP). These methodologies allow selecting the most suitable KPIs for measuring performance. The RM is used before the AHP to streamline the process of the AHP by deleting redundant KPIs. The KPIs are assessed by professionals. This model results in a list of KPIs each with its weight. (Coppola, et al., 2014)

2.3. Performance Measurement Models

2.3.1. Balanced Scorecard (BSC)

Balanced Scorecard was created as an alternative for the performance measurement models of that time. Those models only measured the financial aspects of performance. The principle on which the BSC is built is that *customer satisfaction leads to financial success.* BSC is one of the most used performance measurement models among all types of businesses. BSC can be used at different levels of business, At a company level, level of a business unit, or level of a department. When a manager uses BSC, he/she uses four perspectives for this. The objectives that need to be realized, the KPIs that are used to measure the achievement, the targets for the KPIs, and actions that should be taken to achieve the goals. To implement BSC in a company, the current state of the company needs to be analysed. The vision and mission determine the goals. The objectives can be classified into four dimensions; financial, customer, internal processes, and learning and growth. To see if the objectives within the different dimensions reached, indicators need to be defined which include a target value, measuring tool, and measurement frequency. (Kaplan & Norton, 2007)

The BSC model's main advantages are that it includes more than only financial aspects and is in line with the goals of the company. Besides that, it enables management to determine which parts or processes of the company underperform in a blink of an eye. The downsides of the model are that is the BSC model is not a complete measurement system, and the interest of not all the stakeholders is included.

2.3.2. Performance Measurement Matrix (PMM)

The Performance Measurement Matrix is one of the oldest performance measurement models. PPM is a very simple model in two dimensions: Internal or External and (Non-)cost. These dimensions result in four quadrants in which the different measures will be placed. This is a flexible model, which can integrate different types of business performance. One of the disadvantages is that PMM does not take human resources and customers into account. Besides that, the performance measurement process is not clearly defined. (Keegan, Eiler, & Jones, 1989)

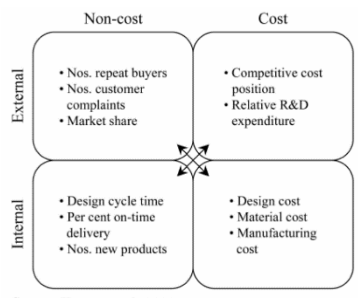

Figure 6 Performance Measurement Matrix

2.3.3. DOE/NV

The model DOE/NV was created by the US Department of Energy Nevada Operations Office, which gave the name to the model. This model can be used to measure performance in all departments of a company and consists of eleven phases: (Bellman, Droemer, Lohman, & Miller, 194)

During the first phase, the Process Flow Identification, the key processes are identified. Next, within the key processes, the critical activity is determined. This is an activity that has an impact on the efficiency, effectiveness, quality, productivity, time and safety of the execution of a process. In the third phase, the performance objectives are defined. This results in a list of goals for each critical activity. The fourth phase consists of five steps; define the problem, identify the data that is going to be transformed to performance measures, set the location of the required data, determine the approach, and determine the frequency of the measurements. In the fifth phase, a list of responsibilities is created. This list consist of which people are responsible for the collecting, processing and analysing of the data on the performance. The sixth phase is the phase of data collection. Here it is determined whether the collected data is relevant and enough. In the next phase, raw data is transformed into performance measures, on which data analysis can be applied. During the eighth phase, the actual achieved performance is compared to the goals which are defined in phase three to see on which measures steps need to be taken to improve the performance. Sometimes it is smart to review the goals set in phase three to check if they are defined correctly. The next phase is about defining the actions that need to be taken if the performance does not achieve the goals. Phase ten is to perform the corrective actions from the last phase. Phase ten can be skipped is there are no corrective actions necessary. The eleventh and last phase is the re-evaluation of the goals. Most of the companies their needs and expectations change rapidly, that is why it is necessary to re-evaluate. (Bellman, Droemer, Lohman, & Miller, 194)

Although the DOE/NV model is flexible and can be used in all departments of a company, the methodology of the DOE/NV model is undefined and does not give guidance on how to monitor the performance measures and how to identify key processes and activities. (Komantina, Nestic, & Aleksic, 2019)

2.3.4. SCOR

Another commonly used performance measurement model is the Supply Chain Operations Reference (SCOR) model. It was created to give a more reliable assessment of the efficiency of the supply chain. The SCOR model is based on measuring the performance of business processes, in contrast to the performance of the entire supply chain. That is why the SCOR model can also be used at an enterprise level. The model is focusing on satisfying the customer's demand with six key management processes: Plan, Source, Make, Deliver, Return and Enable. To use the model, several steps need to be taken. This includes analysing the current situation of the company's processes and goals, making the operational performance measurable, and comparing this performance with benchmark data. (Wang, Chan, & Pauleen, 2010)

2.4. Visualizations

A dashboard and a performance dashboard are the same, so these terms are interchangeable. A performance dashboard consists of two elements: performance measures and the supporting infrastructure. This supporting infrastructure can be anything from a simple record of data to a complex data warehouse. In this research, the definition of a performance dashboard from Lempinen (Lempinen, 2012) will be used: "an interactive performance management tool consisting of a measurement system and an information system, and supported by the models and processes for information gathering, processing, distribution, and visualization."

Lempinen describes three questions that need to be answered when designing a performance dashboard.

1. What to measure?

2. Where and how to capture data?

3. How to deliver performance information to the users?

There are multiple frameworks and models to categorize KPIs. The Performance measurement matrix, the Performance pyramid, the Balanced Scorecard (BSC), and the Performance Prism are examples of such models (Lempinen, 2012). After a model is chosen for the categorizing of the KPIs, the KPIs need to be formulated. A brainstorm session with executives is a useful way to come to KPIs where the company values can be used as a starting point of the KPI formulation. Besides the company values, it is worthy to look at the existing KPIs, probably these KPIs can be re-used. It is important to have not too many metrics, so the metrics should be carefully examined which are used for informed decision-making and which are just fun to know.

To come to answers for the second and third question the framework of (Noonpakdee, Khunkornsiri, Phothichai, & Danaisawat, 2018) can be used. To capture data and present it to the user, there are three main steps to come to a visualization. Firstly, there is the data source, this can be an ERP, CRM, Sales, or other databases. Secondly, the data need to be ready to be loaded in the visualization, this step is called data preparation. The data preparation can have three parts, which are data validation, data cleaning, and data transformation. Lastly, there is the third step, which is called data analysis & visualization. In this step, the data is used to create a visualization. This can be done using a framework which is explained below (Noonpakdee, Khunkornsiri, Phothichai, & Danaisawat, 2018).

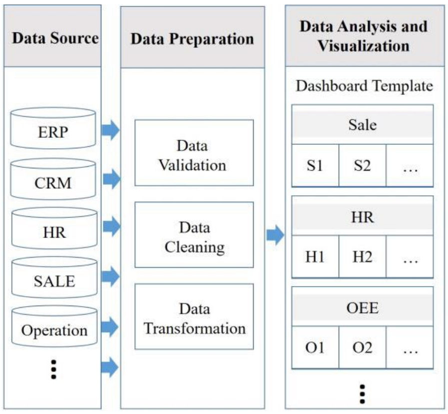

Figure 7 The Data Process

Noonpakdee, Khunkornsiri, Phothichai, & Danaisawat (2018) developed a framework to create dashboards. There are four main elements in this development which are event/business operation, attribute list, visualization, and dashboard capabilities. The event/business operation consists of several dimensions, which each have attributes. In the picture below, the relation between the dimensions and attributes in the example of a sales dashboard is depicted. These dimensions and attributes are used to create the visualization. On a dashboard, the visualization is usually a type of chart. When creating a visualization, the dashboard capabilities need to be considered, which consist of the following nine elements: Dashboard layout, Dashboard design, Presentation, Alerting, Analysis, KPIs/metrics, Dashboard interactivity, Delivery, Architecture.

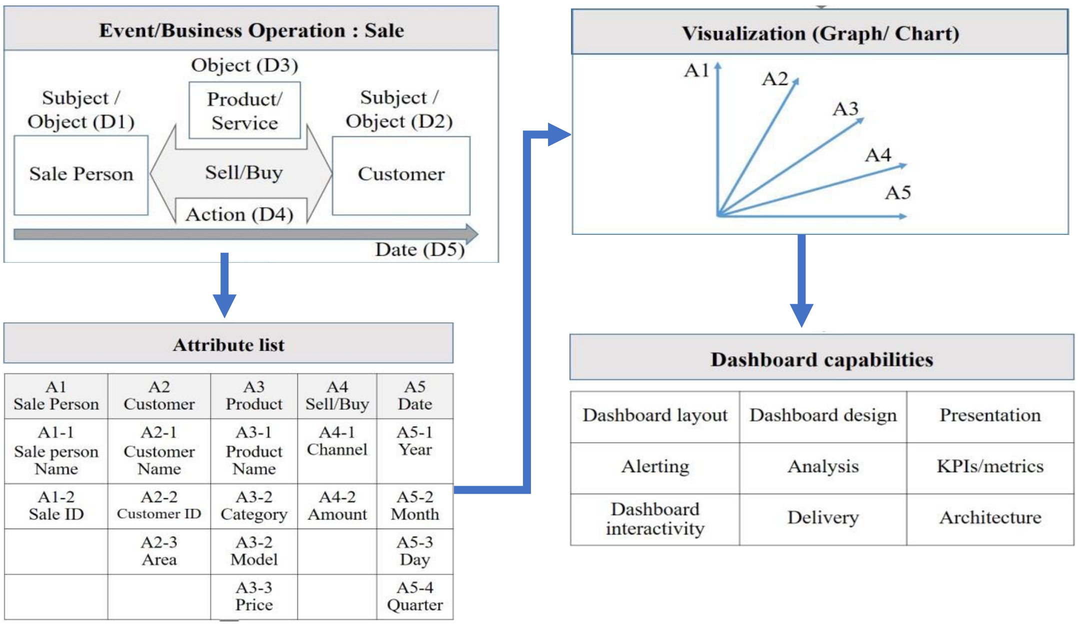

Figure 8 Framework of analysing data for sale dashboard

When presenting a visualization in a dashboard, besides the type of charts, colour is a big influence. The use of colour improves the process of visualization, but excessive use of colour will affect the user in their decision-making. So, frugal use of colour is advised when making a visualization. This problem can be potentially reduced by maximizing the “data-ink ratio”, which measures the proportion of ink used to represent data to the total ink used to print the graph (Yigitbasioglu & Velcu, 2011). Furthermore, a good balance between visual complexity and information utility is required. Visual complexity can be defined as “the degree of difficulty in providing a verbal description of an image” (Lempinen, 2012).

The dashboard should be easy to use considering the different skill levels of the users When designing a dashboard, it is important to know who the user of the dashboard will be because each person has a certain level of numeracy and graph literacy. According to (Dowding, et al., 2018) to design a dashboard it is necessary to know if the end-user has a high or low graph literacy and numeracy. For example, if users have a high graph literacy, they benefit from data visualized in formats like icon arrays, bar charts, and line charts. But if users have low numeracy, they understand the data the best if it is presented in a table or bar chart. In summary, different users need different types of visualizations to reach the best understanding of the dashboard.

3. Current situation of the processes in S&RE.

At this moment, the only thing that is measured related to performance is *productivity*. AWL uses the word productivity in the sense of all billable hours divided total worked hours per employee. Although this can be a measure of performance, this cannot be the only measure.

First, it is necessary to understand the current situation and the way of working of Simulation & Robotics. With this understanding, it will become clear how projects flow through the different departments of AWL and how they interact. With a clear overview of the business processes of S&RE, it will become clearer which aspects are more important for the performance of Simulation & Robotics.

To select which business process modelling language is the most suitable for the Simulation & Robotics department of AWL, it is necessary to know who will make the model and who will use or read the model. In this case, the business process model will be made by the researcher and will be used by both the manager of S&RE and the researcher. The manager has a business background and the researcher has both a business and a technical background. The goal of this model is to discover and map all the processes within S&RE to be able to measure the performance of these processes. Therefore, it is not important to have clear mathematical definitions in the modelling language. It is convenient to be able to map the same processes with fewer elements. To conclude BPMN is selected as the business process modelling language to model the processes within the Simulation & Robotics department of AWL.

To be able to make a Business Process Model (BPM) data needs to be collected from several sources. In this case, data has been collected in two ways; the first one is data from AWL's Quality Management System (QMS), the second is conducting unstructured interviews with the simulation- and robotics engineers.
In the QMS almost every step that needs to be taken when selling, designing, engineering, building, delivering their product is described. The people within the company who are tasked with quality assurance mapped all these steps in the QMS. An example of one of these parts of the whole process is depicted in Figure 9. Figure 9 cannot be just copied into the BPM, because this is only a part of all the activities that are carried out in the S&RE department. The several documents that concern the S&RE department are used as a basis for the BPM.

The second way to gather data for the BPM is through unstructured interviews with the simulation- and robotics engineers of the department. With these interviews, the engineers were asked what their tasks and activities are, which people they have contact with about the projects, and what their milestones are.

When there was a conflict of information between the data from the QMS and the data from the interviews, the manager of S&RE was consulted to discuss which activities, sequences, information flows are the closest to the real practice. All this data was used to create a BPM for the S&RE department. To create this Business Process Model the tool called Bizagi Modeler was used because this tool has a complete functionality of BPMN and is free to use. The complete model is shown in Figure 10. The parts of this model concerning simulation activities or robotics engineering activities are highlighted in respectively Figure 11 and Figure 12.

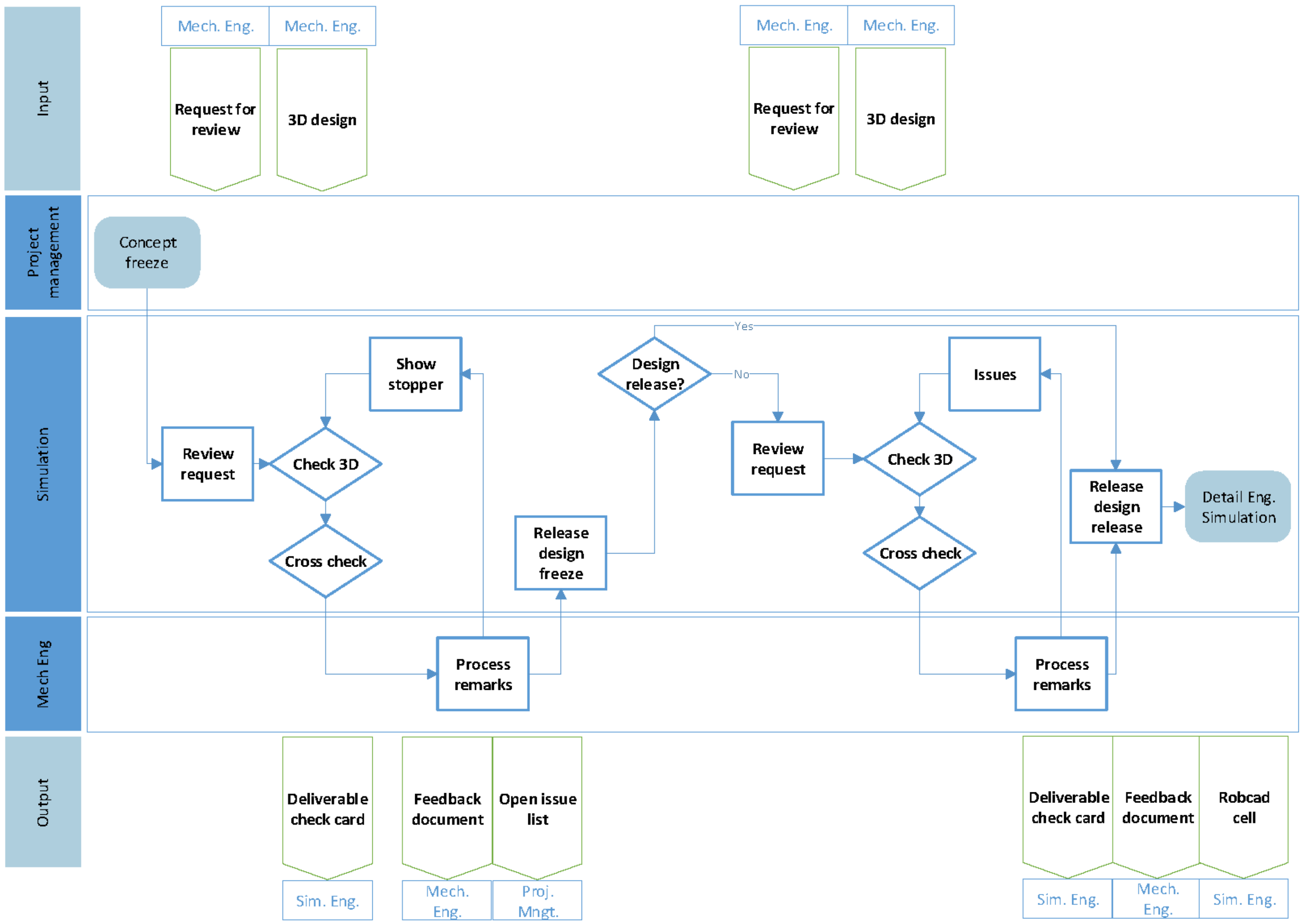

Figure 9 Design Engineering Simulation from QMS

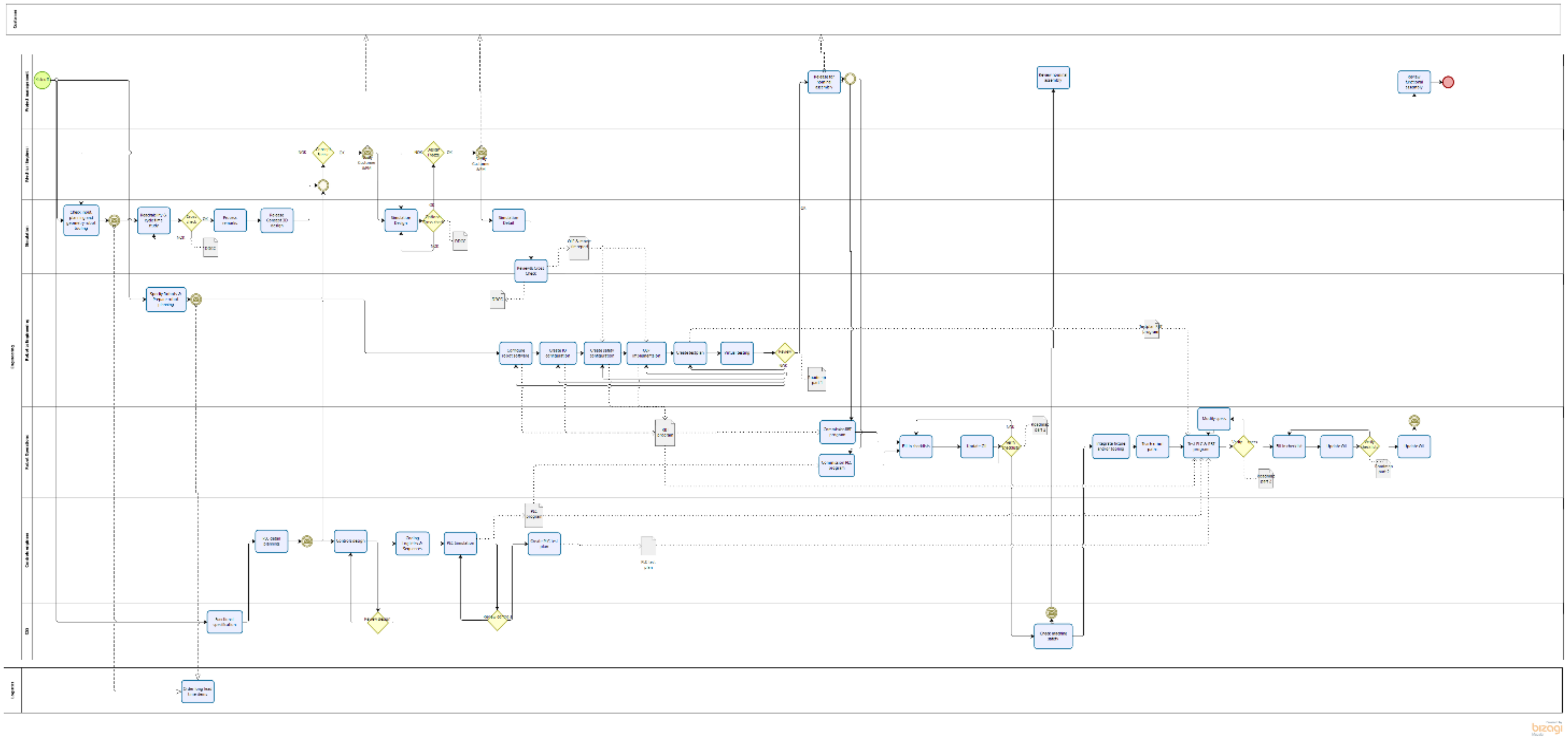

Figure 10 BPM of the S&RE department

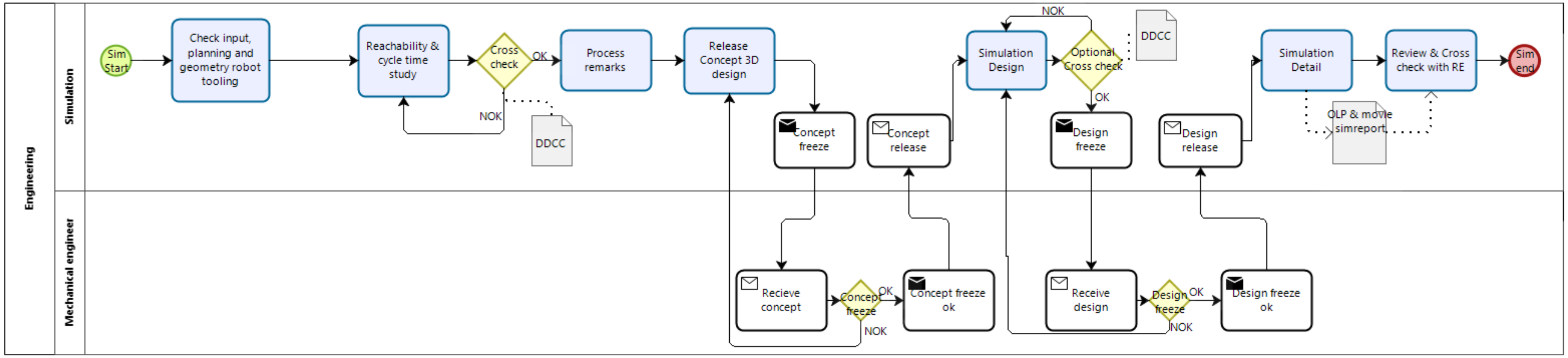

Figure 11 BPM Simulation

When there is a project started where the help of the simulation engineer is needed, the details of the project and what is sold to the customer is sent the simulation engineer. He (or she) checks the planning of the project and fills in his own planning, and checks the geometry of the robot. Then the reachability and calculated cycle time are investigated. When this is done, another simulation engineer cross-checks if everything is done correctly. Then the digital checks list of the project is updated. The lead simulation engineer processes remarks, creates the concept 3D design and sends it to the mechanical engineer. If the concept is approved, the simulation of the design starts. When the simulation is done, there is an optional cross-check by another simulation engineer. If he approves, the simulation is again sent to the mechanical engineer. If also the mechanical engineer approves, the last details of the simulation are added. This results in an off-line program, a simulation report, and a movie. These items are reviewed together with a robotics engineer, who will deal with the next part of the project.

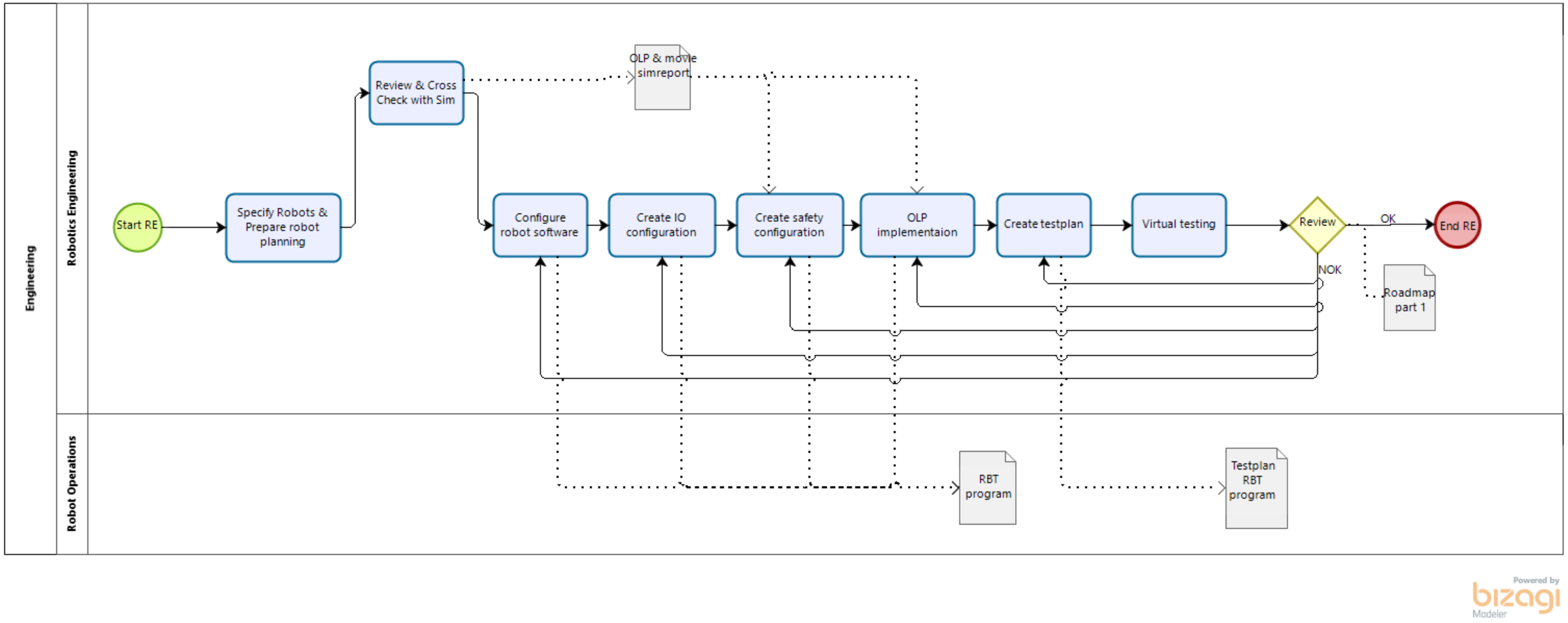

Figure 12 BPM Robotics Engineering

When a project is started, the robotics engineer is notified. He specifies which robots will be used and he makes his planning regarding the project. After the simulation engineer did his work. The robotics engineer checks if everything is in order together with the simulation engineer. The off-line program, simulation report, and movie from the simulation engineer will be used in the safety configuration and the off-line program implementation. The work of the robotics engineer is linear, this means there are sequential steps that are started when the previous step is finished. In the case of the robotics engineer, those steps are: configuring the robot software, creating the IO configuration, creating the safety configuration, implementing the off-line program, creating the test plan, and virtual testing. When all of these steps are finished, another robotics engineer will review the steps taken by the lead robotics engineer. If the label "OK" can be given, the roadmap will be updated. This roadmap is a kind of digital checklist. The robotics program and the test plan will be handed over to the robotics operations department, they will implement the robot program into the robot.

4. Select Key Performance Indicators for S&RE.

To answer the question of how to select KPIs, literature research is conducted. Which KPI's are relevant for branch-specific companies like engineering companies? Selecting good KPI's is necessary to monitor performance and gain insights on how to improve it. The performance needs of S&RE combined with the literature research will result in the selection of the KPI's that can be visualized on the performance dashboard. The KPI assessment methodology (KAM) from Hester et al. (2017) will be used in this research. The KAM has the advantages of being specific for manufacturing companies, being structured and complete. Besides that, the KAM can set-up criteria and their weights separately, just like the method from Horst and Weiss (2015).

Step 1: Identify the target manufacturing process (TMP)

In this research, the goal is to get insights into the performance of the S&RE department. So, for this step, there is not a specific process identified but the performance of S&RE in general.

Step 2: Identify stakeholders

In the process of measuring the performance of S&RE, several stakeholders are identified: the researcher, the supervisor from the University of Twente, the manager of the Simulation & Robotics department, the simulation engineers, and the robotics engineers. The stakeholders are discussed in paragraph 1.1.2.

Step 3: Discuss KPIs used in TMP and Step 4: Decide on KPIs for TMP

In these steps, it must be decided which KPIs are included in the assessment. In the case of S&RE a basis for the KPIs, the list from Scoreboard (2020) is used. This list is expanded with several KPIs which are specific for AWL or the S&RE department, this is done by the researcher and the manager of S&RE.

Step 5: Rank criteria for KPI assessment

In the assessment, not every criterion is equally important. To give weights to the criteria, the criteria are ranked in this step. The criteria from Horst and Weiss (2015) are used. The complete ranking of the criteria can be found in Appendix 9.3 on the first tab.

Step 6: Criteria Weighting Calculation

Equation 3 is used to compute the weight of each criterion, the results are shown in Table 3 Criteria Weights.

$$w_i = \frac{K + 1 - r_i}{\sum_{j=1}^{K} K + 1 - r_i}$$

Equation 3 Rank Sum Method

Where r_i is the rank of the i^{th} criterion, K is the total number of criteria, and w_i is the normalized ratio scale weight of the i^{th} criteria

Criterion	**Weight**	**Criterion**	**Weight**
accurate	11,43%	quantifiable	8,81%
actionable	6,90%	relevant	12,38%
buy-in	4,05%	standardized	6,67%
documented	3,10%	timely	6,19%
independent	7,38%	trackable	2,86%

inexpensive	4,76%	understandable	9,76%
predictive	6,90%	verified	8,81%

Table 3 Criteria Weights

Step 7: Set value function for each criterion

Each KPI is rated on every criterion. It is decided to use a 1 – 10 scale. This scale is used to be able to make clear and larger distinctions between the scores.

Step 8: Assess each KPI score for each criterion

The complete assessment of the KPIs for each criterion can be found in Appendix 9.3 on the second tab.

Step 9: Calculate the KPI score

$$v_{ik} = \frac{\sum_{j=1}^{M} \overline{w}_j v_{ijk}}{\sum_{j=1}^{M} \overline{w}_j}$$

Equation 4 KPI Scores

Using Equation 4, KPI scores were calculated, where M is the number of criteria, v_{ik} is the ith KPI score from the kth stakeholder. v_{ijk} is the ith KPI score, from the kth stakeholder, for the jth effectiveness criterion. The stakeholder average weight of the jth criterion is given by $\overline{w}_j$. Table 4 shows these scores on a scale from 1 – 10.

KPI	**Score**	**KPI**	**Score**
Availability	4,47	Percentage of outage due to changes	4,19
Average hourly fee	5,00	Percentage of outage due to incidents	4,27
Capacity utilization	5,81	Percentage of unit tests covering software code	3,41
Complaints	5,52	Percentage of user requested features	4,23
Contact moments	5,52	Productivity	6,88
Employee satisfaction	5,53	Quality assurance personnel as a percentage of the number of application developers	3,91
Feedback	5,52	Reply time tickets	6,10
Hours breakdown	5,77	S&RE improvements finished	5,95
Hours on customer site pp	5,79	Service Hours	6,63
Hours on work floor pp	5,55	Software development quality	3,36
Internal Customer satisfaction	5,54	System usability scale	2,97
Mean time between failure	4,75	Time kick-off - nominal assembly	5,63
Number of cross checks	7,07	Total service delivery penalties paid	4,20
Number of current projects	6,65	Training hours	7,23
Number of tickets	6,11	Turnover per employee	6,57
On-time delivery	6,05	Turnover per project	6,93
Outsourced hours	7,09	Unit costs of IT services	3,08
Overhead Cost	5,59	Update planning on time	6,13
Overtime hours	6,16	Worked hours/ budgeted hours	6,80

Table 4 KPI Criteria Scores

Step 10: Identify KPI-criterion pair issues and Step 11: Discuss results; document ways to improve

Since the goals of this KPI selection is slightly different from KAM, step 10 and 11 will not be taken. Instead of these steps, a boundary needs to be set for the KPI scores. Each KPI with a higher score than this boundary will be selected for the dashboard. For this research, the boundary will be set at 5,5. This means that 26 of the 38 KPI will be used in the dashboard, these are depicted in Table 5.

Selected KPIs	**Selected KPIs**
Capacity utilization	Outsourced hours
Complaints	Overhead Cost
Contact moments	Overtime hours
Employee satisfaction	Productivity
Feedback	Reply time tickets
Hours breakdown	S&RE improvements finished
Hours on customer site pp	Service Hours
Hours on work floor pp	Time kick-off - nominal assembly
Internal Customer satisfaction	Training hours
Number of cross checks	Turnover per employee
Number of current projects	Turnover per project
Number of tickets	Update planning on time
On-time delivery	Worked hours/ budgeted hours

Table 5 Selected KPIs

5. Performance Measurement Model.

In section 2.3 several performance measurement models are discussed. These models are Balanced Scorecard (BSC), Performance Measurement Matrix (PMM), DOE/NV, and Supply Chain Operations Reference (SCOR). It is important to select the right format for measuring performance. For the department Simulation & Robotics, performance is about satisfying the needs of the *customer* quickly and correctly. This *customer* can be the company that buys the machine, can be the project management or another department. Since the PMM and the SCOR do not include measures about the *customer* these methods are excluded from the selection. The BSC is preferred above the DOE/NV, because there is already some knowledge about the BSC within AWL, and because of the multifunctionality of the method, although the structured steps of the DOE/NV. Besides these arguments, the method of the Balanced Scorecard is more commonly known within the industry.

The Balanced Scorecard uses four dimensions; Financial, Internal Business Processes, Learning & Growth, and Customer. The 26 KPIs that are selected for the dashboard should be assigned to one of these dimensions. There may be doubts about which dimension a specific KPI need to be placed, in that case, the dimension that fits the best is chosen. The 26 KPIs from Table 5 are distributed over the four dimensions, the results can be seen in Figure 13.

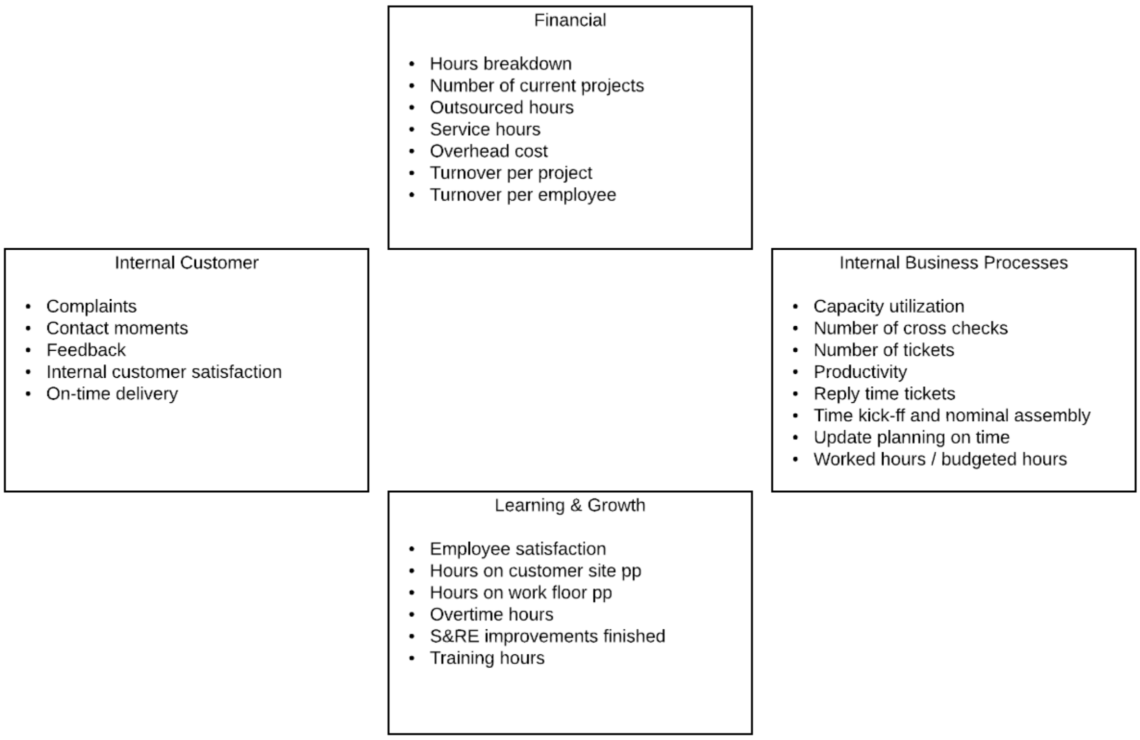

Figure 13 Balanced Scorecard

6. Dashboard Design.

6.1. Requirements for the Dashboard

There are several requirements for the dashboard to fit to make it functional and effective to use. First of all, The whole selection of KPIs from Table 5 should be implemented in the dashboard.

Secondly, according to Lempinen (2012), the type of chart and the use of colour are important when building a performance dashboard. Excessive use of colour can disorient the user, that is why a limited use of colour is required for the dashboard.

Next to that, the users of this dashboard have high numeracy and high graph literacy. This is important to know, to understand how complex the dashboard can and should look like. (Dowding, et al., 2018) Since the users have both high numeracy and a high graph literacy more complex charts can be used. However even people with a high graph literacy cannot oversee a dashboard with 26 KPIs. That is why the dimensions of the Balanced Scorecard are used to divide these 26 KPIs over 4 tabs or so-called sheets.

Lastly, there is a hand full of computer programs in which such a dashboard could be created. Examples of these are Power BI, Tableau, Qlik Sense, or Qlikview. Each of these programs has its advantages and disadvantages of user-friendliness, graph options, data connectivity, etc. AWL already uses Qlikview in their organization. Since licenses for these programs are generally expensive, the choice for a program to create the performance was made easily.

6.2. The Dashboard

The data which are used in the dashboard are not from actual AWL databases. The ICT department of AWL wants to connect the performance dashboard to their databases themselves. That is why almost every piece of data which can be seen in the dashboard is fictional and semi-randomly generated. This is done to give a sense of how the dashboard would look like when it would be connected to the necessary databases.

The dashboard is created for the manager of the department Simulation & Robotics. The KPIs that are selected, are selected in line with the needs of this department. If other departments within the company (or in other companies in the same industry) also desire to use such a performance dashboard, they can redo this research within their department. Identify the current situation and the key processes, select the most suitable KPIs, select the most suitable performance measurement model and tweak the dashboard from this research to their KPIs and needs.

The Dashboard consists of five sheets; one overview sheet and the four other sheets are the four dimensions of the BSC. Each sheet has two parts; on the left, there are the filter buttons to select the specific data that is needed, and on the right the charts of the KPIs. The filter buttons on the different sheets are not the same for every sheet since other charts need other filters.

First, the composition of the sheets will be explained, followed by an explanation in detail of only the charts on the main sheet, since explaining every chart in detail is too much time-consuming.

The first sheet is called “Main”. On this sheet, the four most important KPIs from the different dimensions are combined into the main sheet. In this sheet, the manager gets an overview of how the team is performing.

Figure 14 Main sheet dashboard

The second sheet is about financials. At the Simulation & Robotics department, almost every financial aspect is measured in hours. So, this sheet shows how many hours are spent on projects, service hours, meetings, etc. It also shows the turnover and the number of hours that are outsourced.

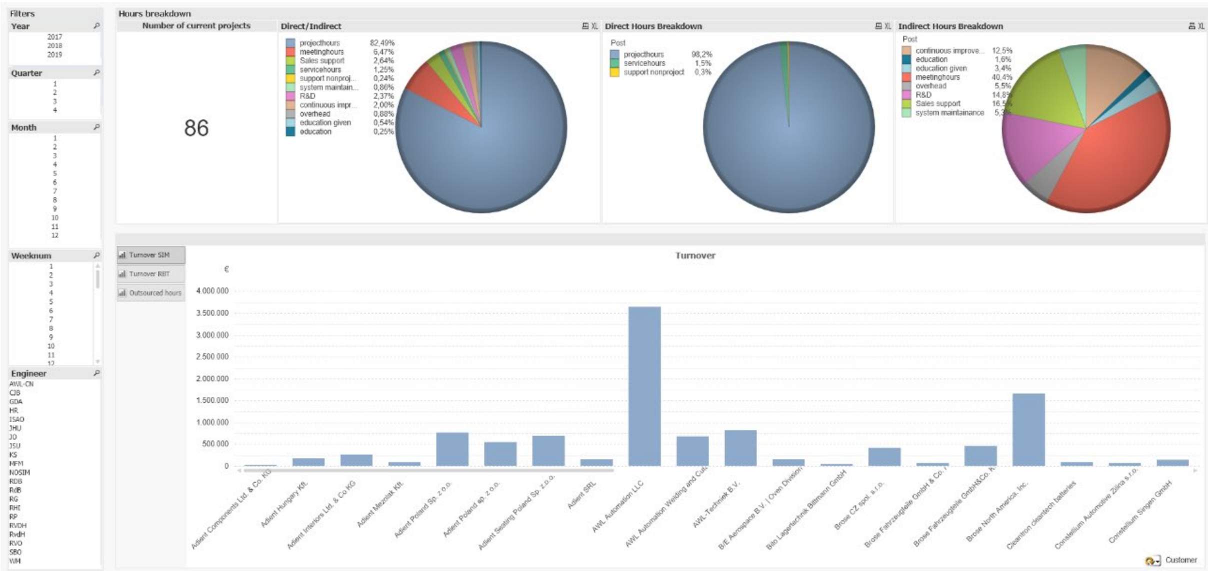

Figure 15 Financial sheet dashboard

The third sheet is about the internal processes in the department. It shows how many percentages of the employees worked hours are billable to customers, how quickly the department responds to issues, if the projects stick to its budget, and how much of the capacity is used.

Figure 16 Internal Business Process sheet dashboard

The fourth sheet is about learning & growth. In this sheet, the number of hours that the employees spent on training can be seen, but also how often they are working with the robots on the work floor or at the customer site. Besides that, the number of improvements the team came up with and finished implementing them in the selected period can be seen.

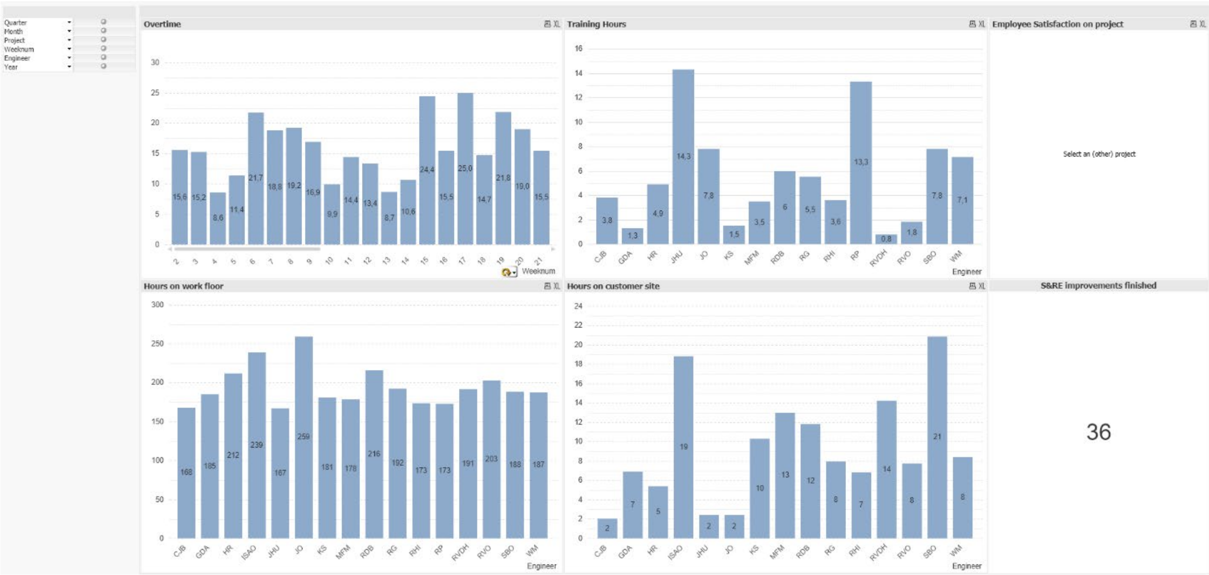

Figure 17 Learning & Growth sheet dashboard

The fifth and last sheet is about the customer. The customer of the Simulation & Robotics department is often another department within AWL, so S&RE's customer is an internal customer. Also, in the case of an internal customer, there are contact moments, moments of feedback, delivery deadlines, a certain level of satisfaction, or in the worst-case complaints. These are all shown in the Internal Customer sheet.

Figure 18 Internal Customer sheet dashboard

The first chart which will be explained in detail is about budgets and worked hours of each project. Each project has a budget of a certain number of hours for the project for the simulation part and a budget of the robotics engineering part. The result of the sum of both budgets minus the sum of worked hours, planned hours and outsourced hours can be seen in Figure 19. When you click on the lower right corner, the dimension changes and the results are not grouped by project but grouped by employee or customer.

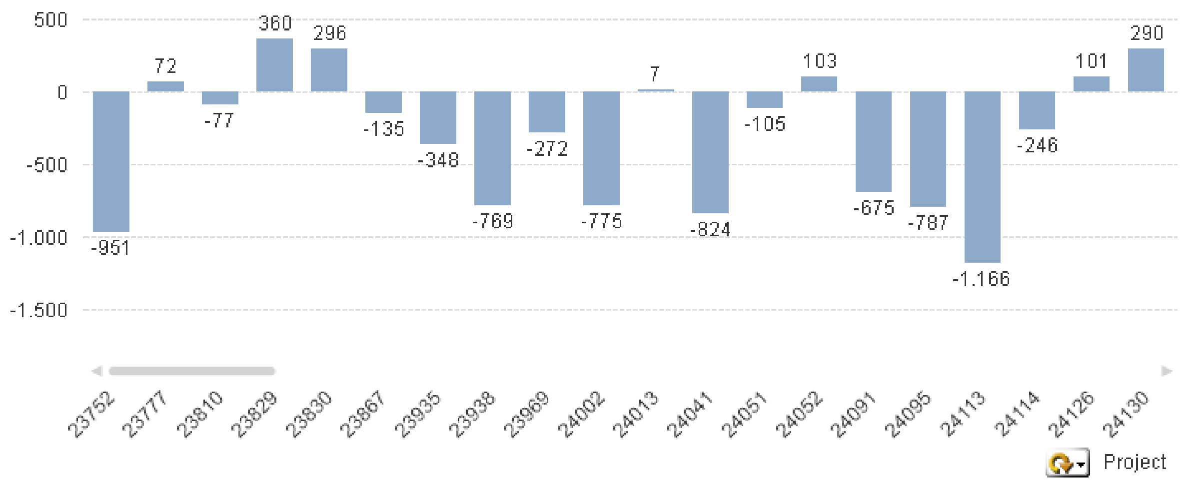

Figure 19 KPI Budget/Worked hours

The second chart is an hour breakdown. This means that it shows how many per cent of the worked hours are spent on a specific subject. This is summed over every employee, customer and the whole period. It is possible to filter for a specific period or employee.

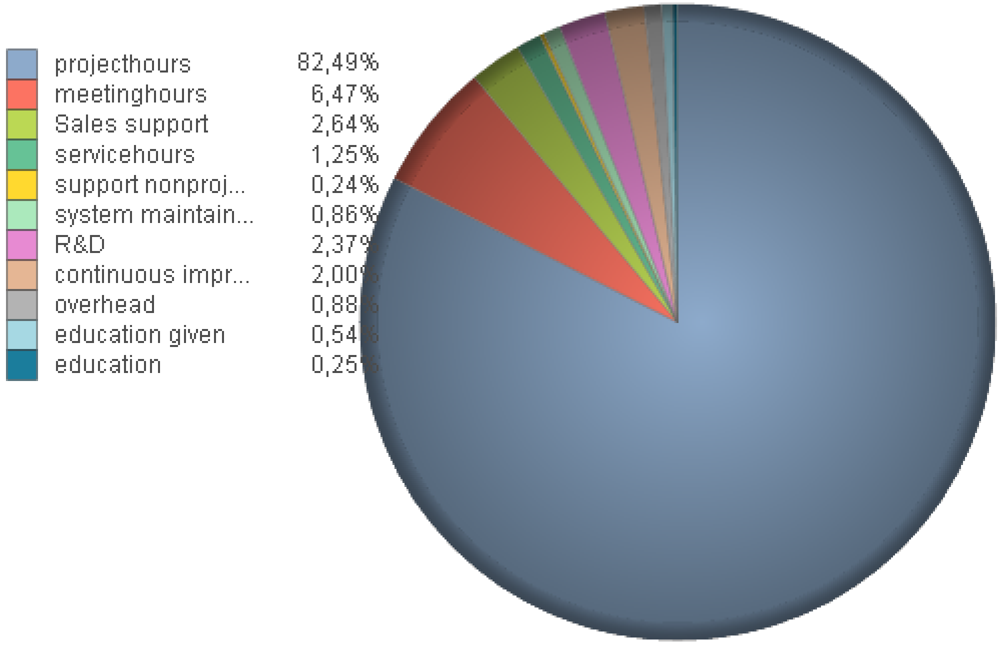

Figure 20 Hours breakdown

The third chart is called On-Time Delivery. This concerns if the delivery deadlines for the S&RE department for the projects are met. Just like the chart in Figure 19, the dimension of this chart can also be changed to Customer, employee or project, to see how many per cent of their projects are delivered before, after the delivery deadline, or just too late (within two days after the deadline).

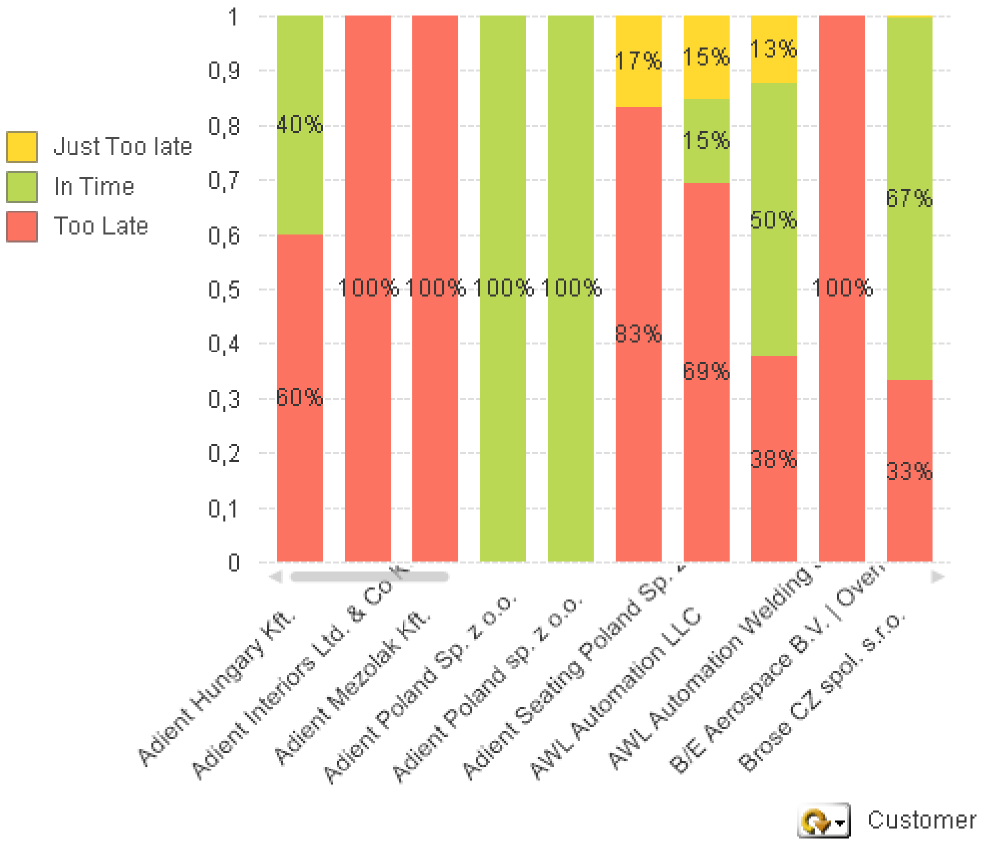

Figure 21 KPI On-time delivery

The fourth and final chart concerns productivity. Within AWL there is a distinction between direct hours and indirect hours. Direct hours are hours that can be billed to customers, so every hour that is booked as a *project hour, service hour,* or *support non-project* is a direct hour. The direct hours divided by the total worked hours is called productivity. This productivity per employee is depicted in Figure 22.

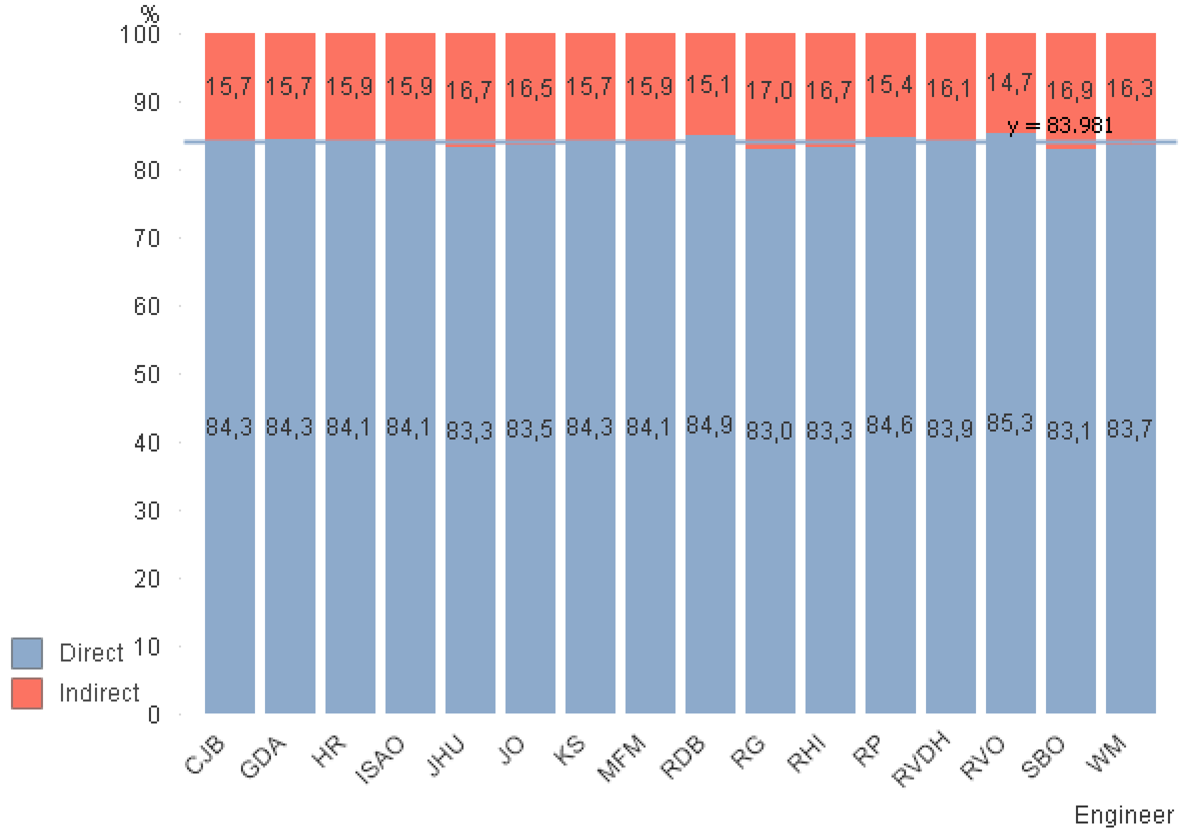

Figure 22 KPI Productivity

6.3. Data model

All these KPIs in the charts above are based on data. For this dashboard, most of the data is generated and therefore fictional. In a situation where the dashboard has been implemented, so it is linked to the ERP system and other data systems of the company, the data model can be built. In the current situation, this can be somewhat harder, because it is unknown how the tables with data exactly would look like. Assumptions have been made on how the different tables from the different sources probably would look like. These generated tables have been linked to each other in a way that can be seen in Figure 23. These linked tables form the data model for the dashboard.

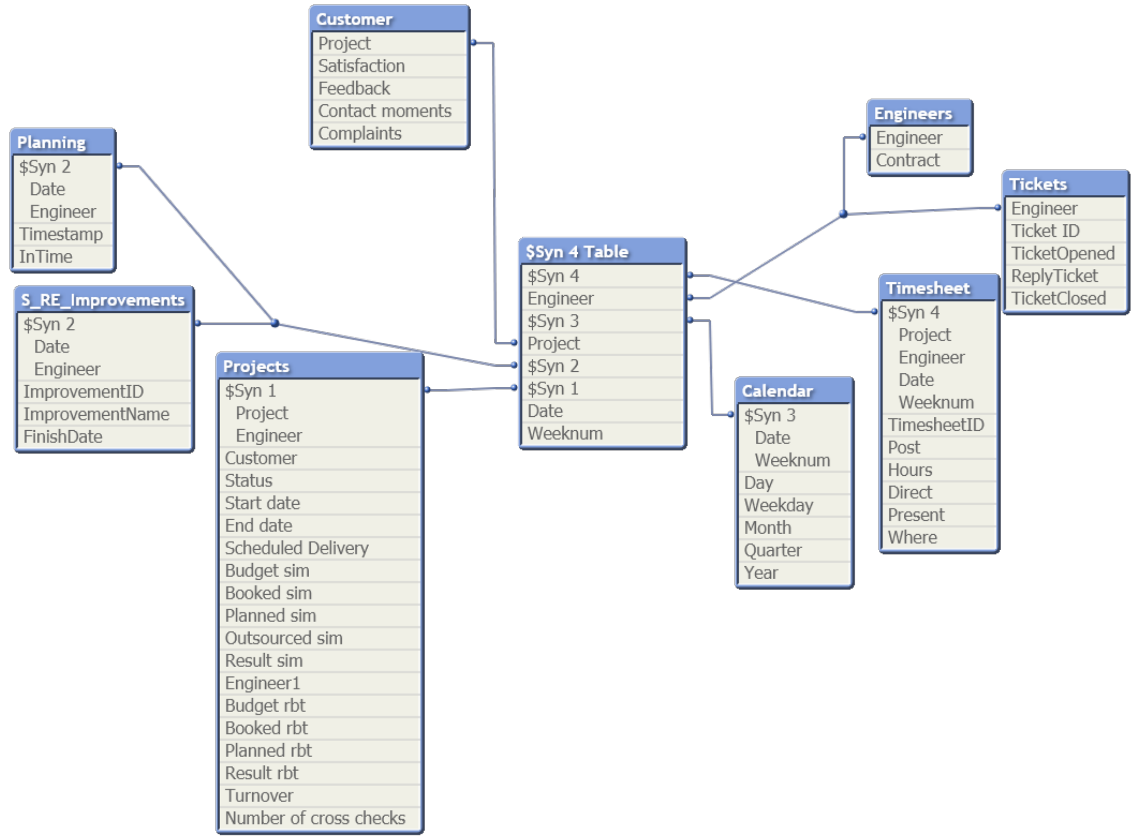

Figure 23 Qlikview data model

7. Evaluation, Conclusion & Discussion.

7.1. Evaluation

To see if the dashboard will be used, the dashboard needs to be evaluated. This was done by showing the developed dashboard to two managers of different departments of AWL, this was followed by a questionnaire about this dashboard. According to Venkatesh et al. (2003), the Unified Theory of Acceptance and Use of Technology (UTAUT) model can be used to evaluate if a certain technological product, in this case, a performance dashboard, can and will be accepted within an organization. Ventatesh et al. (2003) use a list of statements to estimate the UTAUT of the tested technology. This list, which can be found in Appendix 9.5, is used to evaluate the dashboard. The evaluation questionnaire was filled-in by the manager of S&RE and the manager of Robotics Operations.

The complete reactions on the questionnaire can be found in Appendix 9.6. The following paragraph is to summarize the results of the evaluation. Descriptive statistics are not included because this was assessed as having no added value since there are only two respondents.

It is expected that the dashboard will be useful for managers and will help them accomplish their tasks more quickly and therefore increase their productivity. Besides increasing productivity of managers, it can make communication about productivity clearer. It is expected that using and learning how-to-use the dashboard will take low effort. The respondents think using the dashboard is a good idea and it can make work more interesting, so they will like working with the dashboard. The social influence about the dashboard is rather low since not many people know about it within AWL. But it could be the case if the higher management thinks it should be implemented within the whole management layer. There are mixed signals about the facilitating conditions. The managers think they have enough knowledge to use the dashboard, but there is no person available for assistance if difficulties with the dashboard occur. Besides that, it is unknown if the required resources are already there and if the dashboard is compatible with other (already existing) dashboards. Both managers do not have an opinion on the self-efficacy of the dashboard. Generally, the respondents do not feel anxiety towards the dashboard. On the last topic, the behavioural intention to use the dashboard, one manager has no opinion about, the other thinks he is going to use the dashboard in the foreseeable future. To conclude, in general, the dashboard was evaluated positively although there are some doubts about the support if problems with the dashboard would occur.

7.2. Conclusion

During this research, multiple sub-questions are researched and answered to come to an answer to the main research question. In this chapter, the answers to the sub-questions and the main research question will be discussed.

1. What is the current situation of the processes in S&RE?

To answer this question interviews are conducted and the existing structure about the business processes within the department S&RE is researched. With this data, a new business process model is created to be able to see and deeply understand the processes in S&RE.

2. How to select Key Performance Indicators for S&RE?

There are several methods to select KPIs, examples of these are; the method from Horst and Weiss (2015), the Analytic Hierarchy Process (AHP), the KPI assessment method (KAM) from Hester et al. (2017), or the model from Coppola et al. (2014). Not every method is suitable for AWL's case. The KAM is taken as a method for the selection of the KPIs because it is specific for manufacturing companies and well-structured.

3. Which methods can be used for performance measurement?

Literature hands us several methods for measuring performance such as Performance Measurement Matrix (PMM), Supply Chain Operations Reference (SCOR), Balanced Scorecard (BSC), or the method from the department of energy of Nevada (DOE/NV). In this case, the Balanced Scorecard is chosen because it is well-known, applicable to multiple aspects of performance and is a method that is easy to understand.

4. How to visualize the selected KPI's?

Literature does not dictate a specific structure on visualizing KPIs; however, it provides some guidelines on how a dashboard can and should be shaped. Examples of these guidelines are; keep the complexity of the dashboard in line with the numeracy and graph literacy of the users, do not use too many colours, make sure the type of chart is in line with what the KPI should communicate and do not use too many metrics on a sheet.

How can AWL monitor the performance of the department Simulation & Robotics?

The manager of the department Simulation & Robotics can use the performance dashboard that is created in this research. This dashboard is developed with an understanding of the processes within the department, to select to most suitable Key Performance Indicators in the shape of the most suitable Performance Measurement Model with the guidelines of correct visualizations of KPIs. The performance dashboard is the tool to monitor the performance of S&RE in a glance.

7.3. Recommendations to the company

Firstly, to make the performance dashboard work, a data connection with the ERP system of the company is necessary. My first recommendation is to make sure the already available data from the ERP system can be loaded on the dashboard.

The dashboard as it is right now is not ready for use by managers. The data which is necessary to feed some of the KPIs is not created. This should be done by implementing a structured feedback loop when finishing projects. The data of the feedback loop can be visualized in the dashboard. The implementation of such a feedback loop is my second recommendation to AWL.

Lastly, the process of selecting KPIs was done with the department of Simulation & Robotics in mind. If the company would want to create this kind of performance dashboard for every department, the dashboard proposed in this research should be tweaked to the needs and wishes of the other departments. The selection of KPIs should be done separately for each department the selection with the KPI Assessment Methodology (KAM). (Hester, Ezell, Collins, Horst, & Lawsure, 2017)

7.4. Contribution to theory & practice

7.4.1. Contribution to Theory

In this research, the main topic is the combining of the selection of KPIs and the visualisation of those KPIs. The method of selecting KPIs (KAM) used in this research already existed (Hester, Ezell, Collins, Horst, & Lawsure, 2017). This method is specifically designed for manufacturing companies. This research proves that the KPI Assessment Methodology can also be used by an engineering department of a manufacturing company.

Most of the existing research on performance dashboards is focussed on company-level or is focussed on the sales department and only depicts sales-related KPIs. This research focuses on one department and is designed for the manager of this department. The selected department, an engineering department brings certain difficulties with it, since each project they work on is different it makes it hard to compare them. So, a performance dashboard for an engineering department needs to be fundamentally different from a dashboard for a sales department. The method of creating a performance dashboard is not new but applying this in an engineering department is.

7.4.2. Contribution to Practice

This research contributes mostly to the monitoring of the performance of a department. Before this research productivity was the only measure of performance, right now multiple dimensions are used. The dashboard can be used to highlight the strong and poorer parts or activities of the department, so the dashboard can be a foundation to make decisions on to achieve even better performance in the department. Also, the proposed method of selecting KPIs and creating a performance dashboard can be used in other departments to monitor and improve performance there.

7.5. Discussion

In this research, there are several discussion points on the results and on the research itself. These will be discussed in the following paragraph.

The results of this research are a methodology of selecting and displaying KPIs, and an example of how a dashboard for displaying these KPIs for an engineering department could look like. Although the evaluation of the dashboard is rather positive, there are doubts that the results are applicable to other businesses or branches. This has not been applied, and therefore it is uncertain that the methodology proposed in this research will be useful in other environments.

In the steps of assessing the criteria for the selection of the KPIs, only one stakeholder assessed the criteria and the KPIs. This could be biased and have a big influence on which KPIs are selected and which KPIs not. It would be better to let the criteria and KPIs be assessed by multiple stakeholders to avoid any bias.

Not every measure in the dashboard has a target value. If the indicators change over time, the manager does not always know if the indicator changed for the better or the worse. Besides that, the manager would want to know which of the KPIs are the furthest away from its target because this measure deserves the most attention, so it is ideal to have a target value for every KPI.

Another discussion point within the research is that some data for the KPIs are not available within the company or that the IT department of AWL is not willing to give access to all the necessary data. To overcome this lack of data access, most of the databases connected to the dashboard are fictional and semi-randomly generated. This is done to give a sense of how the dashboard would look like when it would be connected to the necessary databases.

This research is conducted as a bachelor's assignment. This means that the research should be carried out within ten weeks. This results in the fact that this research does not include the implementation of the dashboard. Step 5 of the DRSM, the evaluation of the artefact, is done slightly different than usual. Since the dashboard is not fully operational and not implemented yet, it was hard to observe and evaluate how the dashboard functions.

7.5.1. Future Work

In Recommendations to the company, one of the recommendations is about creating a feedback loop when projects are finished. This feedback loop could generate data that can be used for the KPIs in the dashboard. This feedback loop could be researched into detail on how to structure and implement such an idea within an engineering department.

For future work, this research could be replicated within a different but similar company to validate the results of the research. The combination of formulating, selecting and measuring KPIs with designing a dashboard to gain insights into the performance of a team needs a better validation with the discussion points of the paragraph above taken into account.

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9. Appendices.

9.1. Systematic Literature Review

Search string	Scope	Date	# of entries
Search protocol for Scopus			
"Dashboard design"	Title, keywords and abstract	27-09-2019	114
Search protocol for Web of Science			
"Dashboard design"	Topic or title	27-09-2019	39
Total in Endnote			
Removing duplicates			-30
Selecting based on exclusion criteria			-113
Removed after a complete reading			-3
Included after a complete reading			0
Total selected for review			**7**

Table 6 Systematic Literature Review

Nr.	Criteria	Reason for exclusion
1	Pre 2011-articles	The topic of Performance dashboard is rapidly changing, so articles before 2011 are not relevant
2	Automotive topics	These do not refer to Performance dashboards
3	Articles not in English or Dutch	These are not readable for the researcher
4	Learning dashboards topics	These do not refer to performance in companies
5	City dashboards topics	These do not refer to performance in companies

Table 7 Exclusion criteria SLR

Nr.	Title	Author	Subject
1	A framework for analyzing and developing dashboard templates for small and medium enterprises	Noonpakdee W., et al.	Dashboard framework
2	The impact of home care nurses' numeracy and graph literacy on comprehension of visual display information: Implications for dashboard design	Dowding D., et al.	Dashboard users
3	Perceiving learning at a glance: A systematic literature review of learning dashboard research	Schwendimann B.A., et al.	Learning dashboards
4	Supporting Healthcare Executive Managers' Decisions Through Dashboards	Erdem S., Kizilelma T.T., Vural C.A.	BI in healthcare
5	Reflecting design thinking: A case study of the process of designing dashboards	Cahyadi A., Prananto A.	Dashboard design
6	Constructing a design framework for performance dashboards	Lempinen H.	Dashboard framework
7	BI application: Dashboards for healthcare	Zhang X., Gallagher K., Goh S.	BI in healthcare

Table 8 Articles selected for review

9.2. KPI explanation

KPI	Explanation	Unit	Source
Capacity utilization	The number of hours worked in a period divided by the total number of hours that employees will work (according to their contract)	%	Timesheet
Complaints	The number of complaints related to the selected projects	#	Project surveys
Contact moments	The number of contact moments with other departments related to the selected projects	#	Project surveys
Employee satisfaction	The rate of satisfaction for each employee related to the selected projects	1-10	Project surveys
Feedback	The number of times feedback has been given to others related to the selected projects	#	Project surveys
Hours breakdown	Percentage of hours spent on the different items in Timesheet	%	Timesheet
Hours on customer site pp	Number of hours spent on the customer site in the selected period	#	Timesheet
Hours on work floor pp	Number of hours spent on the work floor in the selected period	#	Timesheet
Internal Customer satisfaction	The rate of satisfaction for each *customer* related to the selected projects	1-10	Project surveys
Number of cross checks	Number of cross checks performed within the selected projects	#	Project surveys
Number of current projects	The number of projects that the department is currently working on.	#	Navision
Number of tickets	Number of tickets that are open in the ticket system	#	Ticket system
On-time delivery	Percentage of projects that are delivered before the deadline	%	Navision
Outsourced hours	Number of hours that are outsourced per project	#	Navision
Overhead Cost	Hours that are worked, but cannot be related to any project and are therefore not billable	#	Navision
Overtime hours	Number of hours per employee that are worked more than their contract hours in the selected period	#	Timesheet
Productivity	Percentage of hours worked that are 'billable' to the customer i.e. the sum of hours worked on projects, service and support divided by the total worked hours	%	Timesheet
Reply time tickets	The average time it takes for a reply on a ticket	Time	Ticket system
S&RE improvements finished	"S&RE improvement" is a list of possible improvements for S&RE. This KPI is the number of improvements that are finished and implemented.	#	Excel file on the server
Service Hours	Number of hours worked on service for customers	#	Timesheet
Time kick-off - nominal assembly	The time between the start and the assembly per project	Time	Navision
Training hours	The number of hours spent on training and workshop in the selected period.	#	Timesheet
Turnover per employee	Turnover per employee	€	Navision
Turnover per project	Turnover per project	€	Navision
Update planning on time	Every week employees need to make their planning for the next week, they need to send this to the manager. This KPI displays the percentage of weeks that this planning was sent on time	%	Navision
Worked hours / budgeted hours	This KPI is the number of budgeted hours minus the number of worked hours per project, customer or employee	#	Navision

Table 9 KPI Explanation

9.3. Criterion Comparison

Right-click on Figure 24 and click on [worksheet object] -> [open], to access the complete comparison.

	11,43%
	accurate
Availability	6
Average hourly fee	8
Capacity utilization	7
Complaints	8
Contact moments	6
Employee satisfaction	5
Feedback	5
Hours breakdown	6
Hours on customer site pp	5
Hours on work floor pp	4
Internal Customer satisfaction	3
Mean time between failure (MTBF)	7
Number of cross checks	10
Number of current projects	9
Number of tickets	7
On-time delivery	8
Outsourced hours	10
Overhead Cost	5
Overtime hours	8
Percentage of outage due to changes (planned unavailability)	2
Percentage of outage due to incidents (unplanned unavailability)	4
Percentage of unit tests covering software code	3
Percentage of user requested features	4
Productivity	7
Quality assurance personnel as percentage of the number of application	2
Reply time tickets	8
S&RE improvements finished	7
Service Hours	9
Software development quality	2
System usability scale	2
Time kick-off - nominal assembly	6
Total service delivery penalties paid	4
Training hours	6
Turnover per employee	7
Turnover per project	8
Unit costs of IT services	2
Update planning on time	3
Worked hours/ budgeted hours	5

Figure 24 Criterion Comparison

9.4. Scoreboard KPI list

KPIs for Professional, Scientific, and Technical Services

KPIs	KPIs
Annual billable utilization percentage	Percentage of email spam messages stopped/detected
Availability	Percentage of outage due to changes (planned unavailability)
Availability (excluding planned downtime)	Percentage of outage due to incidents (unplanned unavailability)
The average percentage of CPU utilization	Percentage of service requests resolved within an agreed-on period
The average percentage of memory utilization	Percentage of systems covered by antivirus/antispyware software
Average hourly fee	Percentage of systems with the latest antivirus/antispyware signatures
The average number of virtual images per administrator	Percentage of time lost redeveloping applications as a result of source code loss
Cost of managing processes	Percentage of timesheets in need of correction/validation
Cost of service delivery	Percentage of unit tests covering software code
Deviation of the planned budget for SLA	Percentage of user-requested features
Downtime	Profit per project
Mean time to repair (MTTR)	Quality assurance personnel as a percentage of the number of application developers
Mean time between failure (MTBF)	Software development quality
Number of defects found over a period	System usability scale
Number of outstanding actions of last SLA review	Time ratio for design to development work
Percentage of application development work outsourced	Time-to-market of changes to existing products/services
Percentage of bugs found in-house	Total service delivery penalties paid
Percentage of consultants generating revenue	Unit costs of IT services
Percentage of consulting hours that generate revenue	Workforce turnover rate

Table 10 Scoreboard KPI list

9.5. Evaluation Form

Performance expectancy
I would find the dashboard useful in my job.
Using the dashboard enables me to accomplish tasks more quickly.
Using the dashboard increases my productivity.

Effort expectancy
My interaction with the dashboard would be clear and understandable.
It would be easy for me to become skilful at using the dashboard.
I would find the dashboard easy to use.
Learning to operate the dashboard is easy for me.

Attitude toward using technology
Using the dashboard is a good idea.
The dashboard makes work more interesting.
I like working with the dashboard.

Social influence
People who influence my behaviour think that I should use the dashboard.

People who are important to me think that I should use the dashboard.
In general, the organization has supported the use of the dashboard.

Facilitating conditions
I have the resources necessary to use the dashboard.
I have the knowledge necessary to use the dashboard.
The dashboard is compatible with other dashboards I use.
A specific person (or group) is available for assistance with dashboard difficulties.

Self-efficacy
I could complete a job or task using the dashboard...
If there was no one around to tell me what to do as I go.
If I could call someone for help if I got stuck.
If I had a lot of time to complete the job for which the software was provided.
If I had just the built-in help facility for assistance.

Anxiety
I feel apprehensive about using the dashboard.
It scares me to think that I could lose a lot of information using the dashboard by hitting the wrong key.
The dashboard is somewhat intimidating to me.

Behavioural intention to use the dashboard
I intend to use the dashboard in the next 4 months.
I predict I would use the dashboard in the next 4 months.
I plan to use the dashboard in the next 4 months

9.6. Reactions Evaluation

The first respondent, the manager of Simulation & Robotics, answered the questions or statements with a 5-point Likert scale. The second respondent, the manager of Robotics Operations, treated the questionnaire as if they are open questions. He did not answer the questions about self-efficacy, anxiety, and behavioural intentions to use the dashboard because: “The marked questions are not possible the answer with just an impression with the screenshots”.

Performance expectancy
I would find the dashboard useful in my job.

1. *Strongly agree*
2. *Yes, this can be a useful tool*

Using the dashboard enables me to accomplish tasks more quickly.

1. *Strongly agree*
2. *This is already partly done in the current Qlikview dashboard what I use a lot*

Using the dashboard increases my productivity.

1. *Strongly agree*
2. *I don’t think it will increase productivity (a lot) but I aspect it makes communication more clear*

Effort expectancy
My interaction with the dashboard would be clear and understandable.

1. *Agree*
2. *The overviews a logic*

It would be easy for me to become skilful at using the dashboard.

1. *Strongly agree*
2. *Yes*

I would find the dashboard easy to use.

1. *Agree*
2. *Yes*

Learning to operate the dashboard is easy for me.

1. *Strongly agree*
2. *For now, I only look at the screenshots, so this is hard to judge. With my current experience with Qlikview, I expect that this will be no issue*

Attitude toward using technology

Using the dashboard is a good idea.

1. *Strongly agree*
2. *Yes*

The dashboard makes work more interesting.

1. *Agree*
2. *For me, that is not the case*

I like working with the dashboard.

1. *Agree*
2. *Yes, it will help*

Social influence

People who influence my behaviour think that I should use the dashboard.

1. *Agree*
2. *I think this can be the case if it will be adapted in the whole management layer*

People who are important to me think that I should use the dashboard.

1. *Agree*
2. *This is not the case now*

In general, the organization has supported the use of the dashboard.

1. *Neutral*
2. *This is not the case now*

Facilitating conditions

I have the resources necessary to use the dashboard.

1. *Agree*
2. *No, I can inform my team during team meetings*

I have the knowledge necessary to use the dashboard.

1. *Strongly agree*
2. *Yes, I have this with the current dashboard*

The dashboard is compatible with other dashboards I use.

1. *Agree*
2. *I don't know*

A specific person (or group) is available for assistance with dashboard difficulties.

1. *Neutral*
2. *This is not the case now*

Self-efficacy

I could complete a job or task using the dashboard...

If there was no one around to tell me what to do as I go.

1. *Neutral*
2. *-*

If I could call someone for help if I got stuck.

1. *Neutral*
2. *-*

If I had a lot of time to complete the job for which the software was provided.

1. *Neutral*
2. *-*

If I had just the built-in help facility for assistance.

1. *Neutral*
2. *-*

Anxiety

I feel apprehensive about using the dashboard.

1. *Disagree*
2. *-*

It scares me to think that I could lose a lot of information using the dashboard by hitting the wrong key.

1. *Disagree*
2. *-*

The dashboard is somewhat intimidating to me.

1. *Strongly disagree*
2. *-*

Behavioural intention to use the dashboard

I intend to use the dashboard in the next 4 months.

1. *Strongly agree*
2. *-*

I predict I would use the dashboard in the next 4 months.

1. *Strongly agree*
2. *-*

I plan to use the dashboard in the next 4 months

1. *Strongly agree*
2. *–*