# Towards Control of Capacity at the Spare Parts Production of Nefit

*Master Thesis Report*


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# Preface

This master thesis report is written as part of a graduation project for the study Industrial Engineering and Management at the University of Twente. The graduation project took place from August 2011 till August 2012 for Nefit BV, a production company for wall mounted boilers that is part of the Bosch group. The aim of this master thesis report is to find a method that allows Nefit's Spares Assembly department (SA) to plan their workforce requirements.

First of all I like to thank my mentors of the University of Twente, Matthieu van der Heijden en Waling Bandsma for their support. Their advice helped bringing this report to a higher level and their guidance supported me in completing this master thesis study.

Second, I like to thank the company supervisor, Dirk Booij for his support in collecting the required data and contacting the right people within the Nefit B.V.

Last but not least, I like to thank my father; Jo Janssen for his suggestions in rounding off the master thesis report.

23-08-2012, Enschede

Guus Janssen

## Summary

The Spares Assembly department of Nefit (SA) produces spare parts for boilers for Nefit, Buderus, and Bosch. After moving from Buinen to Deventer, SA was unable to keep up with demand during the high season (October – April). During the low season (April - September), there was overcapacity. Both phenomena where caused by lack of knowledge on the demanded spare parts. Therefore SA could not make a reliable capacity planning for deploying employees efficiently and effectively. This led to low delivery performance while employee costs were high.

The aim of this research is to find a method that allows SA to plan their workforce requirements. The planning method should be able to determine the length of the shift for each week in the planning horizon as well as the assignment of employees to workstations. SA uses 12 workstations, with each workstation corresponding to one skill in which each employee can be trained. Training on a workstation is required before an employee can operate the workstation. This training takes a certain time, dependent on the workstation. The problem to be solved in this master thesis report is therefore defined as:

*"How can SA create insight in the required number of employees and their skills, to ensure availability of the right skills, in the right amount, at the right time?"*

The workforce planning proposed is according to a deterministic model. A deterministic model has been selected as it allows planning to be accurate and reliable enough for the situation of Nefit. At the same time the computational burden of a deterministic model is smaller than for a stochastic model. The workforce planning proposed is a tactical planning model that uses known spare part demand as input. This planning allows timely assignment of employees to the required workstations, while using known demand information. The goal of the model is to minimize the total costs associated with assigning employees to functions, while finishing all demanded spare parts in time. This meets both Nefit's objectives; delivery performance is maintained at high levels, while minimizing production costs.

The proposed workforce planning uses heuristic methods designed for the situation of SA to determine who is assigned to which workstation at what moment in time. The advantage of these heuristics methods is that they create good problem solutions by using simple assignment rules. This makes the planning model computationally less burdensome than exact methods or more complicated heuristic methods. The heuristic methods ensure that production of spare parts is performed before the due date, while smoothing out peaks and valleys in demand. In case in time production is not possible all backlog is finished as soon as possible. Employee assignment is done by deploying the least skilled employees first. Assigning these employees to workstations for which it is toughest to assign an employee to, increases the chance that the remaining employees can operate the remaining workstations. These steps are repeated for all possible combinations of shift lengths over the planning horizon. The solution with the lowest costs over the entire planning horizon is selected.

The proposed workforce planning is compared with the workforce planning currently used by using a test run. This test run is performed over March and April 2012, a period of two months with steady, increasing and decreasing demand, to test the behaviour of both workforce planning methods. The indicators used to measure the performance of both models are:

1. Delivery performance in percentage of products being delivered in time.
2. Costs associated with hiring, firing, training and employing of employees.

### *Conclusions and recommendations*

- The proposed workforce planning is preferred over the current workforce planning because of the relatively large costs reduction of 24% while the delivery performance is decreased from 99.63% to 99.54%. By using a binominal distribution of the delivery performance, no prove was found that any significant differences between to two workforce planning models exist. Also the deviation from the target of 99.7% delivery performance did not prove to be significant.
- Implementing the workforce planning is only possible when assembly times are known. This allows both the available workload as the delivered capacity to be defined in the time in days. This can be done either by SA through time registration, or by the process engineering department through MTM (methods-time-measurement) analysis.
- Due to an error in the output from the ERP system, the delivery dates for each production order are incorrect. This error is to be tracked down by the planning department and the IT department to enable SA to accurately plan the best moment of production. Without these two issues resolved it is impossible for Nefit to perform proper workforce planning and achieve the desired results.
- A shadow run can be used to correct the current workforce planning before full implementation of the proposed workforce planning. The shadow run also allows adjustment to the input of proposed workforce planning before full implementation.
- The implementation and shadow run can best be lead by the supervisor as he will be the operator of the planning. To be able to operate the planning he has received training and is thus the most knowledgeable employee on the workforce planning.

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# Chapter 1: Introduction

The aim of this chapter is to give an introduction to the problem and the problem situation. It will start with a short introduction to the background of the problem, followed by a description of the company of Nefit in which the problem occurs. The final section of this chapter will introduce the problem statement, which is to be solved over the course of this master thesis project.

Acronyms are used for terms that occur frequently. The acronyms will be explained on introduction and are listed in Appendix 1 as well.

## 1.1 Problem Background

Nefit denotes "Nederlands-Amerikaanse Fittingfabriek" and was established in 1948 as an ironworks (Nefit B.V.). Starting from 1965, Nefit has been producing boilers and later heaters under the name Nefit Fasto. After a takeover by Buderus in 1994 and a subsequent takeover of Buderus by Robert Bosch GmbH in 2003, Nefit is now part of Bosch Thermotechnik GmbH (Bosch Termotechnik GmbH, 2011). Bosch Thermotechnik GmbH is an umbrella company for several local and international brands producing heating and cooling systems for both domestic and industrial use.

In November 2010, Nefit closed its production facility in Buinen and moved the production of new boilers to its sister facility in Deventer. The production and distribution of spare parts that also took place at Buinen moved to a new and temporary location in Deventer. As a result of this move, most employees in Buinen left Nefit and many of the control mechanisms fell into disuse. During the 2010/2011 high season, October to April, Nefit struggled to deliver spare parts at the right time, in the right quantity and quality. The result of which was a delivery performance of around 30% to 50%.

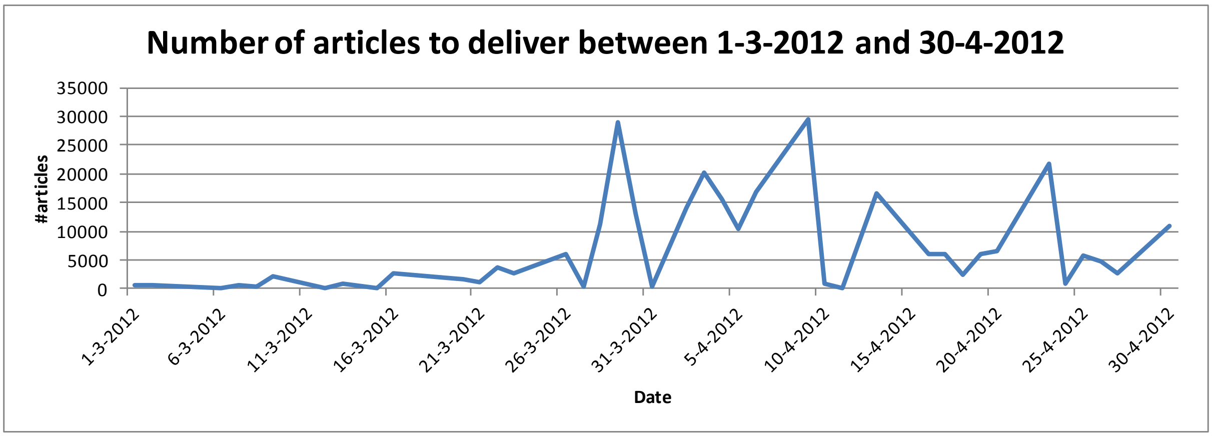
Nefit uses a permanent workforce mainly existing of contracted employees (CE's). Because CE's have a two month notice before they can be fired, Nefit wants to be sure that CE's can work all year round. When demand is higher than can be covered by the permanent workforce, an agency is used to attract temporary employees (TE's). TE's only receive payment for the work they perform and can be fired whenever there is no work for them. However, for every month a TE's works at Nefit, one day will be added to the notice period. TE's come at a higher price than CE's as the agency is to be paid as well. All employees at spares assembly are offered full time jobs, so in general all employees will work equal hours. When there is a shortage of work, all employees should be offered at least three hours of work / pay on any day they come to work. The only way to become a CE is to start as a TE and subsequently get a contract offer from Nefit.

Spares Assembly (SA) trains each employee itself, so that they can work on a specific workstation. Each skill an employee can be trained at equals being able to work at one specific workstation type. To create flexibility in the workforce employees are often trained at several skills, so that they can perform on different workstation types. Table 1 shows the different workstations / skills and the training time associated with them. Table 1 show that training in a skill takes at most one week, where training is done at the workstation based on learning by doing.

| Skill / Work location | Training time (hours) |
|---|---|
| Runner | 40 |
| Tables | 24 |
| Autobag | 40 |
| Tapemachine | 16 |
| Glow-plugs | 4 |
| GLE | 24 |
| Burner housing | 16 |
| ESD workcenter | 24 |
| Speedypack | 40 |
| Cases | 16 |
| BCM | 8 |
| Assembly | 16 |

**Table 1: Training time per skill type**

The disappointing performance was caused by uncertainty in part demand together with inflexible deployment of employees. Spare part demand changes from day to day depending on factors like the weather, customer order patterns and potential quality problems with new boilers. An example of these fluctuations is shown in graph 1 showing the demand in daily number of articles to deliver over March and April 2012. Nefit was overwhelmed by the 2010 / 2011 high season, not being able to react adequately; production capacity was not high enough to meet all demand in time. During the 2011 low season, the opposite problem emerged. Occasionally there was not enough demand to keep the permanent workforce active. During the 2011 / 2012 high season capacity problems re-emerged.




**Graph 1: demand over March and April 2012 in daily number of articles to deliver.**

## 1.2 The problem setting

### 1.2.1 Position of Nefit within Bosch

The Bosch group exists of 285 manufacturing facilities, which all together achieved total sales of 47.3 billion euro's over 2010 (Bosch Termotechnik GmbH, 2011). The Bosch group exists of three business units as shown in figure 1. Thermo technology is part of Consumer Goods and Building Technology. Bosch Thermo technology is divided in seven business units; Nefit BV is the name of production location Deventer which is part of the business unit Wall Mounted Boilers.

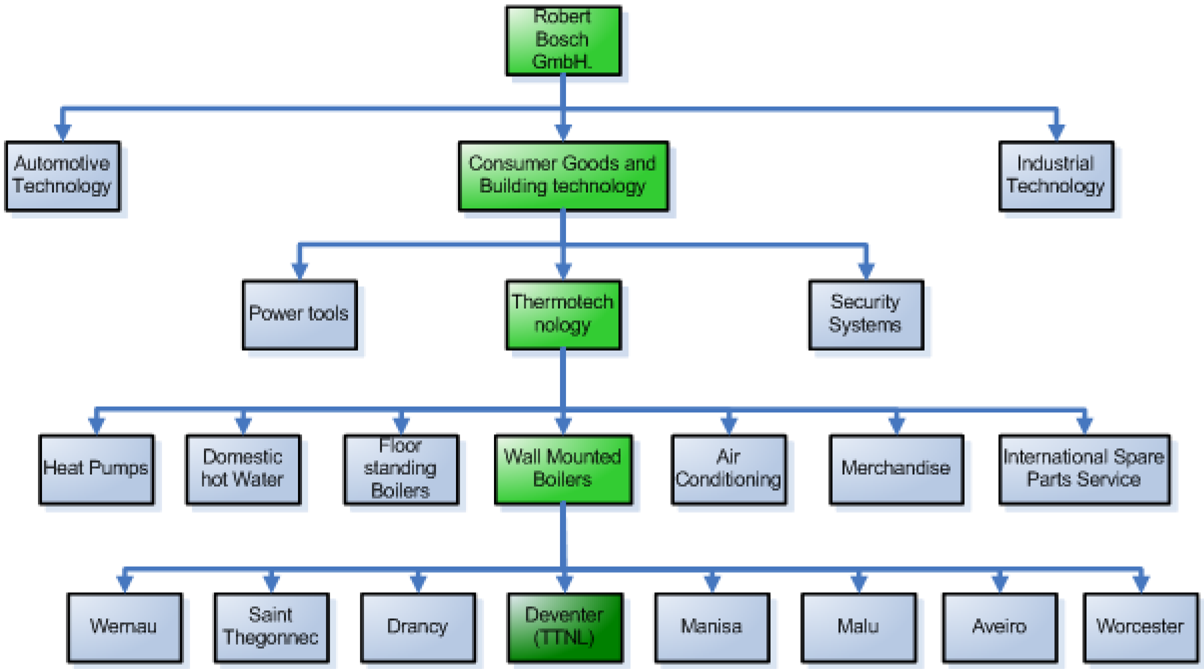


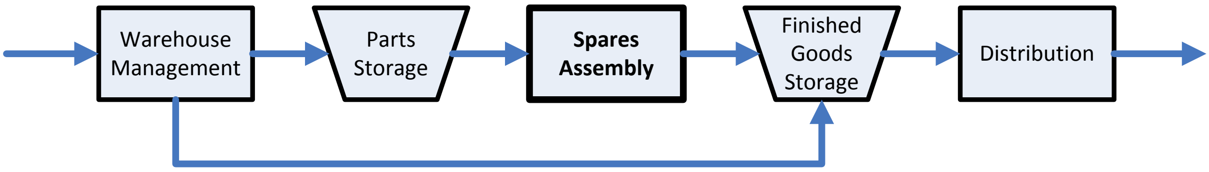

Figure 1: Location of Nefit BV within the organization of Robert Bosch GmbH

Bosch Thermotechnik had total sales of 3.1 billion euro's over 2010. Heating systems, which Nefit is part of, produced total sales of 1.168 million euro's over 2010 (Bosch Termotechnik GmbH, 2011). More than 90% of these sales are made in Europe, making it by far the largest market for Bosch Thermotechnik. In 2010 Bosch Thermotechnik had 13.449 employees and invested around 115 million euro's in Research and Development.

### 1.2.2 The Part Service department of Nefit

Nefit denotes the production facility for wall mounted boilers in Deventer. At this production location boilers are manufactured for several brands, including Nefit, Buderus and Bosch. To comply with Bosch standards, Nefit should be able to supply parts for all boilers produced within the last fifteen years. Production and shipment of these parts is done by the part service (PS) department.

PS consists of three sections, each dedicated to one specific part of the production and distribution process of spare parts. Flowchart 1 shows the sections and the flow of material through the department, followed by a short discussion of each section.




Flowchart 1: sections of part service and the flow of material through the department

1. Warehouse Management is responsible for receiving and checking all incoming purchase parts as well as storage of any part in the warehouse. Here purchase parts are defined as all parts bought from suppliers. Depending on the type of part, purchase parts can be stored in parts storage for further assembly or in finished goods storage for sale directly to customers.

2. Spares Assembly (SA) is responsible for the actual assembly of spare parts requested by the customers and the collection of the required purchase parts and sub-assemblies from the warehouse. Spare parts are products as being sold to the customers of Nefit to replace failed parts. A Spare part can be a single unit or a set of units meant to make a certain repair to a boiler. Sub-assemblies are defined as unfinished spare parts, which can either require further processing to become a spare part or become a set together with other purchase parts or sub assemblies.

3. Distribution is responsible for the shipment of all requested spare parts to internal and external customers. This department collects the requested spare parts and prepares them for shipment. The actual shipment is outsourced to specialized companies.

For more detailed descriptions of the terminology and examples, see appendix 1.

### 1.2.3 Spares Assembly

SA produces around 4000 different SP's, made to specifications set by Bosch or the engineering department of Nefit. Production at SA takes place on order, where production quantities generally range from 1 to 2000 parts. A production order defines the production of one type of SP, the quantity in which it should be produced and the delivery date. There are eleven different workstations; spare parts visit at least three of these workstations before being completed. An example production order can be found in appendix 1.

The demand for spare parts is depending on several factors, including age, failure behaviour, and total production quantity over the past 15 years of a specific part. The result of which is that the ten most requested parts add up to roughly 32% of the total production quantity. Roughly 95% of the production quantity exists of 16% of the parts. This also means there is a large group of spare parts with very low or no demand over a year time.

In general, all parts produced at the spare parts department are meant to be used in order to replace failed parts. Only when production for new boilers is in urgent need for parts, spares may be used to serve in new boilers.

### 1.2.4 Customers

PS distinguishes two different customer types: local customers and international customers. The local customers can be wholesalers, dealers and maintenance employees who are served directly by Nefit. Orders from local customers are delivered from stock. Lead-time for wholesale stores is five days, for dealers and maintenance employees this is one day. SA has eight days to replenish the stock independent of the customer. All together the local customers make up around 40% of the total demand for SP. All international customers are served through a Bosch general warehouse in Lollar. As Nefit has a lead-time of fifteen days for deliveries to Lollar, production is done on order. The international customers are good for around 60% of the total demand for spare parts at Nefit. The consequences for demand uncertainty caused by these lead-time rules are summarized in table 2 below. To relax SA during high season, the ten most requested spare parts by Lollar are delivered from stock as well.

| Planning horizon | Order certainty | |
|---|---|---|
| > 15 days | 0% known | 100 % estimated |
| 8-15 days | 60% known | 40% estimated |
| <= 8 days | 99% known | 1% estimated |

**Table 2: uncertainty in production orders over the planning horizon**

### 1.2.5 Bosch Production System

Important for manufacturing within Bosch, is the Bosch Production System (BPS) (Robert Bosch GmbH, 2008). The objective of BPS is to ensure "the right part, in the right quantity, in the right quality, at the right price, at the right time, at the right place, by eliminating waste existing in the system". Important in doing this is working according to a "pull system", defined as "producing only what the customer wants". In combination with variable demand the assembly of spare parts should be very flexible in terms of product types and quantity. Compliance with the BPS principles is an important issue for Nefit, therefore the demands of BPS form an important guideline for this master thesis project.

## 1.3 The problem statement

To enable in time assembly of requested parts, Nefit wants to ensure availability of the right people, in the right quantity, at the right time. To do this, Nefit wants to known how many employees are required at what moment in time and at what workstation. This should result in a workforce planning that determines the capacity based on available employees and connect capacity to demand. The workforce planning should allow timely recruitment and training of required employees so that the right employees are available at the right quantity and time. This description results in the problem statement defined below.

*"How can SA create insight in the required number of employees and their skills, to ensure availability of the right skills, in the right amount, at the right time?"*

The description above identifies two important issues which have to be taken care of in order to implement workforce planning. First issue is creating visibility of expected demand, allowing PS to respond to changes in time. As described above, SA has fifteen days to assemble two-third of the spare parts, while for the other one third there is an eight-day lead-time. These lead-times can be used to make estimates of the required workload days before production has to take place.

Second issue is creating insight in the amount of parts of each type employees can produce in a certain time period. This allows Nefit to estimate the workload connected to an order. Combining the demand information and the capacity of employees allows PS to estimate what skills are required in what quantity.

## 1.4 Conclusion and Summary

After reading this chapter, the reader should understand what the problem is, that should be solved over the course of this master thesis report. The reader should also understand the problem situation.

The problems emerged after moving the production of spare parts from a production location in Buinen to a production location in Deventer. After this move the Spare Part department was not able to keep up with changes in demand and employees were assigned inefficiently. This results in low delivery performance during high season and low employee utilization during low season. The problem to be solved in this master thesis report is defined as:

*"How can SA create insight in the required number of employees and their skills, to ensure availability of the right skills, in the right amount, at the right time?"*

# Chapter 2: Research Plan

In Chapter 1, the problem faced by Nefit is defined, as well as the setting in which the problem takes place. This chapter aims at devising a plan of approach to solve the problem. The goal of this master thesis project will be defined in paragraph 2.1, leading to sub goals which should be met during the master thesis project. This will be followed by determining the research questions and the connections between them in paragraph 2.2. Paragraph 2.3 will define the scope of the project, followed by the research approach for every chapter in paragraph 2.4. After reading this chapter the goals of the study as well as the methods used to reach them should be clear to the reader.

## 2.1 Goal of the study

As defined in Chapter 1, this research seeks to find a method that allows Nefit to determine the required number of employees and their skills. This should ensure availability of the right skills, in the right amount, at the right time. To do this at any point in time, a planning is required, taking into account the demand of spare parts and the supply of production capacity. The planning horizon of this workforce planning should allow timely recruitment and training of employees, if this is required to meet demand. The goal of the research can thus be defined as:

*"To create a planning which allows timely recruitment and training of employees to meet the demand of spare parts at any point in time, while efficiently using available resources."*

In order to reach this goal, the goal statement is split up in the sub goals described below. By reaching all four sub goals, the problem statement can be solved.

Sub goals:

1. The workforce planning should indicate if people should be hired or fired, to prevent under- or over-capacity.
2. The workforce planning should indicate which employees to train and in what skills.
3. Training and task assignment should be done based on actual demand.
4. The workforce planning should be able to determine what workstation is to be used on what day, for every day in the planning horizon.

As indicated in chapter 1, Bosch uses standardization as an important tool for continuous improvement (Robert Bosch GmbH, 2008). The proposed method is meant to become a standard for use by Nefit. However in order to support continuous improvement, Nefit should be able to adjust the performance of the workforce planning after implementation. In this way the workforce planning can be developed further over the years and adjusted to situational changes within SA.

For developing the workforce planning, no specialized computer programs or ERP (enterprise resource planning) tools are available in which the workforce planning can be executed. For this reason the workforce planning will be designed in a Microsoft Excel document. This should allow the end user to easily operate the workforce planning.

## 2.2 Research questions

To resolve the problem statement and to be able to reach the goal stated above, six research questions (RQ's) have been defined. Each research is a step in solving the problem statement and is answered in a separate chapter. After answering all six RQ's the problem statement should be solved.

1. How should a workforce planning for spare part production be designed, according to the literature?
2. What information is required and how should this information be processed in the workforce planning?
3. What are the current planning methods used at SA, how do they perform and what criteria does SA have for a workforce planning?
4. What is the design of the proposed workforce planning for use by SA?
5. What are the improvements that can be achieved with the proposed workforce planning?
6. How should the workforce planning be implemented by Nefit and what will be its impact?

Because each RQ is one step in solving the problem statement, the RQ's are connected to each other. The RQ's are to be solved in the order in which they are presented. Below each RQ and the connections between them will be discussed.

1. RQ 1 is used to define the workforce planning itself. Answering this question should indicate how the workforce planning should function, what requirements it has on the organization and what output should be generated. The results of RQ's 1 and 2 will provide a basis to compare with the current situation, which is to be defined by answering RQ 3. The results of RQ's 1 and 2 will also provide the groundwork for the proposed workforce planning in RQ 4.
2. The goal of the second RQ is to know what input is required and how to process it. The required information and method of processing is the foundation of the workforce planning, allowing the right output to be received from the workforce planning.
3. Answering RQ 3 should provide insight in the current method of working by Nefit and the performance resulting from this method. The methods are analysed based on the literature knowledge from RQ 1 and 2, defining the gap between literature and reality. The main result will be requirements to the workforce planning to function properly at PS, which will be used when answering RQ 4. The results will also be used as baseline performance when answering RQ 5, as well as guidelines for improvement in answering RQ 6.
4. Answering RQ 4 results in a workforce planning designed specifically to the situation of SA. The theoretical knowledge collected by answering RQ 1 and 2 as well as the criteria defined by answering RQ 3 are used as input. The resulting workforce planning will be the object of research when answering RQ 5 and the object of implementation when answering RQ 6.
5. The aim of RQ 5 is to uncover differences in performance between the current workforce planning method and the proposed workforce planning. The results from answering this RQ are used to determine the performance of the proposed workforce planning and to select the most appropriate planning method. Answering this RQ may also provide topics of interest when answering RQ 6.
6. Answering RQ 6 should provide PS with an implementation plan, which allows successful implementation of the workforce planning into the organization of PS. This is where the work in all previous chapters comes together. The implementation should make use of literature knowledge, as well as characteristics specific to the organization of PS as the workforce planning itself. The implementation should lead to incorporating the workforce planning into

the daily activities of PS. The master thesis project will not include implementation of the workforce planning, but will provide the implementation plan.

## 2.3 Scope

As stated in the RQ's the project will aim specifically at the workforce planning of SA. Because the processes at SA are very different from other departments, the research does not aim to make the workforce planning interchangeable. Also the processes of any department connected with SA will not be affected by the workforce planning. This means that the workforce planning will use available information as provided in the current situation. The aim is to use information already available within Nefit and make this information accessible to PS. Another effect of this is that the workforce planning should aim at handling demand as it is. This master thesis will thus not focus on methods which influence the demand itself or the timing of demand.

The research aims to link the demand of spare parts and the provided capacity at SA with each other. By doing so, the research is limited to production employees only as only their work is directly influenced by demand. Non-production employees like team leaders and administrative personnel cannot be linked directly to demand, planning of their activities it thus not included in the research.

## 2.4 Research Approach

Below a short discussion will follow the research approach for each of the chapters in this master thesis report. Each RQ will be covered in a separate chapter, except for research question one and two, which will be covered together in chapter 3.

### 2.4.1 Literature review (chapter 3)

A literature review will be used to find relevant literature about workforce planning in order to answer RQ's 1 and 2. To make sure that much of the relevant literature can be found, the three methods of finding literature explained below will be applied.

1. The groundwork of the literature study is a literature search on the internet by use of the search engine "Google scholar". This search engine is used because it aims at scientific databases only, but is not limited to one specific database. This allows excess to a broad set of scientific databases. First important search words on the topic are defined, to make sure that a broad and relevant set of articles are found. The amount of "hits" is reduced by adding search words or search rules or excluding some words. When the amount of articles is small enough (<200), all titles are read to select relevant articles. From the selection made in this way, all abstracts are read, to make a final selection of which articles to read. This method allows a broad search for relevant literature on a topic.

2. The second method used is to select articles cited by an article used in the master thesis or selecting articles referring to articles used in the master thesis. This allows going deeper into a topic and finding either newer developments or older views on the topic.

3. The third method used is selecting articles and books suggested by other people who have knowledge on the topic. This is used as a shortcut to find relevant articles. This method on its own, however, might lead to an incomplete selection of relevant literature.

### 2.4.2 Current situation (chapter 4)

To establish what planning activities are currently used and their efficiency, a broad set of methods is used. The groundwork is lead by conducting orientation interviews with the senior staff at PS as described in (Kempen & Kiezer, 2006). Due to the informal nature of these interviews, they only serve to find the required data for the workforce planning and the possible problems with this data. The interviews are not used to collect actual input data or performance data for the current workforce planning. Information on the performance related to the workforce planning is collected from the measurement tools and ERP system used at PS. When not available, information is either collected by observation or by performing the measurements over a short period of time. Validation of the data is done both by employees of Nefit who are involved with the activities measured and by the researcher. This is done because most employees know the processes well, but have no experience with reading the acquired data. An important tool in validating the data is by performing a simulation of the current planning method. A simulation is defined here as running the workforce planning over a time period based on historical demand input. In this situation the workforce planning used will simulate the current planning methods applied at SA. This is used to establish if the collected data can be used to replicate the current situation at SA. The methods used to establish the validity are: event validity, face validity, operational graphics and Turing tests as described by (Sargent, 2009). This simulation will be performed as part of chapter 6.

### 2.4.3 The workforce planning (chapter 5)

As explained in paragraph 2.1 the workforce planning will be developed in a Microsoft Excel file. To reduce file size and decrease run time for the planning, macros will be created in VBA to perform the calculations and visualize the planning.

### 2.4.4 Measurement of workforce planning performance (chapter 6)

The fifth stage of the research will be to establish what improvements can be achieved by using the proposed workforce planning. To establish the difference in behaviour and performance of the workforce planning methods, a test run will be used. Due to large impact on daily operations, unrepeatability, and lack of readily available data, real life testing is not an option. By using simulation with close-to-real data, it is possible to compare model behaviour and make an estimate of the performance differences. Due to its repeatability, it is possible to simulate different settings and situations. As indicated in paragraph 2.4.2, validation will take place by knowledgeable employees of Nefit as well as by the researcher. Validation of the proposed workforce planning will not be used to validate the input data used. This because the same input data is used for simulating the current workforce planning as for simulating the proposed workforce planning.

### 2.4.5 Implementation plan (chapter 7)

The basis of the plan will be the knowledge found in the literature and the knowledge gained during the project about Nefit as well as the planning method. Combining this information will lead to an implementation plan which is suited for the situation of PS. The conditions imposed to PS by the workforce planning give Nefit a guideline of what to do to allow actual implementation.

## 2.5 Conclusion and Summary

In this chapter the goal of the study is defined along with four sub goals which should be met in order to reach the main goal. To solve the problem statement defined in chapter 1, the six RQ's below have been defined. For every research question a short discussion is given on the methods used to answer these questions as well as the methods used to validate the information supplied, whenever this is required. Each research question represents a separate chapter, except for research questions one and two, which share a chapter. After every chapter the associated RQ's should be answered.

The scope of the project is limited to the production employees of spares assembly. The main reason is that spares assembly uses processes that strongly deviate from processes at other departments. Also, only the use of production employees can be linked directly to demand, thus allowing only the production employees to be planned based on demand for spare parts.

After reading chapter two the reader should understand the goal of the study and the methods used to reach this goal.

# Chapter 3: Literature Review

This chapter will cover the results of a literature study conducted in order to find relevant literature covering the topic of workforce planning. For a thorough description of the literature search conducted, the reader is referred to Appendix 2. This chapter will first cover the planning horizon of the workforce planning in paragraph 3.1 and use of uncertainty in a workforce planning in paragraph 3.2. This will result in the selection of a planning type for which the design will be developed in paragraph 3.3. Paragraph 3.4 will form a discussion of methods used to determine the validity of the proposed workforce planning. Last, the implementation strategy will be discussed in paragraph 3.5.

## 3.1 The Planning horizon

Determining the planning horizon is of high importance when determining the functionality of the workforce planning. (Slack, Chambers, & Johnston, 2007) make a distinction between long-term (strategic), medium-term (tactical) and short-term (operational) workforce planning. Each planning type has its own functionality, but is connected to the other two types, unable to function properly if not working together. Below, a short discussion on each planning and the connections between them will be given, concluding with selecting the most appropriate planning for SA.

### 3.1.1 Strategic planning

The Strategic workforce planning as described by Ernst, Jiang, Krishnamoorthy & Sier (2004) is an aggregate planning, used to determine the required number of employees over a period of several months or year. Due to the large planning horizon, it is not possible to accurately assign employees to the required workstations. For this reason the strategic planning in general is used for planning the total expected number of employees. The large planning horizon also makes it impossible to use actual demand information as input. For this reason forecasts of demand are produced based on historical demand (Bard, Morton, & Wang, 2007) or otherwise estimated demand (Azmat & Widmer, 2004; Bihlmaier, Koberstein, & Obst, 2009).

As strategic planning is used to determine the expected required workforce size, strategic planning is capable of supporting the hire & fire decision (Fowler, Wirojanagud, & Gel, 2008). However, this refers to the contracted workforce (Anderson, 2004), or CE’s. TE’s are used to deal with fluctuations not known this far in advance. Therefore it makes no sense to make a hire & fire decision for TE’s based on long-term planning. Other decisions supported by strategic workforce planning are: Employment policies and policies regarding company or government rules and regulations (Azmat & Widmer, 2004) (Ernst, Jiang, Krishnamoorthy & Sier, 2004). Examples of this are use of annualized hours, use of shifts or the allowed lengths of a shift or workweek.

The hire & fire decision made by strategic planning determines largest part of the resources that can be used by the tactical and operational planning. The policy decisions set boundaries for the use of the available resources and define rules regarding the use of employees. These policy decisions have to be taken into account during tactical and operational planning.

### 3.1.2 Tactical planning

As opposed to strategic planning, tactical planning has a time span limited to several months or weeks depending on information availability and user preferences. Due to the smaller planning horizon, at least part of the demand for products is known to the tactical workforce planning. This allows identification of the required skills (Fowler et al., 2008) and thus allocation of employees to workstations. On the other hand planned leave like holidays of employees is known and can be incorporated into the workforce planning.

As employees can be assigned to workstations, tactical planning can be used to support hire & fire decisions for TE, as well as overwork and (cross-)training decisions (Fowler et al., 2008; Subramanian & An, 2008). Assignment of employees also include determination of their work hours per day and workdays per week (Azmat & Widmer, 2004) and subsequent planning of overtime per employee per day (Easton & Rossin, 1997). (Techawiboonwong, Yenradee, & Das, 2006) use a tactical planning to determine assignment of employees based on their level of experience. To assign employees to an appropriate workstation, a loading system should be selected (Slack et al., 2007). The loading system determines how tasks are assigned to employees and the workstations. The loading system may influence the available workload at each workstation. In general a loading system can be finite or infinite, where a finite loading system limits maximum number of jobs assigned to an employee or workstation.

The tactical planning strongly limits the possible decisions that can be made during operational planning. The Tactical planning determines the number of employees at any point in time, the length of their workday and workweek and their skills. This means that after tactical planning, the number of resources is fixed; only assignment of jobs to the available resources will be possible. This poses great restrictions on the operational planning as it cannot influence to total available capacity.

### 3.1.3 Operational planning

The operational planning or roster (Ernst, Jiang, Krishnamoorthy & Sier, 2004) is used to make final adjustments to the use of the workforce, in order to meet demand. The planning horizon of the operational workforce planning is limited to days or hours, allowing (almost) all input to be certain. The operational workforce planning allows use of production orders (PO's) and actually available employees on the day of production.

Operational planning can be used to support assignment of employees to shifts, determining order of production or assignment of orders to workstations (Ernst, Jiang, Krishnamoorthy & Sier, 2004). Operational planning can also support decisions about the number of employees required over the day at each workstation in case of changing demand patterns (Segal, 1974).

### 3.1.4 Planning selection

Based on the description above, the tactical workforce planning has the most appropriate planning horizon and functionality for solving the problems of SA. Most important, the tactical workforce planning can provide SA with the information required for in time preparation to the workload they have to deal with. This will allow SA to deal with the uncertainty in demand it is currently facing. The strategic workforce planning on its turn only determines the permanent workforce and the level of flexibility in tactical and operational workforce planning. The operational planning has the flexibility to assign employees where necessary, but cannot adapt to fluctuations in total demand. Therefore from this point this master thesis report will focus on using tactical workforce planning to solve the problems faced by SA.

## 3.2 Uncertainty

Important in determining the planning method to be used is the choice between deterministic or stochastic models. In deterministic models, variance is not taken into account, so that all information is considered to be determinate (Winston, 2004). Stochastic models on the other hand use variance in one or more variables so that the model may take alternative situations into account. For example, when stating that sickness leave is always expected to be 3%, the sickness leave is modelled as being deterministic. When sickness leave is defined as being between 1% and 3%, with a certain change for any value within this range to be true, the sickness leave is modelled as being stochastic. Below a discussion of deterministic and stochastic models and their functions will be given.

### 3.2.1 Deterministic Models

Deterministic models are widely used in research to test the influence of certain factors on the workforce planning and its performance. (Easton & Rossin, 1997) use a deterministic model to test the effects of overtime scheduling, while (Rong, 2010) presents a model that takes weekend requirements into account. (Huang, Chu, Chu, & Wang, 2009) present a model that takes learning and forgetting in employee's skill level into account. (Nissen, Günther, & Schumann, 2011) use a deterministic model to integrate staff schedules and working time models. (Bard, 2004) uses a deterministic planning model to test a method for selecting appropriate input. Besides this, several general deterministic planning models have been presented to minimize costs (Bard & Purnomo, 2006; Júdice, Martins, & Nunes, 2005) or required workforce size (Segal, 1974; Süer, 1996).

For use in more realistic real-live situations (Stewart, Webster, Ahmad, & Matson, 1994) have developed four deterministic MILP (mixed integer linear programming) models, each with a specific goal. The first model aims at minimizing training costs over the planning horizon. The second model aims at maximizing worker flexibility, while the third model tries to minimize the training time. The fourth model is a composite model, which aims at creating flexibility in the workforce at a cost efficient manner.

The widespread use of deterministic models for more complicated workforce planning problems can be explained in their relatively low complexity compared to stochastic models. An important result of this is that in general deterministic models use less computational time than stochastic models (Bard et al., 2007). The main disadvantage of deterministic models however, is that they are less capable of dealing with realistic problems situations as these in general include uncertainty. Especially in strategic planning, deterministic models are not capable of dealing with realistic planning problems due to the uncertainty in demand ((Bihlmaier et al., 2009). Due to the larger use of known information, this is less of a problem in tactical and operational planning.

### 3.2.2 Stochastic Models

Stochastic methods can be used to deal with uncertainty by adding variation in the model. Stochastic models are mainly used to deal with uncertainty in demand for either strategic planning (Azmat & Widmer, 2004; Bard et al., 2007; Bihlmaier et al., 2009) or tactical planning (Bard et al., 2007; Leung & Wu, 2004; Subramanian & An, 2008; Techawiboonwong et al., 2006). Using other stochastic variables is possible as demonstrated by (Leung & Wu, 2004) using stochastic capacity of machines and costs of employees in tactical planning.

The main advantage of stochastic model is that they may be better capable of solving real life problems than deterministic models. This however comes at the costs of increased computation time when solving the model (Bard et al., 2007). This means that the use of stochastic methods is only appropriate when results are better than when using a deterministic model.

### 3.2.3 Model selection

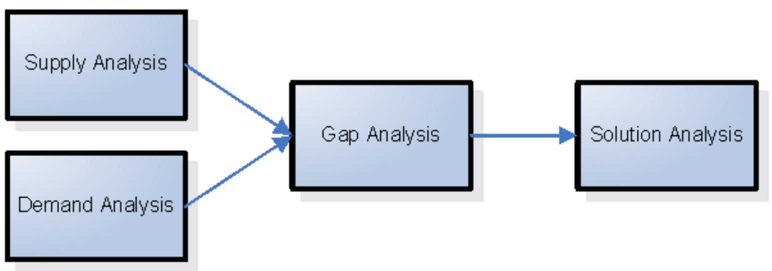
As a model type for the tactical planning at SA, a deterministic one has been selected. Most important in the model selection is that the selected model can accomplish the goal described in paragraph 2.1, being; *"To create a planning which allows timely recruitment and training of employees to meet the demand of spare parts at any point in time, while efficiently using available resources."* Both deterministic and stochastic planning models can be constructed which are able to accomplish this goal.

As both model types can perform the required tasks, the practicality of the models is definite in the choice of model type. As discussed in paragraph 3.2.2, the complexity of stochastic models is very high compared to deterministic model complexity. The running time for Stochastic models may be unnecessary high and impractical in daily use. The complexity may also prevent improvement of the workforce planning after its implementation. The demand is known several days before actual delivery, therefore uncertainty in the input variables is very low. This means that using a more complicated stochastic workforce planning will have a minimal impact on the performance.

A deterministic planning model can thus perform the required tasks, while being the most practical to use of the two model types.

## 3.3 Planning design

In this section a design of a deterministic tactical workforce planning will be given which is based on the literature found about workforce planning. The planning process will be based on the planning design proposed by (Anderson, 2004). This because it is an effective and easily understandable model, which allows the planning process to be broken down in separate steps. Each step can be adjusted separately to improve the outcome of the model, without having to adjust any other step. The four steps are: Supply Analysis, Demand Analysis, Gap Analysis and Solution Analysis. This four-step model is shown in flowchart 2 and will be used as a further guideline through this section of the report.




Flowchart 2: The four step process of Martin Anderson (Anderson, 2004)

### 3.3.1 Supply Analysis

The supply analysis indicates the capacity at any point during the planning horizon, when no action is taken to make any changes. The supply analysis thus includes all variables influencing the production time available at any point in time. These variables will be discussed below.

The workforce size and skill set define the total number of employees and the possible activities each employee can perform (Fowler et al., 2008; Rong, 2010). Untrained employees have empty skill sets, while cross-trained employees have skill sets with more than one skill. The number of possible skill sets can be calculated by $2^U - 1$, where U is the number of skill types available (Rong, 2010). In general a larger and better trained workforce offers more capacity and flexibility of assignment than a smaller and lower skilled workforce.

Planning boundaries represent the minimum and maximum number of employees to assign in the planning (Faaland & Schmitt, 1993). For SA the lower boundary is defined by the employee availability of CE. The maximum hours available is defined by available space, size of controllable workforce, operator skill levels and availability of machines (Süer, 1996).

Employee availability represents the actual amount of hours that the total number of available employees can be assigned to work. The available working hours can be calculated by using the form $H = (E - L)(G + O)$, where:

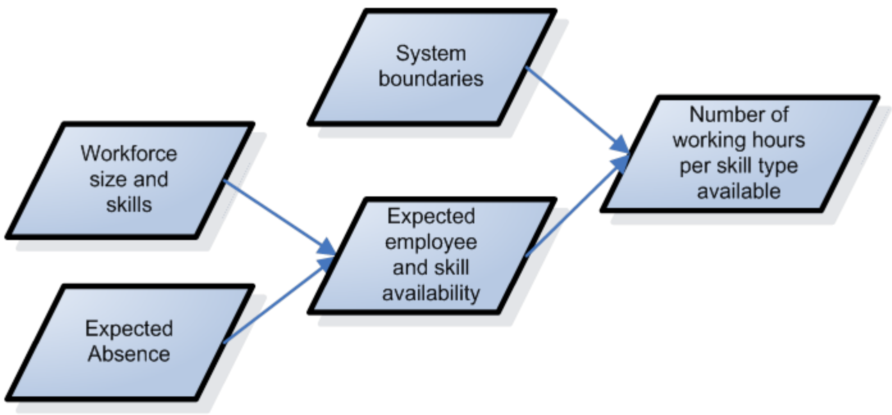
- H = total production hours available
- E = total number of employees available after sickness leave
- L = total planned leave
- G = number of working hours per day
- O = possible overtime hours per day

When using the formula of Bard (2004) for historical sickness leave, $\left(E = T - \frac{\alpha_{WF}}{100}T\right)$ the resulting formula to calculate total available hours is: $H = \left(T - \frac{\alpha_{WF}}{100}T - L\right)(G + O)$, where:

- T = total workforce size
- $\alpha_{WF}$ = percentage of workforce that is unavailable

Bard (2004) proposes either to use over-time to deal with absence or to plan extra TE to cover expected absence.

Flowchart 3 given below indicates how the variables are connected to each other and together make up the employee availability.




Flowchart 3: Model of Supply analysis

### 3.3.2 Demand Analysis

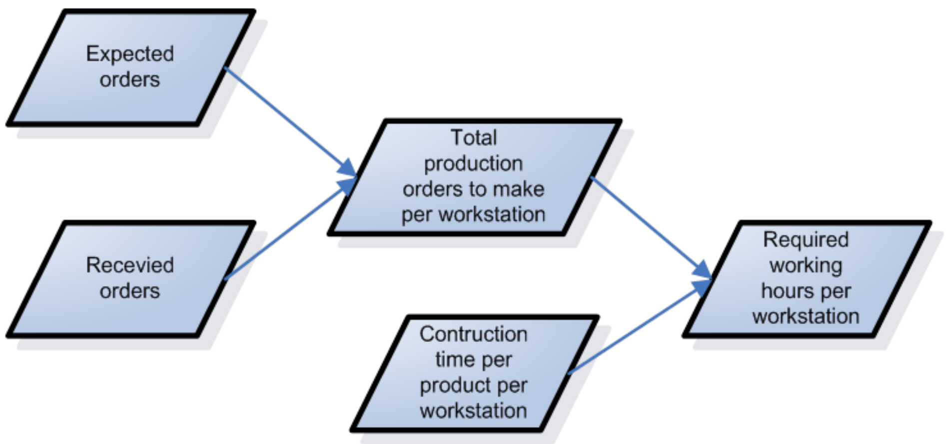
The demand analysis translates the demand of spare parts into the required amount of work that has to be performed to complete all orders in time. To do this, the POs have to be translated into working hours required to finish these orders. Below, the required variables will be discussed which allow translation of demand into the required production hours.

Spare part demand in tactical workforce planning can be divided in known demand and expected demand (Slack et al., 2007). For spare assembly, known demand refers to the released production orders (RPO's), while estimated demand exists of all expected purchase orders (EPO's) that are not yet received. For reliable planning the estimated demand should be a fraction of the known demand. Because SA uses several workstations with different orders, demand is to be determined per workstation.

Production time of each product at each workstation is a key element in determining the required number of employees. To compare the supply of production hours with the demand, both variables can be defined either in working hours (Bard et al., 2007), (Azmat & Widmer, 2004), (Fowler et al., 2008) or number of products handled per time unit (Júdice et al., 2005), (Faaland & Schmitt, 1993). To determine the required number of employees, the total working hours required needs to be calculated. The total working hours is thus used to determine production time of each product at each workstation.

Flowchart 4 shows the connection between the variables and how they together form the required working hours per skill type. The required working hours per skill type can now be calculated as: $\sum_p A_{sp}(U_p + K_p) = W_s$ where,

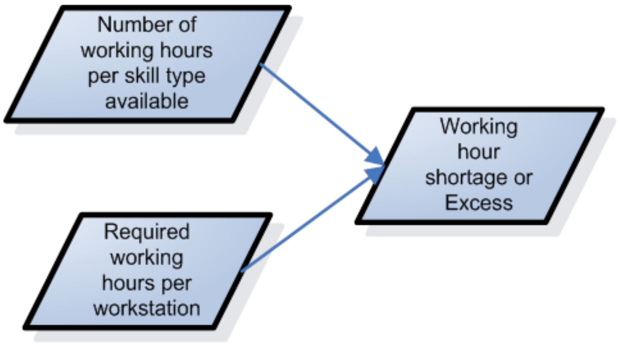
- $A_{sp}$ = assembly time for product p on Workstation s
- $U_p$ = expected amount of units to produce of product p
- $K_p$ = known amount of units to produce of product p
- $W_s$ = Required working hours on workstation s




Flowchart 4: Demand Analysis

### 3.3.3 Gap Analysis

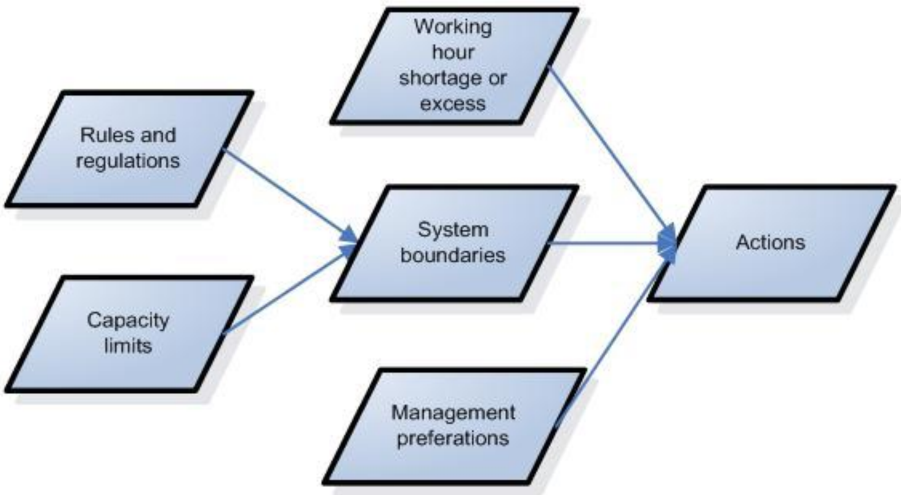
The gap analysis as defined by (Anderson, 2004) compares the available working hours with the required working hours. This has to be done for every skill type available, so that training requirements can be defined as well. The available working hours per skill type is the result of the supply analysis, whereas the required working hours per workstation is the result of the demand analysis. Note that, while each skill corresponds to all activities on one workstation, no further processing of the data is required. The gap analysis calculates the excess or shortage capacity provided by SA for each workstation .The gap analysis corresponding to this situation is shown in flowchart 5. In the situation of Nefit however cross training prevents easy calculation of the gap for each skill type individually. Employees with more than one skill can still work at no more than one workstation at the same time. The number of employees which can be assigned to each skill is dependent on the assignment of employees to other skills. This problem is to be solved during the solution analysis, where an assignment strategy is used to solve this issue.




Flowchart 5: Gap Analysis

### 3.3.4 Solution Analysis

The solution analysis provides the user with actions to be taken to change the situation if necessary. The gap analysis serves as main input to the solution analysis. Whenever the gap analysis indicates a difference between the demanded and the supplied production hours, action should be taken. These actions must be such that the result will be conform government and company rules and regulations (Azmat & Widmer, 2004), (Ernst, Jiang, Krishnamoorthy & Sier, 2004). Also the actions are subject to limits of the system itself and management considerations (Bard, 2004). Management considerations represent the preferred actions management likes to take in every situation. For example, management might prefer reduction of overwork hours above reduction of TE available so that flexibility to deal with uncertainty is maintained. Flowchart 6 shows the connection between the factors described above and represents the solution analysis.




Flowchart 6: Solution Analysis

To perform the solution analysis a model is required that enables creation of a planning and can determine what actions have to be taken. To do this, model 1 of (Stewart et al., 1994) has been selected, this model is given below. The aim of this model is to minimize the training costs for employees, while ensuring that production capacity can meet the demand. This model thus results in an efficient planning allowing SA to assign the right amount of employees to keep up with demand.

This model can thus help with achieving the goal defined in paragraph 2.1. Model 1 of (Stewart et al., 1994) is given below.

Objective function:

Min. $\sum_{i\in I}\sum_{j\in J}\sum_{k\in K} C_{ijk}X_{ijk}$ (1)

Subject to:

$\sum_{p\in P}\sum_{j\in J}\sum_{k\in K} T_{pjk}Y_{pijk} \leq R$ For each $i \in I$ (2)

$Y_{pjk} \leq U_{pjk}X_{ijk}$ For each $p \in P, j \in J, k \in K_j$ (3)

$\sum_{p\in P}\sum_{i\in I}\sum_{k\in K_j} T_{pjk}Y_{pjk} \leq RM_j$ For each $j \in J$ (4)

$\sum_{i\in I} Y_{pijk} = \frac{N_p}{HQ}$ For each $p \in P, j \in J, k \in K_j$ (5)

Where

- $X_{ijk}$ = 1, if worker i is trained on machine j at skill level k, $X_{ijk}$ = 0, if otherwise.
- $Y_{pijk}$ = the number of units per shift of product p that worker I processes on machine j at skill level k. $Y_{pjk}$ is a continuous variable.
- $C_{ijk}$ = costs of training worker i on machine j at level k, $C_{ijk}$ = 0 if the employee is already trained at that specific skill.
- $N_p$ = total number of product p required in the planning horizon.
- $H$= number of days in the planning horizon.
- $Q$ = number of shifts per day.
- $R$ = duration of each shift.
- $T_{pjk}$ = processing time per unit for product p on machine j al level k.
- $M_j$ = the number of machines of type j.
- $U_{pjk}$ = maximum number of units of product p that can be produced in one shift by one worker on machine j at level k (calculated as: $\frac{R}{T_{pjk}}$)

The objective function (1) of this model is to minimize the total costs of training employees. Constraint (2) makes sure that no employee has a shift time longer than R time units. Constraint (3) has two functions, first is ensuring that employees process at most the maximum possible for one person. Second function is that it forces the 0 / 1 variable $X_{ijk}$ to 1 if training is required. Constraint (4) is similar to constraint (2), but allows no machine to operate more hours per shift than available in that shift. To ensure that the planning model does not simply assign no training at all by not performing certain jobs, constraint (5) is used. This makes sure that all required products are being processed during the planning horizon.

## 3.4 Model and data validation

To ensure correctness of the model and data used, the model has to be validated. By comparing the model and the outcome with the real system and the actual output it is possible to determine model correctness.

As pointed out by (Sargent, 2009) this validation can be done by the creator, the end user or by an independent party. Although assigning an independent party is seen as the most reliable validation method, this is a time consuming and expensive option. Validation by the end user is the second preferred method, as the end user has best knowledge about the real system. Validation by the creator of a model is often seen as inferior as the creator is judging his own work.

Due to the high costs for validation by an independent party and the relative low impact of the model, this is not an option. To validate the workforce planning this is done by both the end user as well as the creator. This way the knowledge about the workforce planning of the creator can be used in combination with the knowledge about the actual situation of the end user.

(Sargent, 2009) describes a variety of methods which can be used to determine the validity of a simulation model. From these methods a selection has been made which can be performed with the available information while providing a basis to determine the validity. The selected methods will be discussed below, for the complete list of methods, reference is made to (Sargent, 2009).

- Event validity: Comparing the events which occur in the model with the events that occur in real live. In case of the workforce planning this can be hiring, firing or training patterns. This validating method is performed by the end user and the creator of the model.
- Face validity: Employees of Nefit which are knowledgeable about the system are asked if the behaviour of the model as well as the model rules correspond with the reality. This means that the model is judged on its logic, rather than the output it creates. This method cannot be performed by the creator of the model, and will thus only be done by the end user.
- Operational graphics: Displaying the values of the performance indicators used to establish the correctness of the performance behaviour. This method is thus focused on the output of the model rather than its logic. This validating method is performed by the end user and the creator of the model.
- Turing tests: Is similar as face validity but with its focus on model output. Employees of Nefit knowledgeable about the system are used to establish whether the outfit is comparable with reality or not. As with face validity, this method is performed by the end user of the model.

## 3.5 Implementation strategy

For implementation of new work methods like the workforce planning a distinction is made between top-down and bottom-up implementation (Daft, 1978; Joseph, Gunton, & Day, 2007). Top-down models are based on leaders who give directions on the implementation, which are carried out by implementation staff. In such a situation the end result is pre-defined and the implementation is a result of a new policy. Bottom-up models use the implementation to define new policy during the implementation process. This means that stakeholders have to anticipate to an outcome of the implementation process which is not certain when starting with the implementation. Hybrid models combine top-down with bottom-up implementation strategies (Joseph et al., 2007).

(Hayes, 2007), defines six variables which can be used to determine the strategy type to be used. These variables are discussed below:

1. The higher the urgency and stakes involved with an implementation the better the arguments for a top-down strategy. Low urgency and low stakes involved makes bottom-up more attractive.
2. Top-down strategies require a clearly defined goal, while bottom-up strategies perform better when the end state is unsure.
3. Bottom-up strategies do well when resistance is high, while top-down strategies do better when resistance is low.
4. When all data required for the implementation process is available a top-down strategy will be suitable. A bottom-up strategy is more suitable when information is scarce or can be found with other stakeholders.
5. Top-down strategies perform best when other stakeholders trust the change manager. If trust in the change manager is low, bottom-up strategies may perform better.
6. When the level of commitment required from others is low, top-down strategies are most suitable. When required commitment from others is high a bottom up strategy is more suitable.

(Joseph et al., 2007) point out that independent of the implementation strategy, stakeholder support is always important. How to handle stakeholders is dependent on their importance on the project and their position towards project.

## 3.6 Conclusion and summary

The aim of this chapter is to answer research questions 1 and 2, defining the required input data and the methods of analyzing this data. This allows comparing of the current situation at Nefit with the theoretical situation and allows defining a new method of workforce planning.

There are three different planning types that can be used to determine the required workforce, being strategic (long-term), tactical (medium-term) and operational (short-term) planning. These planning types differ in the length of the planning horizon as well as functionality. From these planning types the tactical planning is selected, as it offers the right tools to deal with the uncertainty that SA faces.

Another choice made in this chapter is between using a stochastic or a deterministic model. The decision is made to use a deterministic model. The reason is that although stochastic models are more accurate, this advantage is expected to be small while the complexity is expected to outweigh this advantage.

The planning process used exists of four steps: supply analysis, demand analysis, gap analysis and solution analysis. The supply analysis involves determining the capacity available at any point in time during the planning horizon. The demand analysis determines the required working hours in order to cover all demand at any point in time during the planning horizon. The difference between the supply and demand is calculated in the gap analysis. The Gap analysis shows the shortage or excess of employees when no changes in capacity or demand are made. To solve any differences, the solution analysis is used to provide actions that should be taken to match the supply with the demand.

To perform the solution analysis model one of (Stewart et al., 1994) has been selected. This model aims at minimizing the training costs for employees while meeting demand for products over the planning horizon. This model will therefore deliver a workforce planning, which makes efficient use of employees.

The model is to be validated by both the end user and the creator of the model. This way knowledge about the model is combined with knowledge about the real world situation. Validation of the model is done by a series of methods, being: event validity, face validity, operational graphics and Turing tests, as described by (Sargent, 2009).

Important for the implementation strategy is to determine whether a top-down, bottom-up or hybrid approach is to be selected. This choice is dependent on six factors being: the urgency, the clarity of the goal, expected resistance, data availability, trust in the change manager and dependency on stakeholders.

# Chapter 4: Current Workforce planning activities at Spares Assembly

This chapter will describe the current situation at SA in detail and define the workforce planning methods currently employed at SA. The workforce planning methods defined here will be compared with the methods described in chapter 3. Wherever possible, the performance of the current workforce planning methods is discussed.

Because the current workforce planning methods are discussed in based on the finding in chapter 3, this chapter will analyse the workforce planning methods through the same steps. In paragraph 4.1 the different planning types are discussed and the decisions made within each planning type at SA are defined. This allows paragraph 4.2 to focus on a detailed description of the medium-term planning activities that are performed.

## 4.1 Planning types

At this moment SA uses no clearly defined workforce planning methods, but allows management of SA to plan based on personal preferences. One of the results is that the planning types as defined in paragraph 3.1, being; strategic, tactical and operational planning, are not recognized by SA. For a better understanding of the planning methods used, each planning decision made by SA will be discussed in the planning type it is part of, according to chapter 3. Exceptions to this are made only if a planning decision is clearly made as part of a different planning type than described in chapter 3.

### 4.1.1 Strategic planning

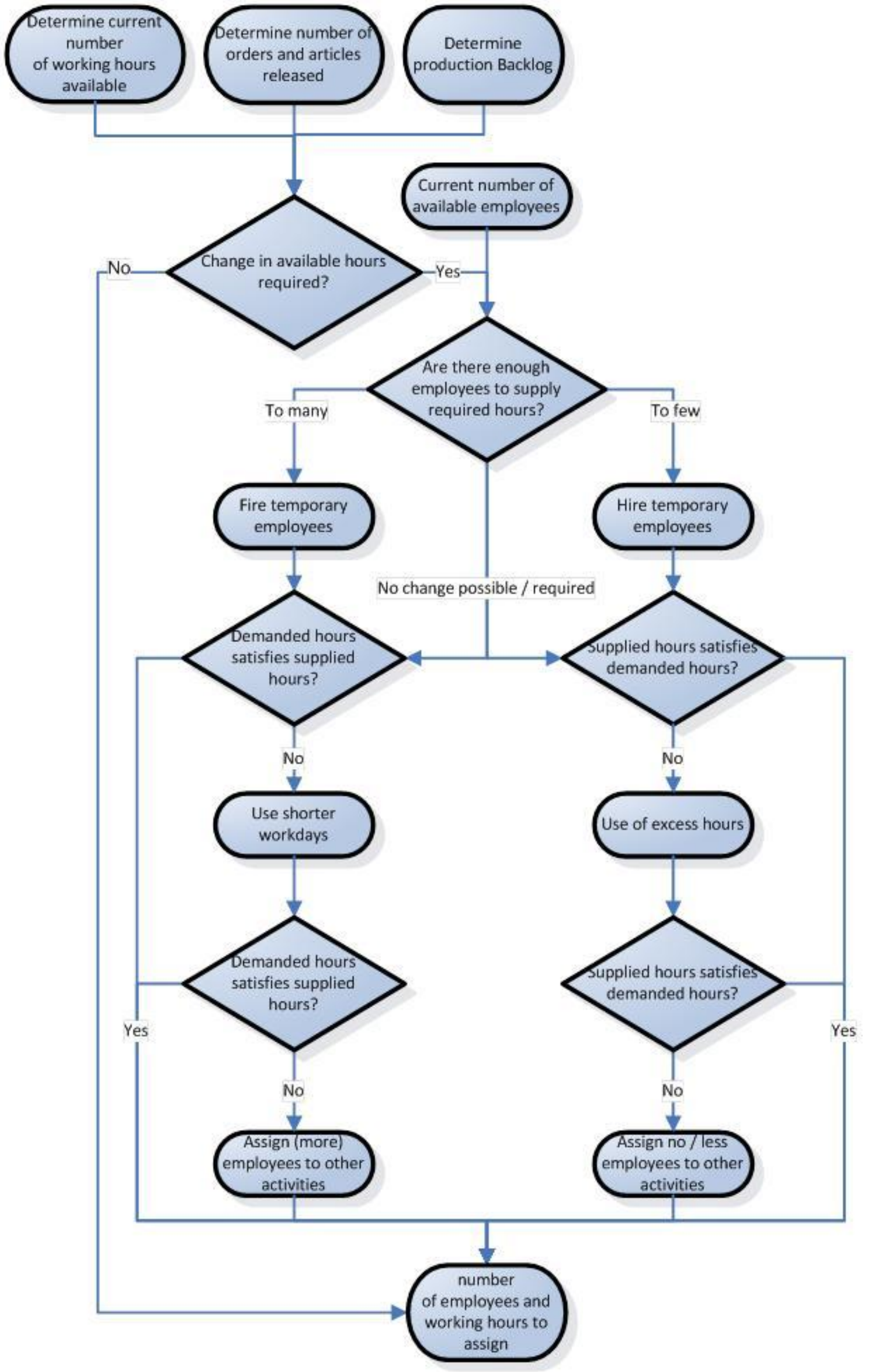
Important in planning short-term employee availability is the ratio between TE's and CE's. Currently the general rule is applied that CE's should make up at least 40% of the workforce at any time. The permanent workforce is sized such that during low season employees are still offered enough work to keep going. In general a safety margin is applied such that a small number of TE's are part of the permanent workforce as well. Because the permanent workforce is being built up over 2011, the CE's made up between 15% and 50% of the total workforce in 2011, dependent on the season. This is thus lower than the target set by SA.

To add extra flexibility, SA uses a flexible system for determining the length of the workday. Employees can be assigned to work between 6 and 8.5 hours, although in practice only workdays rounded to at least half an hour are used. The length of the workday is set in the previous week, and remains the same over the entire workweek. As the standard workweek contains 37.5 hours, any excess or shortage time is stored and used as compensation at a later moment in time. This system is used to increase flexibility of the workforce, while reducing overtime hours. During the year at most eighty overtime or shortage hours are allowed to be stored at any point in time. On the 31st of December, any excess or shortage in hours higher than forty is to be compensated. As part of this system Nefit has agreed to schedule no planned overtime or working on Saturdays and Sundays. Overtime or working in weekends is only allowed in case of disruptions of the production process, like lengthy machine failure, causing backlog in production.

Currently SA switches between a one and two shift workday depending on the expected workload over the year. In general SA starts to work in two shifts at the first of October and returns to one shift at the first of April. These moments are traditionally seen as, respectively, start and end of the high season for boilers and its spare parts.

### 4.1.2 Tactical planning

The tactical planning activities currently performed at SA aim at assigning the right number of employees to the available workstations and determining the required workday length. Flowchart 7 shows the decision process used by SA to determine the number of employees required for production and the length of the workday.




Flowchart 7: Currently applied method to determine required number of employees and working hours

The main input for determining if action has to be taken is the number of purchase orders available and articles that have to be assembled. New purchase orders are printed three times per day, at 6 am, 12 am and 4 pm. Using the number of PO's and articles to assemble in combination with the workstations where orders need to be processed, the supervisor can make a rough estimate of the required capacity. Because on-time delivery performance is an important performance indicator, the presence of backlog order is seen as a reason to increase capacity. To keep track of backlog and other outstanding orders, an overview is retrieved from the ERP system at the start and end of the shift and after every order release.

The first step in planning is to establish if any change from the current situation is required. This is done by the supervisor based on his estimate of available work. Although sometimes very small, in general every week actions are taken to adjust the production capacity supplied.

The second step in the decision process used is to determine the number of employees required to deal with the spare part demand. This is done by the supervisor as well, based on the same information as used for the previous step. When SA struggles to keep up with demand and a workload of several days is available, the supervisor tends to hire extra TE's. Mostly more than one new TE is hired when a hiring decision is made and these employees will become available within a workweek. In any other situation, the number of employees is kept at the same level, meaning that no firing decision is made in the tactical planning process.

The third step in the current process is to determine the length of the shift for employees. This shift length is set based on the estimate of the workload by the supervisor. In general the length of the workday is set at the latest possible moment, based on the workload estimated at that moment. When there is work for only a few days or less, the length of the workday is generally chosen to be 7.5 hours or shorter. When there is work available for several days, the length of the workday will in general exceed 7.5 hours.

The last step in the current decision process is to determine whether or not to assign employees to non-production activities. This is done by the team leaders, who base their decision on their own estimate of the workload as well as the non-production work available. In general it can be said that the same rules apply here as with the hiring decision. When SA struggles to keep up with demand and a workload of several days is available, employees will only be assigned to non-production activities if necessary. When this is not the case, employees are assigned to any outstanding non-production activity.

Training of employees is determined by the team leaders and is done as shown in figure 10. These decisions are triggered either when team leaders require a skill that is unavailable or when they expect that such a situation will occur. Depending on the trigger, training either takes place when required for production or when the team leader expects there is time left for training.

After it is decided that an employee is to be trained it has to be decided in which skill an employee is to be trained. This may seem very straightforward but due to cross training, more employees knowing one skill can relieve other employees who are able to perform other skills. Therefore training in the required skill is not always necessary. In combination with this decision an employee is selected who should be trained. Only employees perceived as capable are selected. For this reason sometimes a skill may be selected for an employee, as well as an employee may be selected for a certain skill.

The loading system currently used at SA is best defined as an infinite loading system, as production orders are released without taking capacity into account. The peaks and troughs shown in figure 1 are passed on directly to SA, who will react to the workload at that point in time. This will reflect on the workforce as well.

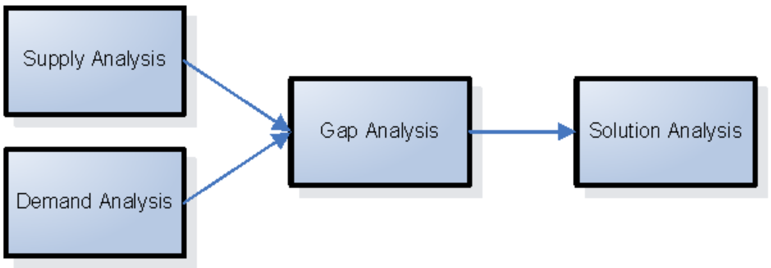
### 4.1.3 Operational planning

Operational planning at SA has its main focus on the assignment of employees to specific tasks that they will perform. In general these tasks remain the same over a one-week period, but during a day employees may be re-assigned to workstations where they are required more. These short-term switches may also lead to training of employees in certain skills. This can because of a sudden necessity of a skill or because there is unexpected time for training.

In contrast with the literature, the current operational planning at SA is concerned with firing of employees. This in general occurs when there is no more work available, forcing SA to stop all production activities. At this point TE's are either fired or sent home for the day and CE's are sent home for the day as well. This is done because high uncertainty in demand encourages management to aim at finishing all available orders as soon as possible. Hence, TE's will not be fired unless strictly necessary, as demand might increase at any point in time.

## 4.2 Current Planning design

In this chapter current planning activities in regard with the tactical planning are explained further. This is done to create a better understanding of the requirements SA has for a tactical workforce planning and the situation in which it has to operate. As with the planning type, Nefit uses no clearly defined model or planning method. For a better understanding of the workforce planning activities at Nefit, all planning activities will be discussed in light of the four step model of (Anderson, 2004). The model is thus not used by Nefit and the steps are not performed as clearly divided as in the model. For convenience the model, already shown as flowchart 2 in section 3.3, is shown again in flowchart 8.




Flowchart 8: The four step process of Martin Anderson (Anderson, 2004)

### 4.2.1 Supply analysis

SA uses several tools to measure the supply of capacity based on employee availability. These tools are described below, with the resulting values for the variables measured.

### *Skill availability*

SA uses a skill matrix where the skills of all employees are listed; an example is given in appendix 3. As explained in paragraph 4.1.2 employees with highly perceived abilities are trained in more skills than other employees. For this reason the skill matrix is used to support decisions on who to offer a contract as well. This skill matrix is to be used as input in the workforce planning to indicate the number of employees available and what jobs they can perform.

### *Employee availability*

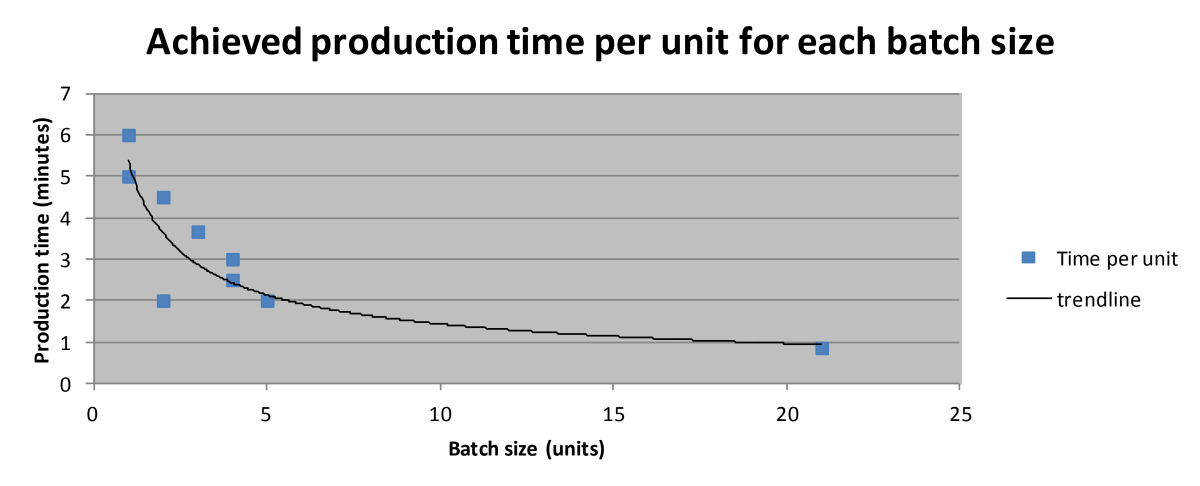
To monitor the availability of employees, SA uses an employee planning. The employee planning is a document with a rolling horizon in which the absence of employees is planned and monitored. This document is used as input in determining which employees are available at any point in time. The historical information on absence levels and planned leave is used to set an estimate for future sickness leave. Current unplanned absence at SA is around 3%.

### *Throughput times*

The main issue SA is struggling with is determining the throughput times for PO's through the entire SA department and through every workstation. All 4000 different spare parts have their own routings and activities connected with them. The effect is that throughput times for most PO's are unique. The throughput times are mainly depending on order size, the product itself and the workstations where the PO is handled. Therefore, each workstation may provide an upper boundary for production capacity for a certain range of products.

The current system used by SA to measure the throughput times is by registration of the start and finish times for every PO at every workstation. From this information an overview is created for every product, as shown in Appendix 4. The advantage of this method is that it can deliver a large quantity of data over a relative short period of time. The data created is also based on actual achieved production times instead of theoretical achievable times. The main disadvantage is that the method is not exact, since production times for the entire order are rounded off to full minutes for each workstation. The method of measuring allows noise to enter the data as well. It is possible that a fraction time between start en finish is not spend on production of that order.

The example given in graph 2 shows a typical relation between the production time and the production quantity. This line clearly shows that larger quantities require less production time per unit than smaller quantities. This is caused by setup times at workstations and other actions that have to be performed in equal measure for all production sizes. An example of this may be the walking time for order pickers to the pick location. Note that due to the labour intensive activities, production time is the larger part of the total production costs. For reliable estimation of the production time and costs it is therefore advisable to set a standard production quantity for each spare part. The forthcoming standardised production time can then be used as input in the workforce planning.

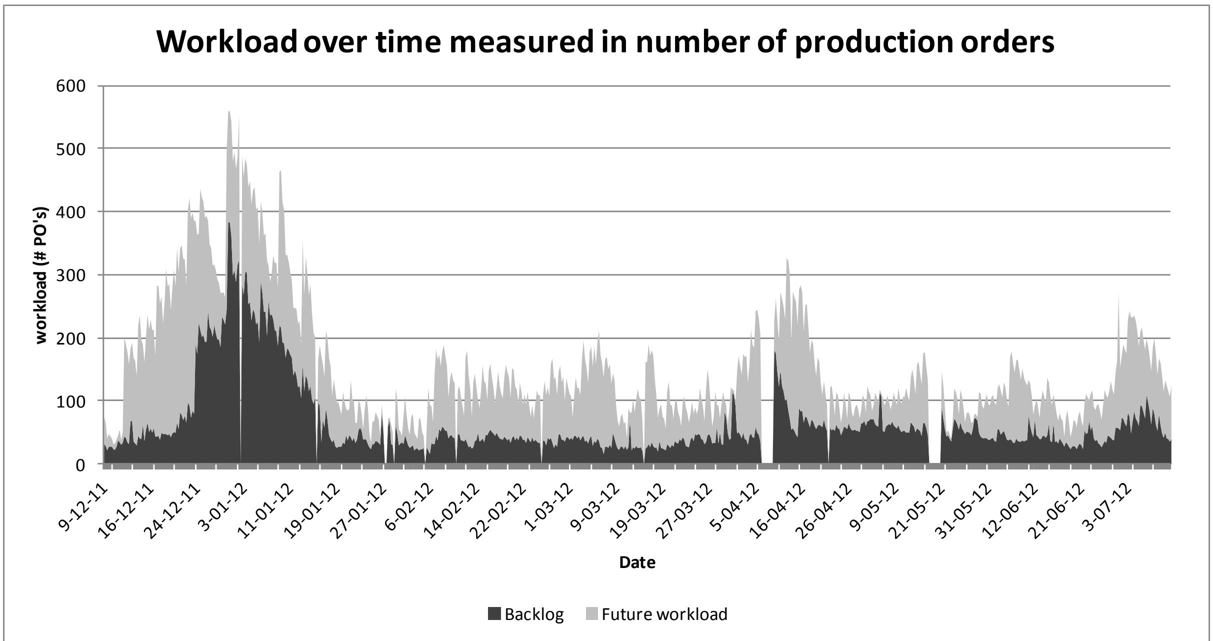



Graph 2: achieved production time per unit for each batch size.

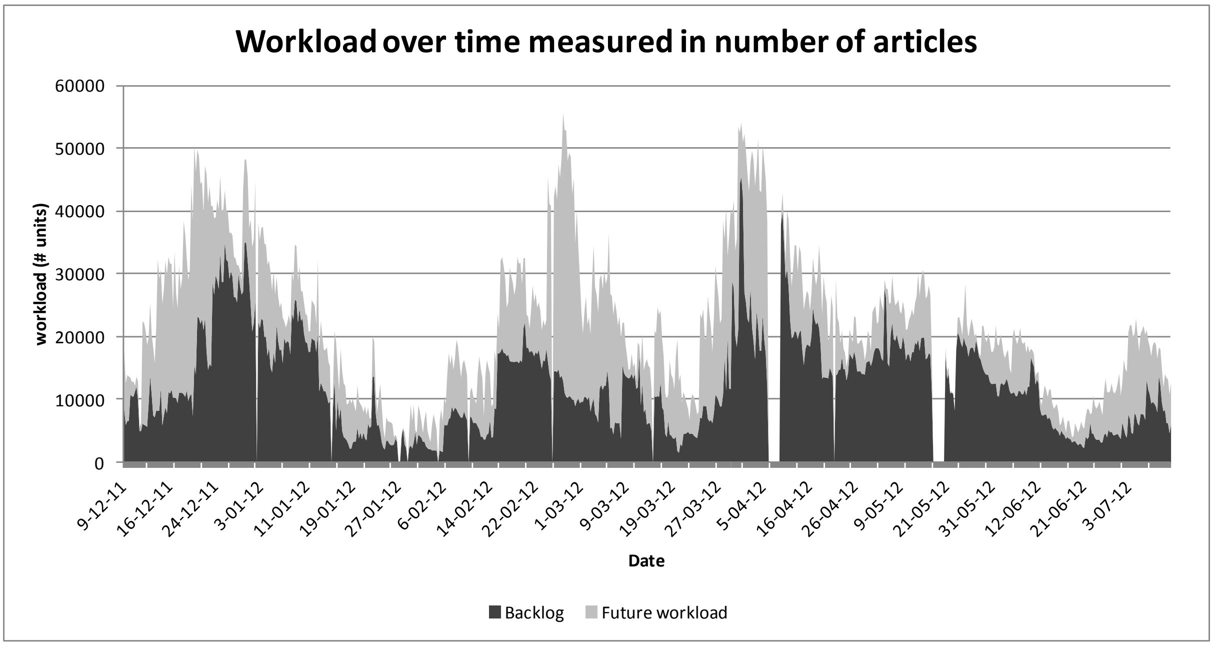
### 4.2.2 Demand analysis

To keep track of actual demand at SA, the registration used to count available PO's and the number of articles to produce as described in paragraph 4.1.2 is used. This registration method is used to count the PO's that are released for production, for every day within the planning horizon. The same is done for the total number of articles that have to be produced. Because PO's cannot yet be connected with a production time, this is the most reliable method available to establish the workload.

Graphs 3 and 4 show respectively the number of production orders released and the number of products released. A distinction is made between; backlog orders and orders that do not have to be finished before the date of measurement. A short discussion of the information found in these figures is given below.




Graph 3: Available workload over time measured in number of production orders




Graph 4: Available workload over time measured in number of articles

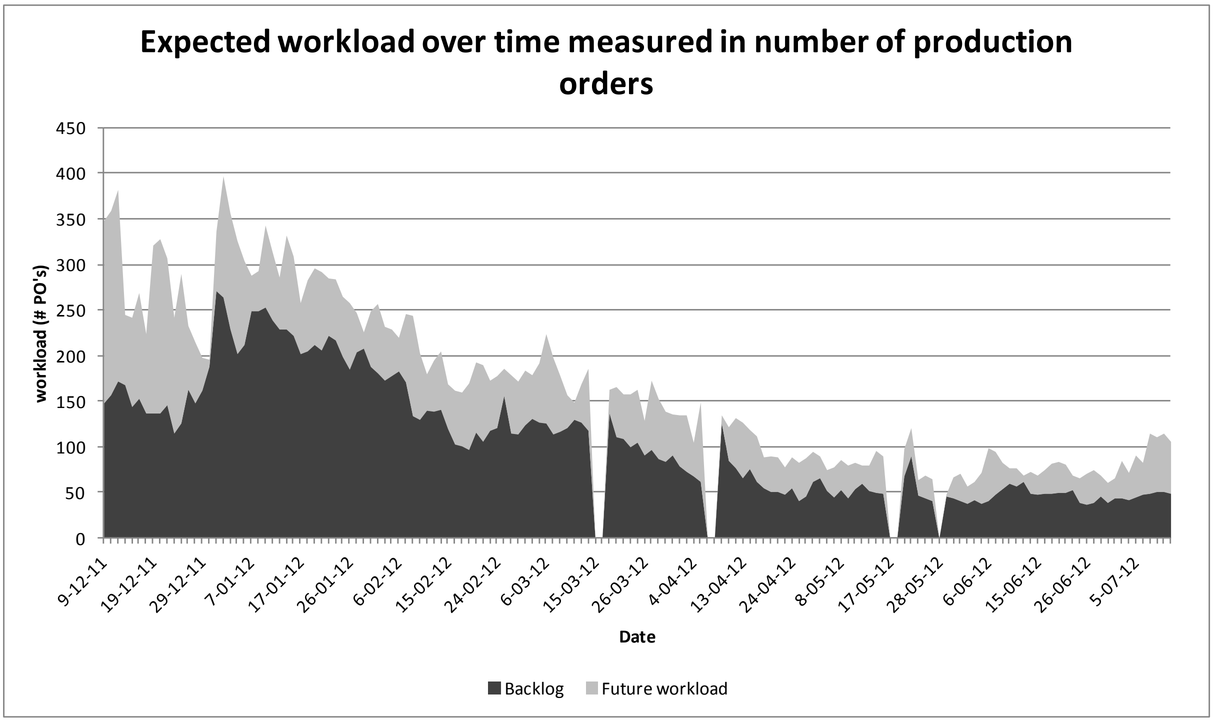
In general it can be seen that the graphs show continuous change in the workload available at each point in time. This is mainly caused by PO's which are released at pre-set times and not continuously. This is shown best by the sudden peaks shown around 27-2-2012 and 2-4-2012. Peaks like these are mainly caused by one of two reasons. First cause is orders coming from the warehouse in Lollar, ordering several products at the same time in large quantities. The second cause is delivery of large amount of purchase parts to SP, so that a large number of PO's are to be released. Some days several small orders may be finished over a period. At other days one or two larger orders or no order at all may be finished during the same period.

Over time it can be seen that there is a wave movement in the graphs. For example, the period between 13-12-2011 and 16-01-2012 has high workload availability indicating a peak demand and possible capacity shortage over that period. The period between 20-1-2012 and 7-2-2012 however is a clear example of a period with low workload availability. This indicates where the capacity can easily keep up with demand. As employees will not be fired before SA is completely out of work, this situation occasionally occurs after peaks in demand.

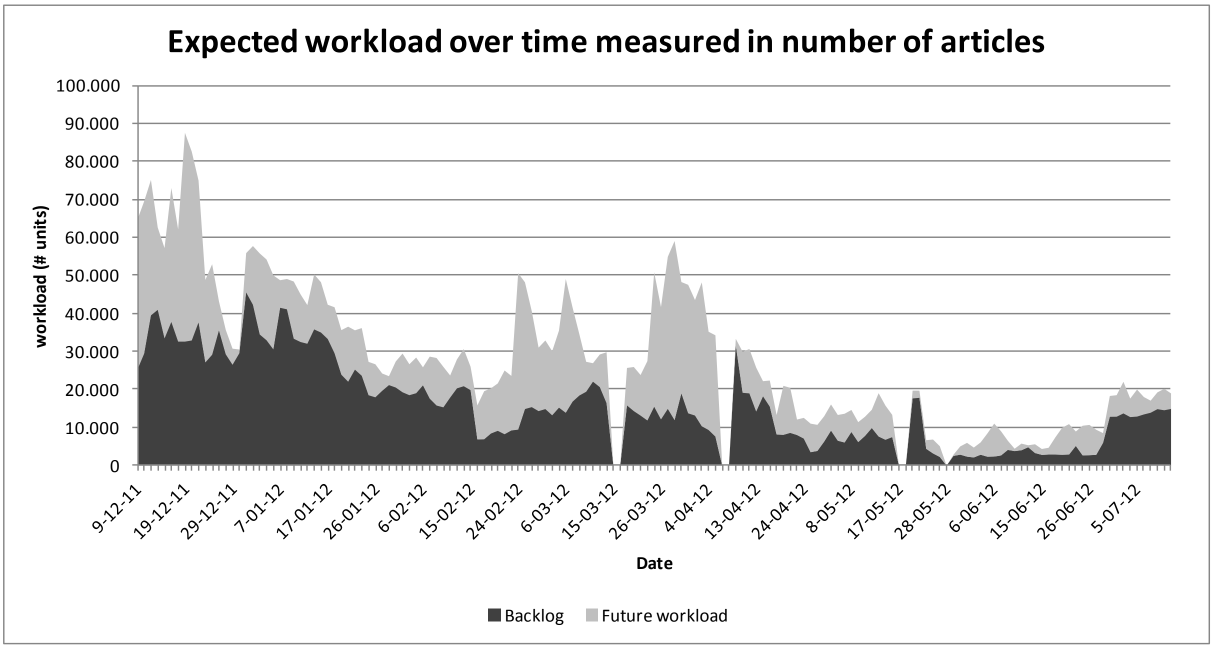
Both graphs seem to indicate that SA suffers from facing backlog in production at all time during the measurement period. This is caused by an error in the production orders released, which assigns all PO's to earlier finishing dates than when they are actually acquired. Even though the indicated delivery date may be passed, there might still be enough time for completion of a PO. This has great implications for the workforce planning, as unavailability of the actual delivery date makes it impossible to produce a reliable and efficient planning.

The fourth notable effect is that at no point in time there was absolutely no workload available. This is mainly due to two reasons. Firstly some orders may already be finished but not yet signed off as complete, thus still show up in the ERP system as available workload. Secondly some orders may be blocked from production due to errors in the order, the product or stock levels of required purchase parts. For these reasons the available workload is not likely to reach zero, even though SA has to send people home.

Comparable with graph 3 and 4 above are the graphs 5 and 6 shown below. Graphs 5 and 6 show, respectively, the number of PO's and the number of products that are not released for production yet. This workload has arrived in its production period, but no stock is available at that point in time. This explains the source of one of the main causes of sudden peaks explained earlier in this paragraph. These peaks are shown here as sudden declines, as can be found around 22-12-2011. Both graphs show a steady decline in workload, especially from the beginning of 2012. This is a clear sign of reducing demand while moving into the low season.




Graph 5: Expected workload over time measured in number of production orders




Graph 6: Expected workload over time measured in number of articles

### 4.2.3 Gap Analysis

As indicated in paragraph 4.1.2, the supervisor generally establishes whether there is a difference between demand of production hours and the supply. For this step there is no method or tool used, that can be used to define the gap. This is an important weakness in the current planning method, as the gap is not quantified.

### 4.2.4 Solution Analysis

The solution analysis is currently made by the supervisor of SA, as is done with the GAP analysis. The skill matrix and employee planning described in paragraph 4.2.1 are used to establish the supply of production capacity. The production order registration described in paragraph 4.2.2 is used to establish the demand in capacity. The information from these three tools taken together is used in the process of determining how to cover the required demand. Although they function as input, they do not indicate how any possible capacity problems are to be solved. This is done by the supervisor according to the method shown in flowchart 7. The lack of a well defined solution analysis means that there is a great risk of deviating from standard procedures. If the supervisor is absent, the decision process is likely to be different, affecting the performance of SA.

## 4.3 Conclusions and Summary

In this chapter the current situation at PS is discussed based on the literature review in chapter 3. None of the four steps of Martin Anderson (Anderson, 2004) is conducted in a way that it can be identified as such. However the currently used information at PS and the method of planning employees do offer some of the functionalities required according to the model.

SA does not use clearly defined workforce planning methods. As such SA does not consider the workforce planning activities to be divided into strategic, tactical and operational. A workforce planning model like the model proposed by (Anderson, 2004), or any other model is thus not used either. Most of the planning decisions included in the tactical planning however are performed by SA within the planning horizon belonging to tactical planning. Only the firing decision for TE's is pushed further back in the planning and is made as part of the operational planning. This method often results in high employee use followed by sudden firing of many TE’s and a period of low employee use. The decisions affecting the production capacity of SA are mostly made by the supervisor based on his own insights and planning rules.

For the tactical planning, most information required in the supply and demand is either not available or is of low quality. Most importantly, the delivery date on the demand information is incorrect and the throughput times of PO’s at every workstation are unknown. These pieces of information form the basis for proper workforce planning. Currently the missing information makes it impossible to accurately establish the demand of parts and the supply of capacity in terms of required and provided production time. The demand for spare parts proofs to be very unstable. Planning issues like low stock levels form extra problems for the on time delivery of spare parts. SA has to deal with sudden peaks in demand as well as several weeks of very low or very high demand.

Although not recognized as being gap analysis and solution analysis, all activities part of these two analyses are completely performed by the supervisor. This is done by using tools and methods which are not clearly defined and are developed by the supervisor himself. The gap between required and provided production time cannot be quantified. The solutions obtained are specific to the supervisor, making it hard for others to use the same solution methods in absence of the supervisor.

# Chapter 5: Design of the workforce planning

This chapter combines the theoretical knowledge from chapter 3 with the practical knowledge from chapter 4 into a workforce planning usable to SA. The chapter will start with the theoretical model developed by (Stewart et al., 1994). In paragraph 1, a variance of this model will be created, that can create an optimal schedule specific to SA. After determining this optimal model, it will be followed by a discussion of the practicality and usability of the model in paragraph 5.2. Paragraph 5.3 will be used to address the issues discussed in paragraph 5.2 and come with a proposal workforce planning. This proposal workforce planning will be used as alternative to the currently used workforce planning methods.

## 5.1 Theoretical Model

The model described by (Stewart et al., 1994) needs to be adjusted in order to fit the situation at SA. The differences between the model and reality are summarized below:

1. SA assigns employees to a workstation for an entire day, whereas the model allows switching between workstations.
2. The model only takes training costs into account, while at SA there are other costs involved as well. These costs are hiring & firing costs, employee's salary and training costs.
3. The model makes a distinction in skill levels, whereas at SA only a difference in available skills is defined.
4. The model aims to have finished all work at the end of the planning period, while at SA most orders have to be finished earlier during the planning horizon. Therefore a finishing date for each order should be added to the model.

For a better understanding of the changes made to the model of (Stewart et al., 1994), this model as given in paragraph 3.3.4 is shown again below. In paragraph 5.1.1 the changes in the model as well as the developed model will be discussed.

Objective function:

Min. $\sum_{i \in I} \sum_{j \in J} \sum_{k \in K} C_{ijk} X_{ijk}$ (1)

Subject to:

$\sum_{p \in P} \sum_{j \in J} \sum_{k \in K} T_{pjk} Y_{pijk} \leq R$ For each $i \in I$ (2)

$Y_{pjk} \leq U_{pjk} X_{ijk}$ For each $p \in P, j \in J, k \in K_j$ (3)

$\sum_{p \in P} \sum_{i \in I} \sum_{k \in K_j} T_{pjk} Y_{pjk} \leq RM_j$ For each $j \in J$ (4)

$\sum_{i \in I} Y_{pijk} = \frac{N_p}{HQ}$ For each $p \in P, j \in J, k \in K_j$ (5)

Where

- $X_{ijk}$ = 1, if worker i is trained on machine j at skill level k, $X_{ijk}$ = 0, if otherwise.
- $Y_{pijk}$ = the number of units per shift of product p that worker I processes on machine j at skill level k. $Y_{pjk}$ is a continuous variable.

- $C_{ijk}$ = costs of training worker i on machine j at level k, $C_{ijk}$ = 0 if the employee is already trained at that specific skill.
- $N_p$ = total number of product p required in the planning horizon.
- $H$= number of days in the planning horizon.
- $Q$ = number of shifts per day.
- $R$ = duration of each shift.
- $T_{pjk}$ = processing time per unit for product p on machine j al level k.
- $M_j$ = the number of machines of type j.
- $U_{pjk}$ = maximum number of units of product p that can be produced in one shift by one worker on machine j at level k (calculated as: $\frac{R}{T_{pjk}}$)

### 5.1.1 MILP model

**Indices**

| | |
|---|---|
| $i = worker$ | $i = 1,\ldots,I$ |
| $j = skill$ type | $j = 1,\ldots,J$ |
| $p = product$ | $p = 1,\ldots,P$ |
| $d = day$ | $d = 1,\ldots,D$ |
| $w = week$ | $w = 0,\ldots,W$ |
| $q = shift$ | $q = 1,\ldots,Q$ |

**Parameters**

$M_j$ = number of workstations that require skill type j

$N_{pd}$ = total number of product p required before the end of day d

$T_{pj}$ = processing time in days for each unit of product p when performing skill type j

$t_j$ = time in days required for one employee to be trained in skill type j

$C_{id}$ = cost of assigning operator i to work at day d

$R_w$ = length of the workday in hours in week w

$S_{ijd}$ = 1 if operator i has skill j on day d, 0 if otherwise (represents the skills set)

**Decision Variables**

$X_{ijqd}$ = 1 if operator i is assigned to machine j on shift q at day d, 0 if otherwise

$Z_{ijqd}$ = 1 if operator i receives training in skill j on shift q at day d, 0 if otherwise

**Objective function**

$$Min. \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{q=1}^{Q}\sum_{d=1}^{D} C_{id} X_{ijqd} + \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{q=1}^{Q}\sum_{d=1}^{D} C_{id} Z_{ijqd} \tag{11}$$

Subject to

$$\sum_{p=1}^{P}\sum_{d=1}^{D} N_{pd} T_{pj} \le R_w \sum_{i-1}^{I}\sum_{q=1}^{Q}\sum_{d=1}^{D} X_{ijqd} \qquad \text{For } j = 1,\ldots,J, w = 1,\ldots,W \tag{12}$$

$$\sum_{i=1}^{I} X_{ijqd} \le M_j \qquad \text{For } j = 1,\ldots,J, q = 1,\ldots,Q, d = 1,\ldots,D \tag{13}$$

$$\sum_{i=1}^{I} Z_{ijqd} \leq \sum_{i=1}^{I} X_{ijqd} \qquad \text{For } j=1,...,J, d=1,...,D, q=1,...,Q \qquad (14)$$

$$\sum_{d=1}^{D}\sum_{j=1}^{J}\sum_{q=1}^{Q} X_{ijqd} + \sum_{d=1}^{D}\sum_{j=1}^{J}\sum_{q=1}^{Q} Z_{ijqd} \leq 1 \qquad (15)$$

$$\sum_{d=1}^{d-1}\sum_{q=1}^{Q} Z_{ijqd} \geq t_j \sum_{q=1}^{Q} X_{ijqd} - S_{ijd-1} \qquad \text{For each } i=1,...,I, j=1,...,J, d=1,...,D \qquad (16)$$

**Model description**

The objective function (11) is as used by (Stewart et al., 1994), extended with the training costs $\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{q=1}^{Q}\sum_{d=1}^{D} C_{id} Z_{ijqd}$ . In this model the training costs required to perform a skill are not assigned to the day that an employee is assigned individually on that workstation. Trainings costs are assigned to each day when training takes place; this allows training to be assigned to individual days instead of consecutive days. The objective function minimizes the total costs associated with assigning employees to the required workstations for both production and training. Note that $C_{id}$ includes all costs associated with assigning employee I to work on a specific day, or not assigning this employee to work on that day. This may include hiring / firing costs, training costs and any other costs connected to the assignment of an employee. Constraint (12) is similar to constraint (5) used by (Stewart et al., 1994), but is changed such that it allows assignment of employees to entire days of work instead of single production orders. Constraint (12) ensures that enough employees are available to make all orders before or on their assigned due date. Constraint (13) limits the number of employees which can be assigned to any type of workstation during a single shift to the number of workstations of that type available. Constraint (14) limits the number of employees that can be assigned to training in a specific skill on a certain day. The number of employees who can be trained is limited to the number of skilled employees working on that workstation on that day. Constraint (15) makes sure that an employee is assigned to at most one skill type on each day. This can be either for training or for production on the associated workstation. Constraint (16) ensures that any employee without the required skill receives enough training days before producing on the assigned workstation. Although convenient, training does not have to take place in consecutive days. This constraint is used to trigger the 0/1 variable $Z_{ijqd}$ when training is required. The variables $X_{ijqd} - S_{ijd-1}$ will only be higher than 0 if the employee is assigned to perform the skill but is not trained to do so. In that situation the variable $Z_{ijqd}$ is triggered the number of times there are training days required for that skill.

**Assumptions**

An overview is given of the assumptions used by the model explained above. A detailed discussion of these assumptions can be found in Appendix 5.

1. One employee is assigned to one workstation for an entire day
2. Costs of employees do not change over the planning horizon, the same as in (Stewart et al., 1994)
3. One employee can train no more than one other employee in a certain skills, this training will always take place on the workstation requiring that type of skill
4. An employee being trained will not increase nor decrease the production quantity

5. Breakdown time or changeover time is assumed to be zero
6. Each worker is assumed to be available during an entire shift in the planning horizon
7. No differences exist among workers other than their skill set and their contract type
8. Incomplete jobs at the end of the shift can be continued next shift without loss of time.

Employees are not assigned to a shift by the workforce planning, as this is part of the long-term planning process. The parameter “shift” is only used to ensure that the correct number of workstations is taken into account. There is no overlap when assigning two shift and both shifts use the same equipment. Machine capacity for two shifts is thus double the capacity for one shift.

The model described above does not take different shift lengths into account that can be selected for each week. To do this, complete enumeration is used over all possible shift length combinations within the planning horizon. Week 0 is defined here as the first contained in the planning horizon, which by definition has already started when activating the workforce planning. The shift length of week 0 will thus be fixed. The planning horizon for which shift lengths have to be determined is two or three weeks. For example the 15-day planning horizon ends in week two if the day of planning is a Monday, where this Monday is part of week 0. Planning in all other days of the week will result in a planning horizon of 15 days covering 4 weeks. For every week there are six shift length options to choose from while only the shift length for week 0 is fixed. The number of possible shift length combinations is thus either 36 (6 x 6) when planning on Mondays or 216 (6 x 6 x 6) when planning on any other day.

## 5.2 practicality of the MILP model

When considering the objective function of the (11) MILP model, every employee is to be assigned to either no work station or one of the available workstations. If there are no workstations the only solution is assigning all employees to no workstation. For every extra workstation the number of possible (feasible and infeasible) solutions is multiplied with itself, as each employee can be assigned to all workstations. This means that there are $i^{(j+1)}$ possible solutions for each day, I being the number of employees and J the number of skill types. For each extra day included in the planning horizon the number of solutions is again multiplied with itself as all solutions for one day are also possible for the other days. This means that over the planning horizon there are $(i^{(j+1)})^d$ possible solutions, with D as the number of days in the planning horizon. By determining the best solution for every shift length combination, the number of solutions increases to $L \times (i^{(j+1)})^d$, where L is the number of possible shift length combinations.

For an example with 3 employees, 2 skills types and a 3-day horizon with 2 possible shift lengths the problem size would thus be: $2 \times (3^3)^3 = 39366$ possible solutions (including infeasible solutions). As the problem in the situation of SA has up to 100 employees, 11 skill types and a 15-day planning horizon with up to 216 different shift length combinations the problem will contain immeasurably many solutions, meaning it will be very hard to find an optimal solution. As indicated no specialised software is available to SA for solving such a problem, but this is to be done in Microsoft Excel. Solving such a problem to optimality within a reasonable time is therefore impossible.

The factor that influences the problem size most is the planning horizon. For example the problem described above with 3 employees, 2 skill types, a 3-day planning horizon and 2 possible shift lengths. When solving for individual days, the problem size is reduced to $L \times i^{(j+1)} = 2 \times 3^3 = 54$

possible solutions per day. When solving all days within the 3-day planning horizon separately the example problem would have 162 solutions, a factor 243 less than the original problem. Thus planning each day independently reduces the problem size, although only each separate problem will be solved to optimality, not the entire problem. The number of possible solutions will then be reduced to $15 \times 26 \times 100^{12} = 3.9 \times 10^{26}$ - still a large problem to solve to optimality.

Further reductions of the problem size can be achieved by splitting the workload over the shifts before solving the MILP. This can be done as teams are similar and are able to perform the same tasks. This means that the number of employees to schedule is halved, but scheduling has to be done twice. The number of possible solutions is now further reduced to: $2 \times L \times \left(\frac{1}{2} \times i\right)^{(j+1)} = 2 \times 15 \times 26 \times 50^{12} = 1.9 \times 10^{23}$. This method will only allow the problem for each shift on each day to be solved to optimality. This may affect the result over the entire planning horizon as an optimal solution as a solution on one day affects the solution for another day. The result for each day is optimal, given the decisions made in for the planning of previously planned days.

Even after these reductions it is not possible to solve the problem to optimality within several minutes time, which is convenient for everyday use. For this reason the next paragraph will focus on finding a heuristic method that can find a good solution within reasonable time.

## 5.3 Proposed workforce planning

The proposed workforce planning differs from the MILP model in two ways. Firstly the problem is split in smaller problems, which will be solved independently of each other. As calculated in paragraph 5.2 this will greatly reduce the problem size and will make it easier to solve. However as proofed in paragraph 5.2 as well, splitting of the problems alone is not enough. The second difference from the MILP is that the proposed workforce planning method will make use of heuristic methods to solve the different parts of the planning process. These heuristic methods aim at finding close to optimal problem solutions instead of solving the problem to optimality.

The planning process will now exist of the six steps defined below, where each step is already defined in paragraph 5.1 and 5.2.

- ➔ Step 1: Determine shift length for each weak in the planning horizon
- ➔ Step 2: Determine what activities to perform at what day
- ➔ Step 3: Determine which shift has to perform what activities
- ➔ Step 4: Assignment of employees to workstations
- ➔ Step 5: Repeat previous steps until all possible shift length combinations are explored
- ➔ Step 6: Select the solution with the best results over the entire planning horizon

The first step is to determine the length of the shift for each week. Steps 2 and 3 are part of the problem size reductions proposed in paragraph 5.2. In step 2 the workload is divided among all days within the planning horizon. In step 3 the workload for each day is divided over the available shifts. Step 4 is the actual assignment of employees to available tasks. Steps 5 and 6 are to make sure that all shift lengths allowed are explored and the best option is selected.

### Step 1: Determine shift length

This step is used to set the shift length for each week in the planning horizon before starting the workforce planning process. For model simplicity and stability, the shift length in each week may be no longer than the shift length of previous week, plus half an hour. Similarly, the shift length may be no shorter than previous weeks shift length minus half an hour. This was the original rule of the flexible system at SA, which is incorporated in the model. By not allowing large differences in shift length, the flexibility is reduced, but stability for the employees is increased.

Table 3 shows a possible combination of shift lengths, within the range that is allowed by applying the rules explained above. Depending on the day of planning and the shift length at week 0, there are between 26 and 5 possible shift length combinations. When allowing each possible shift length at each week there are 36 to 216 possible shift length combinations. The reduction in possibilities thus reduces computational time for the model by up to 43 times.

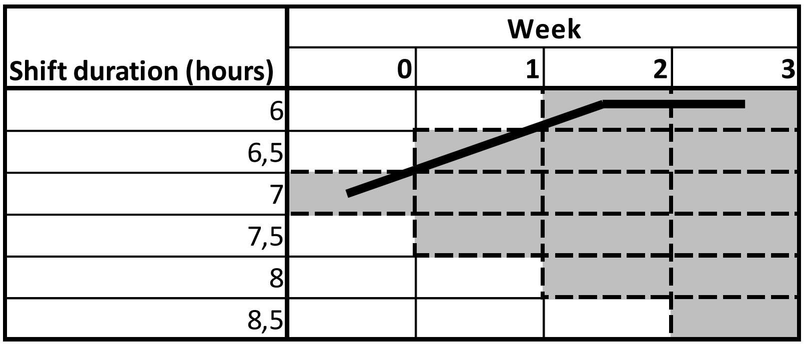



Table 3: example shift length combination and range of shift length possibilities for a four week period.

The costs of each schedule depends on the timing of work as well as the amount of work compared with the available production time. The costs are thus depending on how each schedule turns out to be. This means there are no simple rules that can be used to determine the best shift length combination. For this reason all possible shift length combinations allowed by the rules explained above are tried by using complete enumeration.

To create a planning for all possible shift length combinations, a systematic method is used. The workforce planning starts with the lowest possible number of hours per shift for each week. From this point all possible shift length combinations will be tried one by one as explained in table 4.

| | Week 0 | Week 1 | Week 2 | Week 3 | |
|---|---|---|---|---|---|
| **Combination 1** | 7 | 6,5 | 6 | 6 | (determine shortest possible shift lengths) |
| **Combination 2** | 7 | 6,5 | 6 | 6,5 | (Increase shift length of last week with half an hour) |
| **Combination 3** | 7 | 6,5 | 6,5 | 6 | (Increase shift length in week 2 with half an hour and decrease shift length in week 3 with half an hour) |
| **Combination …** | " | " | " | " | |
| **Combination …** | " | " | " | " | |
| **Combination 26** | 7 | 7,5 | 8 | 8,5 | (Combination of longest possible shift lengths) |

Table 4: Overview of systematic method used to walk through all possible shift length combinations.

### Step 2: Workload assignment among days:

The workload assignment among days basically functions as the demand analysis. Here the available production orders are used to define how large the workload is. The workload is then divided over the days in the planning horizon by the rules explained below.

1. The production time assigned to each machine type on each day may not exceed available machine time for that machine type.
2. If possible enough production time should be provided to complete processing of all production orders before the due date. If this is not possible, the excess workload is considered backlog (see next step).
3. Backlog orders are to be processed as soon as possible.
4. Reduce local peaks in demand for production time by moving demand to earlier dates.

Because only the due date is fixed, it is possible to stabilize demand in processing time by moving the moment an order is processed forward.

The production time required is defined in workdays, as this allows assignment of employees to workloads of full days. To make sure that the workload will cover full workdays in any situation the method demonstrated by figure 2 on the following page is used. Figure 2 show that the workload for a specific workstation for each day is assigned to the day when this workstation is first required. However, when the workstation has received a workload of a full day, the model will start with building up the workload at another day. Again the first day that this workstation is required by the workload is selected. To ensure availability of enough production time, fractions of days will always be rounded up to full workdays. In reality employees will be assigned to work on a different workstation in a situation like this, thus deviating from the workforce planning. This however will only be a minor deviation, as it will only occur if there is no further production at that workstation during the planning horizon.

After defining the workload in days it is time to determine at what time the workload should be processed. Again; time is defined in days, as production orders have a delivery date specified in days as well. Essentially step two thus involves assigning days of workload to a certain day when it should be processed.

Figure 3 shows an example of the required workload per day after completing the process defined above. It shows that there is a peak workload of eight production days while there is a maximum capacity of four production days (4 workstations) per day. The first step in solving this is to move production forward, as done in figure 4. This ensures on time delivery. For the used example, this is not enough to restrict peak demand to the maximum capacity. For this reason the only solution is to move production to a moment in time past the due date, as done in figure 5. All work re-scheduled to a later moment will become backlog and will thus be scheduled as soon as possible. In this way the workforce planning ensures that capacity restrictions are met and a more stable workload is created over the days. Assigning workstations to days is done in the order in which they are given in the planning. For every day in the planning horizon at most one day of workload for a single workstation can be re-scheduled before moving to the next workstation. The workload at any day is not reduced further than the maximum capacity. This prevents that all work on one type of workstation is moved forward at once while obstructing re-scheduling for other workstations. This process is repeated until there are no capacity problems for any workstation at any day or moving forward of workload is not possible anymore.

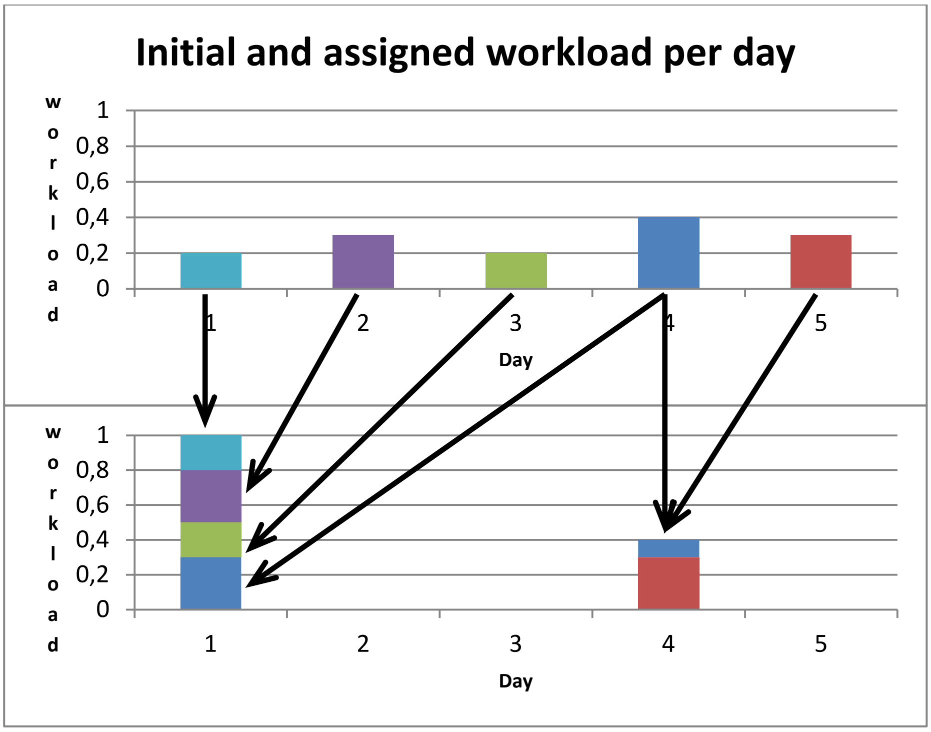



Figure 2: Assignment of workload to days in the planning horizon

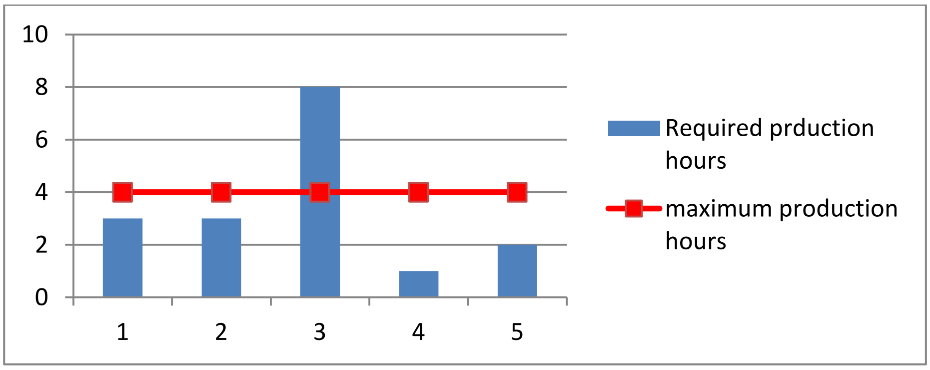



Figure 3: example of workload over five day planning horizon

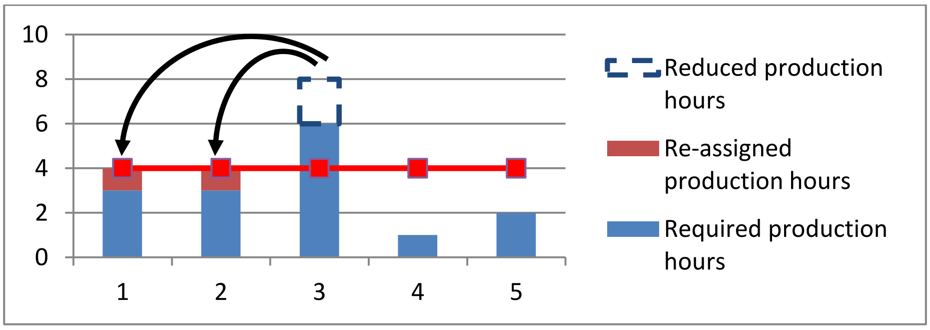



Figure 4: Reduction of over utilization by moving workload to an earlier date

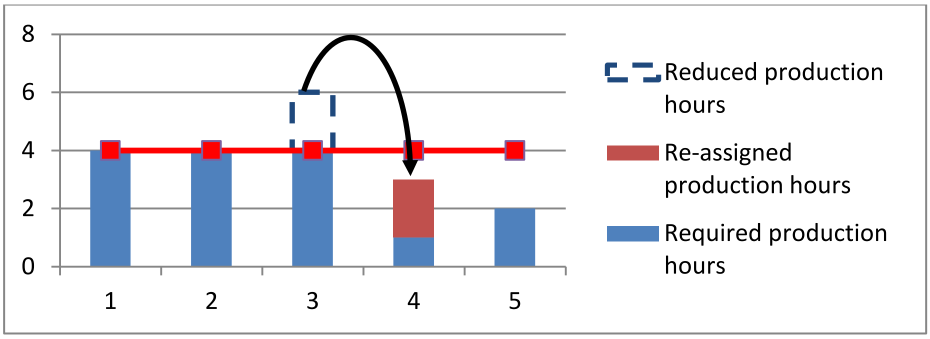



Figure 5: Reduction of over utilization by moving workload to a later date

### Step 3: Divide tasks among shifts:

When assigning tasks to the two shifts it is assumed that both shifts can perform all required tasks equally well. This means that no tasks have to be done explicitly in a specific shift. This assumption is realistic as the workforce is split up in teams with the concept of equality in mind. So, both teams are equal of size and are roughly equally skilled. This means that the total workload can be divided between both shifts by splitting the workload for each workstation in half. Each shift is assigned one half of the total workload, as shown in figure 6. When the required number of employees on a workstation is uneven, one of the shifts will be assigned one day of workload extra. As shown in figure 6 however, if this occurs more than once, the extra workload will be assigned to the teams in turn.


Figure 6: assignment of tasks between two shifts.

### Step 4: employee assignment

The employee assignment is an important part of the planning, as it contains the gap analysis and the major part of the solution analysis. The reason to combine the gap analysis with the solution analysis is because, in the situation of SA, they are connected with each other. As there are several different skills and employees are often cross-trained, the size and location of the gap is influenced by the employee assignment. The workstations that are selected latest for employee assignment have the highest chance that there are not enough employees. Each step in the employee assignment affects whether training may be required for assignment of employees to specific workstations and how many employees may need training. When a gap is encountered, continuing with assigning employees is only possible when defining a solution to dissolve the gap. For this reason, employee assignment contains the gap analysis as well as the solution analysis. The required training is strongly dependent on how employees and workstations are selected for assignment.

Employees are assigned to a workstation based on the workstation they can operate and the uniqueness of their skills. The model selects one workstation on which tasks have to be performed and one employee who should perform this task. The methods used for workstation selection and employee selection are discussed below. Important for both methods is the order in which respectively the workstations and the employees are selected.

#### *Workstation selection*

When selecting a workstation for assignment it is important that this selection minimizes the chance that assignment of employees to other workstations will require training. In other words, all other workstations should be easier to assign employees to than the selected workstation. This translates into a score indicating the gap between customer demand and supply of workforce, which is calculated by the following formula: $P_w = S_w - R_w$, where:

- $P_w$ = number of points assigned to workstation w.
- $S_w$= supplied number of employees who can operate that workstation.
- $R_w$= Required number of employees operating that workstation in order to meet demand.

This gap is used because it indicates how many employees can be assigned to other workstations without compromising assignment of employees to that specific workstation. The workstation with the largest gap thus has the biggest chance that any previous assignments do not compromise the assignment of employees to that workstation.

The workstation to select is the workstation with the smallest gap and thus the lowest score. When an employee who can operate that workstation is assigned to another workstation, chances are smallest that there are not enough employees with the required skill.

#### *Employee selection*

For employee selection the most important variable is the availability of the required skill. To make sure the right employee is selected, the following formula is used: $P_e = \sum_{s \in S} \frac{T_{es}}{N_s}$, where:

- $P_e$ = relative value of employee e for Nefit.
- $T_{es}$ = 1 if employee e has skill s, 0 if not.
- $N_s$ = Total number of employees who have skill s.

- The reason for using a ratio here is because not only the quantity of skills is important, but the relative uniqueness of these skills as well. By dividing each skill point by the total number of employees with the same skill, a weight is given to owning each skill. By summing all relative scores, the relative value of an employee is shown by the variable $P_e$. High value for $P_e$ means many and/or unique skills while low value for $P_e$ means few and/or common skills.
- To make sure that contracted employees are preferred over temporary employees, an extra ten points are added to the $P_e$ value for temporary employees. This ensures that TE will be the first to become inactive, unless they have a skill which cannot be performed by an available contracted employee.
- If one or more employees with the required skill are still available, the employee with the skill and the lowest value for $P_e$ is to be selected. In here, the relative value of an employee plays an important part. Employees with a high relative value are not assigned if not necessary. In this way, high value employees can be assigned to perform skills that can only be performed by a few employees. Also after assigning all other employees, high value employees have in general the best chance to know the skills required as they are trained broadly.
- If one or more employees are available, none with the required skill, the employee with the lowest value for $P_e$ is to be selected. This way a low value employee is trained, thus attaining a higher value for Nefit. Training an inflexible employee also increases workforce flexibility more than training an already flexible employee.
- If no employee is available, a new employee is to be hired and trained in the required skill.
- Note that employees and workstations connected with each other on a specific day cannot be re-assigned on that day. However, after scheduling according to above rules, any job assigned to an employee, will be moved to the first possible moment the employee can perform the job. This way capacity is kept free for when it is required and TE may be finished with their assigned tasks earlier.

#### Step 5: Repeat previous steps until all possible shift length combinations are explored:

As explained in paragraph 5.1, there are between 5 and 26 options for the different shift lengths. Step 5 will ensure that steps 1 to 4 are repeated until all possible shift length combinations have been tried.

#### Step 6: Select the solution with the best results over the entire planning horizon:

From all shift length combinations tried one option will be selected in step 6 which performs best. The best performing planning solution is the solution which produces a feasible planning at minimal costs over the entire planning period. The best performing solution will be presented to the user of the planning as the proposed workforce planning.

## 5.4 Conclusions and Summary

In this chapter the workforce proposed workforce planning is discussed. First an MILP formulation is developed, based on the model of (Stewart et al., 1994). After establishing that using this model is not realistic in any practical situation occurring at SA, a model is proposed based on heuristic methods. Although the solutions created by this model will not be optimal, this problem is much easier to solve. The six steps of the heuristic are defined below.

➔ Step 1: determine shift length

- ➔ Step 2: workload assignment among days
- ➔ Step 3: Divide tasks among shifts
- ➔ Step 4: Employee assignment
- ➔ Step 5: Repeat previous steps until all possible shift length combinations are explored
- ➔ Step 6: Select the solution with the best results over the entire planning horizon

Each step in the model serves its own purpose in finding a good solution to the workforce planning problem inserted. The employee assignment replaces most of the functions performed by the MILP. The proposed workforce planning selects repeatedly a workstation and an employee and connects them with each other. In general, the aim of the workforce planning is to connect the workstation toughest to find an operator for, with the least skilled employee who can operate it. This way, in any further step the chances are biggest that employees with the required skill are still available to operate the remaining workstations.

# Chapter 6: Proposed Workforce Planning Performance

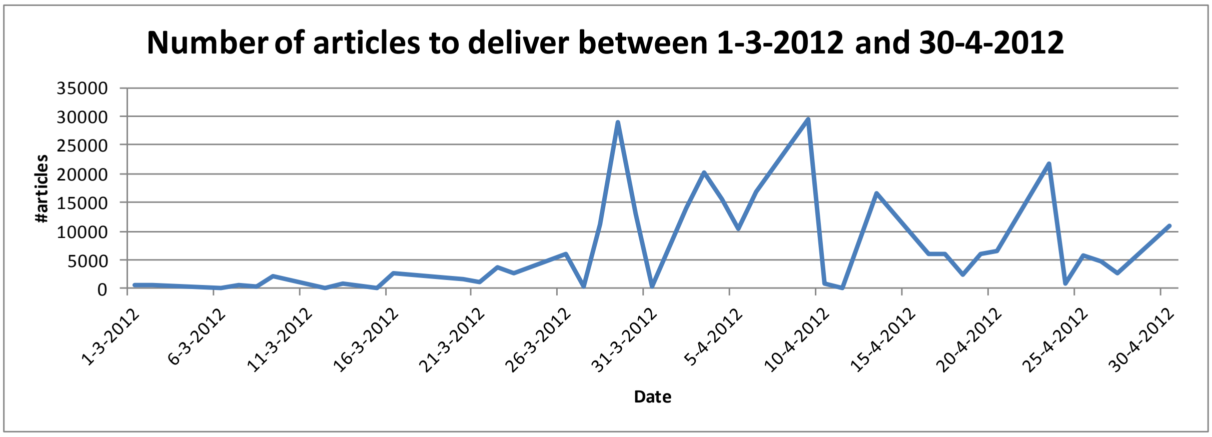
After creating a proposal workforce planning, this chapter will be used to compare its performance with the current situation. This is to establish if the proposed workforce planning can improve the performance of SP. The performance of the current situation as well as the proposed workforce planning will be measured by two performance indicators. By doing so the performance of both models is measured according to the same standards, as well as the goals set by SA.

The first step in this chapter is to define the test setup and the configurations of all relevant variables. This will be done in paragraph 6.1. In paragraph 6.2 the workforce planning methods currently used will be formalized into a model. Paragraph 6.3 will give a short discussion of the performance indicators used for comparing the two workforce planning methods. After this, the results of the test will be discussed in paragraph 6.4.

## 6.1 Test design

The testing of the workforce planning methods is done by running the workforce planning with historical input data. The outcome of the proposed workforce planning is compared with the outcome for the current workforce planning methods. This method is used as it provides repeatability of the test and accurate control over the variables, also testing can be performed without serious real life consequences.  Another advantage is that a dry run allows the use of estimated data, as for the throughput time not enough accurate data is available to make a real life planning. The current workforce planning method is simulated by translating the planning methods explained in chapter 3 into planning rules by which a planning can be constructed.

The demand data used for the test run is actual demand gathered over a period from 01-03-2012 until 3-04-2012, as shown in graph 7. This period is selected because most of March was a period with relatively low demand, followed by a peak at the beginning of April. At the end of this period, again there is relatively low demand. This pattern allows investigation of model behavior with increasing demand, shrinking demand and relatively stable demand.




Graph 7: demand over March and April 2012 in daily number of articles to deliver.

The required production times for each product exist of fixed time (setup time) and time per unit. Due to information shortage, no production times are available for the different products. Therefore estimates of the production times are made, for every workstation, based on observed times. Production times have been established by the trainee in March 2012. Although these times are not real production times, they serve their purpose as they allow the testing of production patterns similar to the real situation. In terms of validity this means that the test may not provide an accurate representation of the demand expressed in time. The demand patterns will remain intact however, as the patterns are mostly based on the number of orders and units required by the customers. The processing times on each workstation are given in table 5. The workstations each PO has to visit are defined by the real routings of PO's.

| Workstation | fixed time | | time per unit | |
|---|---|---|---|---|
| | average | std.dev | average | std.dev |
| **Runner** | 420 | 120 | 3 | 0,3 |
| **Table** | 480 | 180 | 60 | 20 |
| **Autobag** | 300 | 120 | 20 | 10 |
| **Tapemachine** | 300 | 120 | 30 | 10 |
| **Glow-plug** | 600 | 240 | 40 | 3 |
| **GLE** | 900 | 300 | 1500 | 300 |
| **Burner housing** | 300 | 120 | 360 | 120 |
| **ESD Workcenter** | 600 | 120 | 80 | 30 |
| **Speedypack** | 600 | 120 | 900 | 180 |
| **Case** | 900 | 240 | 300 | 30 |
| **BCM** | 120 | 18 | 60 | 10 |
| **Assembly** | 600 | 120 | 240 | 60 |

Table 5: production time per workstation in seconds

In the test run a permanent workforce of nine employees is used, while enough TE's can be assigned if this is required according to the workforce planning. The number of employees is selected such that it is more than enough to cover low demand; however, to cover high demand, more employees are required. To simplify the test setup, these employees are available during the entire planning horizon. No sickness is taken into account as well. The skills of the permanent workforce are from nine randomly selected production employees of SA and can be found in Appendix 3. TE's have no skills when they are first assigned to any task, thus they require training before they can perform any tasks.

At the start of the test run the length of the shift is eight hours. This matches a normal workday at SA.

The maximum number of employees that can be assigned to each workstation is set by the real situation at SA. The number of workstations available of each type is given in table 6. The training times for each workstation are as shown in table 1 of chapter 1.

| Workstation | Maximum number of employees |
|---|---|
| Runner | 5 |
| Table | 6 |
| Autobag | 5 |
| Tapemachine | 2 |
| Glow-plug | 10 |
| GLE | 2 |
| Bruner housing | 3 |
| ESD Workcenter | 3 |
| Speedypack | 2 |
| Case | 2 |
| BCM | 1 |
| Assembly | 2 |

Table 6: maximum number of employees which can be assigned to any workstation

To determine the performance of the workforce planning, costs are used as based on the actual situation at Nefit. The costs influenced by the workforce planning are as shown in table 7.

| Cost location | Costs in euro's | per |
|---|---|---|
| Salary CE | 184 | day |
| Salary TE | 184 | day |
| Hiring TE | 500 | employee |
| Firing TE | 0 | employee |

Table 7: costs influencing the workforce planning

Starting from 01-03-2012, a test run for both workforce planning methods will be conducted over each day until the last orders have been finished. During this testing period the workforce planning will determine the shift length and employee assignment to any tasks. This includes the number of employees used and the training they will receive. The costs and on time delivery performance will be measured for the entire test period. To be able to perform a test run for both workforce planning methods, the current model needs to be formalized. This is done as described in paragraph 6.2 below.

## 6.2 Current workforce planning

While the current workforce planning is discussed in detail already in chapter 4, it is not yet translated into an actually formalized planning. Below the characteristics of the current planning are discussed and are translated into planning rules. This planning will enable a comparison to be made with the proposed workforce planning by use of the test run.

- The most important characteristic for the current workforce planning is the method of assigning workload to employees. For the test run, all workload will be processed as early as possible. The only limitations here are the number of workstations of each type available and the number of available employees. Note that for the proposed workforce planning the workload determines the number of employees. In the current workforce planning the number of employees is important in determining the workload processed.
- The number of employees available will normally be the same as for the previous day. Only when there is not enough work available, all TE's who cannot be assigned to any function will be fired. This corresponds with the policy defined in paragraph 4.1.2. To simulate the hiring policy, each time the workload covers more than five days, two more employees are hired. The workload is measured in the same way as for the proposed workforce planning.

- The length of the workday is based on the workload as shown in table 8. The larger the workload compared to the available workforce, the longer the shift length will be.

| Workload (days) | Shift length (hours) |
|---|---|
| < 1 | 6 |
| 1-2 | 6,5 |
| 2-3 | 7 |
| 3-4 | 7,5 |
| 4-5 | 8 |
| >5 | 8,5 |

**Table 8: shift length for each level of workload available**

- Assignment of employees to certain workstations and training will be done according to the same rules as for the proposed workforce planning. The real situation uses no principles deviating from the proposed rules. This means that here too the least skilled employee is assigned to the workstation with the smallest gap between demanded employees and supplied employees for that workstation.

The planning logic described above has been confirmed with the Supervisor of SA. Although as indicated in chapter 4, in real life the rules are defined more loosely, the rules defined above represent the logic used in practice.

## 6.3 Performance indicators

Based on the goal defined in paragraph 2.1, stated again below, there are two performance indicators that can be used to measure the performance for each workforce planning.

*"To create a planning which allows timely recruitment and training of employees to meet the demand of spare parts at any point in time, while efficiently using available resources."*

The first part of the research goal states that the workforce planning should allow "timely recruitment and training of employees to meet the demand of spare parts at any point in time". This suggests that meeting the demand of spare parts is dependent of in time recruitment and training of employees. By measuring the delivery performance (level of on time delivery), it is assumed that in-time recruitment and training is measured as well. This however, does not mean that in reality in-time recruitment and training is the only factor influencing the delivery performance. In the test run, other factors like late delivery to SA by suppliers or blocked production orders are neglected. The delivery performance will thus be an accurate measure of in-time recruitment and training. The higher the delivery performance is, the better the workforce planning functions for SA.

The second part of the goal statement defines that this should be done "while efficiently using available resources". All resources supplied to the production of spare parts can be translated into certain costs. For SA efficient use of resources can thus be translated into cost efficiency of the planning. In general it can be said that the planning which delivers the same (or similar) delivery performance with lowest costs uses resources most efficiently. Therefore, costs are used as a measure for efficiency.

Note that no costs are connected to late delivery of spare parts. Although delivery performance is seen as very important to Nefit, no penalties for late delivery to any customer are defined. Nefit thus faces no direct financial effects of late deliveries. Therefore there is no common variable influencing both performance indicators and both performance indicators are required to create a complete overview of the performance.

The performance indicators used for testing of the performance of both workforce planning methods are:

1. Delivery performance in percentage of products being delivered in time.
2. Costs associated with hiring, firing, training and employing of employees.

## 6.4 Test results

The results from both test runs show are clear differences between the current and the proposed workforce planning. These differences will be discussed below.

### 6.4.1 Delivery performance

Over the period of the test run the proposed workforce planning missed at total of 10 out of 2152 deadlines, while the current workforce planning missed 8. Therefore the delivery performance moves from 99.63% for the current workforce planning to 99.54% for the proposed workforce planning. The difference can be explained by the fact that the current workforce planning will always be fast with starting the production of each PO. The proposed workforce planning moves production closer to the delivery date, this may cause late delivery in some situations. Note that both planning methods are not able to deliver the 99.7% delivery performance required by Nefit. This is partly because the orders in day 1-14 have to be performed without the fifteen day planning horizon. This means that it may not be possible to finish these orders in time, while in a normal situation it is. For example: both planning methods where unable to prevent backlog occurring at day 2, 3 and 10.

To determine the significance of the differences between the current workforce planning method, the proposed workforce planning and the target value, a binominal distribution is used. In here, late delivery is seen as failure while in-time delivery is seen as a success.

The first hypothesis states that the proposed workforce planning has a 99.7% delivery performance, as required by Nefit. By using a left-sided significance level of 5%, the hypothesis is rejected when the chance (p) for the measured value is below 5%. The proposed planning has 10 failures out of 2152 production orders, while the chance of success should be 99.7%. The value for p = 0.12, thus there is no proof that the proposed workforce planning truly performs below the required 99.7%.

Based on the former result it is logical that with a p-value of 0.32 no proof could be found that the current workforce planning methods perform below the required 99.7%. Also no proof could be found that the proposed workforce planning performs any different than the current workforce planning. When assuming there are 10 failures with a success chance of 99.63, the p-value is 0.28. Based on the test run; no significant differences between both planning methods where found in terms of delivery performance. Also, neither one of the planning methods is proven to perform below the required level.

On the other hand, backlog is dealt with more efficiently. The sum of all backlog production over the planning horizon is 24 for the current workforce planning while just 19 for the proposed workforce planning. This means that although late delivery may occur more often, the backlog is less severe.

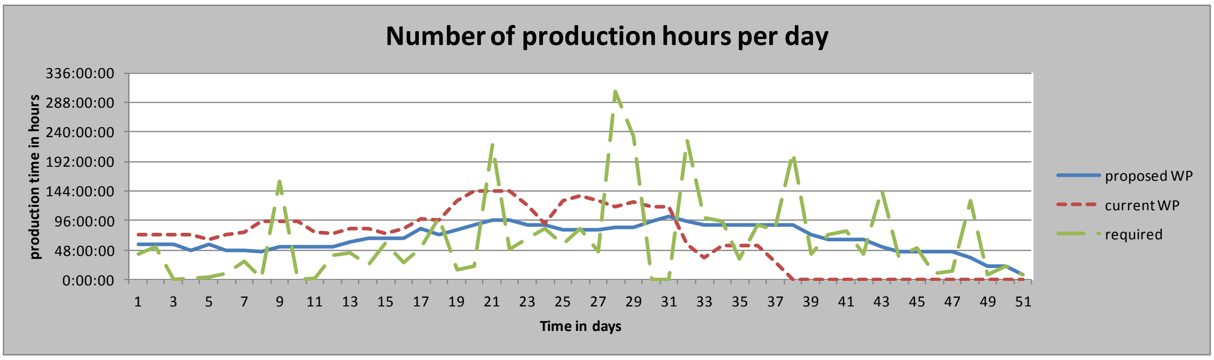
### 6.4.2 Workforce costs

The current method starts by hiring two more employees as shown by the peak in costs in graph 8. By repeatedly hiring two more employees (days 7, 14, 15 and 16) not only peak costs are increased in terms of hiring costs, but salary costs as well. This is shown by a stepwise increase in total costs after every peak. At day 29, however, a first sign of overcapacity is shown when one employee is fired, slightly reducing costs. This is followed by firing all TE's at day 32, reducing the costs to the level required to maintain the CE's. From this point on no extra TE's are hired anymore. Graph 9 clearly shows that the production levels are higher than required at almost every day before day 31. Note that this is possible because the PO's are known fifteen days before they are required. At day 31 there is a strong decrease in production followed by complete stop of production at day 38. This is because all PO's are finished 13 days before the last PO is required. Although this pattern is strengthened by the test period being finite (resulting in no demand after a certain date), this pattern is similar as seen in the real system. Often the workload builds up to several days, when a peak in demand occurs, measures like hiring employees and long shift lengths are triggered. After the peak the production capacity remains the same until no work is left. This causes the temporary employees to be fired resulting in low capacity. This allows the process to repeat itself.

The instability of the production levels shown in graph 9, compared to the stable personnel costs shown in graph 8 is caused by training of employees. Employees in training are still employed by Nefit and thus receive pay; however they will not assemble any products. Regular training of employees will thus reduce total production capacity as long as the training takes place.

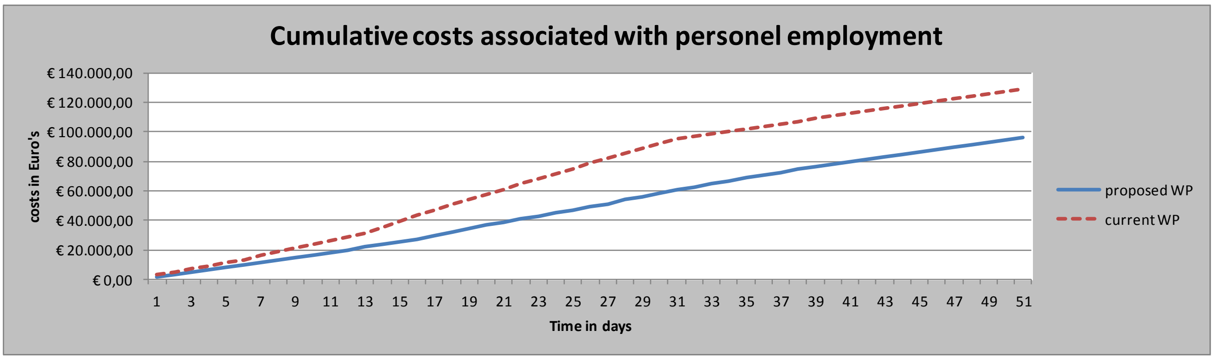
The proposed workforce planning method starts off with using CE's only for the first 16 days as shown in graph 8. At this point, however, not all CE's are assigned to production at all points in time. After 17, 19 and 28 days a total of four employees are hired to increase production so that peak demand can be covered. At day 22 and day 32 one person is fired, the other two are fired at day 40. From this point the number of employees assigned is again equal to the number of CE's available. Also graph 9 shows less fluctuation for the proposed workforce planning as for the current workforce planning. Most importantly, production continues till day 51.


**Graph 8: costs associated with personnel employment for both workforce planning methods**

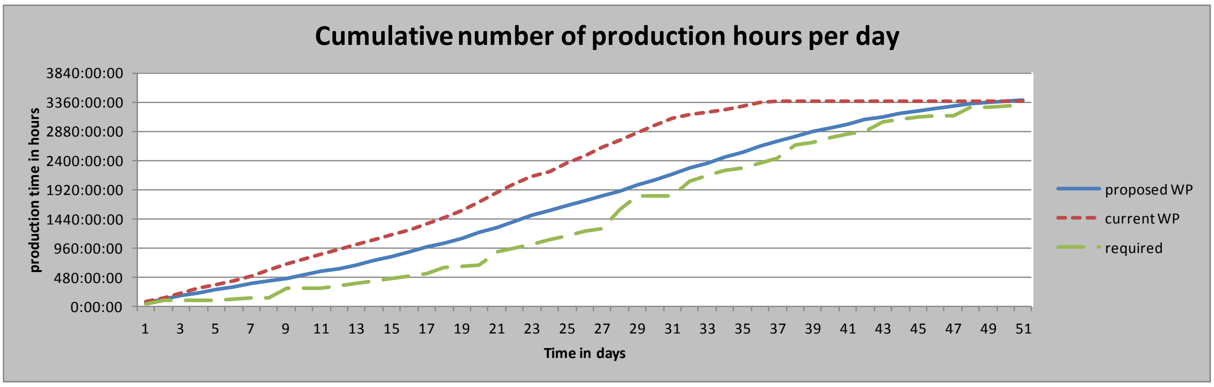



Graph 9: number of production hours per day for both workforce planning methods, compared with the required number.

The difference between the two methods can be seen clearly in graphs 10 and 11, respectively showing the cumulative costs of the workforce planning and the cumulative production hours over the planning period. Graph 11 clearly shows that the proposed workforce planning generates only slightly more capacity than required. This while the current workforce planning clearly generates overcapacity, producing far more that required until all production available is finished at day 38 in this example. The small over-capacity of the proposed workforce planning can be explained by the full workdays which employees are assigned to. For every workstation up to almost a full workday of capacity may be delivered more than required.




Graph 10: cumulative costs associated with personnel employment for both workforce planning methods




Graph 11: cumulative number of production hours per day for both workforce planning methods, compared with the required number.

Another interesting difference is that the current workforce planning employed an average of 13 employees over the test period, while the proposed workforce planning employed only 10. When only taking into account the employees assigned to workstations, these values become respectively 10.1 and 8.3. This difference can be explained by the extra training required with the current workforce planning method used. As well as smoothing out total demand over the planning horizon by the proposed workforce planning, this is also done for each workstation. Because the current workforce planning allows large peaks at certain workstations, many employees with certain skills are required. Alternating peaks at different workstations call for much training of employees to cover these peaks.

A summary of the test results is given in table 9. Regarding financial performance, backlog length and employee deployment, the proposed workforce planning performs much better than the current workforce planning. However, the current workforce planning provides a slightly higher delivery performance. Despite the slightly reduced delivery performance, the relatively large cost reductions justify implementation of the proposed workforce planning.

| | current WP | proposed WP | % reduction |
|---|---|---|---|
| costs | €132K | €100K | 24% |
| delivery performance | 99,63% | 99,54% | 0,09% |
| backlog days | 24 | 19 | 21% |

Table 9: overview of performance difference between proposed workforce planning and current workforce planning

## 6.5 Conclusion and summary

In this chapter, the performance of both the current workforce planning and the proposed workforce planning are discussed and compared with each other. The methods are compared by means of a simulation of both workforce planning's. This method allows full control over all variables as well as the tests to be repeated.

To be able to simulate the current workforce planning it is translated into planning rules that can be used by the simulation model. These planning rules are summarized below:

- Hire new employees when workload for SA is larger than 5 days.
- Fire employees only when there is no work available for them to work on anymore.
- Always assign all available employees to a workstation, thus finish all orders as soon as possible.
- The basic shift length is 6 hours. For every full day of workload available, half an hour is added. The shift length, however, is not allowed to be longer than 8.5 hours.

Based on the goal statement from chapter 2, two performance indicators have been defined, as stated below.

1. Delivery performance in percentage of products being delivered in time.
2. Costs associated with hiring, firing, training and employing of employees.

The results clearly show that the proposed workforce planning was able to plan all activities at lower cost. The current workforce planning used €132K over the planning horizon while the proposed workforce planning used €99K. The in-time delivery performance of the current workforce planning proved to be slightly better than for the proposed workforce planning. The current workforce planning only delivered 0.37% of the orders late, while the proposed workforce planning was late in 0.46% of the PO's. Both planning methods however, perform under the requested 99.7% on-time delivery. The sum of days that delivery was late is 24 for the current workforce planning and 19 for the proposed workforce planning. This means that on average when backlog occurs, the backlog for the proposed workforce planning was less severe than for the current workforce planning. The high costs reductions justify implementation of the proposed workforce planning, despite the small reduction in delivery performance.

# Chapter 7: Implementation plan

The aim of chapter 7 is to help Nefit with the implementation of the workforce planning into the daily activities of PS. This chapter will introduce a method that can be used for implementation and will focus on the steps to take for successful implementation. The literature study in chapter 3, specifically paragraph 3.5 is used to support the implementation strategy. Current situation as described in chapter 4 and the proposed workforce planning as described in chapter 5 will be used to support the implementation plan.

This chapter will start with a discussion on how to acquire all data required for the proposed workforce planning in paragraph 7.1. This will be followed by a discussion on the operator training in paragraph 7.2. In paragraph 7.3 will discuss the use of a test period in which the proposed workforce planning can be used as shadow planning as well. Changes to be expected when using the workforce planning are discussed in paragraph 7.4. Paragraph 7.5 will discuss the implementation strategy to select. Paragraph 7.6 will introduce a time schedule in which the planning is to be implemented.

## 7.1 Data collection

For the workforce planning to function properly there are several input variables required, as given in the paragraph 3.3. The variables are listed below:

- Processing time for each order on each workstation
- Type and number of products to be processed before what date
- Number of employees available on each day and the skills these employees have
- Shift length in week 0
- Costs associated with assignment or non-assignment of employees to workstations
- Number of workstations of each type available
- What product will be handled at the workstation

Below a discussion will be given on how to collect each of the variables described above. If the required information can be readily found in the control systems of Nefit this will be indicated. If information is not readily available, a method will be given which allows retrieving the required information.

### 7.1.1 Throughput times

Establishing the processing time for each product at each workstation should have the highest priority when implementing the workforce planning. This because the processing times are the groundwork of any successful planning and Nefit is far from knowing these times. Collecting the processing times however, can be a lengthy operation as there is no easy way of doing this.

Normally, Nefit uses the MTM analysis (International MTM directorate, 2004) to establish the assembly time for one unit of each product and for the setup and finishing time separately. In this situation the actual activities are being filmed and activities are analysed and optimised based on standard times for each movement of an employee. This method provides a very accurate processing time, and helps with the optimization of the production process at the same time. The disadvantage of this method is that doing this for all products assembled at SA may take several years and is very labour intensive. An extra employee is required so that he can accompany the employee performing his tasks during the entire process and film all activities performed. After this the filmed process is analyzed step by step, examining each action performed thoroughly. Because the processing times need to be updated with every change in the process, this method will continue to require a high level of effort.

A simplified alternative is called throughput time measurement, where a stopwatch is used to measure the processing times. Although the processing times are established in the same way as with the MTM analysis, no actual analysis of the process takes place. Although still labour intensive and time consuming, this method can be used for much faster acquiring the processing times than MTM analysis. The main reason is because thorough analysis of each action performed will not be required anymore. Also updating of the processing times will require less time than for the MTM analysis. Nefit still estimates that this process takes several months when these measurements are performed by one or two employees.

A different way of measuring the throughput times is by registration of the throughput times at each workstation. This means that all employees register when they start with a certain production order and when they are finished with it. Although this requires employees to continuously register their working times, this is less labour intensive than MTM. Another advantage is that for every production order the production time for that product is registered. The measurement process is not dependent on an external employee, but is performed as part of the processes the production employees perform. Depending on the production levels, this means that between 50 and 150 PO's are measured for each workstation they are processed at. The main disadvantage is that more noise may be included in the date. It is not sure that an employee performs his tasks according to the standards given or that he/she is not disrupted during his tasks. Although this may reduce accuracy of the measurement, this noise should be taken into account as reflection of the reality. Another disadvantage is that this method requires most effort from employees at the same moment when production is highest.

A third method is by calculating a theoretical production time for each production order. This is currently used to establish the costs for the production of SP's. However the correctness of this method is hard to check (without using any of the other two options). Including all variables required for accurate calculation of the production times for each product at each workstation may make the calculation complicated as well. However, if a proper calculation can be made based on a small number of influential factors, the production time can be established for all products without high labour utilization. At this moment SA has not enough insight in the variables influencing the production times to be able to construct such a calculation.

At this point all available data on processing times, which is accepted as accurate, may be used as input in the workforce planning, independent of its origin. For the missing information it is advised to use the time registration method, as it can produce a high quantity of reasonably useful data. This way the workforce planning can be implemented in months rather than years, especially as the employees required for throughput time measurement are not yet available. Time registration can be used to obtain a critical mass, before employees become available to measure the throughput times in more detail.

The time registration process is to be performed by the production employees at SA as it is done simultaneously with processing of the production orders. As all production orders are measured, no coordination is required. The MTM analysis is to be performed by a process engineer, who is trained in performing MTM analyses. As MTM analysis is performed only on a part of the production orders for certain spare parts, this should be coordinated to ensure the right production orders are selected. This coordination is to be done by the supervisor as the supervisor knows what production orders are most important and which process have been updated.

### 7.1.2 Establishing demand

The type of products to be processed is visible on the production order together with the quantity and due date. This information is already being collected by the work preparation colleagues. This information is thus readily available to SA and can be used in the workforce planning.

As explained in paragraph 4.2, the due dates known to SA are incorrect, making it impossible to perform accurate workforce planning. The problem is incorporated into the production planning of the ERP system used at the planning department. Because the ERP system used will be replaced at the start of 2013, no changes to the current system are applied. To solve this problem, the planning department and it department should track down the variables that influence the delivery date on the production order. This allows them to change any incorrect planning rules or to use the right variables in planning of production orders. This should then allow SA to receive the production orders with the correct delivery dates. The alternative option would be to wait until January 2013 when the new ERP system is activated. At that point it should be possible to ensure that the correct delivery dates are given.

### 7.1.3 Employee absence

The availability of employees has to be established for the planning horizon. This can in general simply be done by checking the absence administration. As employee sickness is unknown upfront, the average historical absence level can be used to compensate for the expected sickness. The average sickness level at SA is available in the employee planning of Nefit, which is used to keep track of employee availability. Regular checking the average sickness level over recent history will be enough to supply an up to date estimate of the sickness level.

### 7.1.4 Employee skills

At Nefit a skill matrix is used to indicate on what workstation each employee can work. This can be used as input for the workforce planning to determine the requirement of training. The skill matrix only has to be updated when new employees are starting at SA or when existing employees learn a new skill. The skill matrix is updated regularly by the team leaders.

### 7.1.5 Shift length in week 0

The basis for a feasible workforce planning is a shift length within the rules of Nefit. To create such a schedule the shift length in week 0 is required. This is known when the workforce planning is used, requiring no further data collection.

The shift length has to be updated each week and will remain the same over the entire week.

### 7.1.6 Costs associated with assignment or non-assignment of employees to functions

Assigning employees to a function or not assigning available employees all have their costs. This mainly exists of employee salary and hiring / firing costs. These are known up-front and will in general be fixed for a longer time period.

An update in the costs only has to take place when salary changes occur or when costs for hiring or firing of employees change. This will happen at most a few times per year. This information is to be kept up to date by an employee who can access the financial information regarding employees. Therefore the head of the department should ensure that the costs are changed in the workforce planning every time a change occurs.

### 7.1.7 Number available workstations of each type

The number of workstations of each type sets the number of employees that can be assigned to that type of workstation. Also the maximum capacity per shift is set by the number of workstations. Although this information is crucial, this information is known upfront and can thus easily be used as input in the workforce planning.

The number of workstations only has to be updated when new workstations are created or old ones are closed. Because this is a hardware change that often requires investments, this will not occur often. Everybody in the SA department has access to this information. It is thus easiest that this is kept up to date by somebody who already works with the workforce planning. Therefore the supervisor can best be assigned to do this, as he will use the workforce planning on a daily basis.

### 7.1.8 Production order routing

Each product has its own route through the production process. This route is defined in the ERP system and can be collected from this system. A change in the routings occurs when new products are developed or when products are changed. In some situations the routing of a product may change either due to changes in the product or due to availability of new equipment (and thus routings).

Collecting of this data requires knowledge of the ERP system and access right to this information. Only key users for the ERP system or trained employees will know how to draw this information from the ERP system. For this reason, this task can best be performed by a key user. This information should be retrieved every three or four months or straight after introducing a large quantity of new spare part types. New spare part types are generally introduced in large quantities when a new boiler is introduced to the market. At such a moment updating of the routing will yield the largest advantages.

## 7.2 Workforce planning operator

The workforce planning is to be operated by an employee who is allowed to make decisions regarding hiring and firing of employees. He/she should also know what effects each decision has on the planning. Because an employee can be trained in operating the workforce planning, important in determining who is to operate the workforce planning is the right to make decisions. Currently the supervisor makes all decisions related to the workforce planning, so it is logical that the supervisor uses the workforce planning as well. The supervisor of SA has the right to make all decisions related to planning the workforce.

The supervisor received training on operating the workforce planning system provided in Microsoft Excel. This training was given as part of the traineeship period. The training was provided in one or two sessions explaining the sheets functions and most importantly, the planning logic. The training aimed at understanding the information provided by the workforce planning and knowing the effect of the input on the output given by the planning. In this way the supervisor is not limited to simply copying the results but can analyze them en make the correct decisions. The required training was provided as part of the master thesis project. Not providing the required training would mean that Nefit will not be able to implement the proposed workforce planning.

To support in the training of the supervisor and understanding of the workforce planning a work instruction was provided as part of the master thesis study. This work instruction can be found in appendix 6. The work instruction is to be used as user manual for the workforce planning. This work instruction explains the functions of the workforce planning thoroughly and should be easy accessible for the supervisor after the training period.

After the training, the supervisor will have the best understanding of the workforce planning and is responsible for its use. The supervisor also has the rights and responsibilities, which make him a suitable employee for leading the implementation.

## 7.3 Testing period / Shadow planning

Before implementing the workforce planning, the proposed workforce planning can be used as a shadow planning for the current workforce planning methods. During this time, the accuracy of the system and its input parameters can be tested. When implementing the planning, any deviations from reality may adversely affect the performance of the workforce planning. The aim of a testing period is to correctly adjust the input parameters so that the planned times correspond with expected times. Most attention is to be paid to correctness of absent levels, production times for each unit at each workstation and possible safety buffers for unexpected rush orders. Only when the workforce planning can accurately simulate the reality of Nefit, the planning can be used.

During the period that the proposed workforce planning is used as a shadow planning for the current planning methods, it can also be used to support in planning decisions. When the shadow planning deviates from the current planning it is possible to make decisions based on it. For example: It is known that currently more employees are hired than necessary when demand is rising. In such a situation the shadow planning can be used to determine if hiring of employees is really necessary. In this way the strengths of the proposed planning can be used before full implementation and a transition period between both planning methods is created.

The testing should be performed by the supervisor as he will lead the implementation in total. This testing period may also help the supervisor in understanding the logic of the planning. By starting the test phase after the training of the supervisor it can be used as an extension of the training period as well.

## 7.4 Influence of the proposed workforce planning on part service

The method of assigning employees to workstations changes drastically and employee training and hiring / firing may be based on different logic. However, the influence on daily activities is limited. The workforce planning aims at ensuring that the work that has to be done can be finished in time. Work methods themselves don’t change by using a different workforce planning. The biggest effect will be that a more robust workforce planning can help with a more stable work environment. The workforce planning should help with limiting the changes in the number of employees available. Thus employees have more clarity in the availability of work in the near future.

The most important change compared to current workforce planning practices is the timing of processing of the production orders. At this moment processing of production orders takes place as soon as capacity is available. This may result in early-finished work when there is excess capacity or in backlog when there is a capacity shortage. However as the workforce planning adjusts the available capacity to the demand, the workforce planning continuously strives towards processing production orders just before their due date. Working ahead of schedule or working behind schedule is minimized. Opposing to what happens now is that although production orders may be released, the workforce planning tries to smooth out production over the planning period. At the same time the workforce planning pushes the moment of production closer to the due date.

## 7.5 Implementation strategy

To determine the implementation strategy, the six variables defined by Hayes (2007)are used. These variables are: the urgency, the clarity of the goal, expected resistance, data availability, trust in the change manager and dependency on stakeholders.

- The urgency of the implementation is not very high, as not implementing poses no direct threat to the daily operations. However due to the large financial improvements implementation should take place as soon as possible. This does not strongly support specifically a top-down approach or a bottom-up approach.
- The goal as well as the expected end result of the implementation is very clear. The workforce planning as supplied as part of this master thesis project is to be implemented in the daily activities of Nefit. The methods of data collecting are pre-defined. This is strongly in support of a top-down model.
- As indicated in paragraph 7.4, the changes when implementing the workforce planning notable to SA are limited. Therefore it is not likely that there will be much resistance to implementing the workforce planning. There is only a small group of stakeholders, which exists of managers who support implementation of the workforce planning. This strongly supports use of a top-down approach to implementation.
- As indicated in paragraph 7.1, most data required is readily available. The assembly times are not completely known to SA, but collecting mechanisms are already in place. The largest deficiency in the supply of data is the lack of correct delivery dates. SA has to ensure that together with the production orders, correct delivery date for each order is supplied. This supports the bottom-up approach.
- As there are no contradicting interests from stakeholders, there is no reason for stakeholders not to trust the change manager in the implementation process. This supports a top-down approach.
- For most information required, SA is not dependent on external stakeholders. Only for receiving the correct delivery dates, SA is dependent on the planning department. When gathering the assembly time by use of MTM or throughput time analysis, SA is dependent on process engineering as well. When time registration is used, SA can collect the assembly times completely independently. This supports a bottom-up approach over a top-down approach.

The results tend to prefer a top-down approach over a bottom-up approach; however the data collection may require a collaborative approach with other departments. Most important is that the workforce planning and most data collecting methods are already defined. This allows a top-down approach to implementation where the supervisor is the responsible change manager. With regard to collecting the processing times and ensuring the correct delivery dates, a bottom-up approach is proposed. This means that the SA department should work together with both the planning department as process engineering to implement data collecting methods and create the required policies to manage these methods.

## 7.6 Implementation schedule

As indicated above, most time will go into collecting the data required for proper functioning of the workforce planning. Especially the assembly time of each product has to be established. Also time must be invested in training the supervisor how to use the workforce planning. Although collecting data mostly has to be done by PS itself, the training has to be given during the master thesis period. After data has been collected for about 70% of the workload, a test period should be used to define the right control and input values for the situation at PS. In figure 10 below a schedule is given for the implementation of the Workforce planning

| ID | Task Name | Start | Finish | Duration | aug 2012 | | | | sep 2012 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 5-8 | 12-8 | 19-8 | 26-8 | 2-9 | 9-9 | 16-9 | 23-9 |
| 1 | Creating work instruction | 6-8-2012 | 17-8-2012 | 2w | | | | | | | | |
| 2 | Training of Supervisor | 13-8-2012 | 17-8-2012 | 1w | | | | | | | | |
| 3 | Collecting input | 6-8-2012 | 21-9-2012 | 7w | | | | | | | | |
| 4 | Shadow running | 3-9-2012 | 21-9-2012 | 3w | | | | | | | | |
| 5 | Adjusting input variables | 10-9-2012 | 21-9-2012 | 2w | | | | | | | | |
| 6 | Start operation of workforce planning | 24-9-2012 | 28-9-2012 | 1w | | | | | | | | |

**Figure 7: Workforce planning implementation schedule**

As can be seen in figure 7, collecting input takes most time in the implementation process. This is caused by the time it takes to gather the assembly times for the spare parts. The assembly times are very important in creating an accurate workforce planning, making it important that this data is correct. At this moment about 400 production orders per week are completed. As 800 products make up of about 80% of the total production quantity this means that in about two weeks most of these 800 product types would have been processed. To receive accurate measurements more than one production order for each product type should be measured. This means that by using this method for two months enough data can be collected to make a start with the workforce planning. However, data should be continued to be collected to receive more detailed information and information on the other 20% of product types. Also continuous updating of data can be used to make sure the data is still up to date even though products or production processes are changing.

Before the workforce planning can be implemented, it is important that the supervisor can work with the planning. To do this a work instruction was made and the supervisor should be trained by the researcher. Besides production times, all other input described in paragraph 6.1 should be collected as well. Because this data is mostly readily available, one week time is reserved to do this.

For testing, three weeks are reserved. After testing the workforce planning can be used to plan the workforce. Although this is estimated to start in seven or eight weeks, the actual time is depending on when enough data is collected to make reliable estimates.

## 7.7 Conclusions and Summary

This chapter aims to support PS in implementing the workforce planning in the daily activities of PS. The chapter pays special attention to the gathering of information, discussing methods to find the required input. Especially collecting data concerning the production times of each product type requires attention and time before the workforce planning can be used. To gather this data, three methods are proposed being: MTM analysis / throughput time measurements, time registration and calculating of production time. Because of the accurateness and quantity in which it makes data available the time registration method is preferred. Even when using this method it is estimated to take two months before enough data is gathered for proper workforce planning. When the planning is used, time measurement cannot be stopped as not all data is gathered yet at this point in time and production times may change over time. The other data required for the workforce planning is available within PS and can thus be collected within a short time period. This leaves enough time for testing the input parameters of the workforce planning before the workforce planning is used to actually determine the assignment of employees. During this time of testing the proposed workforce planning can be used as a shadow planning to the current workforce planning methods. This allows adjustments to the current planning if the proposed workforce planning gives strong deviations from the current workforce planning methods.

Operating the workforce planning as well as testing and implementation is the responsibility of the supervisor. The supervisor will be the most knowledgeable employee on the workforce planning and has the right to make the required decisions. This makes the supervisor the most capable employee for successful implementation and testing of the workforce planning.

The implementation can best be performed based on a top-down approach where the supervisor is responsible for the implementation for the workforce planning. The main reason is that the workforce planning and most information gathering methods are already pre-defined. Thus no new solution has to be devised during the implementation process. Ensuring that delivery dates are correct as well as gathering assembly times will require a bottom-up approach. Here the SA department should work together with the planning department and process engineering in implementing data collection methods and devising policy to support them.

# Chapter 8: Conclusions and recommendations

In this master thesis report a tactical planning method is given which can support Nefit with assigning the right number of employees to the right workstations in order to deliver the required spare parts in time. The method used is a heuristic one, which selects the least skilled employee in combination with the workstation which is hardest to assign an employee to. This method is designed for its computational simplicity in combination with a reasonable accuracy. The results of chapter 6 clearly state that the proposed workforce planning excels the currently used workforce planning methods in term of costs associated to employees. This however comes at the costs of a small reduction in delivery performance. As the increased costs performance outweighs the relatively small decrease in delivery performance, it is recommended to implement the WP by use of the implementation plan given in chapter 7.

The WP proposed here is designed specifically to the setting at Nefit, where a chase demand plan is used with a 15 day lead time for 60% of the spare parts and an 8 day lead time for 40% of the spare parts. The workforce is characterized by two different employee types, being contracted and temporary employees. In the tactical workforce planning the number of contracted employees is assumed as given, while the number of temporary employees can be determined by the workforce planning. Each employee has an employee specific set of skills and each skill corresponds to being able to operate one workstation.

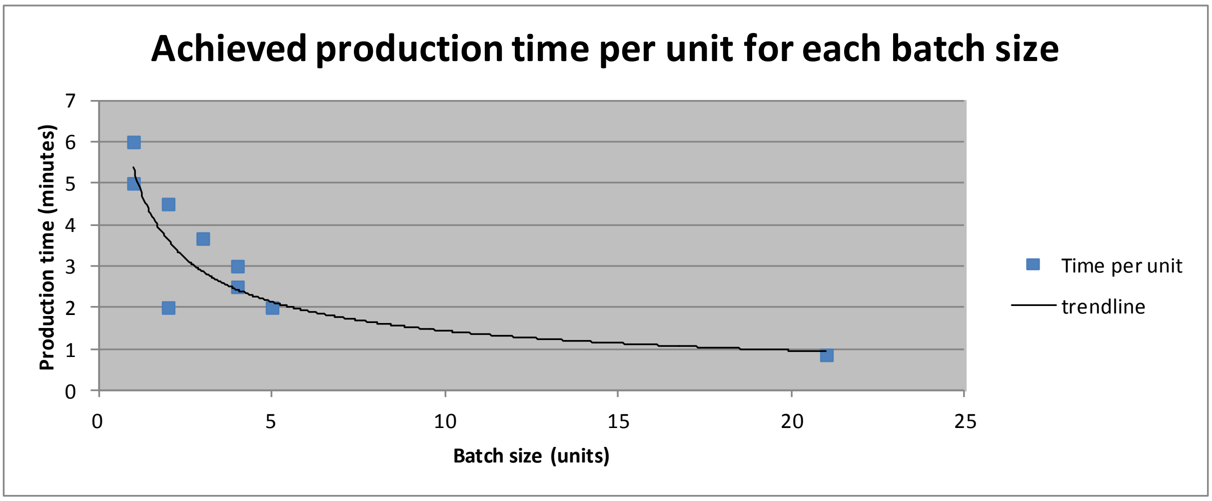
After implementation of the workforce planning as described in this master thesis report, there are several improvements possible at Nefit that may allow more efficient use of employee’s. Some of these options are discussed below.

As indicated in chapter 4, Nefit makes no use of a clearly defined strategic or operational planning. Strategic and operational planning both play part in more efficient use of employees. After implementing the proposed workforce planning, the possible advantage of operational planning may be limited. The only function an operational planning may perform is assignment of employees to workstations based on actual performance during the production. This however can relatively easily be done without use of an advanced planning. The strategic planning at this point in time is relatively static, as the changing from one to two shifts is done at the same point in time every year. The contracted workforce is fixed as well. Applying more advanced planning here may help efficiency by obtaining a more suitable number of contracted employees. The long-term planning will also help to select the right moment to switch between a one or two shift schedule.

The performance of the workforce planning is strongly dependent on the input coming from the planning department. Currently the workforce planning can only use production orders which are released for production. However production orders may be known before release, or production orders may be released later due to delivery problems. This information is not known with SA so that this can only be estimated by use of a standard percentage. By incorporating the workforce planning into the activities of the planning department it is possible to make better estimations of the required capacity.

As indicated in chapter 7 one of the main issues to deal with is the measurement of production times at each workstation for each spare part. At first, the time registration method advised will enable the creation of a large basis for the production times at each workstation. As a standard, Bosch uses the MTM analysis for the measurement of throughput times as well as establishing the production costs of spare parts. For this reason it is recommended to start with the MTM analysis as soon as possible and use this information to update the production times from the time registration. In this way more accurate times can be obtained and the production costs can be updated as well. Updating production costs by use of a method any other than MTM analysis is not allowed.

The typical production time to batch size ratio shown in graph 2 of chapter 4 is again shown in graph 12 below. The graph shows that the larger the batch size the lower the production time per unit. This effect is because some of the production time is independent of the batch size (for example, the setup time). When increasing the batch size, the fixed production time is thus shared over several units. This effect is largest for small batch sizes as each unit increase is a large factor of the total batch size. Note that, as done in previous chapters, production times can directly be translated into costs. A time-inefficient process is thus a cost-inefficient process as well.




Graph 12: achieved production time per unit for each batch size.

Currently Nefit uses no fixed batch size for many products or a batch size based on the size of the carrier (for example, pallet or bin) for that product type. Single units or batches below ten units are still often produced, while costs per unit may be high. It is recommended to use a cost per unit calculation to determine the batch sizes for each spare part. In this calculation not only the production costs, but other costs dependent on batch size, like storage costs, should be included. This may reduce total costs for Nefit as production costs per unit can be reduced. In the example of graph 12, using batch size 1 takes around 5.5 minutes per batch while using batch size 5 takes around 10 minutes to assemble. Using a batch size of 20 units would take around 20 minutes to assemble. Although the assembly times for each spare part are different, in general batches below 10 units should be avoided.

Another option for increasing batch sizes is to combine production orders for the same spare part. Occasionally there are more production orders for the same spare part type. This allows combining production orders to artificially create a larger order. This allows the same benefits as using larger order batches. Note that correct batch sizes would reduce the chance that there is more than one order for the same spare part. On the other hand, making correct use of the long lead times may increase the chance that there are several orders for the same spare part. If orders wait longer before assembling the chance is larger that during that time another order for the same product is being created.

As indicated in paragraph 1.2.4, the ten most requested spare parts by Lollar are delivered from stock instead of produced to stock. This is done to improve the delivery performance while taking the pressure off SA. The disadvantage however is that, being the ten most requested parts, these are ordered regularly and often in large quantities. This means that stock costs for these parts are high while production costs are low even when producing to order. When using the proposed workforce planning it is possible to estimate in time when these large quantities need to be processed. This means that if these orders can be delivered in time as well, stock costs can be reduced.

As indicated in paragraph 6.4.2, training of employees causes fluctuations in production capacity. Employees being trained can temporarily not be assigned to any functions, thus the capacity for the department is temporarily reduced. When several employees require training, this may have serious consequences on the capacity. Training may be required when new employees are needed to cover demand in production time. However training may also be required when employees do not have the required skills. SA should train employees as much as possible during periods of low demand, ensuring that all permanent employees are broadly trained. This way, limited training is required in periods of high demand, so that employees are available for production.

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# Appendix 1: Terminology

For a better understanding of the current situation at Nefit, the definitions used in this master thesis report will be given below. For a better understanding, examples are provided for the most important terms used.

A **spare part** is a SKU sold by Nefit to its customers in order to replace failed parts. A spare part will always be part of a larger finished product and will as such serve no purpose to the final customer when on its own. An example spare part is shown in appendix 4.

A **Purchase part** is a SKU as it is bought from the suppliers of Nefit. A purchase part may be sold directly to customers as being a spare part, or may require assembling with other purchase parts to become a SP.

A **sub-assembly** is defined here as an unfinished spare part which has received only part of the processing required before it can be sold.

**Part service (PS)** is the department within Nefit responsible for the entire process from PP arriving at Nefit to SPs being sent to customers. This mainly involves receiving of PPs, storage of PPs as well as SPs, assembling of SPs and sending of SPs.

**Spares assembly (SA)** is the department within PS solely responsible to the assembly of PPs into SPs.

A **customer order** is a statement containing the SPs a customer wants to receive, in what quantity and at what date.

A **production order** is a residue of the CO defining one spare part which has to be assembled by SA in the given quantity, before the given date. A PO may only contain one type of spare parts to finish, which may exist of several PPs, depending on the spare part to assemble. An example of a production order is shown in appendix 4.

**Contracted employees (CE)** are in service of Nefit and are contracted for a period of at least one year or longer. Permanent employees have the right of a two month notice when being fired.

**Temporary employees (TE)** are employees hired through an agency which dispatches employees to Nefit. TE can be fired with no or short prior notice. All employees at Nefit start as TE; they can be offered a contract by Nefit, thus becoming permanent employees.

A **Workstation** is defined as a production location where a specific set of actions can be performed to assemble a SP. At each type of workstation a limited number of actions can be performed. There may be more than one workstations of a specific type, where each workstation can be operated by one employee.

The **skills** of an employee are defined as the set of functions an employee can perform without help from other employees. The skills within PS are defined as such that one skill is linked directly to being able of operating one type of workstation. Each workstation thus requires one skill to learn and each skill gives excess to one workstation.

The **production planning** determines the POs which are released to spares assemble at what point in time and when these orders should be finished by SA. The production planning used at Nefit indicates no specific time at which an order should be produced in each workstation. The production planning also does not ensure that all released orders can be produced within the given time.

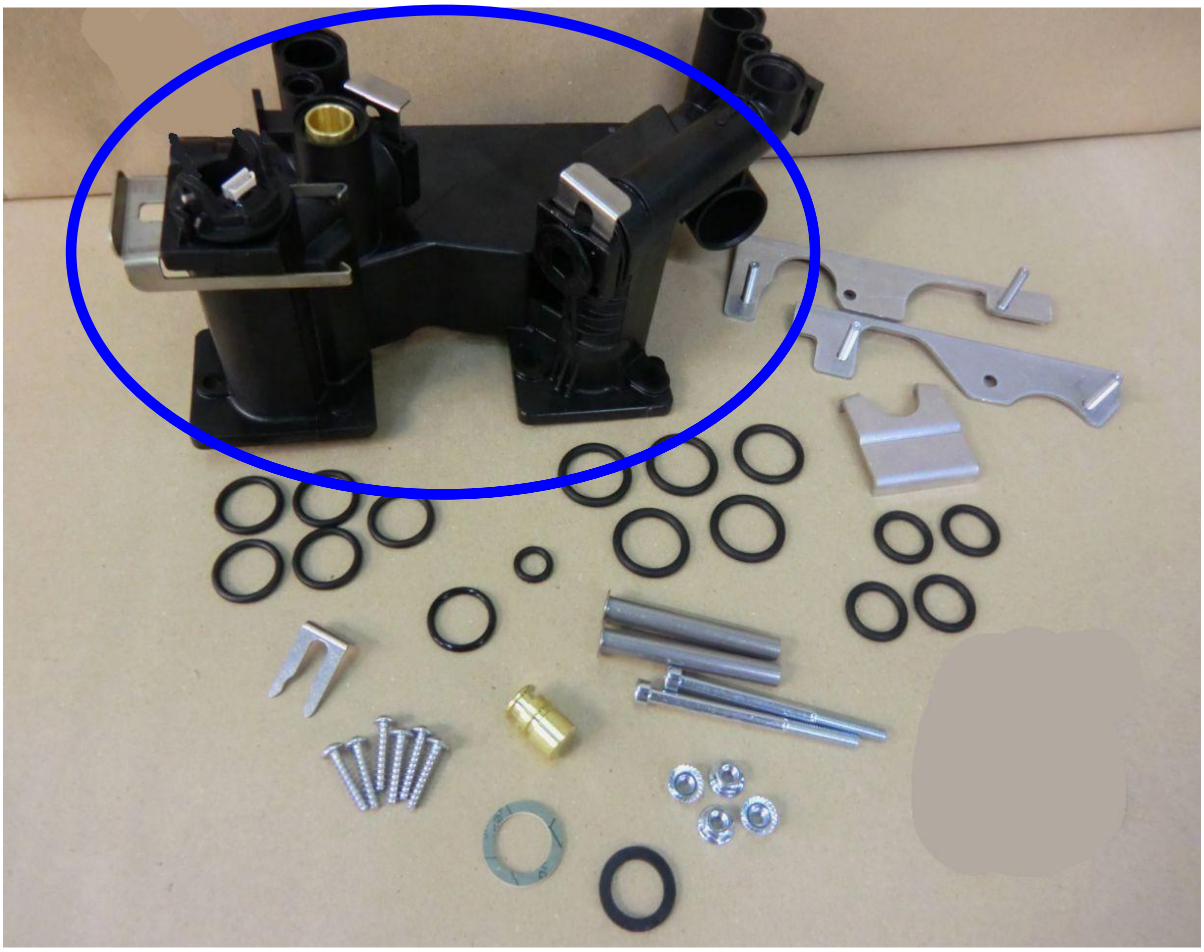
The **workforce planning** is defined as a planning determining the number of employees required by SA at each workstation at each point in time during its planning horizon. In this study the production planning is used as input to the workforce planning only.

The **released production order** refers to the POs which are issued to spares assemble for assembling of the specific SP. In general all SKU's required to finish the POs are available such that all received orders can be finished by SA.

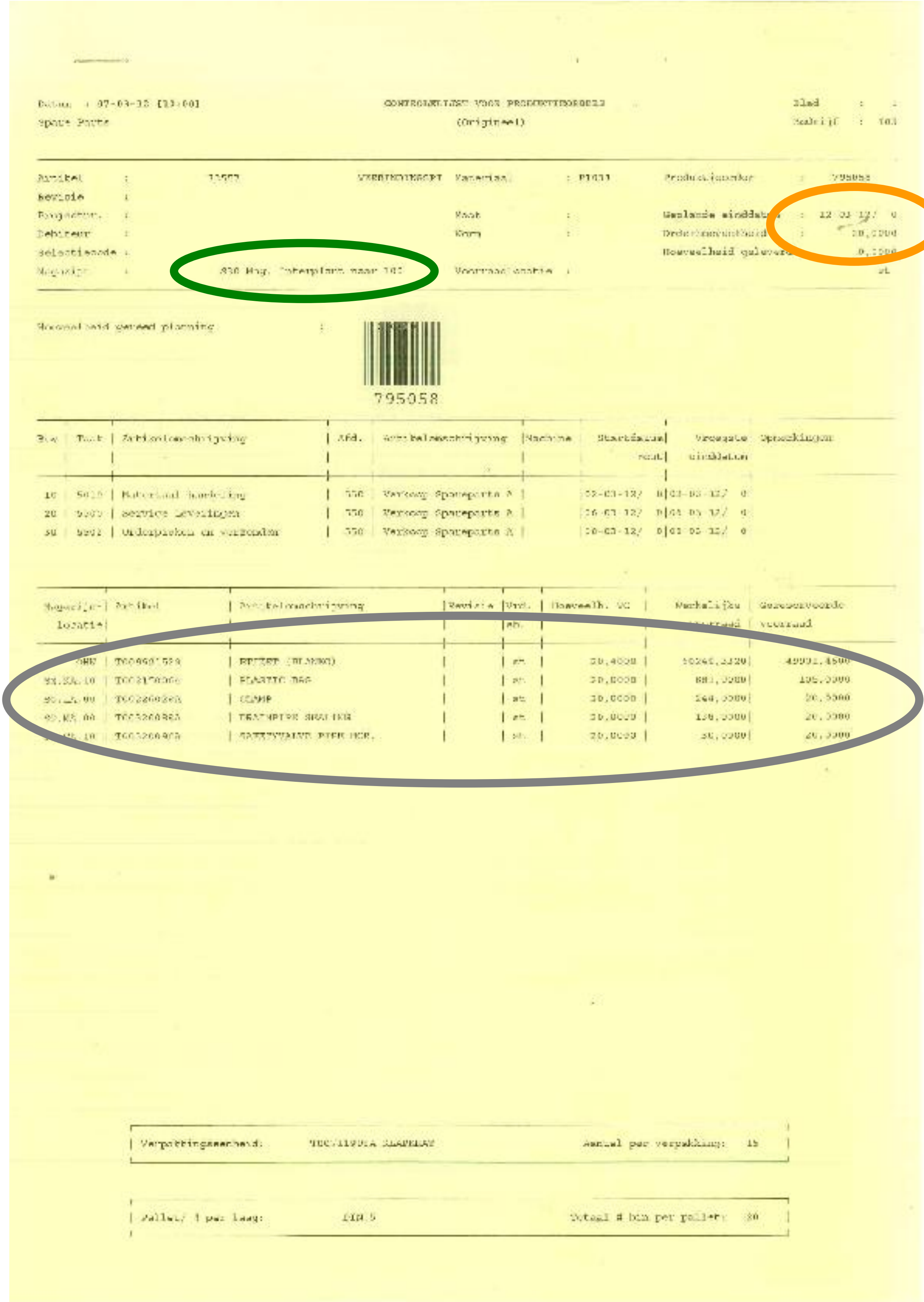
The **expected production order** is those POs which are not issued to SA yet. This can be due to various reasons, like lack of stock in PPs or orders are not released yet. EPOs can also be expected by the forecast but no real orders have been received just yet.

### Examples of terminology

The picture below shows a spare part as produced by the spare part department. The object within the blue circle is a **sub-assembly** constructed from purchase parts, all other articles in the pictures are **purchase parts**. All parts together form a **spare part** as being sold to customers.



The picture on the next page shows a **production order** for a spare part.  The green circle indicates the **spare part** which is to be assembled. In the grey circle the **purchase parts** which are required and the quantities in which they are required to assemble the spare part are shown. Within the orange circle the date can be found on which the product should be finished and the quantity in which the spare part is to be delivered by that date.



Datum : 07-03-12 [13:00] CONTROLELIJST VOOR PRODUCTIEORDERS Blad :
Spare Parts (Origineel) Bedrijf : 103

| | | | | | | |
|---|---|---|---|---|---|---|
| Artikel | : | [illegible] | VERBINDINGSET | Materiaal | : P1031 | Productienummer : 795058 |
| Revisie | : | | | | | |
| Bouwjaar | : | | | Kast | : | Geplande einddatum : 12-03-12/ 0 |
| Debiteur | : | | | Kern | : | Orderhoeveelheid : 20,0000 |
| Selectiecode | : | | | | | Hoeveelheid geleverd : 0,0000 |
| Magazijn | : | 830 Mag. Onderplant naar 103 | | Voorraadlocatie | : | |

Hoeveelheid gereed planning :

795058

| Bew | Taak | Taakomschrijving | Afd. | Afdelingsomschrijving | Machine | Startdatum | Vroegste einddatum | Opmerkingen |
|---|---|---|---|---|---|---|---|---|
| 10 | 5010 | Material handling | 350 | Verkoop Spareparts A | | 02-03-12/ 0 | 02-03-12/ 0 | |
| 20 | 5003 | Service Leveringen | 350 | Verkoop Spareparts A | | 06-03-12/ 0 | 08-03-12/ 0 | |
| 30 | 5002 | Orderpicken en verzenden | 350 | Verkoop Spareparts A | | 08-03-12/ 0 | 08-03-12/ 0 | |

| Magazijnlocatie | Artikel | Artikelomschrijving | Revisie | Vrd. eh. | Hoeveelh. VC | Werkelijke voorraad | Gereserveerde voorraad |
|---|---|---|---|---|---|---|---|
| OHW | T00990[illegible] | STICKER (BLANCO) | | st. | 20,4000 | 50240,2320 | 49991,4500 |
| [illegible] | T00217[illegible] | PLASTIC BAG | | st. | 20,0000 | 881,0000 | 105,0000 |
| [illegible] | T00226[illegible] | CLAMP | | st. | 20,0000 | 244,0000 | 20,0000 |
| [illegible] | T00326[illegible] | HEATPIPE SEALING | | st. | 20,0000 | 138,0000 | 20,0000 |
| [illegible] | T00326[illegible] | SAFETYVALVE PIPE [illegible] | | st. | 20,0000 | 50,0000 | 20,0000 |

Verpakkingseenheid: [illegible] Aantal per verpakking: 15

Pallet/ # per laag: [illegible] Totaal # bin per pallet: 80

## Appendix 2: Literature Study

The literature study aimed at finding articles about workforce planning. In particular articles which focus on methods to plan the workforce based on demand and skills / knowledge available. The literature search was conducted in Google Scholar, because this search engine allows an article search in most of the databases at the same time.

To find the relevant literature the following words where used:

- "workforce planning" (approximately 12,200 hits)
  - Without the word: medical (approximately 5,370 hits)
  - Without the word: health (approximately 2,570 hits)

These words where used together in order to reduce the amount of hits received. Also all articles should have a summary; this makes sure no quotes turn up as search results. When applying these restriction approximately 1,840 articles where found. The last restriction is that only results are given which answer to the demands above in the title and not the entire article. This is to leave out articles that in some way refer to workforce planning while the article is not about the topic. This has led to a total of approximately 284 articles to be found.

At this point no restrictions or search words could be added without a high risk of leaving out potential relevant texts. For this reason the literature study continued with a title search, in which all titles which seem relevant to the study were selected. The content of the title was an important factor, however also, date of publication, number of citations and the publisher, where important factors. These factors are included to ensure high quality of sources, as well as high quality of content. When there was doubt, the article was selected for now, this to ensure that no possibly relevant articles where neglected. This title search resulted in 53 articles which where potentially interesting to the research.

**Lijst naar aanleiding van titel search.**

1. Computer-based data integration and management process for workforce planning and occupational readjustment
2. Integrating workforce planning, human resources, and service planning
3. Workforce planning in mixed model assembly systems
4. Talent management systems: Best practices in technology solutions for recruitment, retention, and workforce planning
5. Applying supply chain optimization techniques to workforce planning problems
6. The metrics of workforce planning
7. Workforce planning at USPS mail processing and distribution centers using stochastic optimization
8. Heuristics for workforce planning with worker differences
9. Workforce planning in synchronous production systems* 1
10. Modelling inherent worker differences for workforce planning
11. An operational process for workforce planning
12. The importance of workforce planning in the NHS in the 1990s
13. Workforce planning in a lotsizing mail processing problem
14. An executive perspective on workforce planning
15. Workforce planning and allocation for mid-volume truck manufacturing: a case study

16. Strategic staffing: A practical toolkit for workforce planning
17. Workforce planning and development processes: A practical guide
18. Operator workforce planning in the transit industry
19. Workforce planning in the printing industry
20. Workforce Planning
21. Seven steps of effective workforce planning
22. Why you need workforce planning
23. Workforce planning with a parallel genetic algorithm
24. Strategic staffing: a comprehensive system for effective workforce planning
25. An optimization approach to workforce planning for the information technology field
26. Workforce planning in the knowledge-based economy
27. A hybridization of Mathematical Programming and search techniques for integrated operation and workforce planning
28. Workforce planning. Catching the drift.
29. Recruiting and Retaining America's Finest: Evidence-Based Lessons for Police Workforce Planning
30. The right person, in the right job, with the right skills, at the right time: A workforce-planning model that goes beyond metrics
31. Models of public sector management for a competitive Australia: A computer simulation model for workforce planning
32. Workforce planning issues in the freight industry
33. Two-stage workforce planning under demand fluctuations and uncertainty
34. Workforce planning with parallel algorithms
35. Parallel metaheuristics for workforce planning
36. Supporting long‐term workforce planning with a dynamic aging chain model: A case study from the service industry
37. Workforce development: planning what you need starts with knowing what you have
38. A successive convex approximation method for multistage workforce capacity planning problem with turnover
39. Planning for a quality workforce
40. “Personnel forcecasting strategic workforce planning”: a proposed simulation cost modeling methodology
41. Workforce planning: is there a right way?
42. SimMan--A simulation model for workforce capacity planning
43. Intelligent Resource Allocation–Solutions and Pathways in a Workforce Planning Problem
44. A flexible MILP model for multiple-shift workforce planning under annualized hours
45. An intelligent decision support system for workforce forecasting and planning
46. Plan for Success: The Business Case for Workforce Planning
47. Parallel Genetic Algorithm for the Workforce Planning Problem
48. Who does workforce planning well?: Workforce review team rapid review summary
49. A Zero-One Integer Programming Model for the Optimum Workforce Capacity Planning with Workload Constraints
50. Workforce planning apparatus for calculating number of workers to be a allocated
51. A detailed workforce planning model including non-linear dependence of the capacity on the size of the staff and cash management
52. WORKFORCE PLANNING SYSTEM, METHOD AND TOOL
53. Method and system for planning of services workforce staffing using hiring, contracting and cross-training

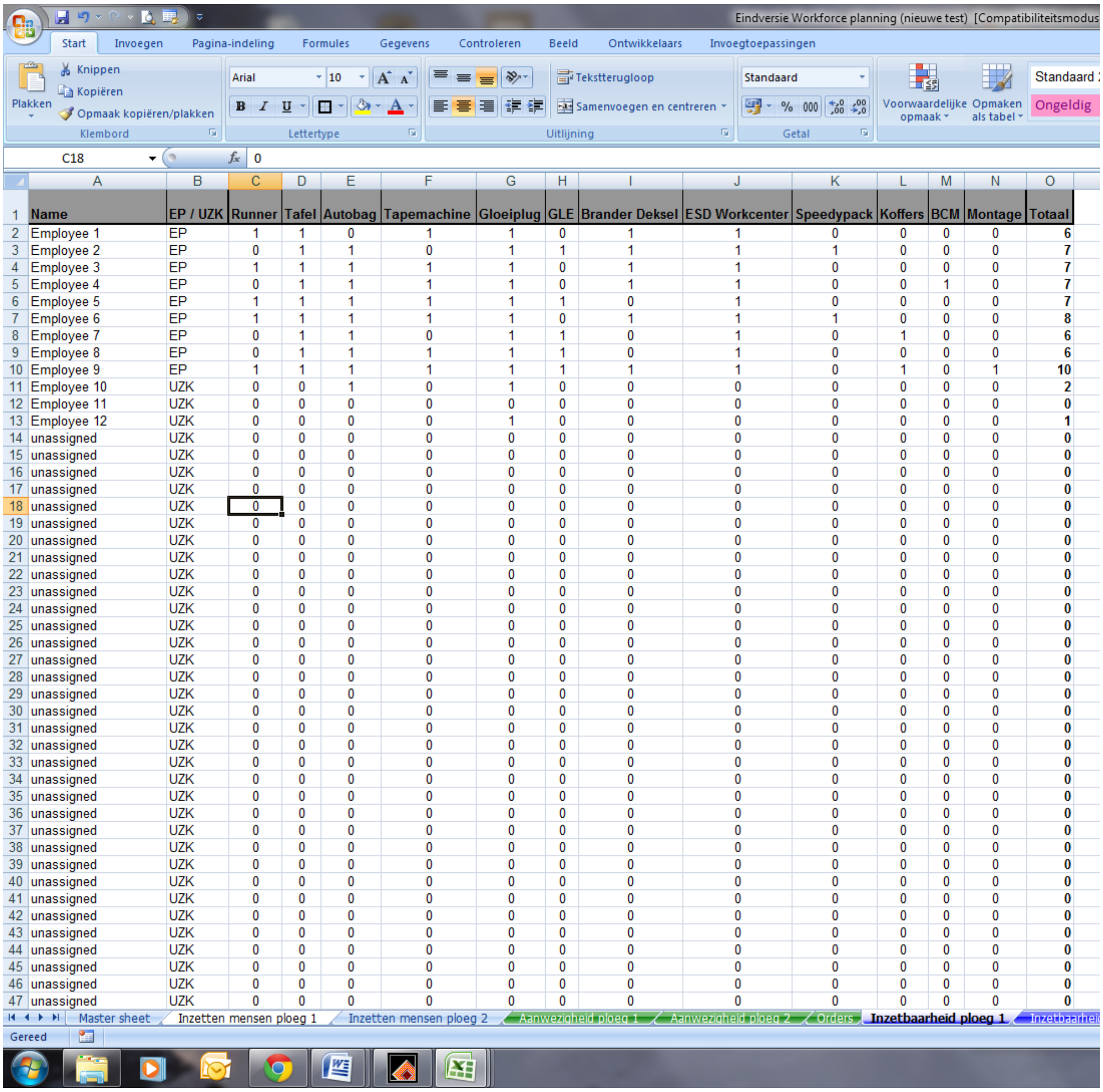
After the title search a final selection for reading was made by selecting based on the abstract. Articles are selected mainly on relevance for the research. To ensure relevance and avoid reading of unnecessary many articles the selection here is tougher than previous selection.

In this part some restrictions have to be taken into account in respect to excess to the articles and abstracts. Only articles are used which can be accessed with either the licences of the Bosch group or the license of the University of Twente.

### Results abstract search

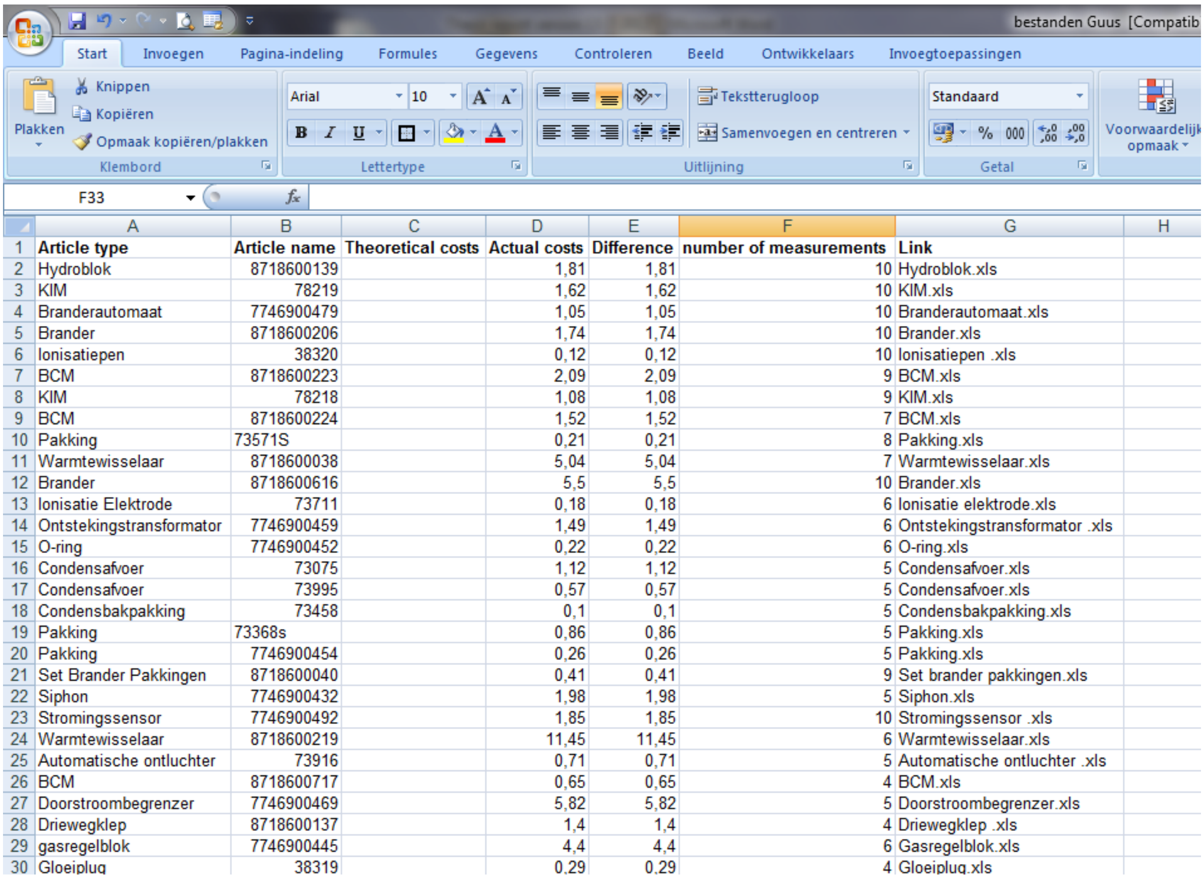
1. Applying supply chain optimization techniques to workforce planning problems (22 citaten (2007))
2. The metrics of workforce planning (19 citaten (2004))
3. Workforce planning at USPS mail processing and distribution centers using stochastic optimization (19 citaten(2007))
4. Heuristics for workforce planning with worker differences (18 citaten (2008))
5. Workforce planning in synchronous production systems* 1 (14 citaten (2002))
6. Modelling inherent worker differences for workforce planning (12 citaten (2007))
7. BOEK!: An operational process for workforce planning (12 citaten (2004))
8. Workforce planning in a lotsizing mail processing problem (9 citaten (2007))
9. Workforce planning and allocation for mid-volume truck manufacturing: a case study (6 citaten (2003))
10. Operator workforce planning in the transit industry (7 citaten (1987))
11. A hybridization of Mathematical Programming and search techniques for integrated operation and workforce planning (3 citaten (2007))
12. Two-stage workforce planning under demand fluctuations and uncertainty (3 citaten (2009))
13. Parallel metaheuristics for workforce planning (2 citaten (2007))
14. Supporting long‐term workforce planning with a dynamic aging chain model: A case study from the service industry (2 citaten (2010))
15. A successive convex approximation method for multistage workforce capacity planning problem with turnover (4 citaten (2008))
16. Intelligent Resource Allocation–Solutions and Pathways in a Workforce Planning Problem (1 citaat (2007))
17. An intelligent decision support system for workforce forecasting and planning (0 citaten (2011))
18. Parallel Genetic Algorithm for the Workforce Planning Problem (0 citaten (2011))

# Appendix 3: Example of skill matrix



| | Name | EP / UZK | Runner | Tafel | Autobag | Tapemachine | Gloeiplug | GLE | Brander Deksel | ESD Workcenter | Speedypack | Koffers | BCM | Montage | Totaal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Employee 1 | EP | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 6 |
| 3 | Employee 2 | EP | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 7 |
| 4 | Employee 3 | EP | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 7 |
| 5 | Employee 4 | EP | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 7 |
| 6 | Employee 5 | EP | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 7 |
| 7 | Employee 6 | EP | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 8 |
| 8 | Employee 7 | EP | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 6 |
| 9 | Employee 8 | EP | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 6 |
| 10 | Employee 9 | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 10 |
| 11 | Employee 10 | UZK | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 12 | Employee 11 | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | Employee 12 | UZK | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 14 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 43 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 44 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 46 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | unassigned | UZK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# Appendix 4: Example of product overview



| 1 | Article type | Article name | Theoretical costs | Actual costs | Difference | number of measurements | Link |
|---|---|---|---|---|---|---|---|
| 2 | Hydroblok | 8718600139 | | 1,81 | 1,81 | 10 | Hydroblok.xls |
| 3 | KIM | 78219 | | 1,62 | 1,62 | 10 | KIM.xls |
| 4 | Branderautomaat | 7746900479 | | 1,05 | 1,05 | 10 | Branderautomaat.xls |
| 5 | Brander | 8718600206 | | 1,74 | 1,74 | 10 | Brander.xls |
| 6 | Ionisatiepen | 38320 | | 0,12 | 0,12 | 10 | Ionisatiepen .xls |
| 7 | BCM | 8718600223 | | 2,09 | 2,09 | 9 | BCM.xls |
| 8 | KIM | 78218 | | 1,08 | 1,08 | 9 | KIM.xls |
| 9 | BCM | 8718600224 | | 1,52 | 1,52 | 7 | BCM.xls |
| 10 | Pakking | 73571S | | 0,21 | 0,21 | 8 | Pakking.xls |
| 11 | Warmtewisselaar | 8718600038 | | 5,04 | 5,04 | 7 | Warmtewisselaar.xls |
| 12 | Brander | 8718600616 | | 5,5 | 5,5 | 10 | Brander.xls |
| 13 | Ionisatie Elektrode | 73711 | | 0,18 | 0,18 | 6 | Ionisatie elektrode.xls |
| 14 | Ontstekingstransformator | 7746900459 | | 1,49 | 1,49 | 6 | Ontstekingstransformator .xls |
| 15 | O-ring | 7746900452 | | 0,22 | 0,22 | 6 | O-ring.xls |
| 16 | Condensafvoer | 73075 | | 1,12 | 1,12 | 5 | Condensafvoer.xls |
| 17 | Condensafvoer | 73995 | | 0,57 | 0,57 | 5 | Condensafvoer.xls |
| 18 | Condensbakpakking | 73458 | | 0,1 | 0,1 | 5 | Condensbakpakking.xls |
| 19 | Pakking | 73368s | | 0,86 | 0,86 | 5 | Pakking.xls |
| 20 | Pakking | 7746900454 | | 0,26 | 0,26 | 5 | Pakking.xls |
| 21 | Set Brander Pakkingen | 8718600040 | | 0,41 | 0,41 | 9 | Set brander pakkingen.xls |
| 22 | Siphon | 7746900432 | | 1,98 | 1,98 | 5 | Siphon.xls |
| 23 | Stromingssensor | 7746900492 | | 1,85 | 1,85 | 10 | Stromingssensor .xls |
| 24 | Warmtewisselaar | 8718600219 | | 11,45 | 11,45 | 6 | Warmtewisselaar.xls |
| 25 | Automatische ontluchter | 73916 | | 0,71 | 0,71 | 5 | Automatische ontluchter .xls |
| 26 | BCM | 8718600717 | | 0,65 | 0,65 | 4 | BCM.xls |
| 27 | Doorstroombegrenzer | 7746900469 | | 5,82 | 5,82 | 5 | Doorstroombegrenzer.xls |
| 28 | Driewegklep | 8718600137 | | 1,4 | 1,4 | 4 | Driewegklep .xls |
| 29 | gasregelblok | 7746900445 | | 4,4 | 4,4 | 6 | Gasregelblok.xls |
| 30 | Gloeiplug | 38319 | | 0,29 | 0,29 | 4 | Gloeiplug.xls |

# Appendix 5: MILP model assumptions

- To create a stable and realistic workforce planning assumption (I) states that; "One employee is assigned to one workstation for an entire day". Any excess capacity on one day is used to assemble products with later due dates. This is a realistic assumption as movement of employees is generally seen as inefficient.
- Assumption (II) is taken from the model of (Stewart et al., 1994), stating that; "Costs of employees don't change over the planning horizon". This assumption will be correct most of the times as employee costs are changed occasionally.
- Employees will train at most one other employee and will do so by doing the activities together (learn by doing). This translates onto assumption (III) stating; "One employee can train no more than one other employee in a certain skill, training will always take place on the workstation for which the trained skill is required".
- When training, two employees perform the function of one employee, this translates into assumption (IV); "An employee being trained will not increase nor decrease the production quantity".
- For simplicity assumption (V) is; "Breakdown time or changeover time is not explicitly considered in the model" as done by (Stewart et al., 1994). As opposed to the model of (Stewart et al., 1994).
- Assumption (VI) "Each worker is assumed to be available during an entire day in the planning horizon" is used for simplicity of the user and is connected to assumption (I). Small deviations from this assumption may take place, but these can generally be solved by switching employees between workstation, if necessary.
- For simplicity assumption (VII) "No differences exist among workers other than their skill set and their contract type" is used. Currently no difference in working speed between the employees is known, by using average speeds the model size can be reduced without losing planning quality. This is also supported by the aim of the planning as the goal is not to maximize production speed, but to understand the time required to for production.
- The aim is to have time available so that all required spare parts can be produced. This means that the workforce planning does not ensure that this is done neither that all jobs stated at a day finished at the same day. This is supported by assumption (VIII) "Not all jobs have to be finished at the end of each day".

# Appendix 6: Workforce planning manual

## Handleiding Workforce Planning

Spare Part Department of Nefit

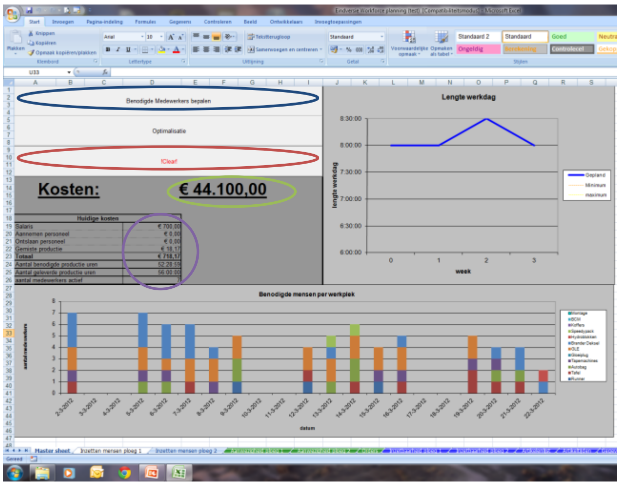
Auteur: Guus Janssen
Datum: 16-8-2012

Alleen voor gebruik door de afdeling samenstellen van Nefit B.V.

## Introductie

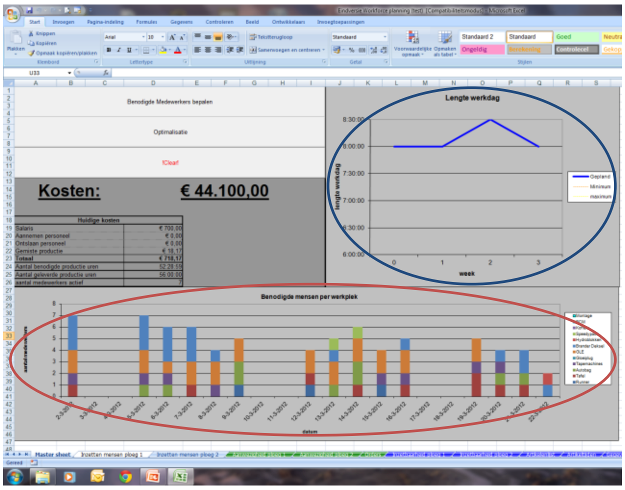
- Voor u ligt de handleiding van 12-8-2012 behorende bij de workforce planning voor de part service afdeling van Nefit.
- De workforce planning is ontwikkeld om op dagelijkse basis te kunnen weergeven hoeveel medewerkers er nodig zijn in productie, aan welke functies zij toegewezen dienen te worden en welke training daarvoor noodzakelijk is.
- De planning bestaat uit een serie sheets die allemaal een eigen functie hebben. Grofweg zijn deze sheets te verdelen in:
  - Sheets die de resultaten tonen (lichtblauw)
  - Input sheets die regelmatig bijgehouden moeten worden (groen)
  - Input sheets die incidenteel gewijzigd moeten worden (donker blauw)
  - Sheets met tussenstappen in de berekening, hiervan is bijhouden of raadplegen door de gebruiker niet noodzakelijk (rood)
- In deze handleiding wordt in eerste instantie per sheet uitgelegd welke informatie er te vinden is en wat de gebruiker erin kan veranderen. Daarna wordt dieper ingegaan op de logica van de planning voor de geïnteresseerden.

# Master Sheet




Dit is het hoofdscherm van de planning en kan gebruikt worden om de planning te genereren en een voorgestelde planning te wissen.
Hier worden de kosten gerelateerd aan de gehele planning weergegeven en kosten voor dag 1, opgesplitst in salaris en kosten voor aannemen of ontslaan van personeel.
Daarnaast wordt aangegeven hoeveel productie uren gevraagd waren op die dag, hoeveel er geleverd zijn en hoeveel mensen daarvoor actief waren.

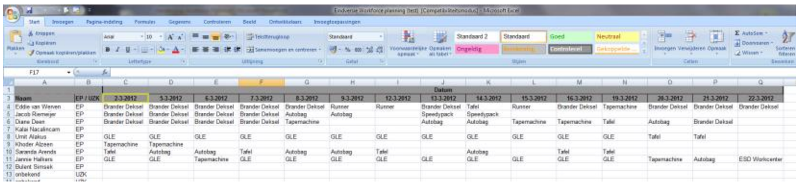
# Master Sheet




De grafiek rechts bovenin dit scherm toont de geplande lengte van de werkdag over een periode van drie weken en die van de huidige week (week 0).

De grafiek onderaan toont hoeveel mensen er aan iedere functie toegewezen moeten worden volgens de gegeven planning.

# Inzetten mensen

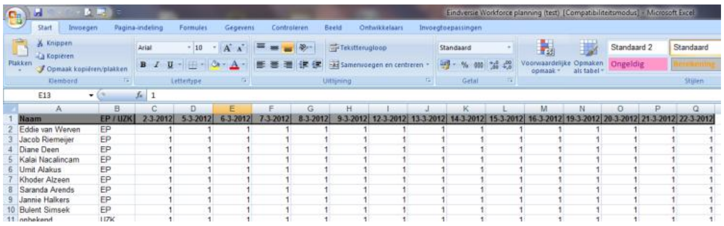


| | | Datum | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Naam | EP / UZK | 2-3-2012 | 5-3-2012 | 6-3-2012 | 7-3-2012 | 8-3-2012 | 9-3-2012 | 12-3-2012 | 13-3-2012 | 14-3-2012 | 15-3-2012 | 16-3-2012 | 19-3-2012 | 20-3-2012 | 21-3-2012 | 22-3-2012 |
| Eddie van Werven | EP | Brander Deksel | Brander Deksel | Brander Deksel | Brander Deksel | Brander Deksel | Runner | Runner | Brander Deksel | Tafel | Runner | Brander Deksel | Tapemachine | Brander Deksel | Brander Deksel | Brander Deksel |
| Jacob Riemeijer | EP | Brander Deksel | Brander Deksel | Brander Deksel | Brander Deksel | Autobag | Autobag | | Speedypack | Speedypack | | | | | | |
| Diane Deen | EP | Brander Deksel | Brander Deksel | Brander Deksel | Brander Deksel | Tapemachine | | | Autobag | Autobag | Tapemachine | Tapemachine | Tafel | Autobag | Brander Deksel | |
| Kalai Nacalincam | EP | | | | | | | | | | | | | | | |
| Umit Alakus | EP | GLE | GLE | GLE | GLE | GLE | GLE | GLE | GLE | GLE | GLE | GLE | GLE | Tafel | Tafel | |
| Khoder Alzeen | EP | Tapemachine | Tapemachine | | | | | | | | | | | | | |
| Saranda Arends | EP | Tafel | Autobag | Autobag | Tafel | Autobag | Autobag | Tafel | | Autobag | | Tafel | Tafel | | | |
| Jannie Halkers | EP | GLE | GLE | Tapemachine | GLE | GLE | GLE | GLE | GLE | GLE | GLE | GLE | GLE | Tapemachine | Autobag | ESD Workcenter |
| Bulent Simsek | EP | | | | | | | | | | | | | | | |
| onbekend | UZK | | | | | | | | | | | | | | | |

Voor zowel ploeg 1 als ploeg 2 is een apart scherm dat een haalbaar voorstel geeft hoe mensen in te zetten gedurende de dagen. Hierbij moet er rekening mee worden gehouden dat de planning gedurende de loop van de dagen kan wijzigen. Een voorstel kan aangepast worden aan voorkeuren van de planner, hierbij moet wel rekening worden gehouden met mogelijk gewijzigde prestatie van de planning.

Het doel van de planning is om medewerkers zo toe te wijzen aan functies dat er een zo hoog mogelijke kans is dat de overgebleven medewerkers nog toegewezen kunnen worden aan andere functies.

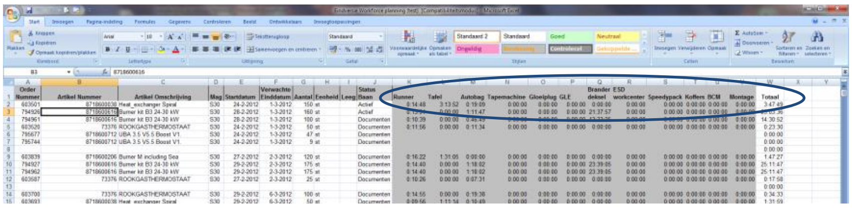
# Aanwezigheid



| Naam | EP / UZK | 2-3-2012 | 5-3-2012 | 6-3-2012 | 7-3-2012 | 8-3-2012 | 9-3-2012 | 12-3-2012 | 13-3-2012 | 14-3-2012 | 15-3-2012 | 16-3-2012 | 19-3-2012 | 20-3-2012 | 21-3-2012 | 22-3-2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eddie van Werven | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Jacob Riemeijer | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Diane Deen | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Kalai Nacalincam | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Umit Alakus | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Khoder Alzeen | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Saranda Arends | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Jannie Halkers | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Bulent Simsek | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| onbekend | UZK | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

De aanwezigheid sheet toont voor iedere medewerker wanneer deze aanwezig is en zo nodig of deze training toegewezen heeft gekregen. Een 1 staat voor volledig beschikbaar om in te zetten. Een 2 en 3 betekenen dat een persoon getraind wordt in een bepaalde functie. In het geval van een 3 is deze training reeds aan de gang (en wordt door de planning niet meer gewijzigd). Tot slot betekend een 0 dat een medewerker niet beschikbaar is om in te zetten op welke manier dan ook. OM correct te blijven zal deze sheet regelmatig bijgehouden moeten worden door de beheerder van de planning. De planner hoeft alleen maar aanwezigheid (1) of afwezigheid (0) aan te geven, de andere opties worden automatisch ingevuld indien noodzakelijk.

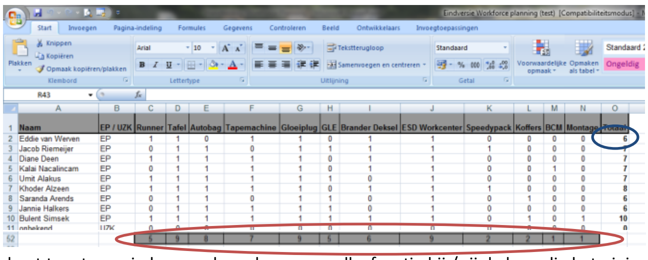
# Orders



Het order overzicht toont alle productie orders die vrijgegeven zijn voor productie en nog niet gefinisht zijn. De informatie kan gekopieerd worden uit het order overzicht dat meermaals per dag geprint wordt. In dit overzicht wordt ook berekend hoeveel productie uren per werkplek er nodig zijn om de order af te ronden.

Deze sheet moet iedere keer dat de planning wordt geactiveerd worden bijgewerkt met de meest up-to-date overzicht van de productie orders. Alleen op deze manier is het systeem in staat een accurate planning te genereren.

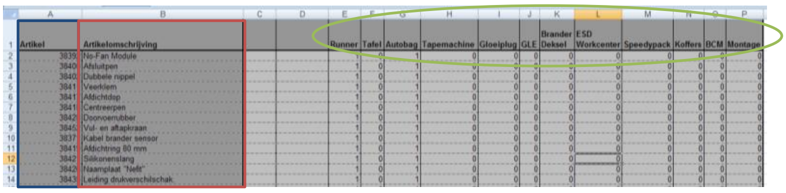
# Inzetbaarheid



| Naam | EP / UZK | Runner | Tafel | Autobag | Tapemachine | Gloeiplug | GLE | Brander Deksel | ESD Workcenter | Speedypack | Koffers | BCM | Montage | Totaal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eddie van Werven | EP | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 6 |
| Jacob Riemeijer | EP | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | [illegible] |
| Diane Deen | EP | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 7 |
| Kalai Nacalincam | EP | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 7 |
| Umit Alakus | EP | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 7 |
| Khoder Alzeen | EP | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 8 |
| Saranda Arends | EP | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 6 |
| Jannie Halkers | EP | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 6 |
| Bulent Simsek | EP | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 10 |
| onbekend | UZK | 0 | [illegible] | [illegible] | [illegible] | [illegible] | 0 | 0 | 0 | [illegible] | [illegible] | [illegible] | 0 | 0 |
| | | 5 | 9 | 8 | 7 | 9 | 5 | 6 | 9 | 2 | 2 | 1 | 1 | |

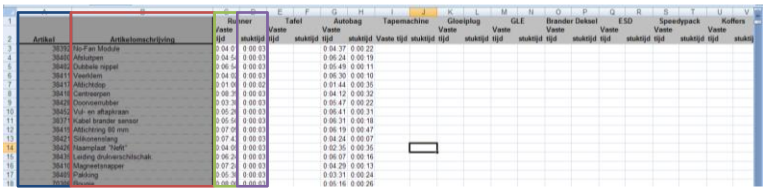
Deze sheet toont voor iedere medewerker voor welke functie hij / zij de benodigde training heeft ontvangen. Hierbij geldt dat een 1 staat voor getraind en een 0 voor ongetraind in die functie. De cel totaal toont op hoeveel functies een persoon inzetbaar is. Dit is een graadmeter voor het gemak waarmee een medewerker ingezet kan worden.
Onderaan de sheet staat het totaal aantal medewerkers dat getraind is op die werkplek. In de toewijzing van personeel aan werkplekken wordt rekening gehouden met de uniekheid van een medewerker. Deze uniekheid wordt bepaalt op basis van de hoeveelheid functies waarin hij / zij getraind is en de totaal hoeveelheid mensen die in een specifieke functie getraind zijn.

# Artikelenlijst




De artikelenlijst toont voor ieder artikel het nummer en een korte omschrijving van het artikel. Vervolgens wordt voor ieder artikel doormiddel van een 0 of 1 aangegeven op welke werkplekken deze behandeld moet worden. Dit vormt dus de routing voor ieder product langs alle werkplekken.

# Artikeltijden



De sheet met artikeltijden toont voor ieder artikel het nummer en geeft een korte omschrijving. Dit komt volledig overeen met de artikelenlijst (zie vorige sheet). Anders dan in de artikelenlijst staat hier per artikel de tijd die nodig is voor assemblage voor iedere werkplek waar het artikel bewerkt wordt. De tijd is onderverdeeld in vaste tijd en stuktijd. De vaste tijd staat voor de tijd die nodig is onafhankelijk van het aantal artikelen dat bewerkt wordt (bv setup tijd). De stuktijd is de tijd die het kost om 1 artikel op die werkplek te bewerken.

Dit vormt de basis voor de productie tijden die per dag nodig geacht worden.

# Gegeven

- De sheet "gegeven" bevat een aantal input waarden essentieel voor de aansturing van de workforce planning. Alle elementen van de sheet "gegeven" zijn onafhankelijk van elkaar te bepalen.
  - Max aantal medewerkers en werkplekken typen
  - Lengte van de werkdag
  - Overzicht van de dag van de week
  - Overzicht van de verwachtte onzekerheden
  - Max aantal medewerkers per werkplek type
  - Trainingstijd per werkplek type
  - Kosten per medewerkertype voor aannemen / ontslaan en salaris.

# Gegeven

Het maximum aantal medewerkers en werkplekken bepaalt de grenzen voor de workforce planning. De workforce planning zal niet meer dan het aantal aangegeven medewerkers inplannen en zal geen rekening houden met meer dan het aantal aangegeven werkplek typen.

| | | |
|---|---|---|
| 2 | **aantal medewerkers ploeg 1** | 50 |
| 3 | **aantal medewerkers ploeg 2** | 0 |
| 4 | **aantal werkplekken** | 12 |
| 5 | | |
| 8 | **Week** | **Werkdaglengte** |
| 9 | | |
| 10 | **0** | 8:00:00 |
| 11 | **1** | 8:00:00 |
| 12 | **2** | 8:30:00 |
| 13 | **3** | 8:00:00 |
| 14 | | |
| 15 | **Huidige datum** | 2-3-2012 |

Hier wordt de lengte van de werkdag vastgelegd. De werkdag van week 0 wordt bepaald op basis van de uitkomst van voorgaande planningen of kan veranderd worden door de gebruiker. De werkdaglengte van de andere weken wordt bij iedere planning opnieuw bepaalt.

De huidige datum wordt door de planning zelf vastgelegd en hier genoteerd. Deze hoeft niet door de gebruiker gewijzigd te worden.

# Gegeven

| | 28-6-2012 | Aantal medewerkers | Dag nr | Dag | Week |
|---|---|---|---|---|---|
| 30 | 28-6-2012 | Aantal medewerkers | Dag nr | Dag | Week |
| 31 | 2-3-2012 | 7 | 6 | vrijdag | 0 |
| 32 | 5-3-2012 | 7 | 2 | maandag | 1 |
| 33 | 6-3-2012 | 6 | 3 | dinsdag | 1 |
| 34 | 7-3-2012 | 6 | 4 | woensdag | 1 |
| 35 | 8-3-2012 | 6 | 5 | donderdag | 1 |
| 36 | 9-3-2012 | 5 | 6 | vrijdag | 1 |
| 37 | 12-3-2012 | 4 | 2 | maandag | 2 |
| 38 | 13-3-2012 | 5 | 3 | dinsdag | 2 |
| 39 | 14-3-2012 | 6 | 4 | woensdag | 2 |
| 40 | 15-3-2012 | 4 | 5 | donderdag | 2 |
| 41 | 16-3-2012 | 5 | 6 | vrijdag | 2 |
| 42 | 19-3-2012 | 5 | 2 | maandag | 3 |
| 43 | 20-3-2012 | 4 | 3 | dinsdag | 3 |
| 44 | 21-3-2012 | 4 | 4 | woensdag | 3 |
| 45 | 22-3-2012 | 2 | 5 | donderdag | 3 |

Dit overzicht toont voor iedere werkdag hoeveel mensen er aan toegewezen zijn. Daarnaast toont het wat voor dag iedere datum is en in welke week die datum daarom valt. Dit is noodzakelijk om te kunnen bepalen hoe lang de werkdag is en dus hoeveel werk er verricht kan worden op die dag.

| | |
|---|---|
| orders onbekend | 10% |
| ziekte | 3% |
| capaciteit gebruiken tot | 80% |
| percentage artikelen bekend | 100% |
| **% vrij laten** | **30%** |
| **ploegendienst** | **nee** |

# Gegeven

Dit overzicht bepaalt hoeveel extra tijd er gerekend wordt boven de reeds bekende productie tijd voor orders. Hiervoor dient een schatting gemaakt te worden van iedere waarde.

Het percentage voor onbekende orders geeft aan hoeveel orders er normaal gesproken nog binnenkomen binnen de aangegeven planning termijn. Dit zijn bijvoorbeeld spoedorders.

De ziekte is een gemiddelde van de uitval van medewerkers door ziekte. Door hier rekening mee te houden kunnen extra medewerkers ingezet worden om dit te compenseren.

De waarde voor “capaciteit gebruiken tot”, geeft aan hoe zwaar het systeem belast moet worden. DIT GAAT PUUR OM PRODUCTIE!. Er moet daarom ook rekening gehouden worden met extra toeslagen voor tijd die niet in productie zit. Hierom wordt een maximum van 80% aangeraden.

Het percentage artikelen bekend is een schatting van de productie last waarvan de productie tijden bepaald zijn. Dit kan voornamelijk ondersteuning bieden wanneer de workforce planning ingevoerd wordt of wanneer er een groot aantal spare parts gemaakt moeten worden van een nieuw type waarvan de productie tijden onbekend zijn.

Het percentage vrij laten wordt op basis van bovenstaande waarden berekend. Dit geeft aan hoe veel extra tijd er ingepland wordt bovenop de tijd die zeker nodig is.

De variabele ploegendienst geeft aan of er in 1 of 2 ploegen wordt gewerkt. “Nee” betekend 1 ploeg en “ja” betekend 2 ploegen. Dit bepaalt hoe de planning de werklast verdeeld over de ploegen.

# Gegeven

| | functie | maximum aantal medewerkers |
|---|---|---|
| 61 | Runner | 5 |
| 62 | Tafel | 6 |
| 63 | Autobag | 5 |
| 64 | Tapemachine | 2 |
| 65 | Gloeiplug | 10 |
| 66 | GLE | 2 |
| 67 | Brander Deksel | 3 |
| 68 | ESD Workcenter | 3 |
| 69 | Speedypack | 2 |
| 70 | Koffers | 2 |
| 71 | BCM | 1 |
| 72 | Montage | 2 |

| 73 | Werkplek | Trainingstijd |
|---|---|---|
| 74 | Runner | 5 |
| 75 | Tafel | 3 |
| 76 | Autobag | 5 |
| 77 | Tapemachine | 2 |
| 78 | Gloeiplug | 1 |
| 79 | GLE | 3 |
| 80 | Brander Deksel | 2 |
| 81 | ESD Workcenter | 3 |
| 82 | Speedypack | 5 |
| 83 | Koffers | 2 |
| 84 | BCM | 1 |
| 85 | Montage | 2 |

Deze overzichten tonen het aantal medewerkers dat maximaal toegewezen kan worden aan iedere werkplek en de tijd die het kost om iemand te trainen voor die werkplek. Dit kan door de gebruiker vastgelegd worden.

Onderstaand overzicht toont de kosten die horen bij het laten werken, aannemen en ontslaan van personeel. Op basis hiervan worden de kosten voor de workforce planning bepaald. De planning zelf is onafhankelijk van de kosten.

| 86 | Kostenposten | Kosten |
|---|---|---|
| 87 | Salaris EP | 100 |
| 88 | Aannamen EP | 0 |
| 89 | Ontslag EP | 4000 |
| 90 | Salaris UZK | 100 |
| 91 | Aannamen UZK | 500 |
| 92 | Ontslag UZK | 0 |
| 93 | Gemiste productie per uur | 10 |

# Gevraagde tijd

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Datum | Runner | Tafel | Autobag | Tapemachine | Gloeiplug | GLE | Brander Deksel | ESD Workcenter | Speedypack | Koffers | BCM | Montage | Totaal |
| 2 | | | | | | | | | | | | | | |
| 3 | 1-03-12 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 |
| 4 | 2-03-12 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 34:29:33 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 34:29:33 |
| 5 | 6-03-12 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 |
| 6 | 7-03-12 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 |
| 7 | 8-03-12 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 |
| 8 | 9-03-12 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 |
| 9 | 12-03-12 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 |
| 10 | 13-03-12 | 0:00:00 | 0:00:00 | 2:09:05 | 0:00:00 | 0:00:00 | 129:35:13 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 131:44:17 |
| 11 | 15-03-12 | 0:00:00 | 0:00:00 | 0:40:12 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:40:12 |
| 12 | 16-03-12 | 2:32:46 | 7:19:25 | 7:19:28 | 19:47:33 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 36:59:11 |
| 13 | 19-03-12 | 3:00:41 | 17:47:20 | 9:49:21 | 0:00:00 | 0:00:00 | 0:00:00 | 6:10:56 | 0:00:00 | 6:49:30 | 0:00:00 | 0:00:00 | 0:00:00 | 43:37:48 |
| 14 | 20-03-12 | 1:59:12 | 0:24:35 | 2:51:39 | 17:31:01 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 0:00:00 | 22:46:27 |
| 15 | 21-03-12 | 2:02:14 | 17:57:24 | 7:26:27 | 0:00:00 | 0:00:00 | 0:00:00 | 27:31:04 | 0:00:00 | 4:11:52 | 0:00:00 | 0:00:00 | 0:00:00 | 59:09:00 |
| 16 | 22-03-12 | 2:24:27 | 7:32:09 | 5:42:59 | 0:00:00 | 0:00:00 | 0:00:00 | 1:42:46 | 5:02:36 | 4:04:21 | 0:00:00 | 0:00:00 | 0:00:00 | 26:29:18 |

De sheet met gevraagde tijd wordt gebruikt om per dag te berekenen hoeveel tijd er van iedere werkplek gevraagd wordt. Deze sheet is puur bedoeld als een tussenstap in het rekenproces van de planning, de gebruiker hoeft hierin dan ook niks aan te passen. De informatie is ook niet nodig om het resultaat van de planning te beoordelen.

# Verdeling Vraag

| | Week | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| functie | maximum aantal medewerkers | 2-3-2012 | 5-3-2012 | 6-3-2012 | 7-3-2012 | 8-3-2012 | 9-3-2012 | 12-3-2012 | 13-3-2012 | 14-3-2012 | 15-3-2012 | 16-3-2012 | 19-3-2012 | 20-3-2012 | 21-3-2012 | 22-3-2012 | |
| Runner | 5 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | |
| Tafel | 6 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 2 | 1 | 1 | 0 | |
| Autobag | 5 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | |
| Tapemachine | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | |
| Gloeiplug | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| GLE | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | |
| Brander Deksel | 3 | 3 | 3 | 3 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 2 | 1 | |
| ESD Workcente | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| Speedypack | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Koffers | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| BCM | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Montage | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | 7 | 7 | 6 | 6 | 4 | 5 | 4 | 5 | 6 | 4 | 5 | 5 | 4 | 4 | 2 | 74 |

De sheet "verdeling vraag" toont bovenstaand overzicht waarin aangegeven wordt hoeveel mensen per dag per werkplek nodig zijn volgens de planning. Een dergelijk overzicht is er voor de gehele afdeling samenstellen als voor ploeg 1 en ploeg 2 apart. Deze overzichten zijn net zoals de sheet "gevraagde tijd" een tussenstap in de berekening. Hierin hoeft dan ook niks veranderd te worden door de gebruiker en deze sheet is niet noodzakelijk om het resultaat van de planning te begrijpen.

# Planning Logica

- De lengte van de werkdag wordt vastgesteld per week. Week 0 (huidige week) is hierbij vooraf door de gebruiker of op basis van de voorgaande week vastgesteld. Voor de weken 1 t/m 3 wordt door de planning een voorstel gedaan. Dit gebeurt als volgt:
  - De werkdag mag hooguit een half uur korter of langer zijn dan de werkdag van de week ervoor (dit zorgt voor stabiliteit in de planning).
  - De werkdag moet minimaal 6 uur duren en mag hooguit 8,5 uur duren.
  - Alle mogelijke opties die aan deze eisen voldoen voor week 1 t/m 3 worden uitgeprobeerd. Er wordt een planning gemaakt op basis van de uren per werkdag en gekeken naar de totale kosten. Deze wordt vergeleken met de kosten van de andere opties. De goedkoopste over de gehele planning horizon wordt geselecteerd.

# Planning Logica

- De dag waarop een taak wordt gepland wordt bepaalt op basis van zowel de leverdatum van de productie order als de totale werkdruk voor iedere werkplek en voor de totale afdeling. Dit gebeurt als volgt:
  - Eerst wordt bepaalt voor iedere werkplek hoeveel uren er nodig zijn en de uiterlijke datum waarop aan die uren voldaan moet zijn.
  - Hieraan wordt het percentage capaciteit toegevoegd dat verwacht wordt dat extra nodig is, maar nog niet zeker is (zie sheets “gegevens”).
  - De orders die al geleverd hadden moeten worden, worden toegevoegd aan de planning, zodat ze zo spoedig mogelijk alsnog afgerond kunnen worden.
  - Wanneer de vraag op een dag voor een werkplek groter is dan geleverd kan worden of de totale vraag die dag groter is dan voorgaande dagen wordt een deel van de werklast naar voren gehaald. Hierbij wordt geprobeerd de werklast zo te verdelen dat alle taken uitgevoerd kunnen worden terwijl de werklast gelijk verdeeld is over de dagen.
  - Wanneer na de vorige stap de vraag op een dag voor een werkplek groter is dan geleverd kan worden, wordt de werklast naar achteren geschoven. Dit resulteert dus in een backlog levering en gebeurt alleen als er geen andere keuze is.
  - Wanneer er sprake is van een ploegendienst word de werklast gelijk verdeeld over de twee ploegen. Dit betekend dus dat de planning ervan uitgaat dat de ploegen ook grofweg gelijk zijn van samenstelling.

# Planning Logica

- Medewerkers worden per dag aan werkplekken toegewezen op basis van de vaardigheden van medewerkers en de vraag naar medewerkers op de verschillende werkplekken. Dit gebeurt als volgt:
  - Voor iedere werkplek wordt vastgestel hoeveel mensen daar kunnen werken en hoeveel mensen er gevraagd worden. Het verschil hierin wordt berekend en daaruit wordt een ranglijst opgebouwd. De werkplek met de kleinste waarde (klein of negatief verschil) krijgt als eerste medewerkers toegewezen. Dit wordt gedaan totdat iedere werkplek voorzien is van medewerkers.
  - Voor iedere werkplek waarop een medewerker kan werken wordt een score van: 1 / het totaal aantal mensen dat op die werkplek kan werken, toegewezen. De totaal score voor iedere werkplek waarop een medewerker kan werken bepaalt de waarde van een medewerker. Voor iedere werkplek wordt een medewerker gezocht met een zo laat mogelijke waarde, die op die werkplek kan werken. Dit zorgt ervoor dat de overgebleven medewerkers een goede kans hebben om aan de overgebleven werkplekken te toegewezen te kunnen worden.
  - Als er geen medewerker meer over is die op een bepaalde werkplek kan functioneren wordt de medewerker met de laagste score uitgekozen om hierin getraind te worden. Dit verhoogt de waarde van de medewerker en verhoogt de flexibiliteit van de afdeling het meest.
  - Medewerkers worden alleen aangenomen als geen van de aanwezige medewerkers beschikbaar is om een taak uit te voeren en een order te laat zou zijn als deze niet uitgevoerd wordt. Daarbij moet er een werkplek zijn waarop hij / zij kan werken en moet hij / zij tijdig getraind kunnen worden om de deadline te halen.

# Planning Logica

- Het kan voorkomen dat een medewerker is toegewezen aan een taak op een dag, maar de dagen ervoor niet. In dit geval wordt deze taak zo ver mogelijk naar voren gehaald in de planning. Dit zorgt ervoor dat deze medewerker eerder vrij komt om andere taken aan te pakken. Voor tijdelijke krachten telt ook dat deze hierdoor niet in dienst blijven omdat ze werk toegewezen hebben gekregen op een latere datum, maar op dat moment zonder zitten.
- De kosten gerelateerd aan de planning worden bepaald op basis van de kosten voor:
  - Aannemen van een medewerker
  - Salaris van een medewerker
  - Ontslaan van een medewerker

  Deze kosten zijn voor zowel vaste krachten als uitzendkrachten apart te bepalen. De kosten worden berekend op basis van het aantal dagen dat een medewerker gedurende de planning periode werkt en of de medewerker al eerder in dienst was of gedurende deze periode aangenomen is. Omdat de planning een eindige horizon gebruikt wordt iedere medewerker aan het einde van de planning periode ontslagen. Hiervoor worden dus de bijbehorende kosten in rekening gebracht.