Bachelor Assignment at United Springs B.V.

United Springs

UNIVERSITY OF TWENTE.

Monitoring Material and Labour

'How can we monitor the labour hours and quantity of materials used per order during the production process?'

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This report is written in British English according to the documentation style within the Sogefi Group.

Abstract

In the high competitive environment of today it is important for companies to charge right prices for their products. This is so important, because too low prices can eventually lead to bankruptcy and too high prices will result in losing customers to competitors. To calculate a good price for a product, the costs per product are required. These costs are hard to determine when the processes within the company are not adapted to gathering the required information and developing such processes is a difficult and hard to structure project. Another obstacle in developing such processes is the fit in the organisation, most general methods do not take into account the other processes and context of the company. This report offers a model for developing a process for the monitoring of the quantity of material and the quantity of labour that is used for the production of a production order and also take into account the other processes and context of the company.

The methodology that is used for developing this method is the Design Science Research Methodology, which offers a six step method with multiple starting points. First the problem is identified and motivated, second the objectives of a solution are defined. The third step is to design and develop the method, which is demonstrated in the fourth step. The fifth step is to evaluate the demonstration and the sixth and last step is to communicate the method. The problem statement that is central in this report is: *'How can we monitor the labour hours and quantity of materials used per order during the production process?'* The associated purpose is to design a method for the development of a process for monitoring material and labour consumption.

Using the Design Science Research Methodology resulted in a two-phase model in which eight steps are fulfilled. The first phase is called the investigation and exists out of four steps: defining the project, analysing the context of the organisation, analysing the processes within the company and determining the main problem. The second phase of the method is called the development and also exists out of four steps: designing multiple solutions, choosing the best solution, communicating, evaluating and improving the solution and implementing the solution.

The demonstration of the method proved the method to be efficient and effective, also the practical perspective of the method proved to be very useful. Two aspects of the method turned out to be improvable. The first point for improvement is the involvement of the employees; these should be involved more in the investigation phase of the method. The second point for improvement is the moment at which information for different solutions is gathered from other companies; when the time horizon of a project is short, this should be done before multiple solutions are developed and not during the development. Also the use of the Analytical Hierarchy Process can be reconsidered.

The project resulted in an efficient and effective method for developing a process for monitoring the material and labour consumption. The practical perspective turned out to be an appreciated aspect of the method. The employee involvement and the moment at which the information gathering from other companies starts, are improved as result of the evaluation.

Introduction

In this report you will find the result of the bachelor assignment I did for United Springs B.V. as last stage of the bachelor program of the study Industrial Engineering and Management at the University of Twente.

The assignment is about developing a method for designing a process for the monitoring material and labour hours so that the costing of orders can be calculated. To accomplish this, different sources are used for analysing the current situation, improving the currently used method and making a plan for implementing the improved method. This method will be tested at United Springs B.V..

United Springs B.V. manufactures springs; the principle of a good spring has not changed that much since the start-up of the first company in 1923. This company was named B.V. Hengelose Verenfabriek Bakker. What did change is the quality, efficiency and technology of the production processes, the applications of new materials and the performance of the fabricated springs.

United Springs B.V. in Hengelo exists out of two business units. The first is evolved out of the Hengelose Verenfabriek Bakker and the second business unit is called Atlas. Hengelose Verenfabriek Bakker (HVB) mostly focuses on producing larger orders and the focus of Atlas is the smaller and more labour-intensive orders. United Springs B.V. is part of Allevard Rejna which is owned by the Sogefi Group.

Allevard Rejna Autosuspensions is currently one of the world's biggest manufacturers of stabilizer bars and coil springs for vehicle suspension. The company has two research and development centres together with twenty manufacturing and commercial sites spread over the globe [30].Like mentioned earlier, Allevard Rejna is part of the Sogefi Group. The Sogefi Group is a world leader in the design and manufacturing of engine filtration, air intake and cooling systems and flexible suspension components, both for the top vehicle manufacturers and the replacement markets [33].

United Springs B.V.is a solution-driven business and manufactures all sorts of springs: wireform springs, clock springs, torsion springs, compression springs, extension springs and pressings and flat forms. The company does not manufacture a catalogue of standard components; everything that is produced is made to meet or exceed the need of customers [35].

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1 Problem identification, motivation and solution objectives

This chapter is the start of the research and includes the first two steps of the methodology: the problem identification and motivation and the defining of the objectives of a solution, later in this chapter the whole methodology will be described. Also some general information about the company that commissioned this research, the demarcation of the research and the planning are included in this first chapter.

1.1 The Research

1.1.1 The Company

Like mentioned in the introduction, this report is about developing a method for designing a process for the monitoring material and labour hours so that the costing of orders can be calculated. This research is commissioned by and will be validated at United Springs B.V.. The company is established in Hengelo and is part of the Sogefi Group. The company produces a large variety of springs for different purposes. United Springs B.V. has about thirty employees of which about half are employed in the production. Unfortunately, there is a problem with keeping up the quantity of materials and the quantity of time used for manufacturing products.

Before the production of an order is started, the quantity of material and labour hours is estimated according to previous completed orders (estimating). When the order is completed the quantity of used materials (costing) needs to be calculated, however when this is done, the method used for determining these quantities are somewhat doubtful. This situation sometimes leads to differences in the estimating and costing, which is obviously not the ideal situation. The absence of a clear and stated method for performing the costing is central to this report.

1.1.2 Problem identification and motivation

Just like United Springs B.V., many small to medium size manufacturing companies do not succeed in determining their depth of production. This brings those companies into difficulties, because knowing the depth of production is very important for a company; it enables companies to determine the right price for their products. When the prices are not right, a company risks selling products for too high or too low prices what can lead to bankruptcy. When prices are too high, customers will buy somewhere else. When the prices are too low, not enough profit will be made to sustain the company.

1.1.3 Objectives of the solution

The purpose of the assignment is designing a method for the development of processes that monitor the costing of orders, or in other words, for developing a process for the monitoring of materials and labour hours so that companies can determine their depth of production. The focus on material and labour consumption is according the assignment stated by the commissioning company. A process for monitoring the labour and quantity of material used during the production will help companies to determine better prices for their products so they can compete against other small and medium size companies without risking bankruptcy.

1.1.4 The Problem Statement

To solve the problem a general problem statement is formulated and some research questions are stated:

'How can we monitor the labour hours and quantity of materials used per order during the production process?'

Definitions:

- Monitoring: observing and collecting information about something during time on a distance with a purpose.
- Materials: raw materials that are integrated during the production process into end products. This does not include materials like: screws, bolts, nuts, tools, etc.
- Order: a request coming from a customer for a specified number of products.

1.2 Research Questions

To give an answer to the problem statement some research questions are formulated to get a better insight into the situation as it is at this moment and into how the situation could be in the future. The research questions and sub research questions are described in this paragraph and its sub paragraphs; this includes an explanation of the value for the research and the approach for each question. The research questions are:

- How is a good method for developing a process developed?
- What is a suitable method for developing a process for monitoring the material consumption and labour hours?
- How can this method be tested?
    - What does the production process of United Springs B.V. look like?
    - What does the process which the materials pass through look like?
    - Which method does United Springs B.V. use for monitoring the materials and labour hours?
    - What causes the differences between the estimating and the costing?

1.2.1 How is a good method for designing a process developed?

The goal of this assignment is the development of a method. To develop a good method it is necessary to know out of which elements a suitable method exist. This research question has as purpose to gather insights into how to compose and what is necessary for composing a good method. The answer to this research question will be found by a literature study. Also much knowledge that is gathered during the bachelor program of Industrial Engineering and Management will be useful.

1.2.2 What is a suitable method for developing a process for monitoring the material consumption and labour hours?

This research question aims to combine all gathered knowledge and information to a method that could be suitable as solution for the stated problem. This method will be tested according to the next research question.

1.2.3 How can this method be tested?

The last research question is the validation of the developed method. United Springs B.V. will be used for this validation and several sub research questions have been stated to guide the validation process. These sub research questions are listed in the following paragraphs 1.2.3.1 to 1.2.3.4.

1.2.3.1 What does the production process of United Springs B.V. look like?

This first sub research question is very important because of two reasons, namely: (1) it is important to map the current situation so that any problems can occur and (2) it is important to be able to put any decisions or assumptions in the perspectives of the company.

In order to be able to map the production process different steps have to be taken. The book 'Operations Management' [23] will help to map the characteristics of the production process, the book 'Business Process Management' [40] will help to map the processes and the book 'Business Intelligence' [7] will be used to analyse the Enterprise Resource Planning system (ERP-system).

The information that is necessary for answering this research question will be almost entirely gathered by interviews with employees of United Springs B.V. and visits to the production line. Also documentation on Vantage, the ERP-system, will be part of the used information.

1.2.3.2 What does the process which the materials pass through look like?

The reasons of importance of this sub research question are the same as that of the previous research question; however the process of the materials is so important for this research that it demands a separate research question. The reasons of importance are: (1) it is important to map the current situation so that any problems can occur and (2) it is important to be able to put any decisions or assumptions in the perspectives of the company.

To answer this research question the book 'Business Process Management' [40] will be used to map the process. Furthermore, the process will be described according to the available information. The information that is necessary for answering this research question will almost entirely gathered by interviews with employees of United Springs B.V. and visits to the production line.

1.2.3.3 Which method does United Springs B.V. use for monitoring the materials and labour hours?

To be able to do an appropriate recommendation in the end, it is necessary to know whether a modification to the current method could be more efficient than implementing a new method. Therefore, the current method for monitoring material and labour hours has to be known. This way it is possible to uncover negative and positive aspects of current method. Negative elements will be avoided and positive aspects can be integrated in the end solution.

The information that is necessary for answering this sub research question will almost entirely be gathered by interviews with employees of United Springs B.V. and visits to the production line. Literature will play a minor role, because this is more a describing question.

1.2.3.4 What causes the differences between the estimating and the costing?

To fulfil the process successfully the cause of the problem has to be clear. Most of the previous research questions have as purpose to gather insights in the situation as it is at this moment. In this research question the cause of the problem is uncovered. On the basis of this cause a solution can be searched. Literature about finding 'the problem' [36] can help.

1.3 Methodology

In this paragraph the used methodology will be described and the demarcation of the research components will be stated. Like stated in paragraph 1.1.3., this research is about designing a scientific method for the development of a method for the monitoring of labour and material during the production process. Pfeffer et al. [16] designed a process model for carrying out design science research based on several papers, which resulted in a commonly accepted framework for carrying out this kind of research and therefore is a good methodology for this research. The steps of this research methodology and their relation to the structure of the report are described in the following paragraph 1.3.1..

1.3.1 Design Science Research Methodology (DSRM)

The DSRM exists out of six steps which are graphically illustrated in Figure 1. The step at which a research begins, depends on the characteristics of the research, this is visible in the box concluding the *Possible Research Entry Points.* This research is problem orientated and so starts at step one.

The first step is the problem identification and motivation, which includes the definition of the specific research problem and the justification of the value of a solution to that problem. Justifying the value of a solution motivates the researcher and the audience of the research to pursue the solution and helps to understand the reasoning associated with the researcher's understanding of the problem. This step is fulfilled in paragraph 1.1.2..

The second step in the DSRM is the defining of the objectives for a solution; this can be quantitative objectives or qualitative objectives. Quantitative objectives are in terms of in which a desirable solution would be better than current ones. Qualitative objectives are descriptions of how a new method is expected to support solutions to the problem. In the case of this research the objectives are qualitative and feasible. The objectives are stated in paragraph 1.1.3..

The third step is the design and development of the artefact, or in this case the method. This includes determination of the desired functionality and the transformation of the solution's objectives into an artefact using knowledge and literature. The literature study is presented in chapter 2 and the actual designing of the method is presented in chapter 3.

During the fourth step United Springs B.V. is involved in the research for the demonstration or validation of the designed method. The company will be used as case study to solve a related problem using the developed method. This step is elaborated in chapter 4.

In the fifth step the developed artefact is evaluated by observing and measuring how well the artefact supports a solution to the problem. This involves comparing the objectives of a solution to actual observed results of the artefact in the demonstration. After the evaluation the researcher(s) can decide to go back to step three, the design and development, to improve the effectiveness of the artefact or to continue to the sixth step, the communication. This evaluation is elaborated in chapter 5.

The sixth step is the communication of the developed artefact, this includes the communication of: the problem and its performance, the artefact, its utility and novelty, the rigor of its design and its effectiveness to researches and other relevant audiences. This step is fulfilled as a conclusion in chapter 6.

A graphical representation of the research steps and the associated chapters in this report is shown in Figure 2.

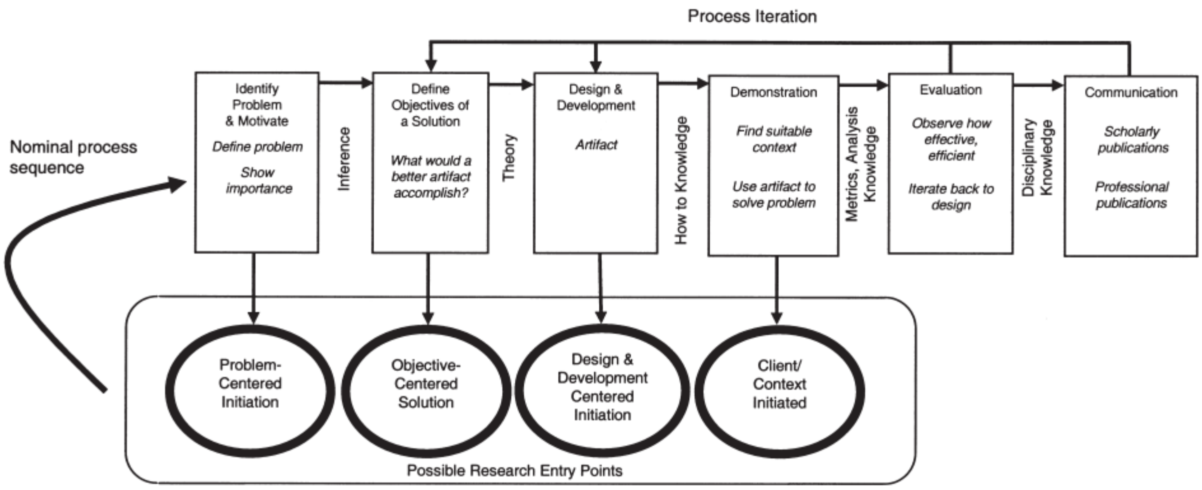

Figure 1. DSRM Process Model.

Step of the DSRM	Description	Related report chapter(s)
Step 1	Problem identification and motivation	Chapter 1
Step 2	Defining of the objectives of a solution	Chapter 1
Step 3	Design and development of the artefact	Chapter 2 and Chapter 3
Step 4	The demonstration of the artefact	Chapter 4
Step 5	The evaluation of the artefact	Chapter 5
Step 6	The communication of the research	Chapter 6

Figure 2. Steps of the DSRM and the related chapters in this report.

1.3.2 Demarcation

In this paragraph the research is delimited so that the scope of the research is feasible and the efficiency is guaranteed.

During this research only the processes of materials and labour within United Springs B.V. are treated. For material this includes the production line and the warehouse. For labour this includes the hours used for producing the end products, the 'overhead' employees are not included in this assignment.

In chapter 4 the production process will be split into two parts, the Hengelose Verenfabriek Bakker part and the Atlas part. Atlas has its own production line and warehouse and is not part of this research, because it is a small fraction of the company, which is working in a traditional method on smaller and more project-orientated orders.

Like stated in the definitions in the problem statement this assignment includes the use of raw materials that are used for integration in the end product. This does not include materials like: screws, bolts, nuts, tools etc.

The implementation of the solution is not part of this assignment. However, a start of a plan for implementation is included. This contains some important issues according the implementation and a method for performing the implementation.

During the literature study the following research fields are investigated: organisation characteristics, cost management, business process management, problem finding in organisations, method engineering, decision processes, and research evaluation. Why this research fields are relevant to the research is explained in the next chapter.

2 Design and Development: Literature study

This chapter is part of step three of the Design Science Research Methodology, the design and development of the artefact. This third step includes a literature study and using the knowledge that is gathered during that literature study for transforming the solution objectives into an artefact in chapter 3. This chapter is about the literature study and includes the comparison of multiple sources for different research fields and their link to each other and the research, with as purpose to answer one of the research questions. This research questions is *'How is a good method for designing a process developed?'* The fields that are investigated are organisation characteristics, cost management, business process management, problem finding in organisations, method engineering, decision processes, and research evaluation.

2.1 Organisation Characteristics

This paragraph is about literature on organisation characteristics, the purpose of this part of the literature study is to be able to understand how to analyse what the culture within an organisation looks like. Knowing the organisational culture is very important, because it makes it possible for the researcher to make small instinctive decisions and assumptions that fit the company. When these small instinctive decisions and assumptions fit the company, the change that the developed solution will be successfully implemented will increase. The paragraph is divided into three parts: the management style, the organisation and the factors that influence the organisation.

2.1.1 The management style

This section is about the management style of a company. The management style of a company determines the way of: cooperation, decision-making, problem solving and interaction in that company. Knowing these manners is important when a method for the development of a process for monitoring labour and material is developed, because it enables the researcher to act conform the organisational context and thereby helps to develop a solution to a problem that fits the organisation.

Boddy [4] divides management styles according to a trade-off between internal and external orientation and a trade-off between the focus and flexibility of an organisation, based on the competing values framework [27] visible in Figure 3. This results in a controlling, collaborating, competing or creating management style. The limitation of this method is that it does not take into account the nature of the production process in a company; it is more a model for non-manufacturing companies.

Where the competing values framework does not take into account the nature of manufacturing processes, the model developed by Shenhar does. Shenhar [31] divides management styles into a conservative style, an entrepreneurial style and a compromise between those two styles, according to the level of technological uncertainty and the scope of the system, see Figure 4.

The scope dimension of this model is classified into three levels: the assembly-level, the system-level or the array-level. An assembly-level process exists out of one or two tasks, for example the assembly of an automobile windshield. A system-level process exists out of multiple assembly-level systems, for example a manufacturing company. An array-level process exists out of multiple system-level processes and is mostly geographically spread, this are mostly big companies that have many subsidiaries around the world.

The technologic uncertainty dimension is divided in four levels according to the level of technology in the company: low-tech (almost no new technologies), medium-tech (less than fifty percent new technologies), high-tech (more than fifty percent new technologies) and super high-tech (almost only new technologies). New technologies are technologies of the latest generation. Low-tech companies have low technologic uncertainty and super high-tech companies have high technologic uncertainty.

Figure 3. The competing values framework.

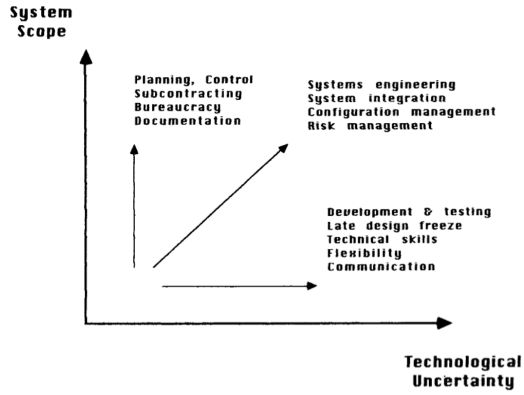

Figure 4. Shenhar's model for management styles.

Where Boddy and Shenhar use the characteristics of the organisations for the determination of the management style, McRitchie [21] focuses on the characteristics of the manager himself or herself. She distinguishes the following management characteristics: a reactive style, micromanaging, inconsistency, avoidance, emotional intelligence, undermanagement, bullies and listening skills. Whether these characteristics are good or bad and a short description of every characteristic is given in Figure 5.

Characteristic	Description	Good or Bad
Reactive	Only act when problems occur.	Bad
Micromanaging	Communicate lack of trust and level of incompetence.	Bad
Inconsistency	State a policy, but allows many exceptions.	Bad
Avoidance	Being afraid of stepping out of the comfort zone.	Bad
Emotional Intelligence	Knowing that feelings of employees do effect the organisation.	Good
Under Management	Well performing team members that get responsibility without training.	Bad
Bullies	Collection of characteristics that characterize the 'in one's own way' managers.	Bad
Listening Skills	Having good listening skills benefits the manager and the employees.	Good

Figure 5. Management characteristics according to Karen McRitchie.

2.1.2 The organisation

Where the management style treated in previous paragraph characterizes the management of an organisation, the organisation itself is also part of the characteristics of an organisation. This involves the structure of the organisation, the internal environment and the external environment. Knowing these characteristics enables the researcher to develop a method that is taking into account all the factors that influence the company.

Understanding the structure of an organisation is very important, because it shows the division of functions and departments what makes it able to understand the processes and tasks within the organisation.

According to Mintzberg [22] the structure of the organisation can be defined by vertical specialisation or horizontal specialisation. Vertical specialisation refers to which responsibilities there are defined at different levels. Horizontal specialisation refers to the degree to which tasks are divided among separate employees, teams or departments. The limitation to this method is that it is too simple, too limited, for the analysis of the current complicated organisational structures.

Another way of analysing the structure of a company is looking whether the company is centralized or decentralized. In a centralized company the decisions are taken at the top of the company. When the structure of a company is decentralized, the decisions are taken further down below in the company. This method is also very limited, because it does not tell anything about the division in the company.

Boddy [4] grouped jobs into: functions, divisions, matrices, teams and networks, see Figure 6. By a graphical illustration of these organisation structures, the structure of a company can easily be determined by comparison of the organisation overview with Boddy's graphical illustrations.

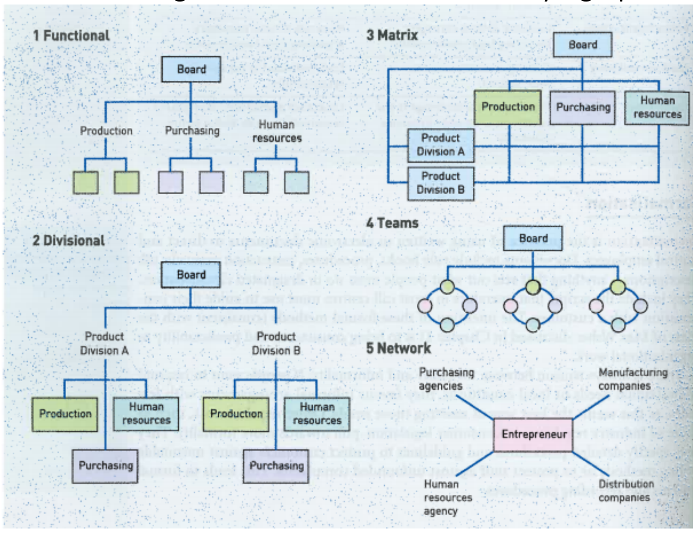

Figure 6. Five organisation structures.

Another characteristic of a manufacturing company is the production process. It is important to know the production process when a method is developed, because the method has to be applied in that production process. When a method does not fit within the context of a production process, the implementation will delay more difficult or will fail.

Slack [23] gives several distinctive objectives for describing production processes. Besides the general objectives like the: throughput rate, throughput time, work in process and process utilization the book also describes several service and manufacturing process types. These different process types are based on different volume quantities and degree of variety and graphically displayed in Figure 7.

Processes are most efficient when the production method belonging to the process type is according to the characteristics of the production process. So a project production process should have a low volume and a high variety, when this is not the case higher costs are the consequence.

Process Type	Characteristics
Project Processes	Discrete and high customized with a long timescale. Low volume and high variety.
Jobbing Processes	Like Project Processes, but with shared operations resources.
Batch Processes	Like Jobbing Processes, but lower variety.
Mass Processes	High volume, low variety.
Continuous Processes	Even higher volumes and almost no variety.
Professional Services	High contact organisations where customers spend a considerable time in the process. High levels of customization.
Service Shops	Mixes of front office and back-office. Characterized by levels of customer contact, customization, volumes of customers and staff discretion. Positioned between Professional services and mass services.
Mass Services	Many customer transactions, involving limited contact time and little customization.

Figure 7. Manufacturing and Service Process types and characteristics (Slack [23]).

2.1.3 Factors that influence the organisation's strategy

This section is about internal and external factors that influence the company. For the understanding of an organisation it is important to know the environment the organisation is competing in, this includes internal and external factors. When these factors are known and the power and the effect of these factors are also known, the development of the method can be adjusted to that environment to ensure a good fit and a smooth implementation.

According to the SWOT analyse developed by Humphrey, the strategy of a company follows out of the fit between the external and internal capabilities. A SWOT analysis is a way of summarising the organisation's strengths and weaknesses relative to external opportunities and threats. The limitation of the SWOT analysis is the fact that it does not include any kind of context to the environment of the organisation.

Forces in the wider world also shape the policies of managers and organisations, the PESTLE analysis helps to indentify the following five external forces: Political, Economic, Socio Cultural, Technological, Environmental and Legal [4]. In comparison to the SWOT analyse, the PESTLE analysis analyses the context of the organisation better, but still does not investigates the competitive environment.

Managers and companies are most affected by their immediate competitive environment, which exists out of five forces. Porter [25] developed a methodology for analysing these forces, which are: potential entrants, industrial competitors, buyers, suppliers and substitutes. The collective strength of these forces determines the profitability of the industry a company is in. The stronger the forces, the less profitable the industry is and vice versa.

2.1.4 Organisation Characteristics: Conclusion

In this paragraph multiple ways to analyse the characteristics of an organisation are treated. These techniques are divided into three parts: the management style, the organisation and the factors that influence the organisation. These three parts and the techniques for each part are summarized in Figure 8.

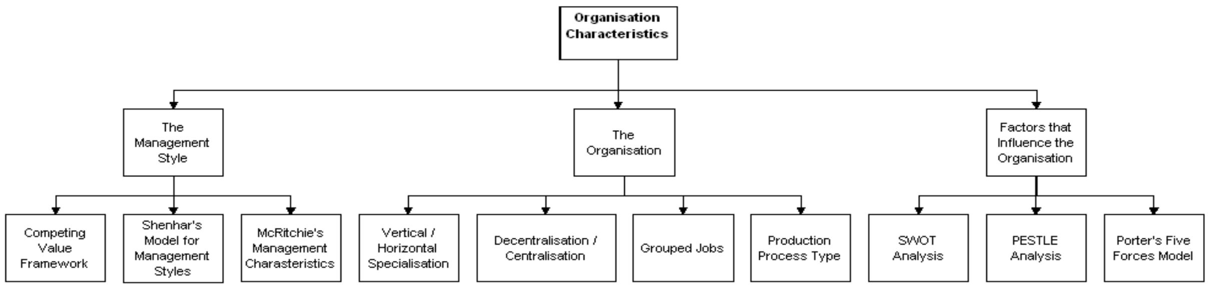

Figure 8. Overview of different techniques for analysing company characteristics.

2.2 Cost Management

This paragraph is about the research field called cost management, literature on this research field can offer methods that have been developed earlier and which can serve as inspiration or guide when a new method is developed.

This research is about developing a method for the monitoring of labour and material, this suggest that the companies on which this method will be applied do not have a monitoring system and therefore use traditional cost management. Because of that, literature about these traditional cost management methods is inapplicable.

This paragraph will be divided into three different parts: first an overarching methodology called Activity Based Costing is brought to the attention, second the existing material monitoring techniques are treated and third the existing techniques for the monitoring of labour hours are treated.

Activity Based Costing is based on a management philosophy called Activity Costing and Input-Output Accounting [34]. Activity Based Costing gives companies a clear insight into the distribution of costs, so that the cost price of products can be calculated accurately. Fixed costs, variable costs and overhead costs are allocated to departments, teams or products.

However, Activity Based Costing is a management philosophy, not a way for determining the depth of production.

Data is needed for the determination of the depth of production. Different approaches have been developed during the years for gathering this data. A good example for gathering data on material is the application of RFID-chips [32]; also the automation of material management [2] and even barcodes can be used for intelligent warehousing [29].

Just like the monitoring of materials, there are different approaches developed for the monitoring of labour. Some rough methods like clocking before and after work and some more refined approaches like magnet keys on cash registers. All of these are attributes to overarching methods.

All these methods are performances on the lowest level in organisations and thereby attributes to a higher-level method for dealing with material use and costs like the Activity Based Costing methodology.

2.3 Business Process Modelling

This paragraph is about literature on different techniques or languages for Business Process Modelling. The whole research is about developing a method for the (re-) engineering of business processes for the monitoring of labour and material, so it is important that the right technique is chosen for the modelling of the processes. Literature about Business Process (Re-) Engineering is discussed in paragraph 2.5.

There are three standards regarding to Business Process Modelling Languages: BPEL, XPDL and BPMN. BPEL, or Business Process Execution Language, is an execution language of which the goal is to provide a definition of web service orchestration [9].

The goal of XPDL, or XML Process Definition Language, is to store and exchange process diagrams [26]. It enables development of a process model in a modelling tool that can be read and edited by another modelling tool. So a XPDL can be transformed into a BPEL model, but a BPEL model cannot be transformed into a XPDL model.

The third Business Process Modelling Language is the Business Process Modelling Notation or BPMN [40]. This is the most used language for displaying a Business Process Model. *"The Business Process Modelling Notation is a standard for capturing business processes in the early phases of systems development."*[28]

The three different Business Process Modelling Languages and their expertises are summarized in Figure 9.

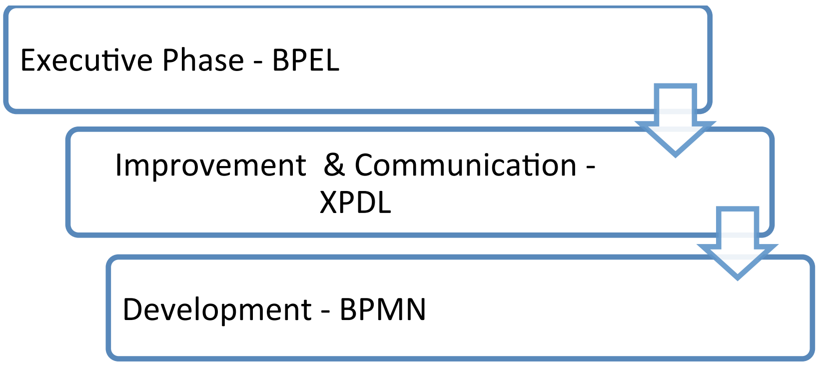

Figure 9. Business Process Modelling standards.

2.4 Problem Finding in Organisations

This paragraph is about literature on finding the problem that causes the bad functioning of a monitoring system for monitoring labour and material in an organisation or the absence of such a monitoring system. Literature on this topic is crucial to the research, because the right problem has to be tackled to end up with a method that solves the problems that really matter.

The first approach is a more science-oriented approach, which include the determination of the problem by defining variables and modelling the problem mathematically [36]. The limitation of these kinds of methods is that it becomes extreme complex very quick and when multiple problems occur it is very difficult to keep an overview of their relation to each other and the main problem.

For those situations Heerkens and Van Winden [11] use the so called 'probleemkluwen', or problem tangle in English. The problem tangle is part of the 'Algemene Bedrijfskunde Probleemaanpak' and suits more practical cases where there are many problems. In a problem tangle these problems are linked to each other with causal relations, with as goal to lead to one or more main problems, see Figure 10.

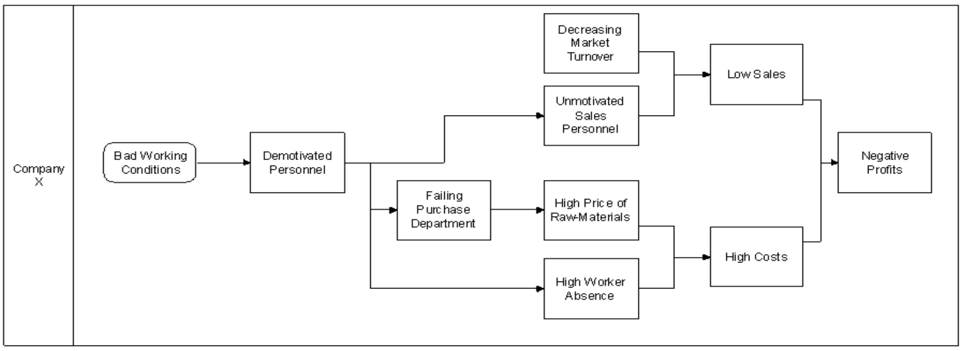

Figure 10. Illustration of a problem tangle.

2.5 Method Engineering

This paragraph is about literature on Method Engineering or Business Process (Re) Design. This is where the research is about and therefore the most important research field.

The handbook 'Business Process Engineering' [12] gives a rough roadmap for what has to be done when a process is (re)designed, but it does not give detailed information of the steps and the success factors of these steps. The methodology suggests a four step plan for the designing of guidelines for the development of a new method. The four steps handed by the handbook 'Business Process Engineering' are:

- Determining the scope of the research/redesign
- Determining the design essentials
- Designing
- Implementation

The handbook also suggests making use of the following points of interest:

- Workplace — ideas coming from employees can help to improve the design. It is not recommended to involve operational workers into decision making processes.
- Arrangement — thinking of the implementation from the start of the process helps to generate a realistic method.
- Copy — making use of (parts of) existing methods can increase the speed of a designing process.

Furthermore, it is recommended to capture the choices, which are made during the process. The purpose of this is to know what can be adjusted when the developed method has to be redesigned.

The handbook for Business Process Engineering does not give an insight into the deeper aspects of the development of a business process, the article 'Business Process Change' by Kettinger [38] does. Kettinger gives the following general introduction on Business Process Redesign: *'...it has been analysed from many perspectives and the overall conclusion is that it is a real organizational change.'* Furthermore, in the beginning Business Process Management was characterized by some kind of trial and error process that had a more chaotic image. This was mostly caused by the bureaucratic and conservative properties of organizations. Nowadays the Business Process Redesign environment and approach are more structured and people get more and more familiar with applying it.

To understand Business Process Redesign better Kettinger initialized three levels of abstraction:

Methodology	… a collection of problem-solving methods governed by a set of principles and a common philosophy for solving targeted problems. [5]
Technique	… a set of precisely described procedures for achieving a standard task. [17]
Tool	… a computer software package to support one or more techniques. [24]

Kettinger also gives an overview of what factors influence processes, see appendix A. These factors can be used when designing a method; all these factors should be taken into account. The five factors each have their own characteristics; in Figure 11 the factors and their characteristics are represented.

Factor	Characteristics
Business Processes	• Inter-Organisational • Cross-Functional • Intra-Functional
Management	• Style • Systems • Measures • Risk Propensity
Information & Technology	• Data and Information • Information Technology • Decision, Simulation & Modelling Tools • Production Technology
Structure	• Formal or Informal Organisations • Teams/Work Groups • Coordination/Control • Jobs
People	• Skills • Behaviour • Culture • Values

Figure 11. Factors that influence business processes and their characteristics.

2.6 Decision Processes

This paragraph is about methods that can be used for choosing between multiple alternatives. In the end phase of a project a choice has to be made between multiple solutions, literature on decision processes will help designing the decision part of the end phase. In general there are two ways of choosing between several alternatives, by logical thinking and discussion with other actors or by using a Multi Criteria Decision Analysis method.

When a choice is made by logical thinking there is a big change that some important things are missed. When it is discussed in a group that change is smaller, but there is a chance that not the best alternative wins, but the person that is best in convincing the others.

When a Multi Criteria Decision-making technique is used, there is still a subjective flavour on the decision, but it is far more structured and some techniques even support justification of the choices that are made. There are three main techniques for Multi Criteria Decision-making, each with its positive and negative aspects: MAUT, SMART and AHP [39].

The Multi Attribute Utility Theory (MAUT) [39] is a technique for making decisions in which high risks are involved, there has to be an uncertainty about factors that are relevant to the decision. It suits simple cases that involve risk, like lotteries, but gets very complicated when multiple criteria are involved.

The Simple Multi-Attribute Rating Technique (SMART) [15] is a technique that divides the large complicated decision into smaller simpler decisions. These criteria get a weight and the attributes score at each criteria. The sum of the scores of the alternatives on the different weighted criteria gives the end score. The scores of the criteria and the alternatives are determined by the use of swing weights. The method called swing weights means that the alternatives are divided on a scale from zero to one hundred (0-100), with zero equal to the worst alternative and one hundred the best alternative. When three alternatives are compared and alternative A scores twenty points, alternative B scores sixty points and alternative C scores eighty points, the improvement of going from alternative A to alternative C (a ‘swing’ of forty points) should be twice as beneficial as a ‘swing’ from alternative A to alternative B (a ‘swing’ of twenty points).

The positive thing about SMART is that it makes it easier for decision makers to handle large and complicated decision. The negative side of the SMART method is the fact that dividing the problem in smaller problems can cause the decision maker to lose sight of the goal of the problem. Losing sight to the goal of the decision process can lead to wrong decisions.

The last method for handling large and difficult decision processes is the Analytic Hierarchy Process (AHP) [41]. The AHP is widely applied to decision problems in areas such as economics and planning, energy policy, material handling and purchasing, project selection, microcomputer selection, budget allocation and forecasting. The process starts with the mapping of the different attributes and alternatives. Next scores are given by comparing two attributes or two alternatives and determine if the one is more important than the other on a scale from one to nine. The next step is to transform these comparisons into weights and afterwards compare the scores of the different options. The last step is to perform a sensitivity analysis.

The good thing about AHP is that the pairwise comparisons are quite easy to make and can be checked on consistency. Criticisms of the AHP method mention the conversion from verbal to numeric scale and the numbering of the scale, they also mention that it is difficult to add new alternatives and the number of comparisons may be large.

This section was about different methods for making decisions in an organisational context. The method that is sufficient for smaller risk related problems is MAUT. The method that is best for more operational and medium large decisions is the AHP. SMART can be used when very large decisions have to be made and it is useful to split the large problem into smaller problems.

2.7 Research Evaluation

This section is about literature on the evaluation of a developed method or process. Evaluation of the developed method is crucial, because it enables the developer to find small or large bugs in his or her design that hinder the functioning of the method. Also possible shortcomings or redundancies can occur.

Aydin [1] developed a generic model for the Model Adaptation Process and identified four factors that influence the adaptation of a method. The first and overarching factor is the situation of the adaption process. The other factors are the agent, the context and fragment.

The situation is a collection of an agent, a context and a fragment at a certain time. The agent is situated at a certain time and plays one or more of the following roles: proposer, designer, mediator or user. The context at a certain time includes all kinds of characteristics and their relations to each other. The fragment is induced at a certain time and is constituted in terms of three dimensions: characteristics, intention and actions.

Aydin's model is very useful for understanding the adaptation process of a method, but does not provide a researcher with a method that can be used in practice.

Just like Aydin, the handbook 'Business Process Engineering' [12] describes the role of the evaluation process and that it should be done, but not how that should be done. Mansar, Reijers and Liman [20] developed a framework for testing a developed method.

They use the work of Brand and Van der Kolk [18] who distinguish four main dimensions in the effects of redesign measures. These dimensions are: time, costs, quality and flexibility. The book 'Operations Management' [23] adds dependability to these dimensions. The evaluation takes place by looking to these dimensions and look in which way they are affected. When the effects are in accordance with the desired effects the evaluation is positive, when this is not the case the process has to be redesigned.

It is important to agree in advance what the desired effects on the dimensions of effects are. Also the awareness of the trade-offs between the dimensions, the 'devil's quadrangle' [18], is important, see Figure 12. This means that a strong effect on the cost dimension can cause a reduced effect on the quality dimension. It is even possible that the strong effect on the cost dimension causes a negative effect on the quality dimension. Therefore, it is important to define the desired and expected outcomes of the validation of the designed process. When the desired effects are compared to the actual effects, the fit within the organization is tested. Looking at the expected effects and the actual effects, the way of working can be reflected.

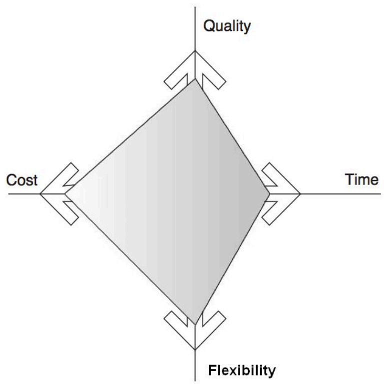

Figure 12. Devil's Quadrangle.

2.8 Literature study: The conclusion

In this chapter the first part of step three of the Design Science Research Methodology is described, this step contains the literature study to gather knowledge to be able to transform the objectives of the solution into an artefact in the next chapter. During this literature research the following research fields were investigated: organisation characteristics, cost management, business process management, problem finding in organisations, method engineering, decision processes and research evaluation.

Some of the literature found in these research fields is used for a general knowledge base and other literature is used for use in the development of the method or to answer a research question. In this paragraph one research question is answered as conclusion of the literature study, this question is *'How is a good method for designing a process developed?'*.

In general the development of a method exists out of two phases, the exploratory phase and an executive phase. In the exploratory phase the project and context of the project are investigated. In the executive phase the result of the project is designed and used.

Moreover, the exploratory phase is not only about investigating the project and the context of the project; it is also about investigating the context of the company that commissions the project, so that the result of the project will be satisfactory. The investigation on the project is about the purpose of the project and the theoretical part of the project, the methodology that will be used. The research on the company is about the characteristics of the company and the expectations of the company.

Of course, the exploratory phase of the method is not only about the design and use of a method, because this suggests that the developed method is perfect operating from the start. It is more plausible that multiple aspects of the method turn out to be not practical at all or that some crucial aspects are missing. Therefore the developed method has to be validated and adjusted according to gathered insights after evaluation.

3 Design and Development: The method

This chapter is about answering the research question *'What is a suitable method for developing a process for monitoring the material consumption and labour hours?'*, or in other words, the design and development of the method for designing a monitoring process for labour and material. The method exists out of two parts, according to the exploratory and executive phase of the method defined in chapter 2. The first part is called *Investigation* and includes the scope of the project, the context of the company, the analysis of the processes within the company and the determination of the main problem. The second part is called *Development*, which includes the design of multiple solutions, the decision process, the communication and improvement and the implementation. See Figure 13 for the model.

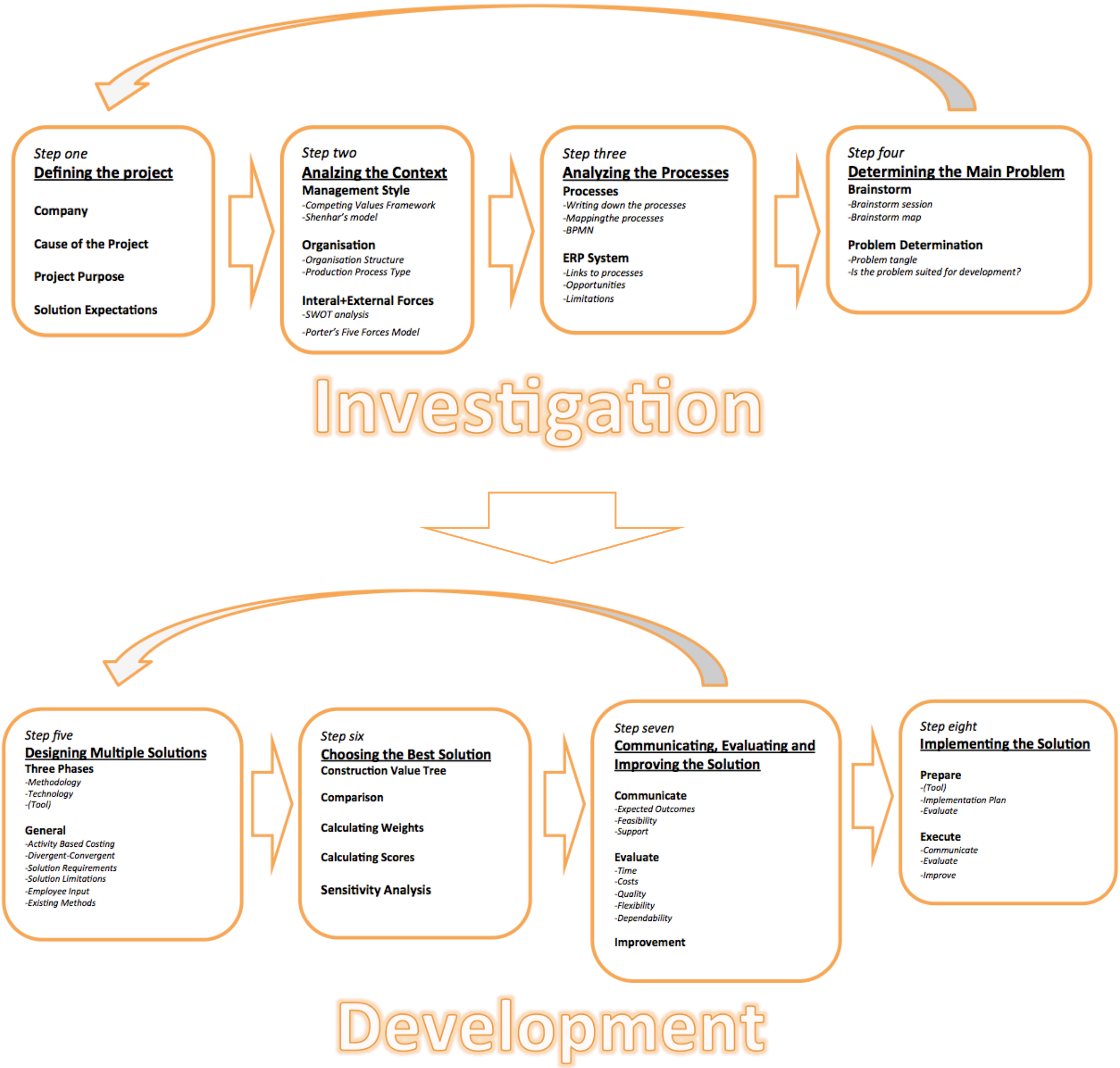

Figure 13. Model for developing a process for monitoring labour and material.

3.1 Investigation

This section is about the first part of the model, the investigation. During the investigation the preparatory work to the development of a process is done. This means that the scope of the research is stated, the context of the company is analysed, the processes within the organisation are analysed and the main problem is determined. Each of these steps will be explained in this section.

3.1.1 Step one: Defining the project

The first step of the model is the determination of the scope of the project. This involves writing down some general information of the company that consolidates the project, the cause of the project, the purpose of the project and the expectations to the solution. The purpose of this step is to make the executor of the project familiar with the company, the purpose of the project and the environment he or she is working in. The most important thing of these objectives is the purpose of the project, because the executer of the projects has to know exactly what the company and its actors are expecting as result of the project.

The purpose of the project and the expectations to the solution should contain a list of requirement and limitations to the solution and definitions and expectations with regard to the time, the costs, the quality, the flexibility and the dependability, based on section 2.7, to enable evaluation in a later step of the method.

The result of this first step of the project should be a clear overview of the company, the purpose of the project and the expected outcome of the project. These objectives are represented in Figure 14 as step one of the method.

Figure 14. Step one: Defining the project.

3.1.2 Step two: Analysing the context of the company

The second step is the analysis of the organizational context. The purpose of this step is to get a better insight in the characteristics of the company and the factors that influence the company. This is important, because a solution has to be implemented into the context of the company, so in the development process the context of the company has to be considered. This step will not be directly visible in the process of working towards a solution; it will build an understanding of the company to make small instinctive decisions and assumptions. To investigate the context of the company, three aspects are treated according to section 2.1: the management style, the organisation and forces that influence the organisation.

3.1.2.1 The management style

The management style has to be analysed by a combination of the competing values framework and the model for management styles by Shenhar [31], the model of McRitchie [21] is not used due the subjective character of that method. The competing values framework will provide the general management style of the company by looking in how far the company is internal or external oriented and by looking to the flexibility of the company.

To analyse the manufacturing aspect of a manufacturing company the model of Shenhar will be used, because it is a reasonable objective model looking to the systems and technology. The scope dimension of this model is classified into three levels: the assembly-level, the system-level or the array-level. The technologic uncertainty dimension is divided in four levels according to the level of technology in the company: low-tech, medium-tech, high-tech and super high-tech.

3.1.2.2 The organisation

The organisation is analysed by looking at the organizational structure and the type of production process. The organisation structure has to be analysed by looking to the organisation overview and analysing whether it is a functional structure, divisional structure, matrix structure, team structure or network structure.

The method for developing a monitoring process will mostly be used in manufacturing companies, because manufacturing companies are the only companies that deal with large and rapidly changing material stocks. Therefore, determining what kind of production process is used is very important for understanding the processes within the company. For this reason the model of Nigel Slack is used to classify the production process in one of the following categories: project processes, jobbing processes, batch processes, mass processes or continuous processes. The service process types that are also included in the model are not included in this method, because this method is developed for manufacturing companies and not for service companies.

3.1.2.3 Factors that influence the company

For the analysis of the internal and external forces that influence the company, two of the three models described in section 2.1.3 are used: the SWOT analysis and Porter's Five Forces model. The PESTEL analysis is not used in this part of the model, because these macro environment factors do not relate that much to the monitoring of labour and materials in manufacturing companies.

The SWOT analysis is used for analysing the internal and external capabilities by looking to the strengths and weaknesses of a company and comparing them to the external threats and opportunities. The limitation of this method is the absence of the environment the organisation is competing in. This is limitation is solved by Porter's Five Forces model.

Porter's Five Forces model identifies the immediate competitive environment of an organisation, which is very important for manufacturing companies. The forces that should be analysed are: potential entrants, industrial competitors, buyers, suppliers and substitutes.

In this section different models and methods are chosen for the analysis of the context of the organisation. The management strategy is analysed by a combination of the Competing Values Framework and the model looking to the systems and technologic uncertainty by Shenhar. The organisation is analysed according to the organizational structure and the process type. At last the internal and external forces that influence the company are identified by a SWOT analyse and Porter's Five Forces model. The output of this step should be a clear overview of the context of the company, so that small instinctive choices and assumptions can be made that fit the company. The result of this step is not directly visible in the solution or in the process of developing the solution; it supports the process. See Figure 15 for a graphical representation of this section in the form of the second step in the method for developing a process for the monitoring of labour and material.

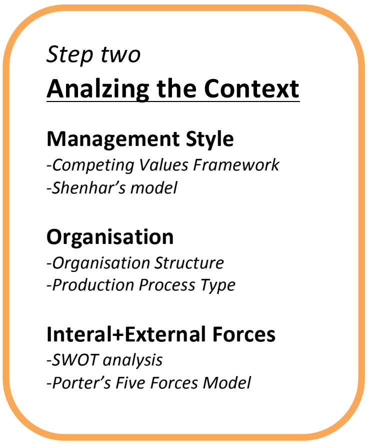

Figure 15. Step two: Analysing the context of the company.

3.1.3 Step three: Analysing the processes in the company

This section is about the third step of the method for developing a process for monitoring labour and material, the analysis of the processes within the company. This is a very important step, because it gives the executor of the project a good insight into what is going on in the company. In this step the ERP system of the company also has to be analysed to make sure the developed solution is supported.

For understanding everything that happens inside the company, the general order process has to be analysed, even though that includes many actors and procedures that have nothing to do with labour or material. Besides the analysis of the general process within the company the material and labour processes have to be analysed in more detail, to ensure every task and procedure is known by the executor of the research.

The analysis should be done in words, but also by modelling the processes with the help of a modelling tool like for example Architect or Bizagi. It is not important which modelling tool is used, they all represent the same processes with the same or other graphics. Something that does matter is the modelling language that is used, for this kind of projects the Business Process Modelling Notation (BPMN) should be used, the symbols used for BPMN are added in Appendix B. The reason that the BPMN is chosen, is that it is an international standard and the models for this project only have an illustrating purpose, so a model that is exchangeable and executable, like the BPEL or XPDL, is not necessary.

For the analysis of the Enterprise Resource Planning System that is used no special method or technique has to be used. This step is about the link of the processes to the ERP System and identifying possible opportunities and limitations with regard to the ERP System. Interviews with the IT department and software related documents will provide enough information for this analysis.

This third step of the method for developing a process that monitors the labour and material is about identifying the processes within the company and their link to the ERP System. The processes have to be described and mapped. For the mapping of processes the BPMN modelling language has to be used in combination with a modelling tool of one's own choice. Also the ERP System itself has to be described according to related documentation and knowledge within the company. The output of this third step should be a set of models that represent the processes within the company. Figure 16 is a graphical representation of the analysis of the processes.

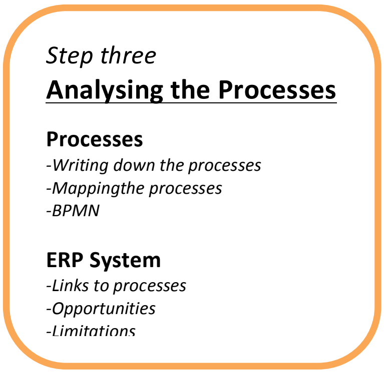

Figure 16. Step three: Analysing the processes within the company.

3.1.4 Step four: Determining the main problem

The fourth step is the last step of the investigation, which is the first of the two parts of the method for developing a process for monitoring labour and material. This step is about determining the problem that causes the bad functioning of a monitoring method within the company or the absence of such a method. First a brainstorm session has to be performed, in this brainstorm session multiple problems are gathered. Next one problem has to be chosen for which a solution is developed in the second part of the project the Development. The input of this step exists out of the output of the three previous phases: the project scope, the company context and the processes within the company.

During the brainstorm session all small, large, important and not important problems and issues can be put forward to make sure nothing is missed. The brainstorm session should not be performed by only one person, but by everybody that is involved in the project. The next step of the brainstorm session is to map all the problems and issues that are forwarded. Start with the cause of the project in the middle and put the big problems in a circle around that cause. The smaller problems and issues follow in a circle around that problems, see Figure 17 for an example.

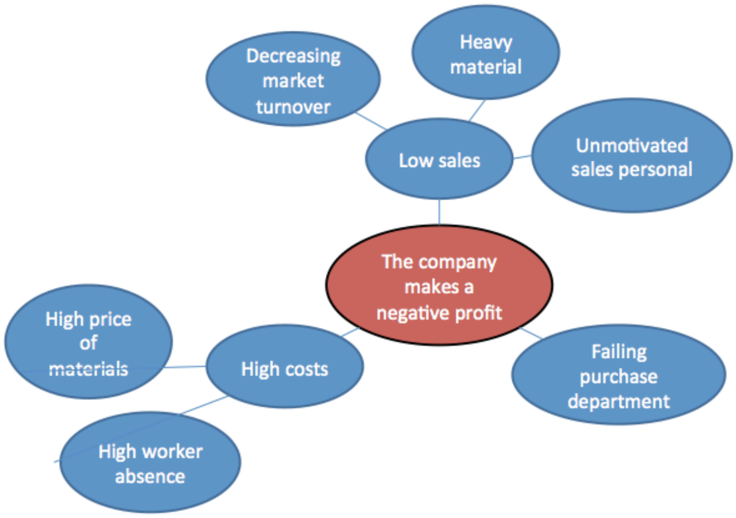

Figure 17. Illustration of brainstorm map.

After the brainstorm session is completed the problem that is going to be solved has to be determined. For determining this problem the problem tangle will be used, because it is a very simple way of connecting and ordering problems in practical situations.

Making the problem tangle is all about connecting problems to each other that have a causal relation. In the end this leads to one or more problems that cause all the other problems. During the drawing of the problem tangle new problems can occur which was not thought of during the brainstorm session. That is not a problem; these problems can be taken into account when the problem tangle is drawn. An example of a problem tangle, based on the brainstorm map in Figure 17, is visible and explained in Figure 18.

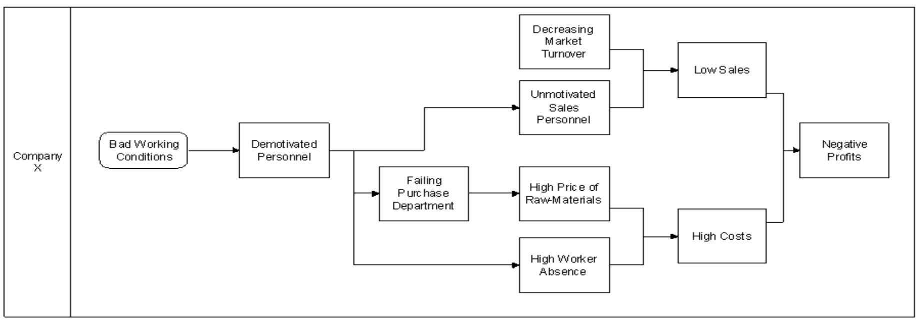

Figure 18. Briefly, you start with the problem on the right that the company is making a negative profit. After investigation is seems that this loss is caused by low sales and high costs. The low sales are caused by decreasing market turnover, which is an external force, and bad performing sales people. After further investigation it seems that the sales people are unmotivated as result of the bad working conditions.

So to find the problem that has to be solved all kinds of problems have to be brought forward in a brainstorm session. The result of this brainstorm session is a brainstorm map which will be transferred into a problem tangle. The problem tangle will illustrate the causal relation between problems and the problem(s) that cause the other problems and will show the main problem(s) that cause(s) all the other problems. A graphical representation of this step is given in Figure 19.

Step four

Determining the Main Problem

Brainstorm

-Brainstorm session

-Brainstorm map

Problem Determination

-Problem tangle

-Is the problem suited for development?

Figure 19. Step four: Determining the main problem.

When the solution is found two things can happen. When the problem is too difficult to solve or is caused by forces that cannot be influenced, the executor of the project has to return to step one, the scope of the project, and the project has to start over again. The purpose of this loop is to make sure nothing is missed in the process and will result in a feasible solution. When the problem seems suited to be solved, the method continues. The output of this step is a problem that is going to be solved in the second part of the method.

After this fourth step is completed, the investigation is done and the next step is part two of the method for developing a process for monitoring labour and material: the development of the solution. To summarize part one of the method, a model of the investigation is presented in Figure 20.

Figure 20. Model for the Investigation part of the method.

3.2 Development

This paragraph is about the development; this is part two of the method for developing a monitoring process for labour and material. Part two exists out of four steps: the design of multiple solutions, choosing the solution, communicating and evaluating the solution and the implementation of the solution. After this part there is a solution designed for solving the problem that caused the absence of or the wrong monitoring process. This results in a new and better process for monitoring the labour and material that is being implemented.

3.2.1 Step five: Designing multiple solutions

This section is about the fifth step of the method, the design of multiple solutions that solve the problem. The input of this step is the problem that is determined in step four that is transformed into a set of solutions in this step. To generate multiple solutions is a difficult process that is hard to structure and therefore the process has to be divided into three phases: methodology, technique and tool.

In every of the three stages it is important to capture choices and to start by working divergent and end with working convergent to ensure that the inventiveness is not limited by practical constraints, but in the end a feasible solution is formed. Also thinking about the requirements and limitations to the solution is very important in every step; this to ensure the solutions fit the organisation. Input from employees and already developed method can also be considered in these phases.

The base of all the solutions should be the Activity Based Costing management philosophy, because the goal of this method is exactly the goal of the process that will be designed by using this method: better insight to what every product costs. Moreover, the Activity Based Costing philosophy is a philosophy that does not offer different standard solutions; these solutions have to be designed according the process that is described below.

The first phase of the development of multiple solutions is the methodology phase. This phase is about different methods or philosophies that solve the problem, these are general terms like: automation, adding manual tasks or adjusting the method that is currently used.

The next step is the technique phase; this phase is about working out the general methods described during the methodology phase. When this phase is fulfilled the result should be an overview of different solutions that are itemized to a level of which tasks should be performed, not how these tasks should be performed.

The last phase is the tool phase. In this phase the solutions are totally elaborated to a package of tasks that are precisely described including the required support systems. This phase has not to be performed in this stage of the project when phase two offers enough information for the decision making described in section 3.2.2.. When phase two offers enough information for the decision making, only the chosen decision has to be worked out in the implementation stage of the project.

Concluding, the design of multiple solutions is based on Activity Based Costing and is divided into three phases: methodology, technique and tool. The third and last phase only has to be performed when the result of phase two is not sufficient for making a decision in the next step of the method for developing a monitoring process. When the results of phase two are sufficient for decision making, the third phase will be performed during the implementation.

During every phase the requirements and limitation to the solution should be considered, also there should be determined whether already existing methods and input from the employees should be taken into account. Choices that are made should be captured and every step should be started working divergent and completed working convergent.

The output if this step is a set of solutions that solve the problem that is determined in step four. See Figure 21 for the graphical illustration of step five of the method.

Step five

Designing Multiple Solutions

Three Phases

-Methodology
-Technology
-(Tool)

General

-Activity Based Costing
-Divergent-Convergent
-Solution Requirements
-Solution Limitations
-Employee Input
-Existing Methods

Figure 21. Step five: Designing multiple solutions.

3.2.2 Step six: Choosing the best solution

This paragraph is about the sixth step of the method for developing a process for monitoring labour and material. This step includes the method that should be used for choosing the solution that solves the problem and suits the organisation and project the best. The input of this step is the set of solutions that are developed in step five.

The method that will be used is the Analytic Hierarchy Process (AHP), because the decision that has to be made will be too large for the MAUT approach and too small and not complex enough for the SMART analysis. Also the use of swing weights will be too difficult, as many actors will have to decide the scores of many alternatives.

The first step of this phase is setting up the decision hierarchy, which is a value tree of the attributes and the different alternatives. In the top of the value tree the general objective is stated, in this case

'Choose a solution'. The general attributes are stated below, in this case 'limitations and requirements'. The final attributes are stated below and beneath this attributes the different alternatives are stated. See Figure 23 for a graphical representation.

The second step is to make the pairwise comparisons of the attributes and the alternatives. This is done by asking the question 'How much more important is alternative 1 compared to alternative 2?'. This is done from the general attributes in the top of the value tree to the alternatives in the bottom of the value tree. The judgements get a score from one to nine (1-9) where the score represent the answers listed in Figure 24, all the comparisons have to be captured in tables.

The third step of the AHP is to transform the comparisons into weights. Normally this is done by a software package, but it can also be done by hand. The weights are calculated and also the inconsistency index is calculated. In Appendix M the calculating method is added, which is obtained from the book 'Decision Analysis for Management Judgment' [41].

The fourth step is the calculation of the scores of the alternatives according to the weights determined in the third step. This is an easy calculation that involves multiplying the weight from the top to the bottom of the value tree; this calculation is also included in Appendix M. The alternative that has the highest total score should be chosen as solution.

The last step of the AHP is the performance of a sensitivity analysis. This analysis can only be performed by the use of the special AHP software packages. When these are not available, logic sense has to be used in combination with the inconsistency check of step three of the method, to determine how reliable the solution is.

All by all the AHP method exists out of 5 steps: constructing a value tree, comparing attributes and alternatives, determining weights, calculating scores and performing a sensitivity analysis. The sensitivity analysis has to be performed by special AHP software packages or has to be done roughly by hand. The output of this step is a solution that is best for solving the problem in the organisation. On overview of this part of the method for developing a monitoring process is visible in Figure 22.

Step six

Choosing the Best Solution

Construction Value Tree

Comparison

Calculating Weights

Calculating Scores

Sensitivity Analysis

Figure 22. Step six: Choosing the best solution.

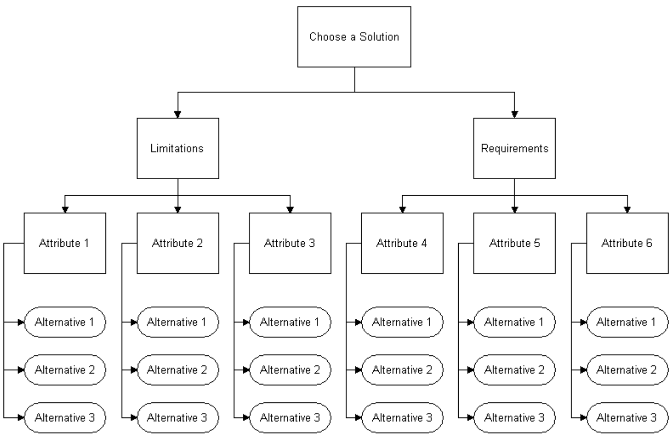

Figure 23. Example of the AHP value tree.

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment moderately favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities of 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.		

Figure 24. Scale for pairwise comparison.

3.2.3 Step seven: Communicating, Evaluating and Improving the Solution

The seventh step of the method for the development of a monitoring process is the communication, evaluation and improvement of the chosen solution. The purpose of this step is to communicate the solution to the company and obtain feedback on the feasibility of the solution, strong and weak points of the solution and the support of the company and its employees. This feedback can be used to make adjustments to the designed solution.

For evaluating the solution the expected outcomes gathered from the employees should be compared to the expected outcomes stated in step one of the method. The dimensions that should be looked at are the ones defined in step one of the method: time, costs, quality, flexibility and dependability. This is based on the work of Brand and Van der Kolk [18] and Slack [23]. The work of Aydin [1] and Van den Berg [12] is not used, because they do not offer a validated framework that can be used.

After the expected outcomes are compared to the desired outcomes, the solution can be adjusted when necessary. When this involves big adjustments the executor of the project has to go back to the designing step and redo that step together with the decision process. When the adjustment is a small modification, the executor can go on to the last step of the method, the implementation. In the end the result of this step should be a fine-tuned solution that is ready for implementation. An overview of the communication, evaluation and improvement step of the method is represented in Figure 25.

Step seven

Communicating, Evaluating and Improving the Solution

Communicate
-Expected Outcomes
-Feasibility
-Support

Evaluate
-Time
-Costs
-Quality
-Flexibility
-Dependability

Improvement

Figure 25. Step seven: Communicating, Evaluating and Improving the solution.

3.2.4 Step eight: Implementing the solution

This section is about the last step of the method for developing a method for monitoring labour and material, the implementation of the solution. When the implementation is completed, the solution is totally integrated in the processes of the company. This step exists out of one or two stages, depending on whether the tool phase of the design of the solution is performed during the design step (step one of the development part of the model) or not.

When the tool phase of the design step of the method is not yet performed that is the first thing that has to be done. In the tool phase the solution is totally elaborated to a package of tasks that are precisely described including the required support systems.

The next phase of the implementation, or the first phase when the tool phase was performed during the design phase, is writing the implementation plan. This includes determining what has to be done, who should do that and in which order these things should be done. Evaluating this implementation plan will help to make it complete and will give the actors a better idea of the whole plan.

The last phase is the execution of the implementation plan. The systematic communicating, reflecting and improving on and of this process is essential for succeeding. After this phase the method reached it end, a process for the monitoring of labour and material is developed and implemented. An overview of the implementation step is presented in Figure 26 and an overview of the development part of the method is represented in Figure 27.

Figure 26. Step eight: Implementing the solution.

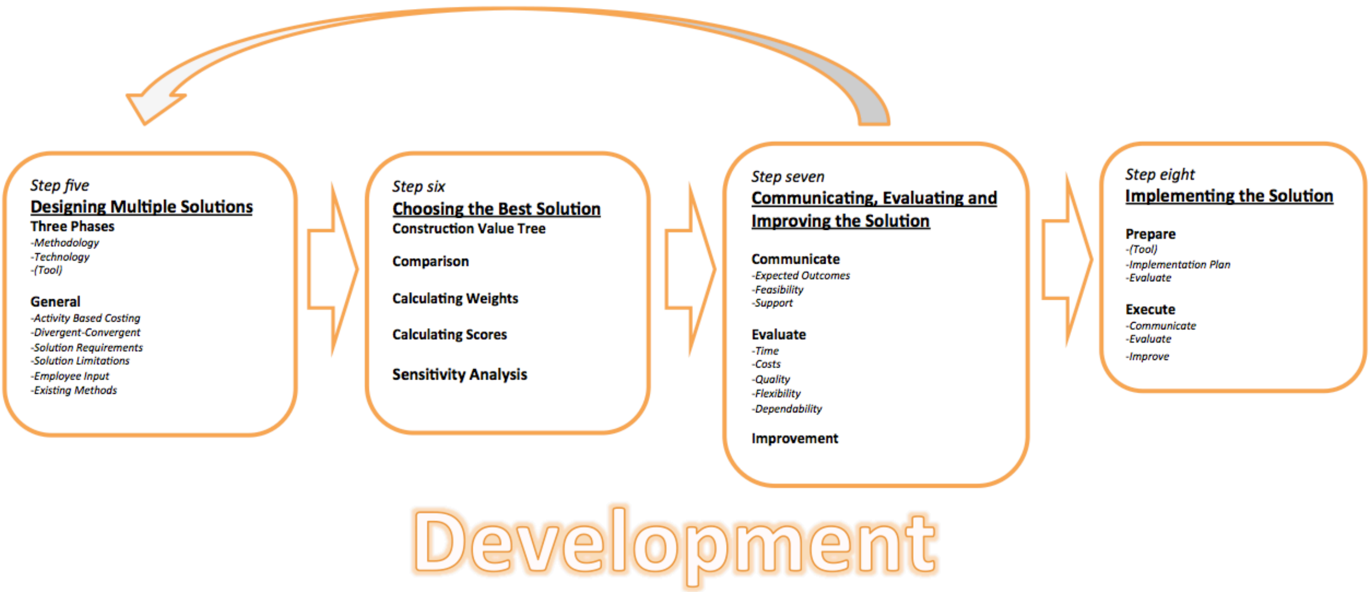

Figure 27. Overview of the development part of the method.

3.3 The method: Conclusion

This chapter was about designing a method for the development of a process for monitoring labour and material. The chapter and method were divided into two parts just like to the exploratory and executive phases of a method defined in chapter 2: the investigation and the development. This paragraph is about summarizing this third chapter to answer the research question *'What is a suitable method for developing a process for monitoring the material consumption and labour hours?'*.

Like the name of the first step suggests, the investigation is about investigating the project and the company. This includes the scope of the project, the context of the company, the processes within the company and the problem within the company.

The second step is the development and is about generating multiple solutions, choosing the best solution by use of a structured method, communicating and improving the solution and as last step the implementation of the solution.

Together the investigation and the development form a suitable method for the development of a process for monitoring labour and material. The whole method was presented in Figure 13.

4 Demonstration

In this chapter the method that is designed in chapter 3 is validated by applying the method in practice, in this case United Springs B.V. is the company that commissions the demonstration. The demonstration is step four of the model for the Design Science Research Methodology. In this case a monitoring process for labour and material will be developed for United Springs B.V. using the method designed in chapter 3. The method will be used by executing the eights steps of the model step by step. In this chapter the research question *'How can this method be tested?'* is answered together with the associated sub-research questions.

4.1 Step one: Defining the project

The first step of the method is determining the scope of the project, this includes some general information on the company, the cause of the project, the purpose of the project and the expectations with regard to the solution. In Figure 28 the first step of the method and its objectives are visible. The output of this step should be a clear problem statement.

Step one

Defining the project

Company

Cause of the Project

Project Purpose

Solution Expectations

Figure 28. Step one of the method.

In the introduction of this report United Springs B.V., the company that commissions this research, is already introduced. In short, United Springs B.V. is a company that produces all kinds of springs. The company is doing well, but one thing that is not as it should be is the monitoring of labour and material. The management has no detailed information on the use of material and labour per production order, this makes it hard to set the right prices for their products. The result is that some of the separate production orders are far more profitable or far less profitable than they should be; this is absolutely not the ideal case and the cause of this project. This makes the purpose of the project clear: developing a process for the monitoring of labour and material.

The management stated some requirements and limitations to the solution, which are listed below and explained and defined in Appendix C.

The solution:

- has to result in a method for a precise calculation of the material and labour consumption
- has to fit in a fixed budget (50.000 euro)
- cannot consume too much time of the employees when it is implemented (5 minutes)
- has to handle the dimensions of the processed materials
- can be understood by all the United Springs B.V. employees
- has to be supported by the United Springs B.V. employees
- has to be conform legal and environmental legislations
- can be implemented within a year.

The result of this first step is a clear problem statement: United Springs B.V. is not able to determine the used labour and material per production order. This project is about developing a process for the monitoring of labour and material, so that the labour and material consumption per production order can be determined.

4.2 Step two: Analysing the context of the company

The second step of the method is the analysis of the context of the organisation. The objectives of this step are visible in Figure 29 and contain an analysis of the management style, an analysis of the organizational characteristics and an analysis of the internal and external forces that influence the company's strategy. The outcome of this step is a clear vision on the environment of the organisation, with as purpose being able to make decisions and assumptions that are in line with the strategy and context of the company.

Step two
Analzing the Context

Management Style
-Competing Values Framework
-Shenhar's model

Organisation
-Organisation Structure
-Production Process Type

Interal+External Forces
-SWOT analysis
-Porter's Five Forces model

Figure 29. Step two of the method.

4.2.1 Management Style

The management style is analysed by use of the Competing Values Framework and Shenhar's model. The Competing Values Framework looks to the trade-off between the internal and external orientation and the trade-off between flexibility and focus. Shenhar's model uses the level of technological uncertainty and the scope of the company.

According to the Competing Values Framework, United Springs B.V. is a company with a collaborating management style. When a problem occurs they try to solve it inside the company by calling a circle. When a circle is called all concerned employees get together to tackle the problem.

According to Shenhar's model, the management style of United Springs B.V. is a mix of an entrepreneurial management style and conservative management style, because United Springs B.V. is medium-tech and can be classified as a system-level company.

4.2.2 Organisation characteristics

The organisation is analysed by looking at the organizational structure and the type of production process. The organizational structure is analysed by comparing the organisation overview to: a functional structure, a divisional structure, a matrix structure, a team structure and a network structure. The production process is analysed by looking to the volumes and variety in the production process.

An organisation overview is added in Appendix D, looking at this overview the division of the company is visible. The company is divided according to the functions of the departments and people, a functional structure.

The production process of United Springs B.V. is split into two departments: Atlas and Hengelose Verenfabriek Bakker (HVB). Like mentioned in the demarcation that is part of chapter 1, Atlas is not part of this research. The production process of HVB is almost totally automated and the volumes are relatively high. There is no case of mass production, because of the high variety. There is also no case of a jobbing process, because of the shared production resources. It follows that the HVB production process is a batch process.

4.2.3 Internal and External Forces

The internal and external factors that influence United Springs B.V. are analysed using the SWOT analysis and Porter's Five forces model. According to the SWOT analyse, the strategy of a company follows from the fit between the external and internal capabilities. A SWOT analysis is a way of summarising the organisation's strengths and weaknesses relative to external opportunities and threats.

Managers and companies are most affected by their immediate competitive environment, which exists out of five forces. These forces are potential entrants, industrial competitors, buyers, suppliers and substitutes. The collective strength of these forces determines the profitability of the industry that a company is in. The stronger the forces, the less profitable the industry is and vice versa.

SWOT - Strengths
Because the company exists for such a long time, United Springs B.V. has a strong customer base. This good supplier-customer relationship is built on trust as United Springs B.V. helps customers from the start of their designing processes. This assistance is a logical consequence of the excellent Research and Development department United Springs B.V. has and accompanied by the proto shop. In the proto shop prototypes of products are made to show the customer what the final product will look like. The Research and Development department is the unique selling point that distinguishes United Springs B.V. from their competitors.

Also the cooperation within the Sogefi group is starting to pay off. When an order request cannot be produced at a certain company the order request is forwarded to an affiliate company. Together the companies that are part of the Sogefi group and manufacture springs can manufacture almost every spring a customer wants.

SWOT - Weaknesses
Where the engineers working for United Springs B.V. are one of the strong points of the company, their machines are a weak point. The engineers can design very high tech springs, but compared to that the machines are starting to get outdated. This has not only to do with the age of the machines, but also with the type of machines and their capabilities. In the near future the machines probably will restrict the company in producing what it is capable of according its knowledge.

The Sogefi group is earlier mentioned as strength, but unfortunately also has to be mentioned as a weakness. Participating in a larger group comes with a lot of benefits, but also with a lot of duties. This involves a lot of time consuming administration and restrictions in entrepreneurial activities.

SWOT - Opportunities
Worldwide products are getting more and more high tech and therefore the demand for custom made springs will grow, especially in the aerospace industry and the health care. United Springs B.V. is specialized in meeting or exceeding customer needs, in other words they produce high tech springs when the customer requires that. This leads to positive expectations for the future.

SWOT - Threats
A threat for almost every manufacturing company are the Low Cost Countries (LCC) where products are made by cheap labour and sold for cost prices, so also for United Springs B.V.. Another threat for United Springs B.V. is the threshold for joining the low technical (not tool-related) spring industry. This threshold is not so high and therefore there are many potential new entrants. The replacement of metal springs by plastic springs, together with the environmental concerns, are also threats for United Springs B.V..

Porter - Potential new entrants
The threat of potential new entrants brings us to the first force of Porter's model. The threshold for new companies to enter the spring industry is relatively low. It depends on the kind of spring you are looking for and especially the machines and knowledge that are needed for producing that kind of spring. Small wire springs can be made without expensive machines and knowledge in the barn in the backyard. Other springs pass through an intensive engineering process and are manufactured by skilled workers on an expensive machine. But in general the threshold for new companies to enter the spring industry is relatively low.

Porter - Competitors
There are a lot competing companies in the spring industry, for example companies from Low Cost Countries (LCC) that sell products against cost prices. They force United Springs B.V. to keep the

prices low, even when United Springs B.V. delivers much higher services (quality, logistics and research and development) in the development process.

Porter - Buyers

In general the customers in the spring industry do not have much power towards manufacturers like United Springs B.V.. When a customer request short delivery times, United Springs B.V. has to keep the materials in stock and the customer has to sign a commitment order that states that the customer has to buy the material when the order is cancelled. So customers cannot force United Springs B.V. to take unnecessary risks.

Porter - Suppliers

The Sogefi Group organizes the procurement; this includes the price negotiation and the agreements on terms and quality, this department is named Sogefi Purchasing. The reason that Sogefi Purchasing negotiates with suppliers is that as a group the economies of scale are higher. But, within the Sogefi group the materials that United Springs B.V. needs are not common, so the economies of scale are not that big. This does not result in power for the suppliers, because in general the materials United Springs B.V. needs are abundant and can be bought from many different suppliers.

Porter - Substitutes

The function of a spring can only be performed by springs. But some things that metal springs can do, can also be done by plastic springs. There is a worldwide trend about avoiding the use of metal for everything and search for alternatives; this is also the case for the spring industry. So the power of substitutes is rising.

The outcome of this step should be a clear vision on the environment of the organisation, with as purpose to be able to make decisions and assumptions that are in line with the strategy of the company. United Springs B.V. is a company with a functional structure that produces in batches. The management style can be described as a mix between conservative and entrepreneurial with a cooperating way of working. The company experiences a lot pressure from competitors and new entrants to the market. The strong points of the company are the large customer base and the level of knowledge within the company.

4.3 Step three: Analysing the processes within the company

This section is about the third step of the method, the analysis of the processes within United Springs B.V.. The objectives of this step are presented in Figure 30; the analysis of the processes includes a written analysis of the processes, mapping of the processes and an analysis of the ERP system that is used. The outcome of this step should be a clear overview over the processes in the company, so that possible problems can occur. During this step the following sub-research questions are answered: *'What does the production process of United Springs B.V. look like?', 'What does the process which the materials pass through look like?' and 'Which method does United Springs B.V. use for monitoring the materials and labour hours?'.*

Step three

Analysing the Processes

Processes

-Writing down the processes

-Mappingthe processes

-BPMN

ERP System

-Links to processes

-Opportunities

-Limitations

Figure 30. Step three of the method.

4.3.1 The order process

The order process can be divided into three phases: routing, pre order and production, these phases will be described one by one in this section. When an order request comes in, the first step is to look if the product is manufactured before. When the desired product is manufactured before, the routing phase can be skipped. So, the routing phase is only for new products.

In the order process of an order there are seven actors/departments that play a significant role:

- The Customer
- The Marketing and Sales Department
- The Research and Development Department
- The Customer Service Department
- The Planning Office
- The Production
- The Warehousing Department

According the three phases and seven actors a model is created which gives an overview of the different processes and relations between them en the actors that are involved. Some activities are so important and/or big that sub processes are created; this is the case for the calculation of the production requirements and quotation, the check of the Planning Department, the clocking activity of the production workers and the tasks within the production. Images of the whole process and sub processes can be found in Appendix E.

Routing

In the routing phase the Marketing and Sales Department roughly judges an order request. This means that there is checked whether United Springs B.V. has the right machines to manufacture the product or not. When this is not the case the department searches for another company in the Sogefi Group which is able to manufacture the product and forward the customer to that affiliated company. When no other affiliated company can manufacture the product, the order request is rejected.

Most of the time United Springs B.V. has the right machines and skills to manufacture the requested product. When this is the case, the Research and Development Department receives the order request and checks whether the product specifications can be met or not. When this is not the case the customer has to adjust the design of the product in cooperation with the Research and Development Department. If the customer is not willing to do that, the order will be lost.

After the Research and Development Department approved the order request, the department calculates the estimates. The estimating includes the expected quantity of material, the expected labour hours, the "bijhoud"[1] percentage and the machine speed; this estimating thereafter is called a quotation. Again the customer has to agree with this quotation before the process goes any further.

Pre Order

After the customer accepted the quotation, the Customer Services Department enters the order into the system. This is the first time the ERP system Vantage is involved, more information about Vantage is provided in paragraph 4.1.3.4.

When the order is entered into the system, the Planning Office checks whether the time horizon defined by the customer is feasible. The machine capacity and labour capacity has to be sufficient to produce the order before the suggested delivery date. Second the material that is necessary for producing the order has to be in stock or have to be delivered in time. If, for any reason, the time horizon is not feasible, the Planning Office makes an adjustment proposal for the customer. The Customer Service Department sends the adjustment proposal to the customer and when the customer accepts the adjustment to the time horizon the production order can be generated and, when necessary, the materials can be ordered.

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[1] The "bijhoud" percentage: the proportion of the set-up time that is necessary to keep the machine running. From now on this will be called operating percentage.

One day before the production of a production order starts, the warehouse employee picks the material that is required for producing that production order from the shelf and brings the material to the machine on which the order will be produced.

Production

During production the production workers can have two main tasks, setting up a machine or operating a machine, see “bijhouden” in the footnotes of this page. It is also possible, and most common, that the production workers are working on multiple orders and tasks at the same time. The ERP system Vantage knows which production workers are working on the different production orders.

Vantage knows this, because the production workers have to clock into the different production orders they are going to work on. When they clock into a production order, they also have to tell Vantage which tasks they are going to perform. Vantage then split the labour equivalent over the different orders, so Vantage does nothing with the operating percentages.

After the production worker has clocked in he or she starts with the first task. When a machine has to be set up, the tooling, material and packaging material are placed and the production is started. This process can take up to more than two days, depending on the type of spring and the type of machine.

When the machine is running the production workers have to keep it working. The most important task of the operating tasks is the quality check of the product. Furthermore, they check if the machine is operating right and whether the machine running out of (packaging) material.

Afterwards the production worker removes the material from the machine and the warehouse department stores the material in the shelves. Before the material is stored, the weight is determined, so that it can be calculated what the used quantity of material is. Unfortunately, this is the ideal situation, which is not the way it happens in real life. Very often the material stays on the machine and is used for the following order to reduce setup times. This can happen multiple times in a row and then the material gets weighted after, for example, five orders. Precisely allocating the quantity of material used on the specific orders is impossible in that case; this research has to change this.

4.3.2 Material process

This section is about the material process within United Spring B.V.. Both the material and the labour processes are important to this project, but the material process is analysed separate, because the whole material process is not included in the order process. The part of the labour process that is relevant for this project is included in the order process, so the labour process is not analysed separately. This section describes the material process in words, the material process is also modelled in Bizagi, this model is represented in Appendix F.

The process starts with a purchase order which comes from the Planning Office. The supplier provides the right materials in the right quantities to United Springs B.V.. United Springs B.V. assumes its suppliers always deliver the right quantities, with a permissible deviation of ten percent.

After the materials arrived at United Springs they get a material label, see Appendix G for an example. More over these material cards in the next paragraph. The labelled materials are stored into the warehouse.

When the warehousing department gets a production order that has to be prepared, the materials are looked up in the warehouse. The next step is to bring the materials to the relevant machine in the production. Since most of the material is very heavy, it is transported by forklift. In Vantage the total quantity of material that is brought to the production is booked to the production.

When the production of an order is completed the left material is brought back and booked to the warehouse. The used quantity of material is booked onto the production order for internal comparison. The material is brought back to the warehouse by the production worker, but the material is booked onto the production order and to the warehouse by the warehouse department, which also stores the material.

When during the production a machine runs out of material, the material card of the processed material is brought to the warehousing department. The warehousing department books the used material onto the right production order. Unfortunately, the material is used for multiple production orders most of the times. In that case material stays in the production area until the last production order is completed. After production the warehouse department estimates the processed material per order and books that onto that order. Almost naturally speaking, the quantities booked onto such production orders are far from realistic.

4.3.3 Monitoring of material and labour

This section is about the way United Springs B.V. monitors the material and labour consumption within the company. First the monitoring of material is treated and after that the monitoring of labour is treated.

Material

The quantities of material used per production order is written on the so-called material label, see Appendix G for an example. These small paper labels are attached to the material and have a front side and a back side. The backside is meant for monitoring the material usage per order in two columns: the order number and the quantity of material left in kilograms or pieces. On the front side the general information is printed:

- Article number
- Description
- Supplier
- Batch number
- Quantity received
- Receive date
- Check date

Officially the back side of the material card should be filled in after each production order, in practice this is not the case, like mentioned earlier. When the material is used for multiple production orders in a row, the quantity of material left will not be checked until the last production run is finished. When this is the case, the actual distribution of the used material cannot be traced anymore. The quantities of the used materials, according to the material card, are booked into the system on the relevant orders so that it can be compared to the estimating made by the Resource and Development Department in the routing phase.

The reason that the material is not weighted in between the different production orders is because of the high setup times. These are caused by the fact that the scale is located in the warehouse and the materials are difficult to handle. It costs too much effort to disassemble the material from the machine in between production orders and weigh it.

When a product is manufactured for the first time the Research and Development Department estimates what the material usage will be. After the production is completed an evaluation takes place of the used material. This means that the weight of the manufactured products is compared to the estimated weight of the products. The total quantity of used material, so including waste and wrong products, is not evaluated. When the conclusion of the evaluation is that there was too much material used, the engineers try to find a way that brings the material consumption for that product down. This evaluation should take place three times for every new product and lessons learned are taken into account with designing new production order.

Labour hours

Like mentioned in the description of the production process, the labour hours are monitored by Vantage. The production workers clock into one or more orders and Vantage splits the labour hours equivalent, which gives not a realistic image compared to the situation on the production line.

There is no structural evaluation of the labour hours that are required for a production order. Sometimes the experience of a production worker is addressed with a question like: *'How many of these machines can you operate at the same time?'*, so that the operation percentage can be adjusted. The set-up time is adjusted more regular, but also not on a structural basis.

4.3.4 Vantage

The Enterprise Resource Planning system that United Springs B.V. uses is Epicor ERP 8.03.408B Vantage. Vantage gives businesses of all sizes the flexibility needed to compete in the market and to fulfil the need of the information-hungry global economy [8]. Epicor ERP is a fully integrated system based on the new True Service Oriented Architecture (SOA), which makes it easy to work everywhere, however and whenever you want [19]. True SOA is more than just a way of communication and web services, the whole business has to be structured in terms of services. [10]

General Information

Vantage exists for ninety percent out of a standard product which is suitable for almost every organization. The other ten percent are customized to the specific wishes of the company where the software is implemented. After the software is implemented, the companies can adjust the program themselves when business processes change. To realize this Business Process Management is supported by the software. To deliver total support, Vantage has thirteen available modules:

- Sales Management
- Customer Relationship Management
- Financial Management
- Supply Chain Management
- Product Management
- Planning and Scheduling
- Product Data Management
- Global Business Management
- Business Architecture
- Governance, Risk and Compliance
- Enterprise Performance Management
- Service Management
- Human Capital Management

Figure 31. Vantage modules implemented at United Springs B.V..

Vantage supports data warehousing, but for the accommodation of its data for most modules it uses databases and not data warehouses. Databases are just for storing the data, which later can be requested for use.

"A date warehouse is a pool of data produced to support decision making; it is also a repository of current and historical data of potential interest to managers throughout the organisation. " [7] Data warehouses are time-based, subject oriented and integrated systems that contain only not adjustable data, data changes are stored as new data. [14]

Vantage within United Springs B.V.

Within United Springs B.V. every employee in the office works with Vantage. In the production area there are two computers on which the production workers can log into Vantage. Like mentioned before, the production workers tell the system what they are going to do and when they are done with their tasks. Remarkable is that Vantage does nothing with the operating percentages, but distributes the labour hours equivalent.

Not all modules that are available for Vantage are implemented at United Springs B.V., the modules that are integrated are (also see Figure 31): Sales Management, Customer Relationship

Management, Financial Management, Supply Chain Management, Product Management, Planning and Scheduling and Product Data Management.

The modules that are most important for this research are Supply Chain Management and Product Management. The Supply Chain Management module contains Warehouse Management, Material Movements, Stock Management and Handheld Support. The Product Management module contains Order Management, Data Collection and Labour Registration.

Vantage does not adjust data, it just stores data and users can add or adjust the data. An overview of the modules and the Vantage database at United Springs B.V. is given in Appendix H.

With the end of the analysis of Vantage, the end of the third step, the analysis of the processes, is reached. The outcome of this step should be a clear overview over the processes in the company; this clear overview will be given here.

The order process exists out of three phases: the routing, the pre-order process and the production. The routing only is passed through when the order involves a new product. The routing is about accepting or rejecting and developing the order. The pre order process is about planning the order and obviously the production is about the production of the order.

The material is monitored by use of a material label. On this label the used quantity of material per order is written down. The problem is that the materials mostly are used for multiple orders without writing down the used amounts in between; material cannot be weighted in between orders, because of the long setup times. When the material is not weighted in between production orders, the used quantity has to be estimated which can result into deviations of hundreds of kilos.

The labour is monitored by Vantage in a very inaccurate way. The production workers use computers to clock into multiple orders and tasks for that order, then Vantage splits the labour equivalent over the different orders the production worker is working on.

The last part of the analysis of the processes within United Springs B.V. is the analysis of the ERP system that the company uses. This software package is called Vantage and has many features that cover all a company can ask for. United Springs B.V. does not use all these features. Vantage can almost be entirely adapted by the IT Department of the company, so expensive IT specialists do not have to be paid very often.

All information gathered in this section is used for finding the problem that has to be solved. This problem is found in the next step and paragraph: determining the main problem.

4.4 Step four: Determining the main problem

This section is about the fourth step of the method, which is the determination of the main problem for which a solution has to be developed. Figure 32 illustrates the two objectives of these steps, the brainstorm session and the problem determination using a problem tangle. The input of this step is the information gathered in the previous phase, the analysis of the processes. The output of this step is a problem that has to be solved to solve the general problem of the project stated in step one. During this step the sub-research question *'What causes the differences between the estimating and the costing?'* is answered.

Step four

Determining the Main Problem

Brainstorm

-Brainstorm session
-Brainstorm map

Problem Determination

-Problem tangle
-Is the problem suited for development?

Figure 32. Step 4 of the method.

4.4.1 Brainstorm map

In the brainstorm session the most important problems and noteworthy items are uncovered. This resulted into four causes of the lack of insight into the material and labour consumption: the Controlling Department has no information, there is no accurate material monitoring, there is no accurate labour monitoring and the features of Vantage are not fully utilized. The brainstorm map is added in Appendix I.

The Controlling Department has no right information on the used quantity of material and labour used, because there is no database with right information. The reason that there is no information available about the material and labour consumption is the lack of systematic evaluation of production order. Only the specifications of final products are checked and sometimes the set-up time is evaluated. The total quantity of material and labour used per production order is not evaluated.

The absence of an accurate way of monitoring the material is a consequence of not weighing the material in between production orders. The reason that the material is not weighted in between orders is that the disassembling the material takes too much time and results in long set-up times.

The consumption of labour for the manufacturing of a production order is not monitored at all. The only information that is gathered is on which production orders a production employee is working at a given time. Vantage does not use the operating percentage. Vantage only splits the labour time equivalent, so that every order gets the same amount of consumed labour.

Vantage is a software package which has many features, but United Springs B.V. does not yet use all these features. For example, Vantage is capable of monitoring the labour consumption very detailed in combination with a handheld device. Also the fact that Vantage does nothing with the operating percentage is a missed opportunity.

4.4.2 Problem tangle

The result of the brainstorm session is an overview of multiple problems and causes that are related to the problem statement. These problems can be connected by causal cause-consequence relations, which results in a problem tangle. This problem tangle is added in Appendix J.

In the problem tangle the problem statement is visible on the right. The fact that United Springs B.V. has no insight into the consumption of material and labour per production order is caused by the lack of available information for the Controlling Department. Without information, the Controlling Department cannot evaluate the correctness of the estimates made by the Research and Development department and so the correctness of the price per product.

The information that the Controlling Department needs exists out of two dimensions, historical data and current data. The current data is gathered to evaluate the production orders and then stored as historical data for comparisons in the future. There is no historical data, because there is no systematic evaluation of the production orders and the right current data is also not gathered. The reason that this evaluation is not taking place on a regular basis is because there is no stated procedure or method.

The current data is not gathered in the right way, because there is no accurate material monitoring and definitely no accurate labour monitoring. There is no accurate labour monitoring, because there is no stated method for monitoring labour and the features that Vantage offers are also not fully utilized. Another reason for the absence of correct current data is the inaccurate material monitoring.

When the material is monitored the correct way, it is weighted in between production orders, to determine the used quantity of material. The material is not weighted, because that takes too much time as results of the unwieldiness and there is no stated procedure that the material should be weighted in between production orders. Also here the features of Vantage are not all used.

So why are not all the features of Vantage utilized? Because of the fact that they were not implemented when Vantage got implemented. So why are not all the features not implemented when Vantage got implemented? Because the management did not think that would be important at that moment, because operating tasks and set-up tasks were segregated at that moment and the budget was not sufficient. So in the end the reason that not all Vantage's features are utilized is that there is no stated method wherein these features are used.

That brings us to the two problems on the left of the problem tangle: there is no stated method and weighing the material consumes too much time. These are the two problems that can be tackled as a start for solving the problem.

The output of this step should be a problem that has to be tackled to solve the general problem of the project stated in step one. The results of the problem tangle are two problems: there is no real method for monitoring labour and the weighing of material costs too much time. The problem that is going to be solved is the fact that a real monitoring method does not exists. The reason that the other problem is not tackled is that weighing the material is only related to the monitoring of material and not to the monitoring of labour.

The result of this fourth step is also the result of the investigation, which is the first of the two parts of the method. The result of this step is also the answer to the sub-research question *'What causes the differences between the estimating and the costing?'*. The problem found in the investigation will be solved in part two of the method; this part is called the development.

4.5 Step five: Designing multiple solutions

This section is about step five of the method, the design of multiple solutions. Some objectives of this step are visible in Figure 33. The input of this step is the problem found in step four, the absence of a method for monitoring labour and material. The outcome of this step is a set of multiple solutions to that problem. This paragraph is, according to the phases in the method, divided into two parts: the methodology and the technique. The tool phase is not included, because the technique phase leads to sufficient detailed solutions for the decision process.

Step five

Designing Multiple Solutions

Three Phases

-Methodology
-Technology
-(Tool)

General

-Activity Based Costing
-Divergent-Convergent
-Solution Requirements
-Solution Limitations
-Employee Input
-Existing Methods

Figure 33. Step five of the method.

4.5.1 Methodology

In general two things can be done to solve the problem within United Springs B.V., the existing process can be slightly adjusted or a new process has to be developed. Designing a new process is the most time consuming choice and will change more in the organisation. More change means a more difficult implementation process and more resistance of employees. In this case the design of a new process will include disassembling the material; otherwise it is just adding some tasks to the existing process. One of the restrictions of the management is that the materials cannot be disassembled in between production orders, so designing a new process is not a possible solution in this case.

When the current process is slightly adjusted the changes are less radically, but the effect can be that the 'better' situation is just an optical illusion. The current process can be adjusted in two ways, by using the devices that are available and designing new tasks or by adding new devices to the process which make the new tasks easier or to replace manual tasks.

4.5.2 Technique

In the case that no additional devices are implemented, there are several ways of monitoring the material consumption. The first way is to determine the total quantity of material used for manufacturing one product and to multiply that with the number of produced products. The machines are capable of counting the manufactured products; in this case the machine makes no distinction between good and bad springs. This is satisfactory, because United Springs B.V. wants to know the total quantities used for the production of one whole production order.

Before the manufacturing process starts, the Research and Development Department calculates the dimensions of a product. The parameters following from this calculation are slightly changed in the production on the basis of the specifications of the materials. When the parameters that are used during production and the number of produced products are known, the total quantity of material used can be calculated. The only thing that is not included at that moment is the quantity of material that is lost during the setup process, but that can be easily estimated by the production workers and is often really small quantity.

Another way of calculating the quantity of materials that is used, is measuring the distance from the material on a roll to the edge of that roll. When the weight before production is known the ratio between the distance from the material to the edge of the roll before and after production can be used for determining the used quantity of material. Theo Buitenhuis designed an Excel sheet with this formula, this excel sheet is added in Appendix K.

Obviously, there are other methods that do not require unnecessary complex methods. An example is weighing the materials before the work on a production order starts and after the work on the production order is finished. The restriction at United Springs B.V. is that the material cannot be disassembled from the machine; this problem can easily be solved by bringing the scale to the material instead of bringing the material to the scale.

The most common way of bringing a scale to the production area is by crane. The scale is fixed to the crane which moves to the desired place in the production. Then the material is weighted and the crane can operate his next job. The problem is that United Springs B.V. does not have a crane that covers the whole production area, so some extra cranes have to be installed for this solution and that solution is too expensive.

Another solution is to use a pallet truck with a build-in scale. Then a production worker has to get the pallet truck and place it under the material and lift it up. This solution does not require any further adjustments, because the material is already prepared for lifting by pallet truck, see Appendix L.

The data gathered by one of the methods above can be written down and entered into the system later manually or it can be entered into the system directly. For entering the data directly into the system a computer is required. A fixed computer would not be practical, because it is almost the same as writing it down and entering it later. The computer has to be near the machines, so computers have to be installed at the machines or the operation workers have to use a handheld device. One of the benefits of handheld devices is that workers can tell the system on what orders they are working, so the problem of labour monitoring is also solved. Vantage supports handheld devices so no other external software has to be linked to the existing software.

Another way of monitoring labour is to use the magnetic cards that are already used for general labour registration. When a card reader is positioned at every machine and production workers clocks into that machine, the labour consumption can be determined easily when vantage knows which order is produced at which machine. This new system can even be combined with the existing labour registration system that is coming from Atimo, so no new software has to be implemented.

There is also an opportunity to make use of the operating percentages that are calculated by the Research and Development Department in the process routing. Evaluation of these operating percentages over 2012 showed that the percentages are (surprisingly) accurate. Besides the inaccuracy of this method another problem is that it cannot be implemented by the IT department of United Springs B.V. themselves, but an external company has to come over to adjust the software so it is capable of using the operating percentages.

The most traditional way to monitor the labour consumption is to use paper. In that case the employees have to write down the times they are working on a specific order and later these times are entered into the system. This is a time-consuming method that probably will lead to employees that do not write down the few minutes they spent in between on small tasks, so this solution is unusable.

Opposite to this traditional method is the most advanced method, the automation. In this case lasers will monitor the material use at the machines and RFID chips or cameras will monitor the labour by dividing the production area into spaces according to the machines in that spaces. When an employee is in the space of a machine for five minutes, the system will book 5 minutes onto the order that is registered at that machine. The system will also book amount of materials that the lasers observed at the machine. The only thing an employee has to do, besides the normal setup and operating tasks, is telling the system which machine is manufacturing which order. This can be done by using manual input, barcodes or RFID chips. Unfortunately this solution is too expensive.

4.5.3 Combining alternatives

In this section the multiple options are combined into a set of different total solutions. A total solution should include a method for monitoring labour and a method for monitoring the quantity of material used.

Out of the multiple ways for determining the material usage, two are chosen as best options: Weighing the material and measuring the material usage. The alternative where the products are counted is not reliable enough according to the Research and Development department, because of the big chance that the counting is not exact enough and set-up losses and other losses are not included.

For the monitoring of labour two of the four options are selected as alternative. These options are: using the operating percentage and using magnetic cards. The use of paper cards on which the hours are written down is too out-dated, too time consuming and not reliable enough. The use of mobile devices would cost too much and most of the features of the mobile devices would not be utilized.

These alternatives are combined into four possible solutions to the problem. These solutions are mentioned and explained below.

The first alternative is called *M-Calc* and includes ***M**easuring* the quantity of used materials and ***Calc**ulating* the used labour. The quantity of material used is calculated by comparing the distance from the material to the edge of the coil before and after production. When the weight of the material at the beginning and the characteristics of the coil are known, the quantity of material that is used can be calculated. The calculation is performed by the employee in the warehouse by using the excel sheet designed by Theo Buitenhuis and the calculated quantities are booked in the relevant production orders. The production workers only write down the measurements on the material card and material label.

The used labour is calculated by the use of the operating percentage. Vantage has to be adjusted so that the software is capable of dividing the labour onto different production orders according to the operating percentage. This has to be done by an IT specialist. When this option is implemented nothing changes for the operation workers, they just log into MES and Vantages does the calculating.

The second alternative is called *M-Clock* and includes ***M**easuring* the quantity of used materials and ***Clock**ing* into a production order at a machine. The quantity of material used is calculated by comparing the distance from the material to the edge of the coil before and after production. When the weight of the material at the beginning and the characteristics of the coil are known, the quantity of material that is used can be calculated. The calculation is performed by the employee in the warehouse by using the excel sheet designed by Theo Buitenhuis and the calculated quantities are booked in the relevant production orders. The production workers only write down the measurements on the material card and material label.

The used labour is determined by the use of a log system that is also used for the hour registration of the employees. Every machine should be equipped with a card reader so that employees can log in. It is also possible to install a couple of terminals spread over the production. When Vantage knows how long an employee was at a certain machine and Vantage knows which production order was produced at that machine, the labour consumption can be determined. To implement this alternative an IT specialist has to build a hub between the registration software of the card readers and Vantage. Also the card readers for every machine have to be purchased and installed.

The third alternative is called *W-Calc* and includes ***W****eighing* the quantity of used materials and ***Calculating*** the used labour. The quantity of material used is determined by weighing the material on the coil before production and after production, the difference between those measurements is the quantity of used material. The material cannot be disassembled between production orders, so the coil has to stay on the machine and the machine and coil have to be lifted together. This is not a problem, because the weight of the machine and coil are the same before and after production, only the weight of the material changes. The weighing is done by a crane with a scale or by a pallet truck with a scale and the weights are written down on the material labels that are already used.

The used labour is calculated by the use of the operating percentage. Vantage has to be adjusted so that the software is capable of dividing the labour onto different production orders according to the operating percentage. This has to be done by an IT specialist. When this option is implemented nothing changes for the operation workers, they just log into MES and Vantages does the calculating.

The fourth alternative is called *W-Clock* and includes ***W****eighing* the quantity of materials used and ***Clock****ing into a production order at a machine.* The quantity of material used is determined by weighing the material on the coil before production and after production, the difference between those measurements is the quantity of used material. The material cannot be disassembled between production orders, so the coil has to stay on the machine and the machine and coil have to be lifted together. This is not a problem, because the weight of the machine and coil are the same before and after production, only the weight of the material changes. The weighing is done by a crane with a scale or by a pallet truck with a scale and the weights are written down on the material labels that are already used.

The used labour is determined by the use of a log system that is also used for the hour registration of the employees. Every machine should be equipped with a card reader so that employees can log in. It is also possible to install a couple of terminals spread over the production. When Vantage knows how long an employee was at a certain machine and Vantage knows which production order was produced at that machine, the labour consumption can be determined. To implement this alternative an IT specialist has to build a hub between the registration software of the card readers and Vantage. Also the card readers for every machine have to be purchased and installed.

4.5.4 Designing Multiple Solutions: Conclusion

In this section multiple options are combined to form five alternatives that solve the problem stated in the previous step of the method. The material monitoring can be done by measuring or weighing the material. The labour monitoring can be done by calculating the used labour or by using card readers. These options were combined into four possible solutions: M-Calc, M-Clock, W-Calc and W-Clock. See Figure 34 for a summary of the solutions and their characteristics.

Name	Material Monitoring	Labour Monitoring	Implementation Requirements
M-Calc	Measuring	Calculating	Vantage module for operating percentages
M-Clock	Measuring	Clocking	Card readers and a hub between software and Vantage
W-Calc	Weighing	Calculating	Pallet truck(s) with scale, crane scale and vantage module for operating percentages
W-Clock	Weighing	Clocking	Pallet truck(s) with scale, crane scale, card readers and a hub between software and Vantage

Figure 34. Multiple solutions and their characteristics.

4.6 Step six: Choosing the best solution

This paragraph is about the sixth step of the method, which is about choosing the best solution by using the Analytic Hierarchy Process. The AHP method includes five steps: constructing a value tree, comparing attributes and alternatives, calculating weights, calculating scores and the sensitivity analysis. The input of this step is the set of solutions that are developed in step five of the method. The output of this step should be a solution that is going to be implemented. The objectives of this step are visible in Figure 35.

Step six

Choosing the Best Solution

Construction Value Tree

Comparison

Calculating Weights

Calculating Scores

Sensitivity Analysis

Figure 35. Step six of the method.

First the attributes have to be determined. The attributes are extracted from the requirements and limitations to the solution. There are two types of attributes in this case, normal criteria and cut-off criteria. Cut-off criteria are so important that they cannot be skipped, but it is also hard to give scores to alternatives on cut-off criteria. An example of a cut-off criterion is that a solution has to be conform the law; it is hard to say that alternative A is better than alternative B on that criterion, but it is also too important to skip. So cut-off criteria are not taken into account during the AHP, but have to be satisfied.

In Figure 36 the requirements and limitations are listed with their corresponding attribute name, whether they are a cut-off criterion or not and their definition. The material handling criterion is a cut-off criterion, because a solution can handle the material or not. The same counts for the legal criterion, something is legal or not. The requirements and limitations are relisted first.

The solution…

- has to result in a method for a precise calculation of the material and labour consumption
- has to fit in a fixed budget (50.000 euro)
- cannot consume too much time of the employees when it is implemented (5 minutes)
- has to handle the dimensions of the processed materials
- can be understood by all the United Springs B.V. employees
- has to be supported by the United Springs B.V. employees
- has to be confirm the legal and environmental legislations
- can be implemented within a year

Requirement or Limitation	Attribute Name	Cut-Off	Definition
Problem solving	Accuracy	No	Accuracy of monitoring data.
Budget	Costs	No	Costs of alternative.
Time consumption	Time	No	Extra time compared to current situation.
Material handling	-	Yes	-
Complexity	Complexity	No	The level of complexity of new tasks.
Support	Support	No	The level of support for the solution.
Legal	-	Yes	-
Implementation	Implementation	No	The implementation complexity and time.

Figure 36. Defining the attributes for the AHP according to the requirements and limitations to the solution.

First: The value tree

The first step of the AHP is setting up the decision hierarchy, or in other words the value tree. This value tree exists out of the attributes (criteria) and the alternative solutions. Multiple levels of attributes are possible, but in this case one level is satisfactory to keep the relations between the attributes clear. The value tree is added in Figure 37.

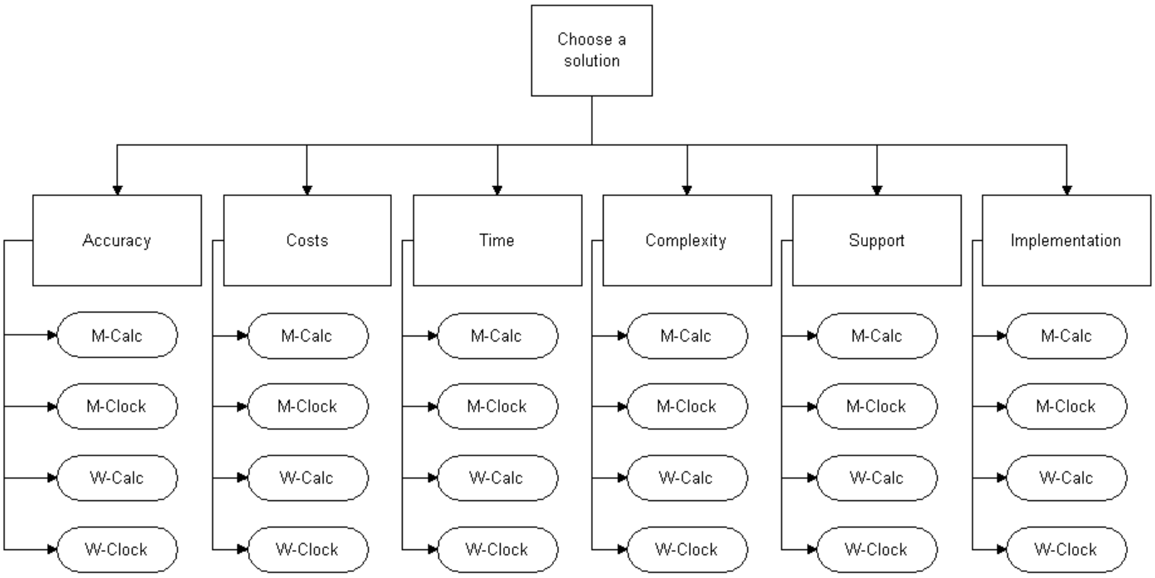

Figure 37. The value tree of the AHP.

Second: Make pairwise comparisons of attributes and alternatives

In this second step of the AHP the different attributes and alternatives are compared to each other. Starting with the attributes, every attribute should be compared to the other attributes to determine which of the two is: equally important (1), weakly more important (3), strongly more important (5), very strongly more important (7) or extremely more important (9). The same applies for the multiple alternative solutions. These comparisons are made by the financial controller, the research and development department and the production manager. All the comparisons are averaged to one set of comparisons; this set is attached in Appendix N.

Third: Transform the comparisons into weights and check the consistency of the decision-makers

The third step of the AHP is transforming the comparisons into weights that sum to one (1). This is a mathematical process; all the calculations are transformed into a Microsoft Office Excel workbook so only the comparisons have to be inserted. The same counts for the consistency check. See Appendix M for the used calculation method. In Appendix O the results are attached.

Fourth: Use the weights to obtain scores for the different options and make a provisional decision

The fourth step of the AHP is transforming the weights of all the attributes and alternatives into scores. These scores determine the relations between the alternatives; the alternative with the highest score is the best solution and the alternative with the lowest score is the worst solution. The winner of the AHP is the solution called M-Clock with a score of 0,3404. The second best solution is W-Clock with a score of 0,3206, the other scores are visible in Appendix O.

Fifth: Perform sensitivity analysis

The fifth and last step of the AHP is performing a sensitivity analysis. Normally this is done by a software package, but in this case this is done by use of logical sense. The average Inconsistency ratio is 0,12 and the individual scores vary between 0,0070 and 0,2475. An inconsistency ratio below 0,10 results in a choice that does not have to be doubted, unfortunately this is not the case. Also the scores of the best alternative and the second best alternative are real close, which makes the choice even more doubtful. The four most important attributes have a better average inconsistency ratio of 0,0772.

Remarkable is that the best solution was different than the solution which was expected to be most favourable. Most people believed that weighing the material would be the best solution, not measuring the quantity of material used. This suggests that the decision makers were not too subjective.

All in all it can be concluded that the AHP resulted in the choice of a feasible solution. The best alternative turned out to be M-Clock, the solution in which the material is measured and the labour consumption is determined by the use of registration terminals. The sensitivity analysis showed that the decision process was not flawless, but it is very plausible that the found solution suits United Springs B.V..

4.7 Step seven: Communicating, Evaluating and Improving the solution

After the best solution is chosen, the solution has to be communicated, evaluated and when improved. Communicating the solution is about gathering information about the expected outcomes, feasibility and support. The evaluation is about comparing the expected outcomes to the desired outcomes on the following objectives: time, costs, quality, flexibility and dependability. The improvement of the solution is about processing the information gathered during the communication and evaluation to improve the solution. The outcome of this step is a solution that is ready for implementation.

Step seven

Communicating, Evaluating and Improving the Solution

Communicate
-Expected Outcomes
-Feasibility
-Support

Evaluate
-Time
-Costs
-Quality
-Flexibility
-Dependability

Improvement

Figure 38. Step seven of the method.

4.7.1 Communication

This section will be split into two sections, one for the material monitoring and one for the monitoring of the labour. For each of these the expected outcomes of the solution are analysed, the feasibility is checked and the support among the employees is probed.

4.7.1.1 Material

For monitoring materials the solution is to measure the quantity of material that is left on the coil by comparing the distance between the material and the edge of the coil before and after production. These measurements will be written down together with the coil-type. Knowing the start weight of the material, the warehouse employee can calculate the quantity of material that is left on the coil by using the Excel sheet made by Theo Buitenhuis. The difference between the weight at the start of the production and the weight that is left is the quantity of material that is used for producing the production order. The warehouse employee books the used material onto the production order and inserts the quantity of material that is left into the system.

The employees expect that this solution maybe is not the most accurate solution, but it is a quick and effective solution. Measuring the distance between the material and the edge of the coil and writing it down will only take a few seconds. Writing down the coil type is also no problem for the production workers, because they know all the coil types and an overview of the different coil types is made and added in Appendix U. In the warehouse the measurements and coil type have to be entered into the Excel sheet en the result has to be entered into the system. Furthermore nothing will change with regard to the current situation.

The solution is feasible, because it is relatively easy to implement and does not require large investments or radical changes. Also the support among the employees is good.

4.7.1.2 Labour

For the monitoring of the labour consumption the best solution is to use a computer system with multiple terminals to register which employee is working at which order at a certain time. This means that the production workers have to clock onto an order at a terminal and the software registers how long this employee is working on that order. Afterwards the time that all the employees worked on an order can be determined.

According to the people at United Springs B.V. it is important to ensure that the additional handlings that are involved with this solution do not consume too much time. Production schedules sometimes are already tight and when the additional tasks consume too much time the support for the solution will be very low.

This support is so important, because it is not likely that everyone will perform his or hers tasks like they should when they do not think it is useful or takes too much time. Therefore enough terminals should be placed and the additional handlings should be kept as easy as possible.

The positive thing about the communication of the solution for the monitoring of the labour consumption is that is likely that the employees will support the solution, because it will lead to exact information about how realistic the planning is. In the current situation the planning is suspected to be unrealistic and by the monitoring of the labour consumption this can be confirmed or invalidated.

4.7.2 Evaluation

This section will also be split into two sections: material and labour. In each section the desired outcomes are compared to the expected outcomes of the solution on the following dimensions: time, costs, quality, flexibility and dependability. The desired outcomes are coming from the requirements to the solution and some additional information of the management.

The time dimension states that it can be expected that the solution requires extra time in the production, but that additional time cannot be too large with a limit of five minutes per employee per order (material) or day (labour). The costs of the solutions may not exceed 50.000,- euro's and the lower the costs, the more desirable the solution. A little side note is that the costs have to be in line with the benefits the solution offers. The quality of products may not be affected in a negative way. Furthermore, the flexibility of and within the production cannot decrease that much and it is also not desirable that the United Springs B.V. gets more dependable of customers or suppliers. So only a change in time, flexibility and additional costs are acceptable.

4.7.2.1 Material

The solution for the monitoring of the material is satisfying for all the dimensions. It requires a minimum amount of time when it is implemented, the implementation is relatively easy and the costs are low. Furthermore a test showed that the method is accurate enough and the employees are willing to cooperate. The only suggestion the employees did was to develop a special measure instrument for measuring the distance of the material to the edge of the coil.

4.7.2.2 Labour

The solution for the monitoring of the labour consumption per order is also satisfying for all dimensions, but definitely has more negative effects compared to the effects of the solution for the monitoring of material. This solution consumes more time, is more difficult to implement, is more expensive and decreases flexibility a little. But that are the costs of getting insight into the depth of production.

4.7.3 Improvement of the solution

The logical consequence of the evaluation is that, in this stage, the solution does not have to be improved, because the expected outcomes are in accordance with the desired outcomes.

4.8 Step eight: Implementing the solution

The last step of the method is about implementing the solution. This step exists out of the preparation and the execution. The preparation can exist out of two or three steps; in this case the preparation of the implementation exists out of three steps, because the tool phase of developing the solution is not yet executed. The preparation of the implementation of the method starts with this tool phase, after that the implementation plan has to be written and evaluated.

The execution only exists out of one step and that is executing the implementation plan. During this step it is important to communicate and to evaluate. When an evaluation offers an opportunity for improvement, take that chance and improve the solution.

Step eight
Implementing the Solution

Prepare
-(Tool)
-Implementation Plan
-Evaluate

Execute
-Communicate
-Evaluate
-Improve

Figure 39. Step eight of the method.

4.8.1 Preparation

The preparation for the implementation will be done separately for the material monitoring and the labour monitoring. Although each preparation exists out of three steps, these sections will be an ongoing story, because the three steps are dynamic processes that continuously interact with each other.

Before the plan for the implementation can be made, the solution has to be developed more in detail, this is what the tool phase is about. The tool phase is part of the development of multiple solutions in step five of the method, but when it is possible the tool phase can be postponed to the implementation of the solution to safe time. The tool phase is about elaborating the solution to a package of tasks that are precisely described including the required support systems.

Making the implementation plan is about determining the steps that have to be fulfilled to implement the solution and the order in which these steps have to be fulfilled. This implementation plan has to be evaluated by communicating it to the employees and by taking their comments into account. Because of the dynamic process this evaluation automatically takes place during the tool phase and making the implementation plan.

4.8.1.1 Material

Calculating the amount of material used was chosen as best solution for the material monitoring. Theo Buitenhuis already designed an Excel sheet for this. This sheet uses the radius of the coil on which the material is stored, the radius of its axis, the distance between the edge of the coil and the material and the weight of the material as reference. After production the distance between the edge of the coil and the material is compared to this distance before production and the used quantity of material is calculated. Unfortunately there were some issues with this method.

The most important issue was that the formula and thereby also the Excel sheet were only usable for coils and not for rings and bundles. Another issue was that the database with information about the coils was not complete and incorrect. Also the large number of required fields that have to be filled will not be contributory to the support of the employees.

These issues were solved by developing an Excel workbook with different sheets for the coils, the coil database and the rings. See Appendix S for screenshots of this excel workbook. The steel bundles were not included, because these are almost impossible to measure and that material is almost never used for continuous production on different orders. For calculating the material used on rings the formula had to be adjusted. Also the number of fields that have to be filled and the number of tasks that have to be fulfilled by the production workers are brought back to a minimum to enhance support.

Because of these adjustments the result of the calculations is not the quantity of used material for producing an order, but the quantity of material left after producing an order.

Comparing this to the quantity of material before production (according to the systems) results in the quantity used during production.

To support the collection of the required information about the material, the material card and material label have to be adjusted, more over these adjustments in the following section.

The new material monitoring process

In this section the new material process and its tasks will be explained. In the end of this section all the required data and tasks that have to be fulfilled will be listed by function. Before the process is outlined some terms have to be explained. The difference between coils and rings is that material is wrapped around a coil, rings only exist out of material; see Figure 40 and Figure 41. Bundles are wire steel, like some coils, but then without the coil. A material batch of coils only exists out of one coil, but a material batch of rings exists out of multiple rings. Therefore the calculation and the required information for rings are totally different compared to the calculation and required information for coils.

For calculating the quantity of material used from a coil the following information is required: the coil type, the original weight of the unused coil, the original distance of the edge of the coil to the material of the unused coil and the distance between the edge of the coil and the material after production. The coil type and the original weight of the coil are entered into the system when the material enters the company and printed on the material label. The original distance between the edge of the coil and the material is written down on the material label by the production worker that uses the material for the first time. The reason that this distance is not written down when the material enters the company is that the material is sealed in plastic when it is delivered. The distance between the edge of the coil and the material is measured after completing a production order. After the production order is completed all these information has to be written down on the material card that comes with the production order. This means that the coil type, original weight and original distance have to be copied from the material label and the distance after production has to be measured. An example of a material card and the material label are added in Appendix P and Appendix G, more over the new material card and material label later on. See Figure 42 for the coil measuring instructions.

For calculating the quantity of material used from a ring the following information is required: the original weight of an unused material batch, the number of rings, the distance of an unused ring, the inside diameter of a ring, the number of unused rings after production and the distance of any used ring. The original weight of the material batch and the number of rings are entered into the system when the material is delivered, this information is printed on the material label. The distance of an unused ring and the inside diameter of a ring is measured by the production worker that uses the material for the first time and written down on the material label. The reason that this distance is not written down when the material enters the company is that the material is sealed in plastic when it is delivered. The number of unused rings and the distance after production are count, measured and written down on the material card after the production of an order is completed. Together with this distance and number of unused rings the original weight of an unused material batch, the number of rings, the distance of an unused ring and the inside diameter of a ring should be copied from the material label. The measuring instructions are explained in Figure 43.

Figure 40. Coils.

Figure 41. Rings.

Figure 42. Measuring method for coils. Translation of the instruction: Lay the measuring bar on top of the coil and measure distance A, the distance between the underside of the measuring bar and the material.

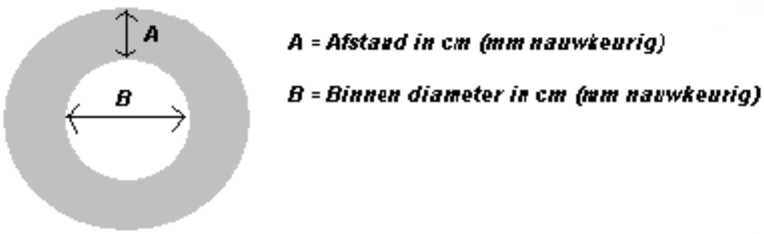

Figure 43. Measuring method for rings. Translation of the instruction: A = Distance in centimetres (mm accurate), B= Inside diameter in centimetres (mm accurate).

The solution requires additional fields on the material label and material card like mentioned earlier, therefore new material cards and labels are designed. Three versions of the material card and material label are designed: one for coils, one for rings and one universal version. These new material cards and material labels are visible in Appendix Q1 to Appendix Q6.

The next step is to describe the new process the materials pass through. The process starts in the warehouse where the materials are delivered. When the materials are delivered, the total quantity is entered into the system and the system is told whether the material is delivered on a coil, in rings or in bundles. When the material is delivered on a coil, the coil type is entered also. When the material is delivered in rings, the number of rings is also entered into the system.

When a production order is released out of the Planning Office, the material card is printed. When the material is used for multiple orders in a row and does not get back to the warehouse in between, the new designed material cards are printed so the required information can be written down. The important thing is that this information only has to be gathered when the material is used for multiple orders in a row. When the material is not used for multiple orders in a row, the material returns to the warehouse where it is weighted. So the new designed material cards are only printed when the information is needed. When a coil is used the material card for coils is printed, when rings are used the material card for rings is printed and when the material is on a bundle no special material card is printed, because these materials are almost always returned to the warehouse. When the production order is released out of the Planning Office the material is delivered to the machine with the material card, the material label is always fixed to the material itself.

When the production worker arrives at the machine he or she checks if the material is used for multiple orders in a row. When this is not the case the normal work can go on. When the material is used for multiple orders in a row, the production worker has to determine whether the material is used before by looking if the material label is filled. When the material is not used before, he or she fills the empty fields on the material label. When the material label is already filled, i.e., the material has been used before, he or she can continue his or her work.

After the production of an order is completed two things can happen. When the material is returned to the warehouse nothing has to be measured, the warehouse employee weighs the material and enters the difference between the weight before and after production into the system. When the material is used for another order, the production worker measures what he needs to fill in on the material card. After the material card is filled it is returned to the Warehouse Department.

The warehouse employee enters the information from the material card into the Excel sheet and compares the weight that is left to the weight before production. The difference between these two is entered into the system so that the system knows how much material is used for the production of that order and how much material is left. After this step the process for a specific production order is fulfilled and it starts over again for another production order.

Summarizing this section about the new process for material monitoring is done by the following table which is visible in Figure 44. The table shows what information has to be gathered for material that is used for multiple orders in a row, who gathers that data and when it is gathered.

	Required information	Collector	Time in process
Coil	Original weight	Warehouse	At delivery
	Coil type	Warehouse	At delivery
	Original distance	Production Worker	Before first usage
	Distance after production	Production Worker	After production
Ring	Original weight	Warehouse	At delivery
	Number of rings at delivery	Warehouse	At delivery
	Distance unused ring	Production Worker	Before first usage
	Inside diameter	Production Worker	Before first usage
	Number of unused rings after production	Production Worker	After production
	Distance of used ring after production	Production Worker	After production

Figure 44. Summarizing table for the material monitoring process.

4.8.1.2 Labour

For the monitoring of labour a more automated approach was chosen compared to the calculation method for monitoring the material. The labour is going to be monitored by a computer system. This means that order numbers will identify productions orders and magnetic cards will identify the employee that is going to work on that production order. Two things are very important with regard to this kind of system: the software has to be linked to Vantage and there should be enough terminals.

First the software, the software has to provide real time information to the ERP system. Also the information about an order in the labour monitoring system has to be linked to the information about an order in Vantage. It would simply cost too much time to copy and paste information about an order from the labour monitor system and Vantage into Excel and execute some calculations.

Second the number of terminals that have to be installed. A terminal is a small computer at which an employee can tell the system that he or she is going to work on a certain order. Some terminals can even register the kind of task the employee is going to perform. Troublesome about working with terminals is that they have a fixed position, i.e. they are mounted onto a pole or to the wall and this means that the employees have to walk to the terminal to tell the system what they are going to do. When the employees have to walk long distances the process gets really inefficient and the chance that all employees actively use the terminals will decrease.

The new labour monitoring process

In this section the new process and its tasks will be explained. This process requires only one combination of information, how many labour hours were consumed for the production of an order. It would be useful when these labour hours can be split into an overview of employees and time periods. It is not necessary that this could be done in Vantage; Vantage only needs the total quantity of labour consumed. It would be useful if this distribution can be given in the special labour software.

To gather this information the orders have to be identified, this is done by its unique number. Depending on the kind of terminal, this code can be entered manually or by the use of barcodes. These barcodes are not yet printed onto the production orders, but that can be done by Vantage. When these barcodes are printed onto the production order, the employees can easily scan the barcode to let the system know that they are going to work on that order.

It is not only the order number that should be identified, also the employee that is working on that order should be known by the system. This can be done in several ways. Every employee can get his or hers unique number that has to be entered manually, but this method is very error prone. Using badges with barcodes or magnetic cards is far more reliable.

The minimum number of terminals that should be placed is eight. This number is determined by the management of United Springs B.V. and ensures that the employees do not waste too much time on clocking in and out of an order. The ideal situation is to place a terminal at every machine, but depending on the costs of the chosen terminal this might be too expensive.

So the required information and instruments are determined and the process can be described. This process starts with the employee entering the building of United Springs B.V. in Hengelo. He or she clocks in to the general terminal at the entrance of the building, the system now knows this specific employee is in the building. Now he or she prepares for work and enters the production and gets the production orders he or she will be working on the following hours. These orders could be setup tasks or operation tasks.

The next step is to clock into the order that the employee is going to work on. First he or she clocks in with his or hers unique number. Next the order number is entered and, when the terminal supports this, the employee can choose the kind of tasks he or she is going to perform. Then the work can start.

When the production worker finishes his or her task on the production order and is going to work on another production order, he or she has to clock into that new order. First he or she clocks in with his or hers unique number. Next the order number is entered and, when the terminal supports this, the employee can choose the kind of tasks he or she is going to perform. Then the work can start. This process is repeated all day until the employee is going home, then he or she clocks out of the general terminal at the entrance of the building.

It should be possible that the employees can also clock into other things than production orders. These are tasks like cleaning, joining a meeting, taking a break or another general task. This gives the company insight in the quantity of labour consumed by these kinds of overhead activities.

4.8.1.3 The implementation plan

What has to be done to implement the solution? In which order should this be done? Who should do it? These questions are central in this section about the implementation plan. Most of the information in this section would be repetition of what is stated earlier, but in a more clear way.

For implementing the solution in the material sphere the forms are already designed, but should be modelled in Vantage. Inserting the new fields into Vantage should be done by the IT Department. Also the measuring bar should be manufactured and the employees have to be instructed over the new method. The measuring bars are manufactured by the Maintenance Department, the Management should instruct the employees. First the measuring bars should be manufactured, then the employees should be instructed and the last thing to do is to prepare the ERP system so that when it is finished everybody knows what the new fields are for.

Where all the implementation steps for the material monitoring method can be performed internal, the implementation steps for the labour monitoring method are mostly dependent of other companies. The terminals have to be installed and the software has to be linked. The only things that can be done internal is instructing the employees and, when necessary, providing the production order with barcodes. After the software and terminals are chosen, the link between the software and Vantage should be constructed, then the employees should be instructed and the production orders should be provide with a barcode, the last step is to install the terminals. The IT Department should provide the production orders with barcodes, this includes making posters for near the terminals with codes for cleaning and suchlike. The software is linked by IT professionals and the terminals are installed by the manufacturer. Again the Management should instruct the employees about the upcoming chances.

To summarize this section all these actions, actors and the sequence of these actions are presented in the table in Figure 45. After this step the preparation of the implementation of completed and the solution is ready to be implemented. This implementation is not part of this report, because it takes too much time compared to the scope of the bachelor assignment. It is worth mentioning that the solution will be implemented for United Springs B.V..

	Activity	Actor	Sequence
Material	Manufacturing measuring bar	Maintenance Department	1
	Instructing employees	Management	2
	Implementing forms	IT Department	3
Labour	Making software link	IT Professionals Manufacturer	1
	Instructing employees	Management	2
	Implement barcodes	IT Department	3
	Installing the terminals	Manufacturer	4

Figure 45. Implementation activities, actors and sequence.

With the completion of the implementation plan also the demonstration is completed. All eight steps of the method for developing a process for material and labour monitoring are fulfilled. The method resulted in feasible and satisfying solution for United Springs B.V.. In the next chapter this demonstration will be evaluated to determine what went wrong and what went right. By analysing the positive and negative aspects, the method can be improved.

5 Evaluation

The fifth step of the Design Science Research Methodology (DSRM) is the evaluation of the demonstration and thereby the evaluation of the designed method. In this evaluation the effectiveness and efficiency are analysed. This analysis will lead to strong and weak points of the method. These negative points can be improved when that is possible. Not only the opinion and experiences of the designer are important in this evaluation, also the opinion and experiences of United Springs B.V. are important.

To know what the opinion of United Springs B.V. is and what the experiences are, four employees are interviewed. These employees represent the Warehouse Department, Finance Department, Management Team, Administration and Research and Development Department. Summaries of these interviews are added in Appendix R.

First the experiences of the different departments of United Springs B.V. are stated. The second step is to reflect on that experiences and add own experiences. The last step is to determine which aspects of the method can and should be improved.

The conclusions of these interviews concern some positive and negative aspects of the designed method. All the interviewed persons share the positive points. The mentors of the project, Mr. Reterink and Mr. Buitenhuis, also discovered some negative points that can be used for improvement of the method.

Speaking in general terms, the method is very efficient and effective. The method is effective, because material monitoring is done more accurate. The method is efficient, because determining the material weight is done quicker compared to the 'old' situation. The method enables the executor of the project to independently determine the level of depth for every project. Also every step exists out of some relatively easy to perform steps, what keeps the tempo high. Because of the two checkpoints in the method, where has to be decided whether to go back some steps or to continue to the next step, a feasible solution is most likely to be the outcome of the method.

The aspect that is appreciated most about the method is the practical perspective. This includes the extensive analysis of the processes within the company and the context of the company. This makes it possible for the executor of the project to make decisions that are feasible within the company. Also the development of multiple solutions is received as a good method to make sure no alternatives are missed.

Three negative aspects of the method are also identified, those are: the use of the AHP, the stage wherein external data is gathered and the involvement of employees. These negative aspects are explained below.

The use of the AHP for choosing the best solution is criticized because of the difficulty of making decisions without hard data and the translation of the comparisons into numbers by the interviewer and not by the decision makers themselves.

Also the fact that the first time that information is gathered from other companies for possible solutions is during the development, is seen as negative aspect of the method. This is undesirable because one is depending on the speed of other companies. When the project has to be executed in such a short like this one, the speed of the project depends of the speed at which information is available. When this information is requested earlier, the project is not slowed down as result of waiting on others.

The last point of criticism is the involvement of the employees. This involvement could take place from an earlier stage and could be more intense. When the employees are more involved, this involvement would generate more support for the project and the solution.

Now that the experiences within United Springs B.V. are mapped, these can be reflected and the own experiences can be stated. After this step it should be clear which parts of the method should be changed according to the criticism and which parts should stay as they are.

The effectiveness and the efficiency of the method are very good; this is caused by the simple but complete steps of the method. Also the development of multiple solutions and the extensive analysis of the processes within the company and the context of the company are very important. In other words, the practical perspective of the method is very important for successfully completing the project.

The criticism on the AHP for choosing the best solution is shared almost totally by all participants of the interview; it is too difficult for making decision without hard data. The only remark is that the AHP is very useful for determining weights for the different attributes on which the decision is based.

The criticism on the stage in which information is gathered from other companies is partly shared. It is true that waiting on information from other companies is not ideal and could cause a real delay or even a full stop of the project. The other side of this story is that the executor of the project does not gathered all the information he needs for knowing what he wants to know from other companies. This can cause useless work for the executor of the project, the other companies and the chance that in later stages information has to be gathered again. So it is not ideal to gather that information from other companies in an earlier stage, but also not in the development stage. The stage in which this information should be gathered should depend on the period in which the project has to be completed. A longer period means moving the moment for gathering information from other companies to the development so that all the inside information is available. When the period wherein the project has to be completed is shorter, the information should be gathered earlier.

The criticism about the involvement of employees in the project to improve support is also partly shared. However the support for the project and the solution are very important, it is also important to have and keep a fresh look on the organisation and its processes, involving the employees too much can cause this objectiveness to partly disappear. Of course the employees should be involved, but information gathered this way should be checked by the executor of the project by objective observations.

This brings us to two aspects of the method that needs some adjustments: the involvement of employees and the stage wherein information from other companies has to be gathered. Here the method is considered as it is and as it should be on each of these two improvement areas.

The involvement of the employees in the current method is described only in the development of multiple solutions as *'...input from the employees should be taken into account'*, which is not a huge involvement. To give the support of the employees an impulse, these employees should be involved in the beginning of the process and during the development. During the investigation part of the method de employees should be involved in the analysis of the context and the processes. With regard to the development, the second phase of the method, nothing chances.

For determining the point in which the gathering of information from other companies should be started the time scope has to be estimated by the executor of the project. When the time scope of the project is tight, the information should be gathered really early in the process as sort of parallel process. When the time is no restricting factor, the information should not be gathered before all the necessary information is available.

By concluding this chapter the evaluation of the demonstration is completed. This is the fifth step of the Design Science Research Methodology (DSRM). The next step is the communication of the method; this will be done in chapter 6.

All by all it can be concluded that the method is performing well. The method is effective and efficient, has a practical perspective and the divergent-convergent way of working in the development results in good solutions.

Of course the method is not perfect. The involvement of employees should be extended to the first phase of the method and, depending on the time scope of the project, the moment at which information gathering from other companies should be started also.

6 Conclusion and recommendations

This chapter is about the sixth and last step of the Design Science Research Methodology (DSRM), the communication of the designed method. In this case this is the method for developing a process for material and labour monitoring. This method will help companies to determine the right prices for their products so they can compete against other small and medium size companies without risking bankruptcy. The communication includes a summary of the research questions, the method, the limitations and suggestions for further research and the recommendations.

6.1 Research questions

In this report multiple research questions are answered. The first research question is answered in the conclusion of the literature study in chapter 2. The research question that is answered in chapter 2 is '*How is a goof method developed?'.* The second research question that is answered is '*What is a suitable method for developing a process for monitoring the material consumption and labour hours?'.* This question in answered in chapter 3 and is the method where this report is about. A summary of the method is given in section 6.2. The third and last research question is about the demonstration of the method: '*How can this method be tested?'.* This question is where chapter 4, the demonstration, is about. This chapter also includes some sub research questions: '*What does the production process of United Springs B.V. look like?', 'What does the process which the materials pas through look like?', 'Which method does United Springs B.V. use for monitoring the materials and labour hours?'* and *'What causes the difference between the estimating and the costing?'.*

6.2 The method

The method for developing a process for material and labour monitoring exists out of eight steps, which are divided into two phases. These phases are called the investigation and the development. Like the name of the first phase suggests, the investigation is about investigating the project and the company. This includes determining: the scope of the project, the context of the company, the processes within the company and the problem within the company. The second phase is the development and is about generating multiple solutions, choosing the best solution by use of a structured method, communicating and improving the solution and the implementation of the solution.

First the project is defined. This includes a brief introduction to the company, the cause of the project, the purpose of the project and the expectations towards the outcome of the method. The second step is to analyse the context of the company to be able to make decisions and assumptions that fit the company. The context should be analysed by determining the management style, the organisation characteristics and the internal and external forces that influence the corporate strategy. After the context is analysed, the third step is to analyse the processes within the company. This includes describing the processes, mapping the processes and an analysis of the ERP system that is used. Input from employees is important in this step to gain support. The last step of the investigation and thereby the fourth step of the model is about determining the main problem. This is done by a brainstorm session and the use of a problem tangle. When no solvable problem is found, the project should start over again, when a solvable problem is found the project can continue to the development of a solution in the second phase of the method, the development.

The fifth step of the method is the first step of the development phase of the method. This step is about the development of multiple solutions to the problem stated in the fourth and last step of the investigation. This development is divided into three phases: methodology, technique and tool, which work from the development of a general method (methodology) to a detailed set of handlings and procedures (tool). When the technique phase offers enough information for decision making, the tool phase can be postponed to the implementation to safe time. The choice between the multiple alternatives that are developed in the fifth step is made by use of the AHP in combination with logical sense. The AHP is used for determining the importance of different attributes to gain awareness of the important criteria based on which the decision should be made.

After the best solution is chosen, this solution should be communicated, evaluated and improved. This is the seventh step of the method and is the last step before the implementation in step eight. The implementation exists out of two phases: the preparation and the execution. The preparation is about performing the tool phase of the development when that has not been performed during the development and about making and evaluating the implementation plan. The implementation plan is a collection of activities that have to be performed by actors to complete the implementation of the solution. The execution is about executing the implementation plan to realize the developed solution. After the execution is completed, the method has reached its end.

The conclusion of this report is that the Design Science Research Methodology leaded to a good method for developing a process for monitoring material and labour consumption. The method is easy to use, efficient and effective. It emphasizes the practical part of a project wherein the processes and context of the company are very important. After evaluation the involvement of the employees is more emphasized and the moment at which information has to be gathered from other companies is reconsidered.

6.3 Limitations and Future Work

The method is demonstrated at United Springs B.V. in Hengelo. The conclusion of this demonstration was that the method is effective and efficient, but there were also things that can be improved. The employee involvement had to be improved in the earlier stage of the method to gain support. Also the moment in which information should be gathered from other companies should be evaluated. Originally this was done during the development of multiple solutions, but in projects that have to be completed in a short time, this should be done earlier.

For others who intend to use this method it is recommended to maintain the practical perspective of the method and to pay attention to input from the company and its employees. For further research the choice for the AHP can be reconsidered, employee support can be investigated and literature about the implementation can be investigated more thoroughly.

6.4 Recommendations

Two recommendations have to be done to United Springs B.V. to promote the continuation of the developed solution. The first recommendation is about the internal support. The second recommendation is about the development of the process for monitoring labour.

The process for monitoring material is already developed into details. The process for the monitoring of labour isn't. When United Springs B.V. is going to develop this process into more detail, it is important to make sure the employees support the solution. The attitude of the employees is best described as conservative. This results into a sarcastic resistance to change. More support is generated by showing that the plan is serious and by involving the employees into the development.

When this process for the monitoring of labour is further developed, it is important to keep the goal of the project in mind. The devices that have to be purchased are often very expensive and have features that won't be used. Internal communication will help to keep clear which features are really needed and which are unnecessary costs.

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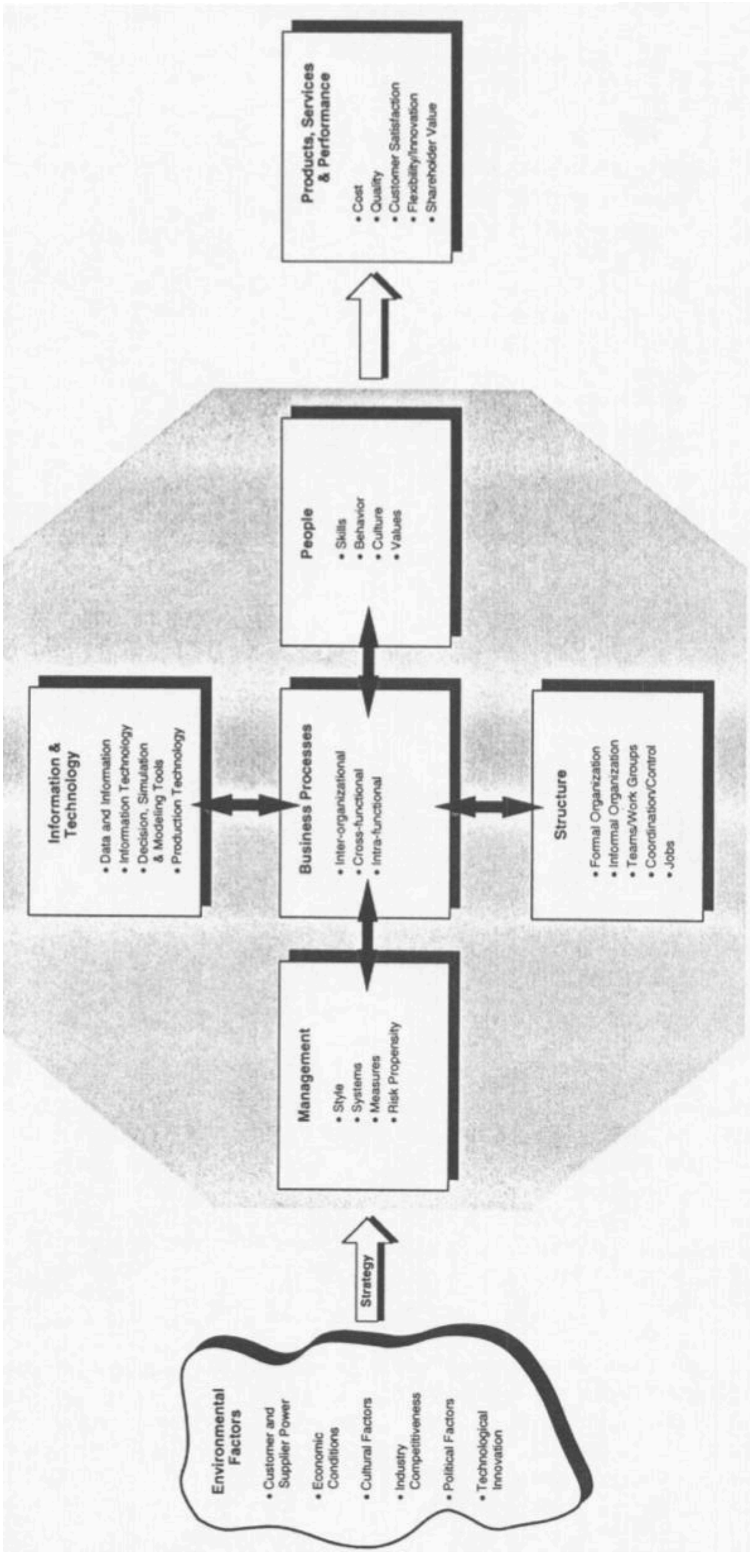
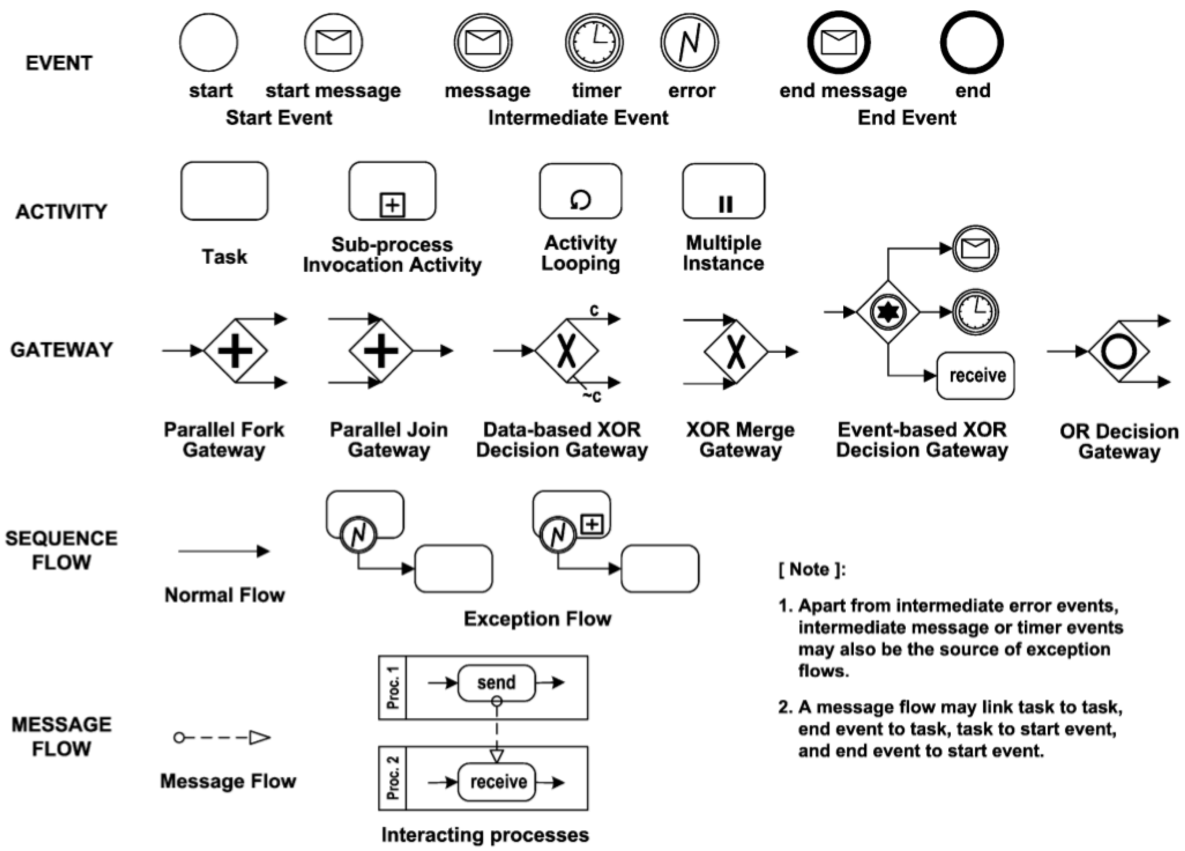
8 Appendix

8.1 Appendix A: Business Process Change Model



8.2 Appendix B: Business Process Modelling Notation



8.3 Appendix C: Explanation and Definition of the requirements and limitations to the solution

The solution has to result in a method for a precise calculation of the material and labour consumption

The most important thing the solution has to do is solve the problems this research is about. It is assumable that every generated solution does that, so how does the one solution distinguish itself from another? That will be done by looking at the accuracy of the method used for gathering and calculating the information. The method used for making those choices is treated in chapter 5.

The solution has to fit in a fixed budget

Another obvious requirement is that the solution has to fit within a fixed budget. The management has set the budget for this project at 50.000 euro. This includes all the items that have to be purchased and the labour hours it takes to implement the solution. The less money a solution consumes, the better it is.

The solution cannot consume too much labour time when it is implemented

Like the previous limitation suggests, the solution is not there to consume much money. This counts for the development of the solution, the implementation of the solution and for the time that the solution is operating in the company. Most of the costs, possibly all the costs, during the operation are the labour costs. In other words, the time that an employee uses for fulfilling the additional steps that are related to the operating of the solution. The less labour time a solution consumes, the better it is. Therefore the management stated a maximum of 5 minutes per production order to determine the weight and a maximum of 5 minutes per day for the registration of labour.

The solution has to handle the dimensions of the processed materials

Within United Springs B.V. there are two main sorts of materials that are processed: wire steel and strip steel. According to the Research and Development department, a possible solution has to handle wire steel with a diameter of maximum 3 millimetres and strip steel with a thickness of maximum 2 millimetres and a width of maximum 20 centimetres.

All the United Springs B.V. employees can understand the solution

Within a company not everybody is highly educated, a possible solution has to take that into account. The way of comparing solutions on this point is comparing the amount of training that is needed, the number of steps that workers have to fulfil and the difficultness of those steps. Also in this case: the less, the better.

The solution has to be supported by the United Springs B.V. employees

When the employees support a solution, the chance that the implementation will be a success is much higher compared to a situation wherein the workers have to adapt their way of doing things in a way they do not like. This is the fit within the organisation. To determine which solution is supported and which solution is not, a survey will be held to get an insight. Solutions that get supported get a high score; solutions that are less supported get a low score.

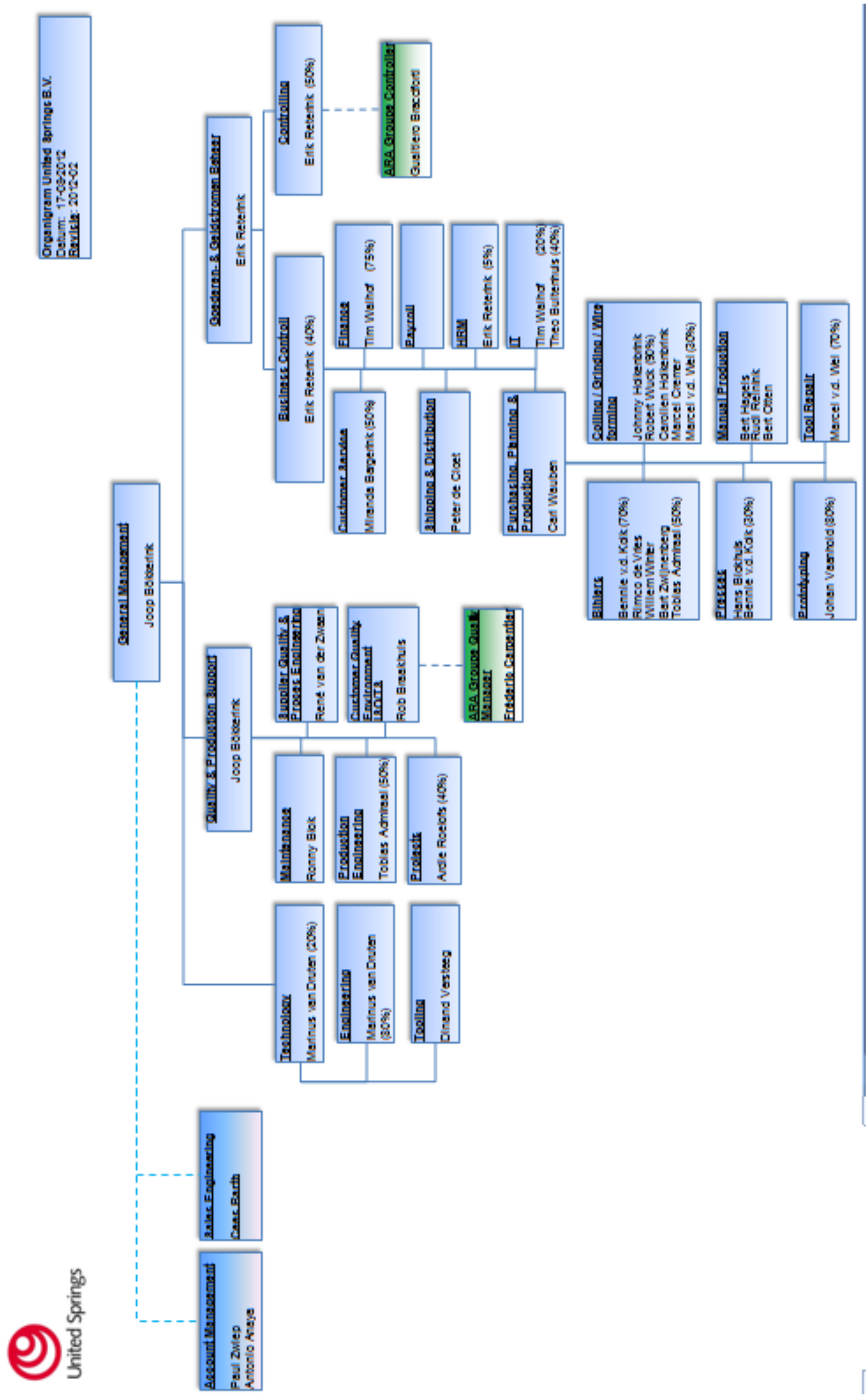
The solution has to be confirm the legal and environmental legislations

It is obvious that a solution that has to be implemented is conform the legislations in that country, both legal and environmental. This is no distinguishing limitation just a limitation that must be met.

The solution can be implemented within a year

The time that it takes to implement the solution can be too long, because the Sogefi group demands that investments have to recoup in one year. That does not mean that it does not make a difference whether the one solution is implemented faster than the other. Also for this restriction counts that faster is better.

8.4 Appendix D: Organisation overview United Springs B.V.



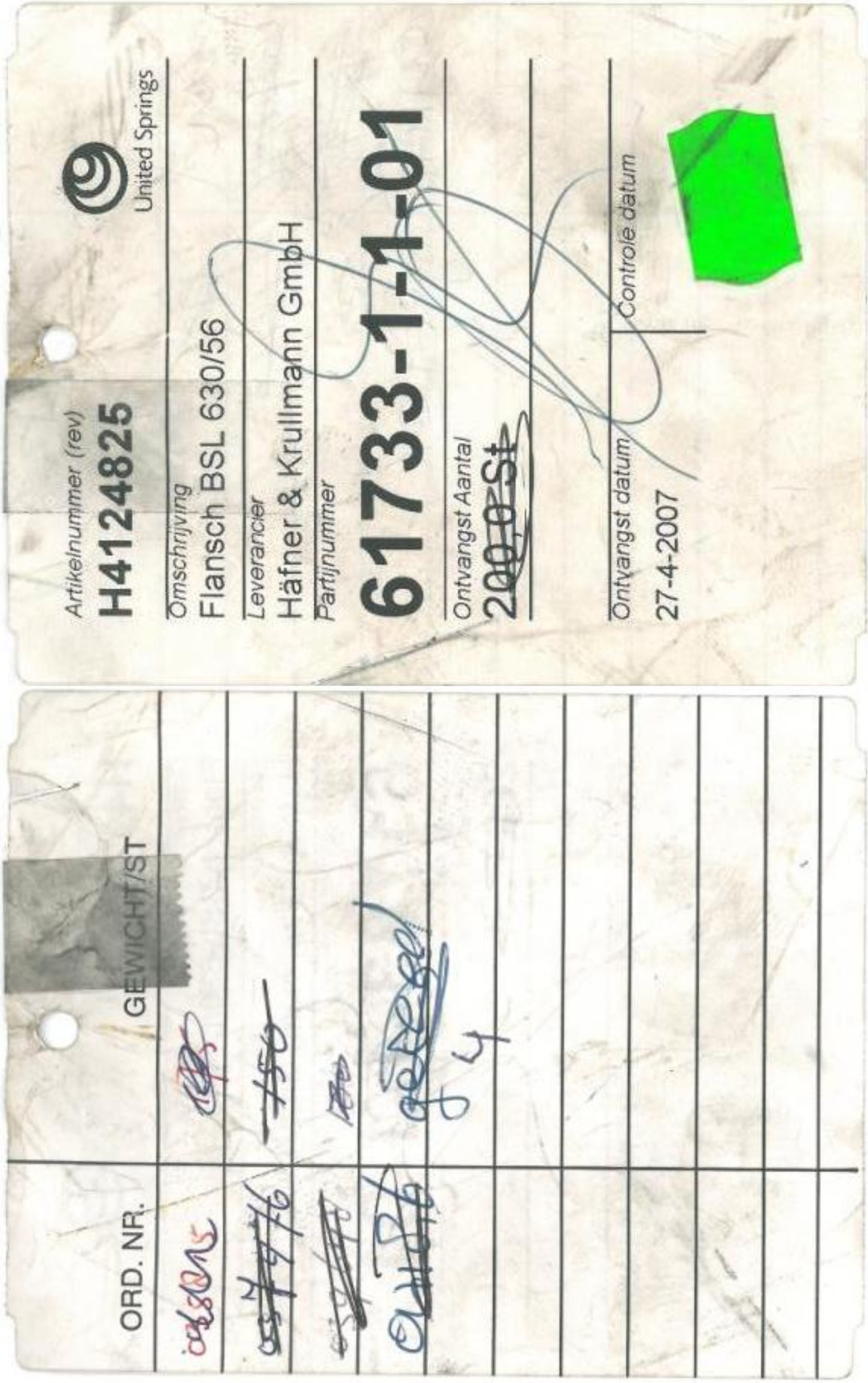
8.5 Appendix E: Order Process

The models that are drawn in Bizagi are too large to include in the appendix of this report. Please send an e-mail to k.degeling@student.utwente.nl or info@koendegeling.nl and I will send you the models

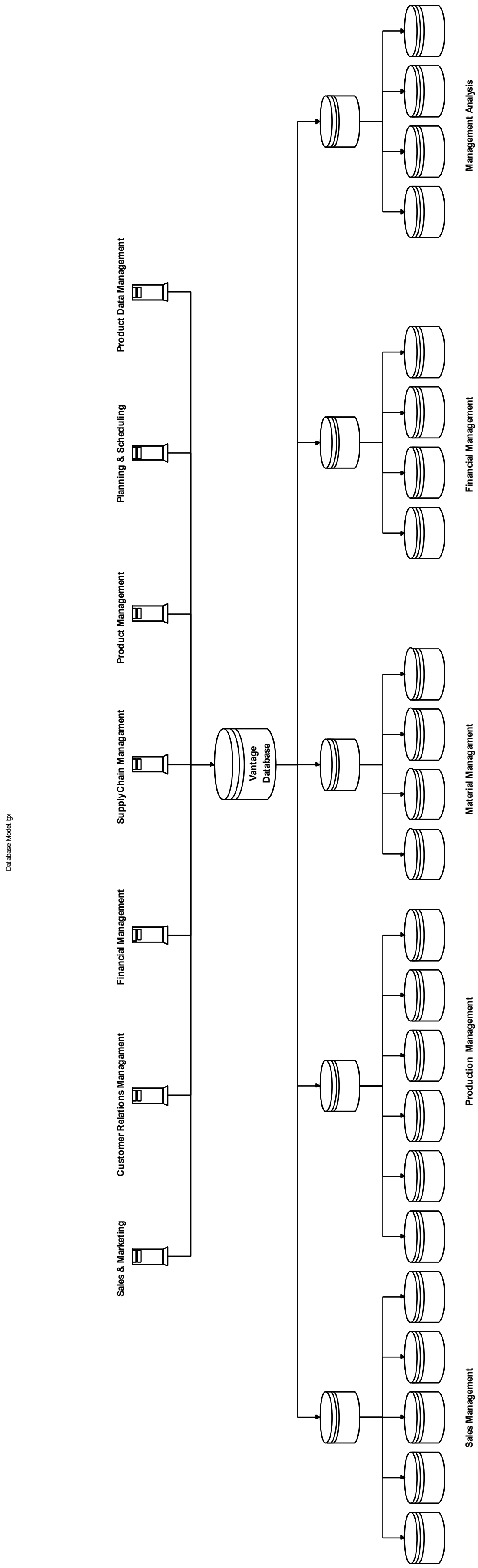
8.6 Appendix F: Material Process

The models that are drawn in Bizagi are too large to include in the appendix of this report. Please send an e-mail to k.degeling@student.utwente.nl or info@koendegeling.nl and I will send you the models

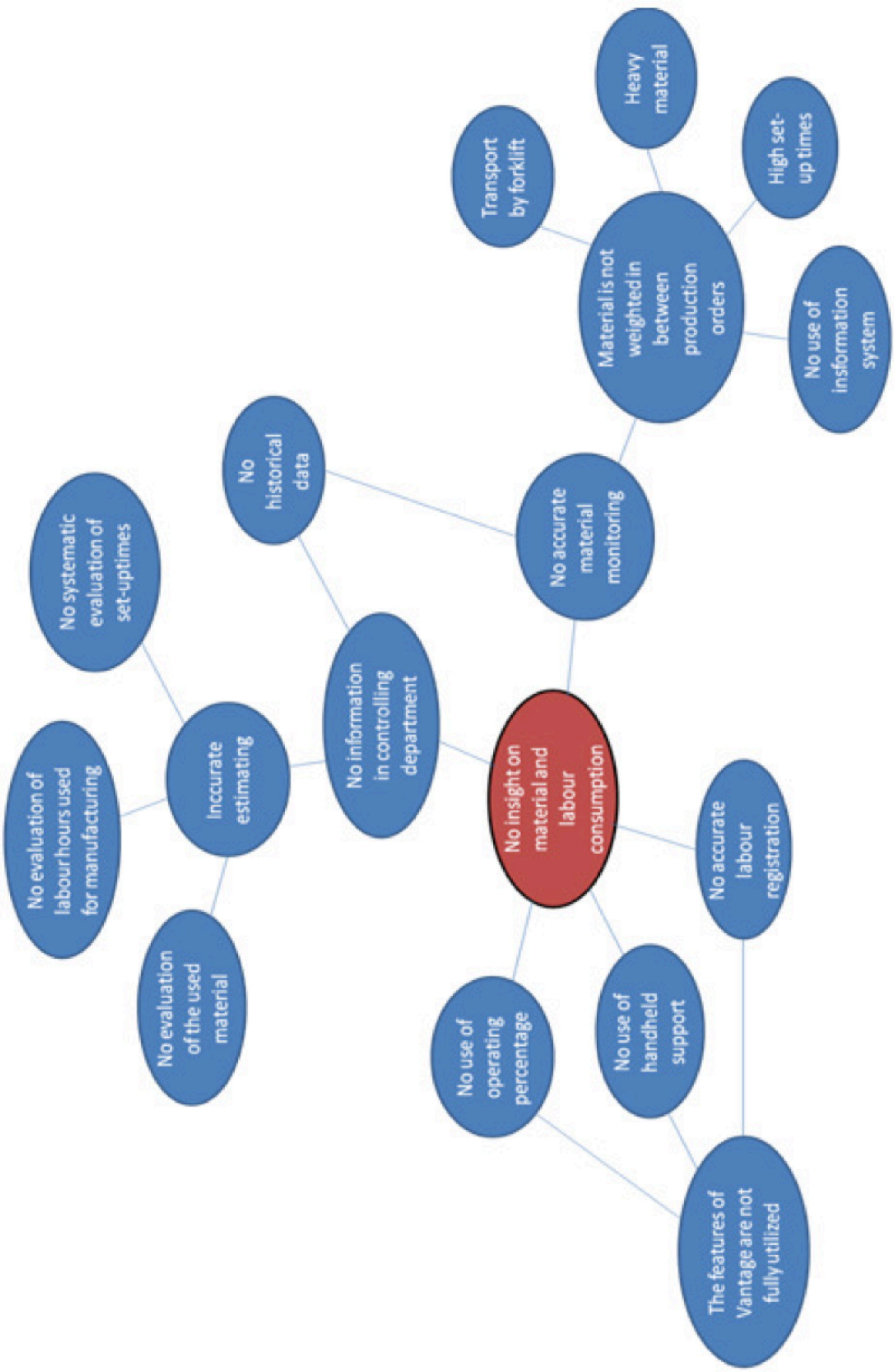
8.7 Appendix G: Material Label



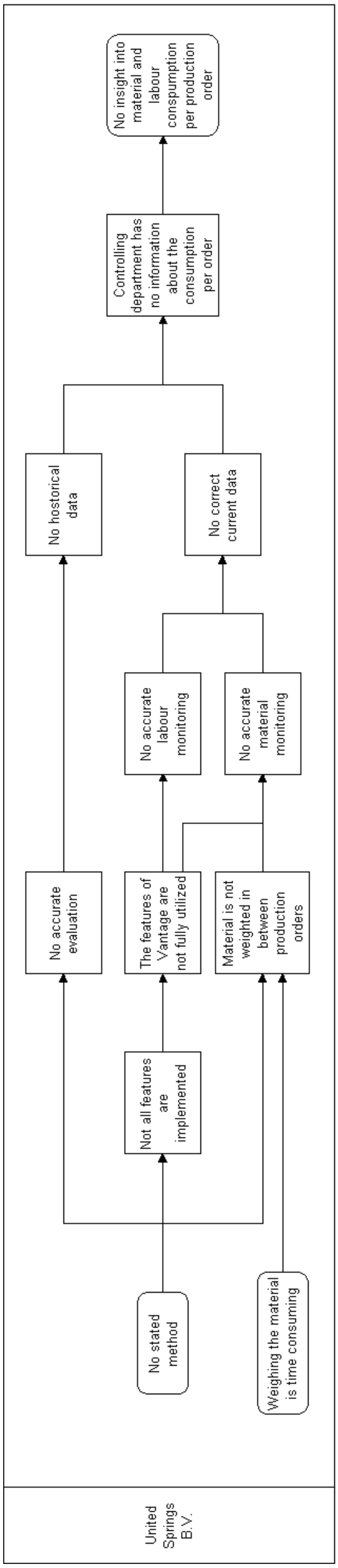
8.8 Appendix H: Vantage Database at United Springs B.V.



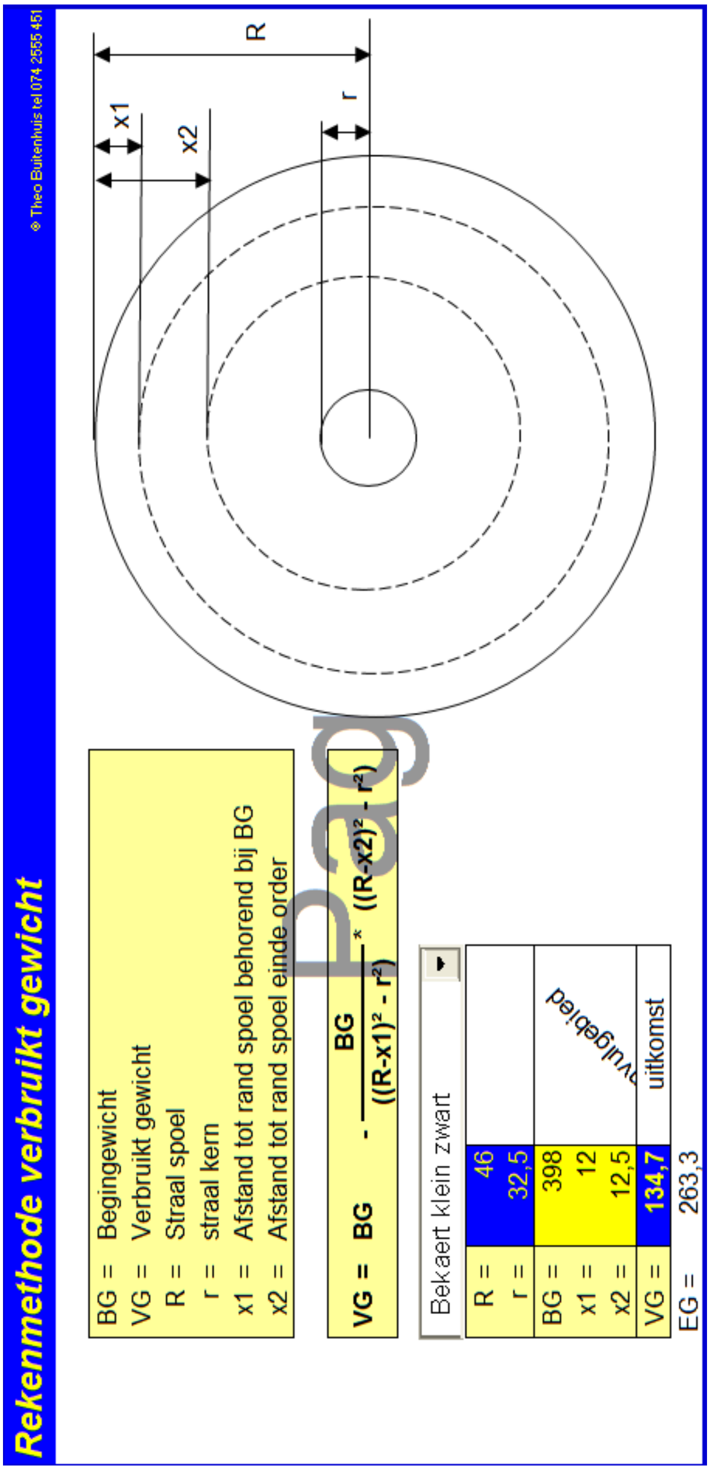
8.9 Appendix I: Brainstorm map



8.10 Appendix J: Problem Tangle



8.11 Appendix K: Excel Sheet for Calculation Material Consumption



8.12 Appendix L: Photo's of the Material in the Production

8.13 Appendix M: Calculation Method for the AHP

On this and the next page you will find copies of the book Decision Analysis for Management Judgement that describes the AHP calculating method.

A is six times more important than C. Any other response would lead to an index greater than zero. Saaty recommends that inconsistency should only be a concern if the ratio exceeds 0.1 (as a rule of thumb), in which case the comparisons should be re-examined. Obviously, there can be no inconsistency in Table 4.2, as only one comparison was made. For Tables 4.3 and 4.4, the inconsistency ratios were 0.059 and 0 respectively. Values of less than 0.1 were also obtained for all of the other tables in the hierarchy. Saaty stresses, however, that minimizing inconsistency should not be the main goal of the analysis. A set of erroneous judgments about importance and preference may be perfectly consistent, but they will not lead to the 'best' decision.

(4) *Use the weights to obtain scores for the different options and make a provisional decision.* Although EXPERT CHOICE will automatically calculate the scores for the options, it is useful to demonstrate how the score for the Aztec machine was obtained. In Figure 4.2, all of the paths that lead from the top of the hierarchy to the Aztec option are identified. All of the weights in each path are then multiplied together, and the results for the different paths summed, as shown below:

$$\begin{aligned}\text{Score for Aztec} = {} & 0.833 \times 0.875 \times 0.222\\ & + 0.833 \times 0.125 \times 0.558\\ & + 0.167 \times 0.569 \times 0.167\\ & + 0.167 \times 0.148 \times 0.286\\ & + 0.167 \times 0.074 \times 0.625\\ & + 0.167 \times 0.209 \times 0.127 = 0.255\end{aligned}$$

Note that the Aztec scores well on attributes that are considered to be relatively unimportant, such as 'Upgrade Costs' (which carries only 0.125 of the 0.833 weight allocated to costs) and 'Speed of Delivery' (which carries only 0.074 of the weight allocated to 'Quality', which itself is relatively unimportant). It scores less well on the more important attributes, so its overall score is relatively low. The scores for all three machines are shown below:

Aztec	0.255
Barton	0.541
Congress	0.204

This clearly suggests that the Barton should be purchased.

(5) *Perform sensitivity analysis.* As in any decision model, it is important to examine how sensitive the preferred course of action is to changes in the judgments made by the decision-maker. Many of these judgments will be 'rough and ready' and the decision-maker may be unsure about exactly what judgments to input

EXPERT CHOICE has a number of facilities for carrying out sensitivity analysis. In dynamic sensitivity analysis, a bar chart shows the weights attached to attributes at a particular level in the hierarchy. By changing the lengths of these bars, the effect on the scores of the alternative courses of action can be examined. Other graphs allow decision-makers to examine the amount of change that can be made to an attribute's weight before the preferred course of action changes.

Performing AHP calculations by hand

If you do not have access to AHP software, then it is possible to obtain approximations of the weights using the following simple procedure. Consider Table 4.3. We first enter the numbers into the lower triangle of the table. For example, as Reliability is four times more important than After-Sales Support, After-Sales Support must be only 1/4 as important as Reliability. This yields the table below:

	Reliability	After-Sales Support	Speed of Delivery	Customization
Reliability	1	4	5	4
After-Sales Support	1/4	1	3	1/2
Speed of Delivery	1/5	1/3	1	1/3
Customization	1/4	2	3	1

Next, we sum the columns of the table and then divide each number in the table by the total of its column. For example, the total of the Reliability column is 1.7. This means that the four values in the Reliability column become 0.588, 0.147, 0.118 and 0.147. The table below shows all the results. Finally, we average the numbers in each row. These averages, which are also shown in the table, can now be used as approximate weights for the four attributes. Similar calculations can be applied to the other tables in the hierarchy.

	Reliability	After-Sales Support	Speed of Delivery	Customization	Average of row
Reliability	0.588	0.545	0.417	0.686	**0.559**
After-Sales Support	0.147	0.136	0.250	0.086	**0.155**
Speed of Delivery	0.118	0.045	0.083	0.057	**0.076**
Customization	0.147	0.273	0.250	0.171	**0.210**

It is also possible to calculate an approximation to the inconsistency ratio by using the following procedure. This may seem involved, but it is easily implemented on a spreadsheet. We will demonstrate the process on Table 4.3:

Step 1: Fill in the lower triangle of the table, as before. Then write the weight for each attribute (or option) at the top of each column. The results are shown below:

	Reliability	After-Sales Support	Speed of Delivery	Customization
Weights	**0.559**	**0.155**	**0.076**	**0.210**
Reliability	1	4	5	4
After-Sales Support	1/4	1	3	1/2
Speed of Delivery	1/5	1/3	1	1/3
Customization	1/4	2	3	1

Step 2: Multiply the weight at the top of each column by each of the numbers in that column. Then sum each row of the resulting table:

	Reliability	After-Sales Support	Speed of Delivery	Customization	Sums
Reliability	0.559	0.620	0.380	0.840	**2.399**
After-Sales Support	0.140	0.155	0.228	0.105	**0.628**
Speed of Delivery	0.112	0.052	0.076	0.070	**0.309**
Customization	0.140	0.310	0.228	0.210	**0.888**

Step 3: Divide each of these sums by the weight for that attribute (or option). Then average the resulting ratios.

	Sums	Weight	Ratio
Reliability	2.399	0.559	**4.291**
After-Sales Support	0.628	0.155	**4.056**
Speed of Delivery	0.309	0.076	**4.078**
Customization	0.888	0.210	**4.221**
		Average ratio	**4.161**

Step 4: An inconsistency index can be calculated using the following formula:

$$\text{Inconsistency index} = \frac{\text{average ratio from step 3} - n}{n - 1}$$

where n is the number of rows in the table we are investigating. In our case, this is 4, so we have

$$\text{Inconsistency index} = \frac{4.161 - 4}{4 - 1} = 0.054$$

Note that, if our table had been perfectly consistent, the average ratio from step 3 would have been 4.0, so our inconsistency index would have had a value of zero.

Step 5: Divide the inconsistency index by the appropriate value from Table 4.5 to obtain the inconsistency ratio. The values in this table were generated by Saaty to estimate the inconsistency indices for random tables. Our inconsistency ratio is therefore $0.054/0.90 = 0.06$. As this is below 0.1, we should have no concerns about inconsistency in this table. Note that this is very close to the 0.059 value produced by EXPERT CHOICE.

Table 4.5 – Random indices for checking the consistency of a table

	n								
	2	3	4	5	6	7	8	9	10
Random index	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The axioms of the AHP

The AHP is based on four axioms:[25]

(1) The *reciprocal axiom* states that, if A and B are options or attributes in the decision hierarchy and A is n times more preferable (or more important or more likely) than B, then B must be $1/n$th as preferable (or important or likely) as A. For example, if Reliability is four times more important that After-Sales Support, then After-Sales Support must be only 1/4 as important as Reliability.

(2) The *homogeneity axiom* states that the elements being compared should not differ by extreme amounts on a criterion. For example, this axiom would be violated if

8.14 Appendix N: AHP Comparisons

Attributes

	Accuracy	Costs	Time	Complexity	Support	Implemetation	-	-	-	-
Accuracy	1	2 4/9	2 4/9	1/2	3	5 1/3				
Costs	2/5	1	2 1/2	2 1/2	3	4				
Time	2/5	2/5	1	1/2	2 3/8	6 2/3				
Complexity	2 1/8	2/5	2	1	1 5/6	6				
Support	1/3	1/3	3/7	5/9	1	5 2/3				
Implemetation	1/5	1/4	1/7	1/6	1/6	1				
-										
-										
-										
-										

Accuracy

	M-Calc	M-Clock	W-Calc	W-Clock	-	-	-	-	-	-
M-Calc	1	1/5	1/4	1/7						
M-Clock	5	1	5	1/3						
W-Calc	4	1/5	1	1/5						
W-Clock	7	3	5	1						
-										
-										
-										
-										
-										
-										

Costs

	M-Calc	M-Clock	W-Calc	W-Clock	-	-	-	-	-	-
M-Calc	1	5	7	9						
M-Clock	1/5	1	5	7						
W-Calc	1/7	1/5	1	3						
W-Clock	1/9	1/7	1/3	1						
-										
-										
-										
-										
-										
-										

Time

	M-Calc	M-Clock	W-Calc	W-Clock	-	-	-	-	-	-
M-Calc	1	1/6	3	1						
M-Clock	6	1	7	3						
W-Calc	1/3	1/7	1	1/6						
W-Clock	1	1/3	6	1						
-										
-										
-										
-										
-										
-										

Complexity

	M-Calc	M-Clock	W-Calc	W-Clock	-	-	-	-	-	-
M-Calc	1	1/7	1/3	1/9						
M-Clock	7	1	2	1/2						
W-Calc	3	1/2	1	1/3						
W-Clock	9	2	3	1						
-										
-										
-										
-										
-										
-										

Support

	M-Calc	M-Clock	W-Calc	W-Clock	-	-	-	-	-	-
M-Calc	1	1/7	5	1/3						
M-Clock	7	1	9	7						
W-Calc	1/5	1/9	1	1/7						
W-Clock	3	1/7	7	1						
-										
-										
-										
-										
-										
-										

Implementation

	M-Calc	M-Clock	W-Calc	W-Clock	-	-	-	-	-	-
M-Calc	1	3	1/3	1						
M-Clock	1/3	1	1	1/3						
W-Calc	3	1	1	3						
W-Clock	1	3	1/3	1						
-										
-										
-										
-										
-										
-										

8.15 Appendix O: Results of the AHP

Scores

Level 1 - Table 1		Level 2 - Table 1		Level 2 - Table 2		Level 2 - Table 3		Level 2 - Table 4		Level 2 - Table 5		Level 2 - Table 6	
Accuracy	0,27514972	M-Calc	0,05293189	M-Calc	0,6127653	M-Calc	0,14786706	M-Calc	0,04974753	M-Calc	0,11453925	M-Calc	0,21875
Costs	0,26851766	M-Clock	0,29117461	M-Clock	0,25505306	M-Clock	0,58027638	M-Clock	0,29936053	M-Clock	0,64396067	M-Clock	0,15625
Time	0,11860658	W-Calc	0,12223893	W-Calc	0,0886962	W-Calc	0,05450953	W-Calc	0,15414455	W-Calc	0,03992777	W-Calc	0,40625
Complexity	0,22937228	W-Clock	0,53365456	W-Clock	0,04348543	W-Clock	0,21734703	W-Clock	0,49674738	W-Clock	0,2015723	W-Clock	0,21875
Support	0,07656388	-	0	-	0	-	0	-	0	-	0	-	0
Implemetation	0,03178987	-	0	-	0	-	0	-	0	-	0	-	0
-	0	-	0	-	0	-	0	-	0	-	0	-	0
-	0	-	0	-	0	-	0	-	0	-	0	-	0
-	0	-	0	-	0	-	0	-	0	-	0	-	0
-	0	-	0	-	0	-	0	-	0	-	0	-	0
Inconsistency Ratio	0,13001704	Inconsistency Ratio	0,11989111	Inconsistency Ratio	0,11687036	Inconsistency Ratio	0,06524101	Inconsistency Ratio	0,00701051	Inconsistency Ratio	0,16311019	Inconsistency Ratio	0,24745625

Scores	
M-Calc	0,22377482
M-Clock	0,34036377
W-Calc	0,11524384
W-Clock	0,32061757
-	0
-	0
-	0
-	0
-	0
-	0

Best alternative :	M-Clock	0,3404

8.16 Appendix P: The 'old' material card

Werkorder 055419

Pag.: 2 of 4
Datum: 21-6-2013

WO:055419

Assembly: 0 **Artikel nummer** H4222 240 0640 **revisie** 1

MATERIAALKAART 10 ***19 juni 2013*** **EG-0070 -**

Materiaal ***H2837018 RVS***

Omschrijving *WIRE 1.4310 RD 1.5 C G240/40*

Benodigd aantal *617,40 KG*

Magazijn *hvb*
Bijbehorende bewerking *10*
RICHT1.4 *WAFIOS R2*
Status *open?*
Materiaal klasse
Voorkeur Lev.

partij	gewicht	Deel / Op

8.17 Appendix Q1: Material card for coils

Werkorder 054381

Pag.: 2 of 4
Datum: 11-4-2013

WO:054381

AUTOMOTIVE

Assembly: 0 Artikel nummer revisie

MATERIAALKAART 10 ***15 april 2013*** **EG-1684 -**

Materiaal

Omschrijving

Benodigd aantal

Magazijn
Bijbehorende bewerking

Status
Materiaal klasse
Voorkeur Lev.

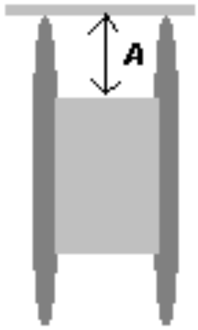
Deze materiaal partij loopt door, dus onderstaande velden moeten worden ingevuld!

Neem deze velden over van het materiaal label:

Ontvangst gewicht	*Spoel type*
Ontvangst afstand	

Vul de volgende velden in na voltooing van de productie:

Afstand



Leg de meetstaaf op de spoel en meet A, de afstand van de onderkant van de meetstaaf tot het materiaal.

WerkorderPortrait.rpt 30-10-08

8.18 Appendix Q2: Material card for rings

Werkorder 054381

Pag.: 2 of 4
Datum: 11-4-2013

WO:054381

AUTOMOTIVE

Assembly: 0 Artikel nummer revisie

MATERIAALKAART 10 *15 april 2013* EG-1684 -

Materiaal

Omschrijving

Benodigd aantal

Magazijn
Bijbehorende bewerking

Status
Materiaal klasse
Voorkeur Lev.

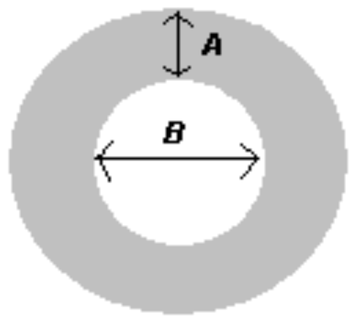
Deze materiaal partij loopt door, dus onderstaande velden moeten worden ingevuld!

Neem deze velden over van het materiaal label:

Ontvangst gewicht	***Aantal ringen***
Afstand volle ring	***Binnen diameter***

Vul de volgende velden in na voltooing van de productie:

Aantal volle ringen	***Afstand eventuele niet-volle ring***



A = Afstand in cm (mm nauwkeurig)

B = Binnen diameter in cm (mm nauwkeurig)

WerkorderPortaal.rpt 30-10-08

8.19 Appendix Q3: Universal material card

Werkorder 054381

Pag.: 2 of 4
Datum: 11-4-2013

WO:054381

AUTOMOTIVE

Assembly: 0 Artikel nummer revisie

MATERIAALKAART 10 *15 april 2013* **EG-1684 -**

Materiaal

Omschrijving

Benodigd aantal

Magazijn
Bijbehorende bewerking

Status
Materiaal klasse
Voorkeur Lev.

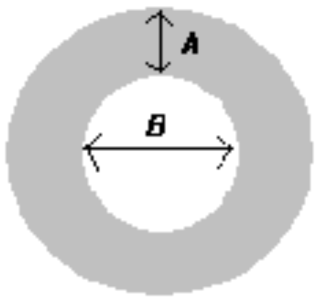
Deze materiaal partij loopt door, dus onderstaande velden moeten worden ingevuld!

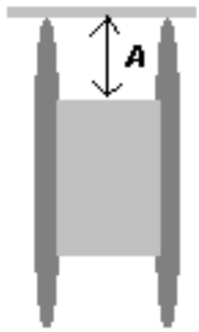
Neem deze velden over van het materiaal label:

Ontvangst gewicht	*Spoel type / Aantal ringen*
Afstand	***Binnen diameter***

Vul de volgende velden in na voltooing van de productie:

Aantal volle ringen	*Afstand niet-volle spoel / ring*





A = Afstand in cm

B = Binnen diameter in cm

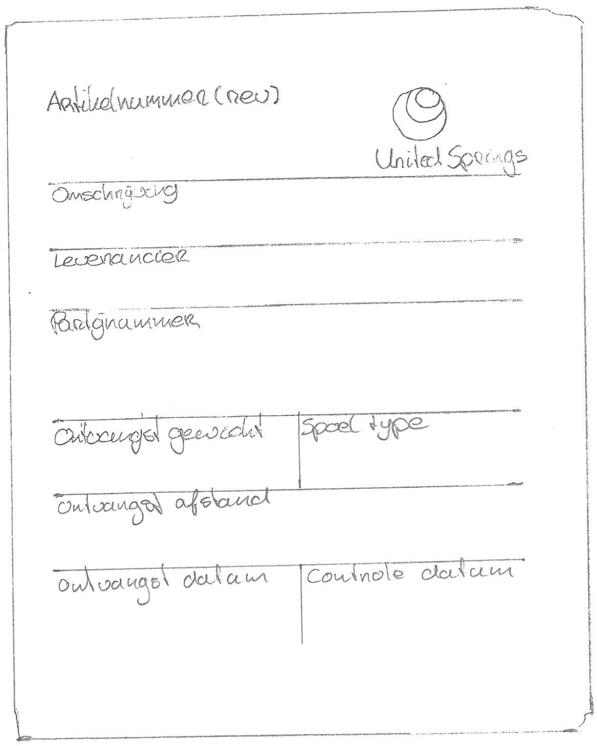
Leg de meetstaaf op de spoel en meet A, de afstand van de onderkant van de meetstaaf tot het materiaal.

WerkorderPortrait.rpt 30-10-08

8.20 Appendix Q4: Material label for coils

United Springs

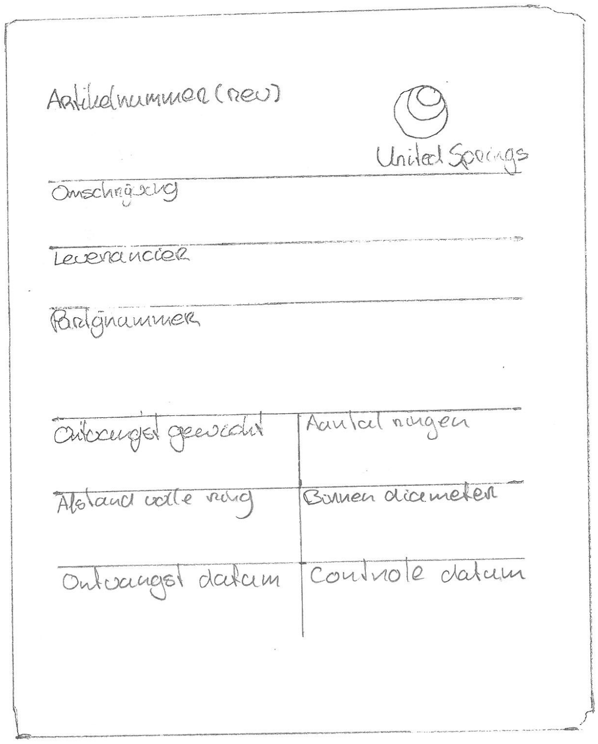
Spoelen



8.21 Appendix Q5: Material label for rings

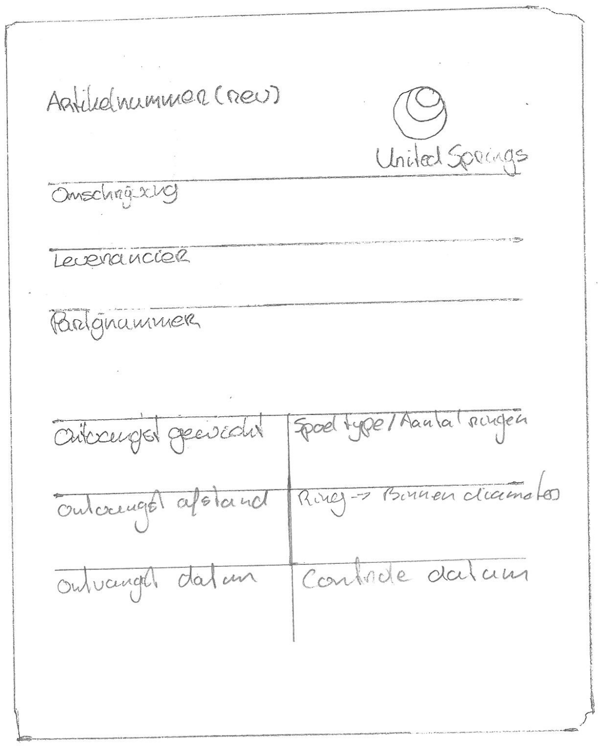
United Springs

Ringen



8.22 Appendix Q6: Universal material label

Universeel



8.23 Appendix R: Summaries of the interviews for the evaluation

Peter de Cloet, Warehouse Department

Peter De Cloet found the method thoroughly and complete, especially the attention for the context of the company and the processes within the company is appreciated. The effectiveness of the method is good; the solution solves the problems in an appropriate way. The efficiency of the method is very good, because the project is ran through very rapidly.

Tim Walhof, Finance Department and Administration

Mr. Walhof praises the practical perspective of the method. Also the fact that multiple solutions are developed and the best is chosen is mentioned as a strong point. The efficiency is good and the effectiveness is consistent with the assignment and the wishes of the company.

Erik Reterink (Assignment Mentor), Controller

Mr. Reterink is glad that the processes and procedures in the company are investigated so extensive. Also the development of multiple solutions of which one is chosen to be implemented is a positive point.

However, the method used for choosing the best solution is not practical and unnecessary. Another point of improvement is the point in the process where external information is gathered about multiple solutions. Now this is done when multiple solutions are developed, but Mr. Reterink would prefer that this information is gathered and used earlier. It must be said that this depends on the length of the project, when the project has to be fulfilled in a short period like this project, the information should be gathered earlier, because otherwise you won't get the information of third parties in time. When the project is spread over a couple of months, this information is not so urgent.

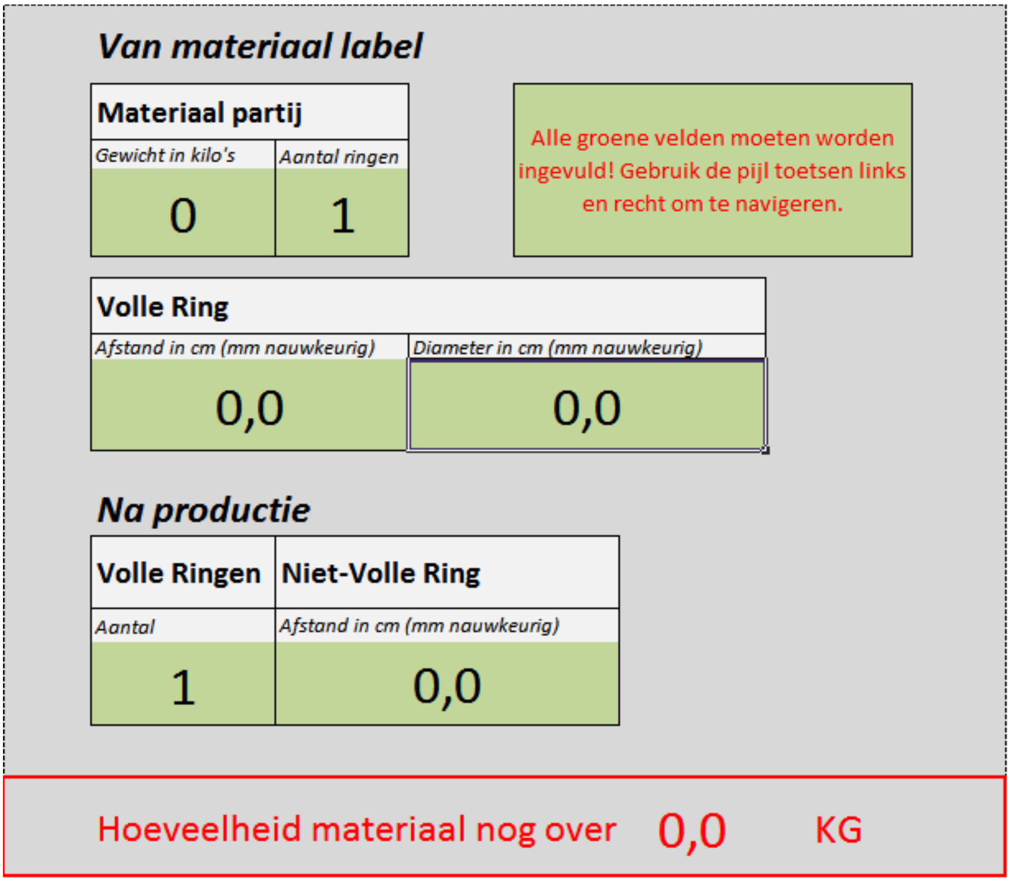
Another point of criticism is the level of involvement of the employees; in the case of United Springs B.V. this could be higher. This level of involvement also depends on the situation; at one company this is more important than at other companies or vice versa. The level of involvement is important for creating support for the project and the solution that is offered at the end of the project.

Theo Buitenhuis (Assignment Mentor), Research and Development Department and IT Department

Theo Buitenhuis joins Mr. Reterink in his opinion about the importance of gathering knowledge in an earlier stage of a project which has to be completed in such a short time. Mr. Buitenhuis also thinks that the AHP is not suitable for making decisions in a situation where the outcomes of the solutions are still a bit vague.

Positive aspects of the method are the development of multiple solutions, the efficiency of the method and the effectiveness.

8.24 Appendix S: Overview of the Excel Workbook



8.25 Appendix T: Personal Reflection

Mandatory to the bachelor assignment is a reflection on the professional functioning during the assignment, which is what you will find in this appendix. The reflection will take place according to the following objectives: project management, independency, functional use of resources and cooperation in the practical environment.

First I will discuss my own performing with regard to the project management. The planning of the assignment was tight with a time horizon of eight weeks. This tight planning forced me to work efficient and effective and resulted in a useful motivation. Another positive thing about this tight planning is that enabled me to spend two weeks at United Springs B.V. for implementing (part) of the solution.

So the planning was good, monitoring the progress was less successful. This resulted in redoing most of the work that was done in the first three weeks. Without receiving feedback I continued to work on the report and the project, ending up with a report that had to be rewritten. From now on I will make sure I receive feedback before continuing to the next phase of a project.

Also the gathering of information from other companies should have been done in an earlier stage. During the assignment this information was requested when it was needed, unfortunately not all the companies responded very rapidly, which resulted in two days of delay. The other side is that in an earlier stage it is not clear which specific information is required. Gathering some general information in an earlier stage and detailed information in a later stage would be better in this case.

The fit between the desires of United Springs B.V. and the University of Twente was good. Of course time is spent on writing some requirements of the University to the report, but the result for United Springs B.V. is not restricted by this additional work. Vice versa United Springs B.V. had no troubles with me working on the report requested by the University of Twente, during work. This resulted in a result of the project that is satisfying for both organizations.

The independency during the performance of the assignment was very good. This was also mentioned by the mentor at United Springs B.V., Mr. Reterink. Of course sometimes the experience of Mr. Reterink or others at United Springs B.V. had to be consulted, but that is logical according the practical perspective of the assignment. In general no unnecessary questions and time were asked to and from the employees of United Springs B.V., other companies or the University of Twente.

In general most of the available resources were used functional. The literature research was effective and efficient. Also the information that was gathered from other companies was requested in a clear way, so the companies could respond quick and with the right information. Unfortunately, not all the companies responded very quick like mentioned earlier. The information that was requested from the employees was also clear and fully utilized, only the moment at which this information was gathered was not optimal. Gathering this information in an earlier phase of the assignment could have been useful.

The cooperation with regard to the practical aspects of the assignment I experienced as well. I learned by who I had to look for which information and also had some real sociable moments. A difficult thing was to be positioned between the management and the production and understanding the points of view of the production workers as well as the point of view of the management. First I found it difficult to make a statement towards others, later on I found that being clear is far more efficient and effective and that it does not have to mean that you insult people personally.

Things I learned during this assignment are: to make appointments in advance to protect the progress, to gather information from other companies in an early stage and to involve the employees more from the start of the project. Positive things I learned, or that are confirmed, about myself are my social and planning skills. In the end I look back at this assignment with a satisfied feeling.

8.26 Appendix U: Overview of the different coil types