

OPTIMIZATION OF THE FUTURE CAPACITY OF WORKERS IN A CONSTRUCTION COMPANY

A RESEARCH ON THE OPTIMAL CAPACITY OF STRUKTON CIVIEL NOORD & OOST
IN ORDER TO DOUBLE THEIR MARKET SHARE



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OF TWENTE.



Strukton
Civiel

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Preface

In front of you is the bachelor thesis “Optimization of the future capacity of workers in a construction company”. This thesis has been written to fulfil the bachelor Industrial Engineering and Management at the University of Twente. I was engaged in writing this thesis from April to July 2019.

The study was undertaken at the request of Strukton Civiel Noord & Oost, the company where I undertook an internship. Together with my supervisors, Jan Hendrik Fischer and Roy Postma, we formulated the research question that has been central to this study. My supervisor from the University of Twente, Dr. D.M. Yazan, has also been very helpful to me. Conducting the research was sometimes hard, but by extensive investigation an answer to the question was found. It was very helpful that my supervisors were always available and willing to answer my queries.

I would like to thank my supervisors for the pleasant cooperation and the support I received from them during my graduation process. Besides, I would like to thank all the other employees of Strukton Civiel Noord & Oost that helped me and therefore enabled me to finish this research. Also, I would like to thank my parents and friends who have been very helpful during my graduation period. They helped me debating my issues together. They helped me to keep myself motivated with their wise counsel.

I hope you enjoy your reading.

Dolf Reineman

Enschede, July 21, 2019

Summary

Strukton Civiel Noord & Oost, a construction company, would like to be a major player in the market of concrete roads. In order to do that, the company wants to double its market share. The organization would therefore like to know what their optimal workers capacity would look like when they would do the projects that are needed in order to double their market share. This resulted in the following research question: *What should the workers capacity of Strukton Civiel Noord & Oost be if they want to double their market share?*

To be able to answer this central question, first the context was analyzed and a literature review has been conducted. This formed the basis to compare the current situation to the desired new situation. In order to determine what the capacity should be if the market share is doubled, two scenarios were drafted which represented a double market share. The choice for two scenarios was made in consideration with the company, these scenarios represent a possible future planning in which six different project types emerge. The main difference between the scenarios is that the second scenario includes projects with the project type airport. This project type comes with more risk, because it is more complex. Each project type needs a certain amount of workers and machines. For each project type the exact amount of workers was determined including the function of these workers and which machine was needed. With the help of this information, the daily demand of workers could be calculated. This demand was used for the optimization of the capacity of workers, in which the total costs of labour were minimised. These costs consist of the labour costs of permanent and flex workers. Flex workers can be hired per individual day. To determine the optimal capacity, a model was made. The problem was based on a linear programming model called the multiperiod work scheduling problem. The model included several constraints, of which the most binding concerned the flex layer of two workers. This means that during the scenarios only two extra external workers can be hired if necessary. This model was run in the program Lingo to determine the optimal capacity composition.

This resulted in the following needs in terms of capacity. If the first scenario is realised, then in total ten workers are needed and a flex layer of two workers, which can be hired if needed. For the second scenario, the optimal capacity was determined for a total capacity of sixteen workers and a flex layer of two workers. In both scenarios, two of the total amount of workers should be foremen and two workers should be engine drivers. The rest of the workers should be hand workers.

It can be concluded that, in order to double the market share Strukton Civiel Noord & Oost has to hire more workers. This was determined by comparing the current capacity with the optimal capacities from the scenarios. If the first scenario is followed, then the company should hire one extra engine driver and one extra hand worker. If the second scenario is followed, then the company should hire one extra engine driver and seven extra hand workers. In both cases the company will often do two projects at the same moment. This means that the company has to work with two teams, which can exchange workers if needed. This will increase the occupancy rate, which means that workers are occupied more days from the total days they are hired.

Further research could focus on including other factors for the optimization, such as efficiency and knowledge of workers. In addition, further research could focus on finding a way to determine a more certain scenario. Because the scenarios determine the outcome of the model, thus the optimal capacity. The better the scenario fits the eventual reality, the more the company can benefit from the optimization.

Samenvatting

Strukton Civiel Noord & Oost, een constructiebedrijf, wil graag een grotere speler worden op de markt van betonwegen. Om dit te bereiken, wil het bedrijf haar marktaandeel verdubbelen. Om dit te kunnen doen wil de organisatie graag weten wat haar capaciteit van mensen moet zijn als ze de projecten wil doen om dit marktaandeel te verdubbelen. Dit resulteerde in de volgende onderzoeksvraag: *Wat moet de werkers capaciteit van Strukton Civiel Noord & Oost zijn als ze haar marktaandeel wil verdubbelen?*

Om deze vraag te beantwoorden, is eerst de context geanalyseerd en een literatuuronderzoek uitgevoerd. Dit vormde de basis om de huidige situatie te vergelijken met de gewenste nieuwe situatie. Om vast te stellen wat de capaciteit zou moeten zijn als het marktaandeel wordt verdubbeld, zijn er twee scenario's opgesteld die een verdubbeld marktaandeel vertegenwoordigden. De keuze voor twee scenario's is gemaakt in overleg met het bedrijf, deze scenario's vertegenwoordigen een mogelijke toekomstige planning waarin zes verschillende project typen voorkomen. Het voornaamste verschil tussen het eerste en tweede scenario is dat in het tweede scenario projecten voorkomen met het project type luchthaven. Dit type project kent hogere risico's. De verschillende project typen hebben allemaal een aantal werkers en machines nodig. Voor elk project type was het exact aantal werkers vastgesteld met daarbij de functie van de werkers en de machine die nodig is. Met behulp van deze informatie was de dagelijkse vraag naar werkers vastgesteld. Deze vraag was gebruikt voor de optimalisatie van de capaciteit van werkers, waarin de totale loonkosten werden geminimaliseerd. Deze kosten bestonden uit de loonkosten van vaste werkers en flexwerkers. Flexwerkers kunnen per dag ingehuurd worden. Om de optimale capaciteit vast te stellen, werd een model opgesteld. Dit model was gebaseerd op een lineair programmeer probleem genaamd het *multi-period work scheduling problem*. Dit model bevatte meerdere restricties, waarvan de meeste bepalende restrictie de flexibele laag van twee werkers betrof. Dit betekent dat tijdens de scenario's maximaal twee flexwerkers kunnen worden ingehuurd als die nodig zijn. Dit model werd uitgerekend met het programma Lingo om zo de optimale capaciteit samenstelling vast te stellen.

Dit resulteerde in de volgende behoefte aan capaciteit. Als het eerste scenario wordt gerealiseerd, dan zijn er in totaal 10 vaste werkers nodig en daarbij een flexibele laag van twee werkers, die kunnen worden ingehuurd indien nodig. Voor het tweede scenario, was de optimale capaciteit vastgesteld op een totale capaciteit van zestien werkers en een flexibele laag van twee werkers. In beide scenario's, moeten twee van het totaal aantal werkers voormannen zijn en twee werkers moeten machinist zijn. De rest van de werkers zouden handwerkers moeten zijn.

Het kan geconcludeerd worden dat om het marktaandeel van Strukton Civiel Noord & Oost te verdubbelen er meer werkers moeten worden aangenomen. Dit was vastgesteld door de huidige capaciteit te vergelijken met de optimale capaciteiten van de scenario's. Als het eerste scenario wordt gevolgd, dan zou het bedrijf een extra machinist en een extra handwerker moeten aannemen. Als het tweede scenario wordt gevolgd, dan zou het bedrijf een extra machinist en zeven handwerkers moeten aannemen. In beide gevallen zal het bedrijf vaak twee projecten tegelijk/op hetzelfde moment uitvoeren. Dit betekent dat het bedrijf zal moeten gaan werken met twee teams, waarbij werkers kunnen worden uitgewisseld tussen teams als dit nodig is. Dit zal de bezettingsgraad laten stijgen, wat betekent dat de werkers meer dagen bezet zijn van de dagen dat ze zijn ingehuurd.

Toekomstig onderzoek zou kunnen focussen op het betrekken van andere factoren in de optimalisatie, zoals efficiëntie en kennis van werkers. Daarnaast, zou toekomstig onderzoek zich kunnen focussen op het vinden van een manier om een meer zeker scenario vast te stellen. Omdat het scenario de uitkomst van het model bepaald, dus ook de optimale capaciteit. Hoe beter het scenario de toekomst vertegenwoordigt, hoe meer voordeel het bedrijf heeft van de optimalisatie.

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1. Introduction

In the introduction chapter the company and the reason for starting this project are described. In addition, the identification of the problem is presented. Finally, the research questions are explained.

1.1. Strukton Civiel

Strukton Civiel Noord & Oost is part of the construction company Strukton Civiel. Strukton Civiel is part of the Strukton Group. Strukton Civiel Noord & Oost is focused on the design, realisation, management and maintenance of infrastructural projects. The organization has multiple departments, including road construction. Road construction consists of several services and products, for example high-quality asphaltting, road maintenance, road & energy, tunnels & bridges, groundwork and concrete roads.

Concrete roads are sustainable and economically attractive quality products. Concrete roads do not suffer from material loss. Therefore, less maintenance is needed and a long lifetime of the product can be guaranteed. The concrete for these roads can be 100% recyclable concrete, which fits the idea of a circular economy. The concrete roads also save in lighting costs, because they have a high reflective power. However, the initial costs are higher for concrete roads in comparison with asphalt roads. Still, in the long-term, costs are saved because of fewer maintenance costs. Besides, the construction of concrete roads takes more time than the construction of asphalt roads. The reason for this is, that the weather conditions have a major influence on the construction of concrete roads. For example, concrete roads cannot be constructed during rain or too much sun, because this affects the quality of the end product. However, this is less a problem when constructing asphalt roads. The construction of these concrete roads will be the subject of this project.

1.2. Reason for starting this project

The idea for starting this project is, that the company of Strukton Civiel Noord & Oost would like to become a major player in the market. To achieve this goal, they would like to double their market share in constructing concrete roads from 5% to 10% in the coming years. At this moment they turn over approximately three to four million euros with their projects each year. Within the company they carry out six different projects of making concrete roads. This varies from making bicycle roads to constructing a runway for an airport. These projects are all quite different, but still need the same basis team of workers. To achieve their goal, they have to run more projects in order to get more revenue. But at this moment multiple problems prevent them from doing this. They do not know on which types of projects they have to focus, because every type of project delivers a different amount of revenue and also has different needs in terms of capacity. Their working capacity consists of people and machinery. In the remaining part of this project, working capacity and capacity will be considered the same.

Moreover, they currently do not have enough working capacity to carry out the number of projects needed for doubling their market share. In the future it will be hard to recruit new workers in order to increase their capacity, because the type of work is not popular among people. Next to that, it is difficult to pass on the know-how to the next generation.

1.3. Problem identification

To make the situation clear and to show which problems cause each other a problem cluster was made. These problems, stated in this problem cluster, are placed in a structured way, so that is clear which problem is causing the other problems. The problem cluster helps in finding the core problem, which is the real problem that is going to be solved.

The problems in the cluster are based on the problem list which can be found in Appendix A.

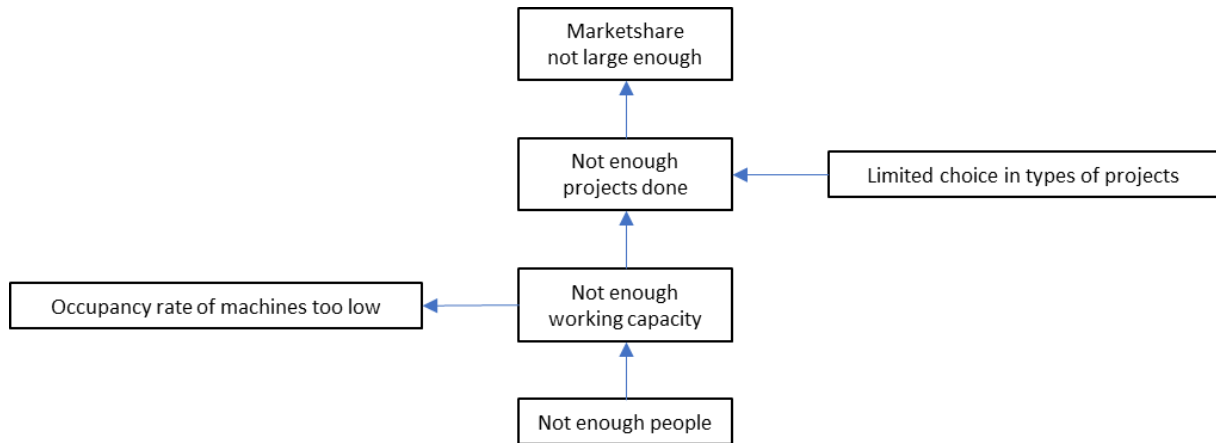


Figure 1: Problem cluster

The core problem:

The company has not enough capacity of workers.

The reason for choosing this as a core problem is, that all the problems of not achieving the market share intended, leads back to having not enough working capacity. Having not enough working capacity is mainly caused by the fact that there are not enough workers available to carry out projects. This problem does not have any causes in the problem cluster and can be influenced. That is why it could be the potential core problem.

As explained before, the company would like to increase their market share from 5% to 10%. To achieve this, the company must carry out more projects. In order to achieve this, the capacity of workers has to be increased, because that is the problem which causes that too few projects are being carried out. Therefore, it is clear that the company needs more workers to increase their market share. The efficiency of the current workers will not be taken into account in this project, because the assumption can be made that these workers already work efficiently and that this cannot be improved. This assumption was made in consultation with the company.

So the company has to increase the capacity from their current capacity to the capacity which can carry out the number of projects needed for a 10% market share. The proper compositions of the capacities have to be determined in order to know the reality and the standard. In other words, the current capacity and what it should be. What it should be will be determined based on the required standard of the market share, which is 10%. The 10% market share is equal to double the projects of the previous year. This item was discussed with the company.

1.4. Research questions

To approach this core problem, knowledge is needed to answer the following research question: *What should the workers capacity of Strukton Civiel Noord & Oost be if they want to double their market share?* To be able to answer this question, the following knowledge questions are made, which are shown below.

- What is the capacity demand of each type of project?
- What is the current capacity?
- Which projects have to be carried out in the future to achieve the 10% market share?

2. Context

In this chapter the current situation and the problem approach are described. First the problem approach is described and next the current situation is described using the planning process in general, the current capacity and the capacity demand per project type. In addition, a description of the market is given.

2.1. The problem approach

The problem approach is described in order to give a better explanation of the actions that are performed to solve the problem. This will help understanding the purpose of the following chapters.

The problem approach consists of several steps to solve the problem. First, the capacity demands per project type was determined. This was needed to calculate the capacity demand during a period of time. Next, the current capacity had to be mapped, to understand what the capacity was.

Besides that, a scenario was needed which showed what type of projects could be carried out during a certain period in the future, aiming at a double market share. Based on that the capacity had to be determined. Together with the company, two scenarios were drafted that represented a slightly different planning with different project types. However, these scenarios represented a comparable market share of 10%.

Then the scenarios were used to determine the daily demand. This was done by joining the information from the first step and the capacity demand per project type with the project type that was planned in the scenarios. With the help of these scenarios the optimal capacity was determined for each scenario. The optimal capacity includes the minimisation of costs and taking into account the costs of workers. The optimal capacity was determined with an optimization method. Then the final step was to compare the current capacity with the optimal capacity for the scenarios. This was done to indicate what kind of extra workers was required for achieving the company's goal in the case of the scenarios. Besides, the occupancy rate was calculated to get an insight in the amount of days that workers are occupied in comparison with the amount of days they are hired.

2.2. The planning process

The planning process describes how the projects are selected and scheduled into a planning. The projects are offered on the open market and through private invitations by a lot of different organizations such as municipalities, provinces and contractors. All of these projects have different requirements such as the duration, the needs in terms of capacity and moment of completion. Moreover, the projects are offered at unpredictable moments.

This offer has a description of a project which explains what has to be done under what conditions. The manager of the concrete roads decides which projects are selected from the offer on the market and the private invitations, based on the project description. This selection is made while taking into account the strategy, the potential revenue, the availability of the capacity and the planning.

Then the project offer is calculated by a person named “the calculator”. This person makes an offer for what price the project could be carried out. The project is acquired when the offer has the lowest price compared to the other offers from competing companies.

When the project is acquired it is scheduled into the planning. This planning is often not fixed, because other projects are also trying to be fitted into the planning which are offered later on the market. These offers are still selected, because those projects are still attractive and are feasible to schedule and carry out. For this reason, the planning has to be changed frequently. Moreover, other factors also influence the planning. As explained before, the weather conditions affect the construction of concrete roads.

When a project is scheduled on a day with bad weather conditions like rain, the project gets delayed and this could affect the planning. Consequently, projects have to be rescheduled. Another reason for rescheduling is that sometimes projects are part of a larger main project and this project determines the moment of construction. This date is often known, but when the main project is delayed it can affect the moment that the smaller project has to be carried out. This may lead to the rescheduling of projects.

2.3. The current capacity

The current capacity is described as the workers and machinery that the company has at their disposal currently. At this moment the company has one team who carries out projects. The composition of the team consists of two foremen, an engine driver and five hand workers.

The foreman is the person in charge at the location of the project. He can also contribute to the work in the same way as a hand worker could do. There is always one foreman at the project. The team consists of two foremen and one of them functions temporarily as a hand worker.

The engine driver controls the machinery and when there is no machinery needed for the project, he functions as a hand worker. The five hand workers carry out several tasks such as encasing, pouring concrete, digging concrete, striking pens and finishing the saw lines.

There are three different machines needed for projects are described below.

The first machine is called the “SP15”, this paving machine is used for line constructions. These line constructions are needed for projects where constructions such as roadside concrete, curbs and barriers are constructed.

The second machine that is used is the “SMGE” or the “MSP50”. This machine is used for the construction of entire roads or so-called pavement constructions. The machine is needed at the projects where bicycle roads, roads and barriers are constructed. This machine is used for pavements with a width up to 5 meters.

The third machine is the “SP1600”. This machine is used for the construction of roads at airports, highways and wide terrain pavements. This machine can only be used for pavements that are between 5 and 16 meters wide.

2.4. The capacity demand per project type

The capacity demand per project type describes the amount of workers and machinery needed for a certain project type. The projects that are carried out by the company can be classified as six different types of projects. These types are described below and also the capacity demand of these project types are described. Besides, the risk level of the project types is described. With risk level is meant that the risk to carry out a project properly and that as a consequence the financial result of that project is most likely good. If the risk is high, the potential profitability of the project is often high, but so is the chance of loss.

Handwork

Handwork is the project type that includes all the projects which are carried out by hand and projects where the team is hired to other companies. An example of this handwork is print concrete, which is applied by hand workers. In both cases the same amount of workers is needed, which is one foreman and five hand workers. In every project type, at least some hand work is executed. This project type has a low risk level.

Roadside concrete

The project type for roadside concrete is meant for the projects where only roadside concrete is constructed, which is a form of a line construction. The capacity demand for this type of project is one foreman, three hand workers and one engine driver. However, when constructing roadside concrete, the machine “SP15” is needed. This project type has a low risk level.

Curbs

The project type curbs is for all the projects where a line construction is constructed except roadside concrete. Not only is it a different project, it also demands a different capacity. Within the project type curbs, curbs of projects can have different shapes but the same amount of workers is needed and the machine “SP15” is needed. For this type of project one foreman, four hand workers and one engine driver are needed. This project type has a low risk level.

Bicycle roads

The project type for bicycle roads contains all the projects where bicycle roads and pavements with similar capacity demands are constructed, such as barriers and roads with a width of 2 meters or more. The roads constructed within these projects can have different widths and for this reason two types of machines can be used, the “SP15” and the “SGME”. The choice of machine depends on the width of the road. The “SP15” is used for roads with a width up to 2 meters and from 2 meters and wider the “SGME” is used. The workers needed for this type of project are one foreman, four hand workers and one engine driver. In the planning of the previous year, only an “SGME” machine was used. Therefore, the assumption is made in the scenarios that the capacity demand of bicycle roads includes an “SGME”. This project type has an average risk level.

Roundabout

The project type for a roundabout includes all the projects where roundabouts are constructed. This construction process consists of a lot of different tasks which are similar to the projects from different project types. During the construction of a roundabout, roads and curbs are constructed. That is why the demand for capacity changes during the project. The project type for a roundabout is the part of the project where the actual roundabout is constructed, which is done by hand. Therefore, the capacity demand for this project type is one foreman and five hand workers. The other parts of constructing a roundabout are described with the other project types. This project type has a high risk level.

Airport

The project type for an airport is for the projects where wide roads on airports are constructed. This project type requires a lot of workers in comparison to other project types. The capacity needed for this project type is one foreman, ten hand workers and an engine driver. For this construction the “SP1600” is needed. This project type has a very high risk level.

Below a table is provided with an overview of the capacity demand per project type. Besides, an extra column is added with the risk level.

Table 2: The capacity demand per project type

Type of project	Nr of foremen	Nr of hand workers	Nr of engine drivers	Type of machine	Risk level
Handwork	1	5	-	-	Low
Roadside concrete	1	3	1	SP15	Low
Curbs	1	4	1	SP15	Low
Bicycle roads	1	4	1	SGME or (SP15)	Average
Roundabout	1	5	-	-	High
Airport	1	10	1	SP1600	Very High

3. Literature review

In this chapter, three important subjects and the intention for this project will be discussed. This is done by using literature. The three subjects are optimization in construction, linear optimization and team formation.

3.1. Optimization in construction

The construction industry is a project-based industry in which effective project scheduling is a challenging task for the construction project management. Optimization is used to effectively schedule these projects. Optimization in construction can focus on a lot of different objectives or even multiple objectives at the same time. The objective of the optimization influences the choice in optimization technique. Next to that the specific situation does also determine what kind of optimization method has to be applied for. Therefore, some examples of the most common optimization problems and commonly used techniques are described below (Kandil, El-rayes, & El-Anwar, 2010).

The first one is resource levelling. In this optimization problem the objective is to minimize the fluctuation in resource usage. This avoids that employees have to be hired or fired, which affects the morale of employees and causes that the benefits of learning and training acquired by employees over time, cannot be used. By minimizing these fluctuations, costs are saved because the productivity of employees is higher and the morale of employees is improved. The difficulty of this problem is that the resource demand of an organization has to be made as uniform as possible and that this predetermined distribution of resource utilization has to be followed in order to meet the project deadlines. Next to that there is the possibility that the resource demand can vary during a period, which makes the problem even more difficult. Another problem can be that the resource demand cannot be satisfied because there are no employees available (Senounci & Eldin, 2004).

The second one is a time-cost optimization problem. The objective is to minimize the total project costs by scheduling the activities of a project in the most optimal schedule. For example, if the duration of a project is made shorter by scheduling, then the direct costs will increase because the same work has to be done faster and consequently additional resources may be needed. But in return the indirect costs will reduce since the duration of the project will be reduced. Besides, there are often constraints that have to be taken into account. An example is that a project has to be finished in a certain amount of time (Veludurthi, Anup, & Sridevi, 2017).

The third one is resource allocation, which looks similar to resource scheduling. Resource allocation is sometimes referred to as constrained-resource scheduling. In this problem a limited amount of resources has to be assigned among several activities (Winston, 2004). Therefore, the objective of resource allocation is to schedule the project activities in a way that a constrained number of resources is used most efficiently, while keeping the duration of a project reasonable. Because using fewer resources, often results in an extension of the duration. That is why this extension has to be kept minimal (Hegazy, 1999).

The fourth one is a combination of the previous optimization problems mentioned. The objective is to optimize construction problems, while taking into account multiple and sometimes conflicting objectives. For example, if the construction costs and time have to be minimized, while the resources utilisation has to be minimal, a trade-off has to be made. This type of problem is more difficult to solve but does often reflect better a real-life construction problem, since this problem takes more objectives into account (Kandil, El-rayes, & El-Anwar, 2010).

There are three types of techniques which are used to solve these optimization problems, which are the heuristic method, the mathematical methods and the evolutionary methods (Veludurthi, Anup, & Sridevi, 2017).

The first technique that had been applied to solve these problems traditionally, is the critical path method (CPM) which is a heuristic method. This technique is easy to understand and to implement but it has serious limitations, for example, it assumes unlimited resources which is very difficult to optimize if a project is more complex. Next to that, this technique often finds a near optimal solution instead of finding the global optimal solution (Veludurthi, Anup, & Sridevi, 2017) (Leu, Yang, & Huang, 2000).

The second technique which is used, are the mathematical methods. These methods are for example linear programming, integer programming, dynamic programming. The methods can find the exact optimal solution but it has complex formulas (Veludurthi, Anup, & Sridevi, 2017). Next to that, this technique has the disadvantage that it cannot solve large and complex problems effectively (Leu, Yang, & Huang, 2000).

The third technique is the genetic algorithm (GA), which is an evolutionary method (Veludurthi, Anup, & Sridevi, 2017). It simulates the evolution process of “survival of the fittest”. The algorithm compares strings on fitness with each other. These strings represent potential solutions and consist of values for the decision variables. The fitness of a string is determined by the performance of the string on the objective function (Senounci & Eldin, 2004). The genetic algorithm consists of three operations. The first operation is the reproduction operation. In this operation the strings get a chance of survival based on their fitness, so that the best strings get reproduced for the next generation. This reproduction does not change the values of the strings, which become parent strings in the next generation. The second and third operations create offsprings from the parent strings by changing values from the parent strings. The second operation is called crossover. In this process the parent string is broken into parts and the parts are exchanged with other parts from another parent string. This leads to offsprings and so to new solutions. These strings are compared to the parent strings to check if these strings are more fit. The third operation that is performed is mutation. In this operation parent strings are randomly changed. This means that values of parent strings are changed when passed on to the offsprings in the next generation. In this way new values are created which did not exist in the parent strings. This operation explores new solution areas which potentiality could have better solutions. This process of “survival of the fittest” is repeated multiple times to eventually find the optimal solution (Hegazy, 1999) (Senounci & Eldin, 2004).

The genetic algorithm is an effective technique for determining an optimal solution when the problem domain is large and can do this for linear and nonlinear problems (Senounci & Eldin, 2004).

3.2. Linear optimization

Linear optimization is often called as linear programming and can be considered the same during the remaining part of this project. Linear programming is a technique for solving optimization problems. An optimization problem is to find the best option from all possibilities in order to maximize or minimize the value of a function (Winston, 2004).

Linear programming is applied to optimization problems which are linear, or so-called linear programming problems. A linear programming problem consist of three elements and can be described as (Winston, 2004, p. 112):

1. A linear function of the decision variables which is maximized or minimized. This function is named the objective function. The decision variables describe the decisions that can be made and is often in the form of $X_1, X_2, \dots, X_n$.
2. A set of constraints that restrict the values of the decision variables that can be assumed. All of the constraints have to be a linear equality or linear inequality.
3. The sign restrictions, which describes if it can only assume nonnegative values for each decision variable, what causes that a sign restriction is added, which is shown as $x_1 \geq 0$. Or that a decision variable may be positive, negative or zero which causes that it is unrestricted in sign (urs).

The objective function consists of the decision variables, which have a coefficient called the objective function coefficient. This represents for example the profit or cost for each variable.

There are many different linear programming problems which require different linear programming models in order to solve them. An important type of a linear programming problem for this project is the multiperiod work scheduling problem (Winston, 2004).

The multiperiod work scheduling is focused on scheduling employees in case a company encounters a changing demand for time. Linear programming is used to minimize the costs of labour for this changing demand. In order to draft this linear programming model some additional steps have to be made.

First the decision variables are determined. However, these decision variables have an additional aspect and that is that the time has to be taken into account. So not only the value of the decision variable is important, but also during which period this decision variable has its value. This results in the following decision variable.

$$x_t = \text{value of decision variable during period } t \quad (t = 1, 2, \dots, n)$$

Next to that stating additional constraints is needed. The decision variables have to satisfy the different demands of the periods. This has to be included in the constraints. An example of a changing demand is shown below, where the demand changes from ten to eight over a period.

$$X_1 + Y_1 \geq 10$$

$$X_2 + Y_2 \geq 8$$

These constraints have to connect variables of different periods, because, sometimes a choice which is made for a decision variable in a period, affects the value of a decision variable in another period. An example of this constraint is given below where a decision variable in one period stays equal in the next period.

$$X_t = X_{t+1}$$

3.3. Team formation in construction

The construction industry is a very dynamic and complex industry according to Raiden, Dainty, and Neale (2004). The industry is project-based with almost each project being different, because the projects are custom-built and have to satisfy the specifications of the client. This results in a fluctuating workload for organizations, because projects have different needs. These fluctuations cause that the need for employees can change significantly. Not only the volume of employees needed can change, but also their skills required. Therefore, the formation of teams changes regularly when a new project is accepted. As a consequence, teams have to form, develop and disband relatively quickly. This makes that effective human resource management is hard to realise. Baiden, Price, and Dainty (2006) also suggest that the composition of teams have to be formed in a way that team members can be brought in or removed from teams if necessary. This way of efficient use of human resources, can contribute to an improved team effectiveness.

In team formation it is important to select team members on the basis of their personality and skills in order to have an effective team. However, the specific skills that are required differ per project and sometimes even within the duration of a single project. Individual employees with important skills might be needed in more than one project at the time. But one should be careful with replacing employees. Raiden, Dainty, and Neale (2004) state, that the performance of teams can be disrupted by changing the formation of teams, especially when key project members are replaced or removed from teams. Therefore, effective Human Resource Management is needed to handle this dynamic project-based context.

Currently, the complex task of human resource management and in particular team formation is often executed by senior managers, based on subjective decision-making and reactive processes. A reason for this is, that they are often not fully informed due to not having access to all the information required for making the deployment judgements.

In order to solve this problem, so that more effective employee resourcing decision-making can be done, two things have to be changed. The opinions and needs of employees have to be incorporated in the decision-making process. This requires a cultural/attitudinal change in the decision-making process since this is currently management-oriented decision process. Besides, a decision-support mechanism is needed. This mechanism should provide all information needed about the human resources. This data should be easily available, for example with an integrated database.

4. Methodology

In this chapter it is described how the research is performed in order to get an answer on the question what the capacity should be. In this research, quantitative and qualitative research is performed. The data collection, the research progress and the data analysis are described. Next to that, the scenario setting, scenario analysis and the optimization model are described.

4.1. Research design

Data collection

The data for this study were collected with three methods: literature research, face-to-face interviews and document analysis.

The literature research focused on the three subjects: optimization in construction, linear optimization and team formation. Information about linear optimization was obtained from the book operations research (Winston, 2004). Scientific articles had been used to collect data about the two other subjects. These articles were found by using Google Scholar. For the literature research only articles were used which are peer reviewed.

The face-to-face interviews were held among employees of the company to gather data about several topics. For these interviews only employees were interviewed who were involved in the scheduling and management of the projects, because they make the decisions about the planning and allocation of the resources.

The topics were focused on acquiring knowledge about the background of the company, the current capacity of the company, the capacity demand per project type and the scenarios for the future demand.

During the face-to-face interviews, minutes had been made, because often a lot of information was provided at the same time. Sometimes the data were too complex or simply too much to write down or could not be provided at that moment. Then a document was provided afterwards and a document analysis was performed to collect the data.

Research progress

The design of the research was to have face-to-face interviews among the Strukton Civiel Noord & Oost employees who were involved in the scheduling and management of projects. All these employees were available to be interviewed at different moments and this was done at the office.

Most of the questions were answered during the interview and the answers were recorded. If the provided information was too complex, too much or could not be provided orally because it had to be looked up, the information was provided afterwards by way of a document. This was often the case when quantitative data had to be provided, which mostly occurred in data about the current capacity, the capacity demand per project type and the scenarios for the future. This data had then been retrieved by conducting a document analysis.

Data analysis

Before the data could be analysed, they had to be processed into Excel. A part of the data, which contains information about the planning of previous years, was used to draft the scenarios for the future demand of the company. These scenarios are needed for the optimization. How these scenarios are constructed, will be explained in chapter 4.2 The scenarios are then analysed in Excel with the help of the other data to create an overview about the capacity demand in future. This results in data which can be used for the optimization. The optimization method will be explained in chapter 4.4.

4.2. Scenario drafting

In this chapter, two scenarios are drafted to get an overview of the capacity demand of workers in the future which can be used for the optimization. These scenarios represent a possible future planning for the company.

The scenarios are based on the face-to-face interviews and the data of the planning of the previous years. Data of the previous years are used, because these reflect the strategy of the company and moreover, there are no other data available to use. The planning of the previous year contains the projects which were chosen based on their strategy and of which the acquisition of the projects had been successful. These types of projects are more likely to be acquired in the future than other types of projects, since they already succeeded in doing this before.

The planning method of projects used by the company is complex and has, for several reasons, no clear defined system. Therefore, it is hard to use the planning method to draft the scenarios and this method will not be used. As explained in chapter 2.2, the company tries to fill the planning with projects in order to get their revenue desired. Projects are selected based on their description of the offer from the market and from private invitations, while taking into account the strategy, potential revenue, the availability of workers and the planning.

Again, as explained in chapter 2.2, the projects which are offered are very difficult to predict. Besides the content, needs in terms of capacity and moment of completion are also difficult to estimate. Moreover, projects still have to be acquired, which often depends on the involvement of other companies as well. This contributes to the fact that it is difficult to predict which projects the company will acquire. Therefore, data about the project offer from the market of previous years, are not used since this does not determine the future project offer from the market. Due to the fact that the future offer from the market is not predictable, the planning method cannot be used to draft the scenarios.

The first scenario is drafted in the following way. In last year's planning the projects are doubled, so that the same type of projects is carried out twice at the same time. The reason for this is, that last year's planning reflects the current market share of which the company intends to double under the same strategy. But not all of the projects can be doubled, because they are limited by the fact that the company does not want to change the amount of machines. There are no other constraints which had to be taken into account, according to the company. To cope with the limited amount of the machines, the following way of scenario drafting is being used.

The first scenario is drafted by doubling last year's planning and scheduling all of the duplicated projects two weeks later than the original projects. This is done to prevent the direct overlap of projects in need of the same machine. The two weeks' delay is based on the project with the longest duration. Then, in order to prevent the direct overlap, all projects had to be postponed for two weeks. The projects which had been scheduled in the last two weeks of the calendar year, are placed in the first two weeks, because otherwise, these projects exceeded the period in which projects could be carried out. By delaying all projects for two weeks, the composition of projects which had been acquired during the previous year, stayed the same.

Not changing the composition of the projects was important, because this reflects the strategy and the acquisition of the company. The project names are replaced by numbers and only the project types are described in the planning due to confidentiality, according to the company. The type of projects that are used in the planning are the same project types as described in chapter 2.4. These first steps that were taken are shown in Appendix B.

The next step was to make the planning feasible, because some projects still overlapped with their capacity demand of the same machine or were planned during holidays. For example, projects lasting two weeks and scheduled before the holidays, had been planned during holidays due to a delay of other projects. To solve this, the projects that could not be carried out at the same moment due to the fact that they required the same machine or the ones that were planned during holidays, had to be rescheduled. These are coloured in the planning.

Rescheduling of projects is used, because during the previous planning, rescheduling was already used in order to make the planning feasible for changes such as new projects or delays, as explained in chapter 2.2. Therefore, rescheduling is used again, to make the scenario feasible because it is similar to the approach that was normally used.

The rescheduling of the projects had been done in two ways: projects were swapped with projects that did not require the same machine or projects were rescheduled to moments which were open in the planning. These actions were performed in the following way. The projects were checked on the ones that overlapped or were planned during holidays, starting at the beginning and working up to the end of the planning. The first project that had to be rescheduled was immediately swapped with the closest possibility that appeared in the planning. This means that the project was swapped with the closest project in the planning that did not exceed the constraints or was moved to the closest open space in the planning. The choice for the closest possible project or open space was made to have the least influence on the execution of a project. Again, this was done while making merely slight changes in the composition of projects. Therefore, the projects were not simply replaced by projects that could fit in easily. In line with this consideration, project 8 was rescheduled before project 6 was rescheduled, since this meant that project 8 would only have to be moved for one day.

Then the next project that had to be rescheduled was swapped or moved in order to make the planning feasible. This was repeated until the entire planning was feasible and met the constraint of one machine and holidays. All projects were swapped or moved as a whole, because in reality that would be more likely or else parts of projects would possibly be spread throughout the planning. Projects are also swapped or moved at most once, in order to limit the impact of the rescheduling. The final scenario that has been established after performing the steps described (Table 3), is shown in Appendix C.

Table 3: Rescheduling actions

Project nr	Action
1	project 1 is moved 28 days earlier
4	project 4 is moved 9 days earlier
6	project 6 is moved 36 days earlier
8	project 8 is moved one day later
9	project 9 is swapped with project 15
13	project 13 is swapped with project 10
14	project 14 is swapped with project 20
26	project 28 is moved 24 days later
28	project 29 is moved 14 days later
29	project 30 is moved 21 days later
32	project 33 is swapped with project 31
34	project 35 is swapped with project 36

The second scenario, which represents a possible future planning, includes a project with the project type airport, made in consultation with the company. This scenario was made to show the effects on the capacity demands when a project with the project type airport is acquired. In the scenario other projects also have to be carried out next to the project with the project type airport, because in reality this would also likely be the case.

The second scenario was drafted by replacing projects from the first scenario with the project type airport. This was done to maintain the composition of projects and the period when projects are planned. The projects after the construction holidays are replaced by the project of type airport. The choice for this moment is based on the current year planning, because the project of type airport is also planned in that period. The projects that are replaced are the projects with the numbers 28 to 37.

The final scenario that has been drafted after the replacement of the projects can be found in Appendix D.

4.3. Scenario analysis

The scenarios are analysed in Excel using the data of the capacity demand per project type from table 2. Each project type on every day, was coupled to its belonging capacity demand. This resulted in an overview of the capacity demand per day.

From the data it can be retrieved that often, two projects are carried out on the same day, which in reality most certainly would not take place on the same location. Therefore, two teams are needed. So, when the project is doubled, the left side of the planning is done by one team and the right side is done by another team. Moreover, the data show that on each day only one machine of each type is needed, so the rescheduling managed to solve the problem of overlap.

In the overview of the capacity demand per day, the capacity demand of both projects on the same day are added. The reason for this is, that the teams can exchange workers among each other if needed and so the composition of the teams is not fixed. Therefore, only the total capacity demand is of importance.

The only fixed thing is, that each team should have a foreman and an engine driver. Should the engine driver not be needed, he can function as a hand worker and could even be exchanged to the other team if necessary. The same applies to a foreman in case that only one project is carried out. So, if only one foreman is needed, the other foreman can function as a hand worker. Therefore, at least two foremen and two engine drivers are needed in the total capacity.

The overview of the capacity demand per day for the first scenario, is shown in Appendix E and for the second scenario in Appendix F. The overviews will be used as a source of information for the optimization model, which will be described in the next chapter.

4.4. Optimization model

The purpose of the optimization model is to calculate what the optimal composition of permanent and flex workers should be during a year while meeting the capacity demand for a certain scenario. The composition is determined by minimizing the total cost of employment of permanent and flex workers. This will describe how much workers are needed and what the ratio will be.

The optimization model was drafted using the literature about linear optimization and the multiperiod work scheduling problem from chapter 3.2. Next to that in the model, the data from the scenario analysis is used.

The model was drafted according to the same three elements as described in chapter 3.2. First the objective function was established. The objective function is the total labour costs of permanent and flex workers.

In the objective function the decision variables are the amount of permanent workers and the amount of flex workers. The decision variable of the amount of permanent workers is defined with X . The decision variables of the amount of flex workers are defined with Y_t , because the day that they are hired is also of importance. This is not the case for the permanent workers because they are hired for the entire year. This leads to the following decision variables:

$X =$ the amount of permanent workers

$Y_t =$ the amount of flex workers on day t (for $t = 1, 2, 3 \dots 220$)

Next to that, in this step information about the labour costs was used since this has to be optimized. The labour costs of workers are the coefficients in the objective function. The labour costs of a permanent worker are given on a yearly basis since the company hires a person for one year, so also has to pay him for one year. The labour costs for a flex worker are given on a daily basis since the company can hire a person for one day and only have to pay him for that day. This resulted in the following objective function:

$$\text{Min } z = 125400X + 520 \sum_{t=1}^{220} Y_t$$

The second step was to add the constraints to the model. These constraints are based on the scenario analysis because the information from that determines what the capacity demand of each day is. So each day the total amount of workers, which is optimized in the objective function have to meet the capacity demands of that day. The amount of workers needed on a day is described with D_t . This resulted in the following constraint:

$$X + Y_t \geq D_t \text{ (for } t = 1, 2, 3, \dots, 220)$$

In this constraint, D_t means the demand per day. But since there are two scenarios this constraint is changed into the demands of each scenario. The demand always has to be met. So, the total capacity should be higher or equal to the demand. The value for D_t is retrieved from the data from the scenario analysis.

Besides, the amount of flex workers available during the period of the scenario is limited to two flex workers, because there are no more flex workers available at that moment. This constraint was drafted in consideration with the company. This resulted in the following constraint:

$$Y_t \leq 2 \text{ (for } t = 1, 2, 3, \dots, 220)$$

The third step was to add the sign restrictions. In this model, the decision variables can only assume nonnegative values. The reason for this is that the company cannot have a minus one worker for instance. Therefore, the following sign restriction was made:

$$X, Y_t \geq 0 \text{ (for } t = 1, 2, 3, \dots, 220)$$

The final model in which all of the three steps are included is shown below in figure 2. This model was run by the program Lingo. The model had to be adapted to the program in order to let the model run, this Lingo model is shown in Appendix G. The Lingo model is the same for both scenarios, except the input values are different. The input values of the required capacity are different for both scenarios, so this is changed in the Lingo model. The Lingo model itself is not changed.

$$\begin{aligned} \text{Min } z &= 125400X + 520 \sum_{t=1}^{220} Y_t \\ \text{s.t.} \\ X + Y_t &\geq D_t \text{ (for } t = 1, 2, 3, \dots, 220) \\ Y_t &\leq 2 \text{ (for } t = 1, 2, 3, \dots, 220) \\ X, Y_t &\geq 0 \text{ (for } t = 1, 2, 3, \dots, 220) \end{aligned}$$

Figure 2: The optimization model

Besides, the occupancy rates will be determined to give an insight in the occupation of the permanent workers under the scenarios. The occupancy rate is also calculated for the previous year, so this could be compared.

This will be done by calculating the weighted average, which is the sum of the different amount of permanent workers times the days that this amount of workers is occupied. This number is then divided by the total capacity of permanent workers times the amount of days they are hired.

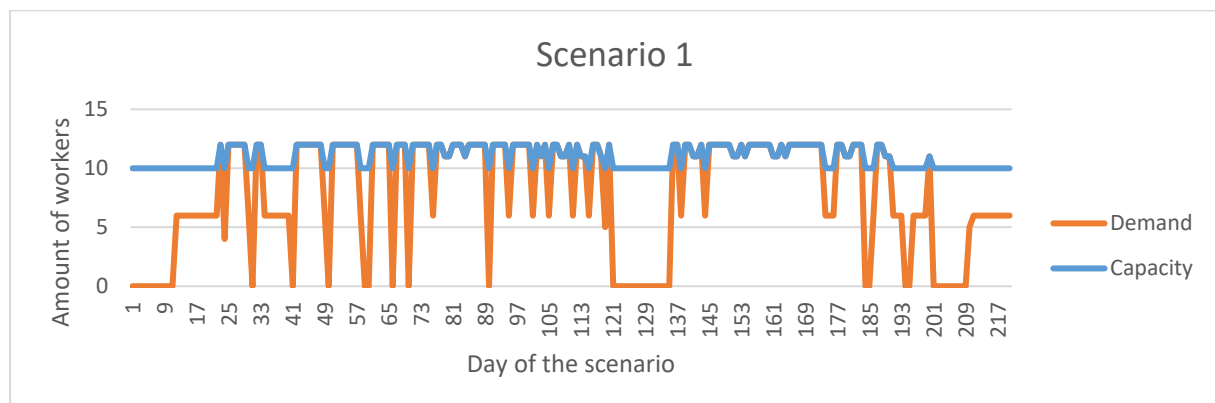
5. Results

The optimal capacity was determined by running the optimization model for each scenario in the program Lingo.

From the objective function could be deducted that, the preference for choosing a permanent or flex worker, was always a flex worker. The reason for this is, that a flex worker is cheaper, even when he is hired for a whole year as in the case of a permanent worker. Therefore, the use of a flex worker is always preferred if based on labour costs, since you can hire the worker only when needed. This was confirmed by the outcome of the Lingo model. This means that the constraint of the amount of flex workers available, determines the outcome of the model, thus the composition of the total capacity. The total capacity has to meet the capacity demand and therefore, the total capacity demand minus the amount flex workers, determines the amount of permanent workers. As explained before, the permanent workers are hired for the whole year. The capacity demand always has to be met, so when a permanent worker is needed for a day, he is hired a whole year. Therefore, the highest capacity demand in a year, determines the amount of permanent workers for the whole year, because on that day the demand has to be met too. The preference is a flex worker, thus the total capacity demand is met by hiring the most flex workers as possible, which is two. The rest of the demand has to be met by employing the permanent workers. These workers are then hired, which means that they are hired for the whole year.

For the first scenario the optimal capacity was determined on 10 permanent workers and a flex layer of two workers. The flex layer can be used if needed, for example, if eleven workers are needed then one flex worker can be hired. The composition of this capacity should consist of two foremen, six hand workers and two engine drivers. This is the composition with the minimal costs, but which is still able to meet the capacity demand of the projects for this scenario.

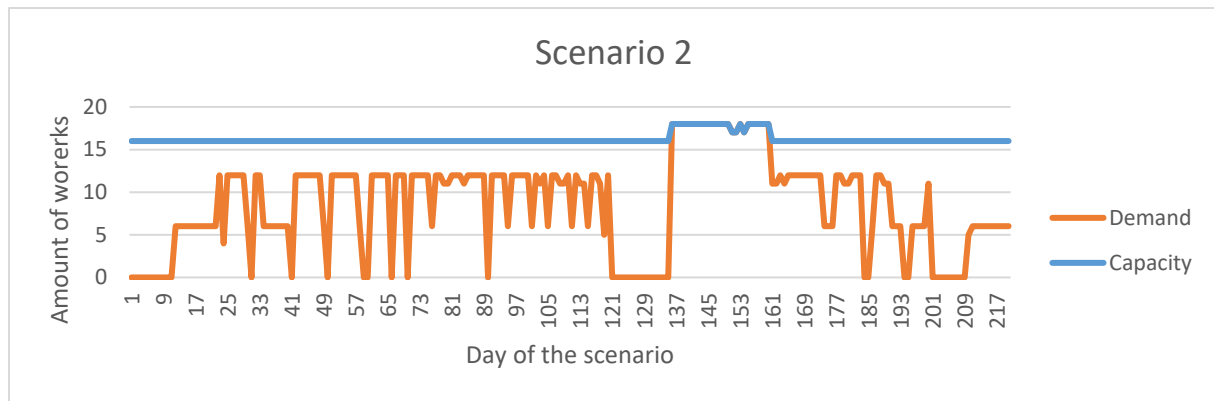
To show that the capacity demand had always been met, a graph was made. Graph 1 shows the demand on each day for a scenario and a line which represents the capacity of the company.



Graph 1: Scenario 1, Capacity demand per day

For the second scenario the optimal capacity was determined on sixteen permanent workers and a flex layer of two workers. The composition of this capacity should consist of two foremen, twelve hand workers and two engine drivers. Again here, the composition with the minimal costs is determined for this scenario.

Also, for this demand a graph was made in order to show that the capacity demand has been met. This is shown in graph 2.



Graph 2: Scenario 2, Capacity demand per day

Besides, the occupancy rates were calculated. The occupancy rate of the first scenario is 69.1%. The occupancy rate of the second scenario is 59,5%. The occupancy rate of the planning of the previous year was 47.0%.

6. Conclusion, discussion and recommendations

In this research, the question *‘What should the workers capacity of Strukton Civiel Noord & Oost be if they want to double their market share?’* was central. The two scenarios that were drafted in this research had different outcomes on what the capacity should be. The difference between the scenarios is, that in the second scenario the project type airport is included. This results, in combination with the normal capacity demand, in that the total capacity demand is eighteen workers. This number is higher compared to the twelve workers needed in the first scenario in which the project type airport was not included. So, the project type airport causes that more workers are needed. It can be concluded that in order to double the market share, which was represented by the scenarios, twelve or eighteen workers are needed depending on the scenarios.

This means that for the scenarios, ten or sixteen permanent workers are needed, because the other two workers can be hired as flex workers if needed. In both scenarios, the composition of the capacity should consist of two foremen and two engine drivers.

At this moment their current capacity is eight workers. The current composition of this team consists of two foremen, an engine driver and five hand workers. The current capacity and the required capacity differ from each other.

To solve this, the company needs one extra engine driver and one extra hand worker in the case of the first scenario. In the case of the second scenario, the company needs one extra engine driver and seven extra hand workers. The other extra two hand workers are covered by the flex layer and can be hired if needed. This total capacity will be used to form two teams, which can exchange workers if needed.

This result corresponded with the expectation that more workers are needed in order to attain the desired market share. At the same time, the expectation was, that two teams are needed, which corresponded with the result. The result also corresponded with the preference for flex workers as was described in the model. The expectation that the possibility to exchange workers between teams would lead to a more optimal solution was also right. The explanation for two teams is logical. Two projects are executed at the same moment, but at different locations. This makes that two teams are needed.

In addition, the occupancy rates were calculated to get an insight in the amount of time the hired workers actually are occupied by executing projects. To calculate this, the average was used. The occupancy rate of the second scenario is lower than the occupancy rate of the first scenario. So, by including the project type airport, the occupancy rate is lower in the case of these scenarios. Nevertheless, the occupancy rate of both scenarios is higher than the occupancy rate of the planning of the previous year, which was 47.0%.

For this research, scenarios were drafted according to specific steps. These scenarios were analysed to determine the possible future demand of workers per day. An optimization model was made to determine the optimal capacity by minimising the cost of labour, based on the scenarios. This model was drafted using the same method to draft a multiperiod work scheduling model as described in the literature. The other data was obtained with face-to-face interviews. Based on this it could be stated that if this research would be repeated, the results would be the same and that consequently the results of the research would be valid.

Contribution

The theoretical contribution of this research is, that the research shows that the multiperiod work scheduling problem can also be applied in the construction sector. This sector is project based and the offer of projects is difficult to predict. However, this research showed, despite the characteristics of the sector, that the method to solve a multiperiod work scheduling problem, still can be applied to determine the optimal capacity for companies in that sector.

The practical contribution of this research is, that the amount of workers needed to achieve the doubled market share, is based on a mathematical method and not only on intuition. So, this objective research confirmed the assumptions of the company that most probably more workers were needed and two teams should be formed.

The research is also valuable in a managerial way. The results help to get insight in what is needed to double the company's market share. It shows which decisions could be made and what possible consequences these might have. This is expressed in the occupancy rates. The increase in occupancy is favourable for the company, because the workers are working more but the company does not have to pay them more.

Shortcomings and restrictions

The methodological limitation of this research is that certain scenarios are used. The scenarios predict a possible future. However, the occurrence of this scenario is uncertain. The optimal capacity is determined based on these scenarios, thus the scenarios determine the outcome. Therefore, the scenarios are a rather large assumption. Still, the choice for this, is well considered, since the future offer of projects is very unpredictable and therefore the future planning as well.

Besides, a practical limitation is that the workers are now valued on their cost and not on their knowledge or efficiency. With knowledge is meant that workers have certain knowledge about constructing concrete roads and experience with the working methods of the company. Permanent workers are able to obtain this experience and knowledge because they are attached to the company through a permanent contract. On the opposite, flex workers do not have the same knowledge or experience with the company's methods. It is needed to have permanent workers with specific knowledge and experience. However, these elements were not included in the model. The model is only focused on costs, which would lead to only having flex workers because they are cheaper. But the company can not carry out projects with only flex workers, because knowledge is needed and the model does not take this into account.

Efficiency could also be important to take into account. A permanent worker might be able to work faster than a flex worker. So, if a permanent worker can do the same amount of work as two flex workers in the same period, then a permanent worker would be cheaper. A reason for this can be that a permanent worker has more knowledge and experience which allows him to work more efficient. This is not taken into account in the model but could influence the results of the optimization.

In short, knowledge and experience were not taken into account in the model, despite their importance. This choice was made in consideration with the company because these are hard to value. Therefore, the solution is cost based. Nevertheless, this means that the optimal solution does not take knowledge or efficiency into account. In practice, this might not always be seen as the optimal solution.

Future directions and recommendations

Further research could therefore include or focus on the knowledge and efficiency factors that were excluded in this research. Besides, further research could focus on exploring a way to determining a more certain scenario for the future. With a more certain scenario is meant that the scenario is based on more information and that the projects that are in the scenario are more likely to be carried out in the future. A similar research could then be carried out, to determine the optimal capacity with the same method as used in this research. The better the scenario fits the possible reality, the more the company can profit from the optimisation.

The recommendation for Strukton Civiel Noord & Oost is to hire extra workers. If the first scenario is followed, then one extra engine driver and one extra hand worker should be hired. For the second scenario, in which the project type airport is included, one engine driver and seven hand workers should be added to the current team. Besides, the company should take into account that they need to work with a flex layer of two hand workers in the case of both scenarios. The choice for which scenario to follow, depends on what the company thinks is most likely to realize in the future. In both cases, the occupancy rate will improve. The company could base this decision on the probability of appearance for both scenarios.

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Appendices

Appendix A

List of problems:

- Capacity is not large enough
- Not enough workers/teams employed
- How will the composition of teams look like
- The “knowhow” is difficult to pass on
- The type of work is not wanted
- The utilization rate of machines is low
- Which projects have to be selected
- The planning is not optimal
- The market share is not large enough
- Not enough projects are carried out
- The offer of projects is diverse

Appendix B

Week	Date	Project number	Type of work Team 1	Type of work Team 2	Project number
8	20-Feb				
	21-Feb				
	22-Feb				
	23-Feb				
	24-Feb				
9	26-Feb				
	27-Feb				
	28-Feb				
	1-Mar				
	2-Mar				
10	5-Mar				
	6-Mar				
	7-Mar				
	8-Mar				
	9-Mar				
11	12-Mar				
	13-Mar				
	14-Mar				
	15-Mar				
	16-Mar				
12	19-Mar			Print concrete	52
	20-Mar			Print concrete	52
	21-Mar	1	Bicycle roads	Print concrete	52
	22-Mar	1	Bicycle roads	Print concrete	52
	23-Mar	1	Bicycle roads	Print concrete	52
13	26-Mar	1	Bicycle roads	Print concrete	52
	27-Mar	1	Bicycle roads	Print concrete	52
	28-Mar	1	Bicycle roads	Print concrete	52
	29-Mar	1	Bicycle roads	Print concrete	52
Good Friday	30-Mar			Print concrete	52
Easter	2-Apr				
	3-Apr	1	Bicycle roads		
	4-Apr	1	Bicycle roads	Bicycle roads	1
	5-Apr	2	Curbs	Bicycle roads	1
	6-Apr	2	Curbs	Bicycle roads	1
15	9-Apr	2	Curbs	Bicycle roads	1
	10-Apr	2	Curbs	Bicycle roads	1
	11-Apr	3	Bicycle roads	Bicycle roads	1
	12-Apr	4	Curbs	Bicycle roads	1

	13-Apr	4	Curbs		
16	16-Apr	5	Bicycle roads		
	17-Apr	5	Bicycle roads	Bicycle roads	1
	18-Apr	5	Bicycle roads	Bicycle roads	1
	19-Apr	5	Bicycle roads	Curbs	2
	20-Apr	5	Bicycle roads	Curbs	2
17	23-Apr	5	Bicycle roads	Curbs	2
	24-Apr	5	Bicycle roads	Curbs	2
	25-Apr	6	Curbs	Bicycle roads	3
	26-Apr	6	Curbs	Curbs	4
Kingsday	27-Apr			Curbs	4
18	30-Apr	6	Curbs	Bicycle roads	5
	1-May	6	Curbs	Bicycle roads	5
	2-May	7	Print concrete	Bicycle roads	5
	3-May	7	Print concrete	Bicycle roads	5
	4-May	7	Print concrete	Bicycle roads	5
19	7-May	8	Curbs	Bicycle roads	5
	8-May	8	Curbs	Bicycle roads	5
	9-May	8	Curbs	Curbs	6
Ascension day	10-May			Curbs	6
Free	11-May				
20	14-May	8	Print concrete	Curbs	6
	15-May	9	Print concrete	Curbs	6
	16-May	8	Print concrete	Print concrete	7
	17-May	8	Curbs	Print concrete	7
	18-May	8	Curbs	Print concrete	7
Pentecost	21-May			Curbs	8
	22-May	8	Roundabout	Curbs	8
	23-May	8	Roundabout	Curbs	8
	24-May	8	Roundabout		
	25-May	8	Roundabout		
22	28-May	9	Curbs	Print concrete	8
	29-May	9	Curbs	Print concrete	9
	30-May	9	Curbs	Print concrete	8
	31-May	10	Print concrete	Curbs	8
	1-Jun	11	Print concrete	Curbs	8
23	4-Jun	11	Curbs		
	5-Jun	12	Print concrete	Roundabout	8
	6-Jun	11	Print concrete	Roundabout	8
	7-Jun	13	Roadside concrete	Roundabout	8
	8-Jun	14	Roadside concrete	Roundabout	8
24	11-Jun	14	Curbs	Curbs	9

	12-Jun	15	Print concrete	Curbs	9
	13-Jun	15	Print concrete	Curbs	9
	14-Jun	15	Print concrete	Print concrete	10
	15-Jun	16	Print concrete	Print concrete	11
25	18-Jun	15	Print concrete	Curbs	11
	19-Jun	17	Print concrete	Print concrete	12
	20-Jun	17	Curbs	Print concrete	11
	21-Jun	17	Curbs	Roadside concrete	13
	22-Jun	17	Curbs	Roadside concrete	14
26	25-Jun	18	Print concrete	Curbs	14
	26-Jun	19	Print concrete	Print concrete	15
	27-Jun	20	Bicycle roads	Print concrete	15
	28-Jun	20	Bicycle roads	Print concrete	15
	29-Jun			Print concrete	16
27	2-Jul	21	Print concrete	Print concrete	15
	3-Jul	22	Print concrete	Print concrete	17
	4-Jul	22	Print concrete	Curbs	17
	5-Jul	23	Print concrete	Curbs	17
	6-Jul	23	Print concrete	Curbs	17
28	9-Jul			Print concrete	18
	10-Jul	24	Curbs	Print concrete	19
	11-Jul	25	Print concrete	Bicycle roads	20
	12-Jul	25	Print concrete	Bicycle roads	20
	13-Jul	26	Bicycle road		
29	16-Jul	26	Bicycle road	Print concrete	21
	17-Jul	26	Bicycle road	Print concrete	22
	18-Jul	26	Roadside concrete	Print concrete	22
	19-Jul	26	Roadside concrete	Print concrete	23
	20-Jul	27	Print concrete	Print concrete	23
30	23-Jul	28	Bicycle road		
	24-Jul	28	Bicycle road	Curbs	24
	25-Jul	28	Roadside concrete	Print concrete	25
	26-Jul	28	Roadside concrete	Print concrete	25
	27-Jul			Bicycle road	26
31	30-Jul	29	Curbs	Bicycle road	26
	31-Jul	29	Curbs	Bicycle road	26
	1-Aug	30	Print concrete	Roadside concrete	26
	2-Aug			Roadside concrete	26
	3-Aug	30	Print concrete	Print concrete	27
32	6-Aug			Bicycle road	28
Construction holiday	7-Aug			Bicycle road	28
Construction holiday	8-Aug			Roadside concrete	28
Construction holiday	9-Aug			Roadside concrete	28

Construction holiday	10-Aug				
33	13-Aug			Curbs	29
Construction holiday	14-Aug			Curbs	29
Construction holiday	15-Aug			Print concrete	30
Construction holiday	16-Aug				
Construction holiday	17-Aug			Print concrete	30
34	20-Aug				
Construction holiday	21-Aug				
Construction holiday	22-Aug				
Construction holiday	23-Aug				
Construction holiday	24-Aug				
35	27-Aug	31	Print concrete		
	28-Aug	31	Print concrete		
	29-Aug	32	Print concrete		
	30-Aug	33	Curbs		
	31-Aug	33	Curbs		
36	3-Sep	34	Bicycle roads		
	4-Sep	34	Bicycle roads		
	5-Sep	34	Print concrete		
	6-Sep	35	Curbs		
	7-Sep	35	Curbs		
37	10-Sep	36	Print concrete	Print concrete	31
	11-Sep	36	Print concrete	Print concrete	31
	12-Sep	37	Print concrete	Print concrete	32
	13-Sep	37	Curbs	Curbs	33
	14-Sep	37	Print concrete	Curbs	33
38	17-Sep	38	Roadside concrete	Bicycle roads	34
	18-Sep	38	Roadside concrete	Bicycle roads	34
	19-Sep	39	Curbs	Print concrete	34
	20-Sep	39	Roadside concrete	Curbs	35
	21-Sep	39	Curbs	Curbs	35
39	24-Sep	40	Bicycle road	Print concrete	36
	25-Sep	40	Bicycle road	Print concrete	36
	26-Sep	41	Print concrete	Print concrete	37
	27-Sep	41	Print concrete	Curbs	37
	28-Sep	41	Print concrete	Print concrete	37
40	1-Oct	42	Print concrete	Roadside concrete	38
	2-Oct	42	Print concrete	Roadside concrete	38
	3-Oct	42	Print concrete	Curbs	39
	4-Oct	42	Print concrete	Roadside concrete	39
	5-Oct	42	Print concrete	Curbs	39
41	8-Oct	42	Print concrete	Bicycle road	40

	9-Oct	42	Print concrete	Bicycle road	40
	10-Oct	42	Print concrete	Print concrete	41
	11-Oct	43	Bicycle road	Print concrete	41
	12-Oct	43	Bicycle road	Print concrete	41
42	15-Oct	44	Print concrete	Print concrete	42
	16-Oct	45	Print concrete	Print concrete	42
	17-Oct	46	Print concrete	Print concrete	42
	18-Oct			Print concrete	42
	19-Oct			Print concrete	42
43	22-Oct			Print concrete	42
	23-Oct	47	Print concrete	Print concrete	42
	24-Oct	47	Print concrete	Print concrete	42
	25-Oct	48	Roadside concrete	Bicycle road	43
	26-Oct	48	Roadside concrete	Bicycle road	43
44	29-Oct	49	Bicycle roads	Print concrete	44
	30-Oct	49	Bicycle roads	Print concrete	45
	31-Oct	49	Bicycle roads	Print concrete	46
	1-Nov				
	2-Nov				
45	5-Nov	50	Bicycle roads		
	6-Nov	50	Bicycle roads	Print concrete	47
	7-Nov	50	Bicycle roads	Print concrete	47
	8-Nov	50	Bicycle roads	Roadside concrete	48
	9-Nov	50	Bicycle roads	Roadside concrete	48
46	12-Nov			Bicycle roads	49
	13-Nov			Bicycle roads	49
	14-Nov			Bicycle roads	49
	15-Nov				
	16-Nov				
47	19-Nov			Bicycle roads	50
	20-Nov			Bicycle roads	50
	21-Nov			Bicycle roads	50
	22-Nov			Bicycle roads	50
	23-Nov	51	Roadside concrete	Bicycle roads	50
48	26-Nov				
	27-Nov				
	28-Nov				
	29-Nov				
	30-Nov				
49	3-Dec				
	4-Dec				
	5-Dec				
	6-Dec				

	7-Dec			Roadside concrete	51
50	10-Dec	52	Print concrete		
	11-Dec	52	Print concrete		
	12-Dec	52	Print concrete		
	13-Dec	52	Print concrete		
	14-Dec	52	Print concrete		
51	17-Dec	52	Print concrete		
	18-Dec	52	Print concrete		
	19-Dec	52	Print concrete		
	20-Dec	52	Print concrete		
	21-Dec	52	Print concrete		

Appendix C

Week	Date	Project number	Type of work Team 1	Type of work Team 2	Project number
8	20-Feb				
	21-Feb				
	22-Feb				
	23-Feb				
	24-Feb				
9	26-Feb				
	27-Feb				
	28-Feb				
	1-Mar				
	2-Mar				
10	5-Mar				
	6-Mar			Bicycle roads	1
	7-Mar			Bicycle roads	1
	8-Mar			Bicycle roads	1
	9-Mar			Bicycle roads	1
11	12-Mar			Bicycle roads	1
	13-Mar			Bicycle roads	1
	14-Mar			Bicycle roads	1
	15-Mar			Bicycle roads	1
	16-Mar			Bicycle roads	1
12	19-Mar			Print concrete	52
	20-Mar			Print concrete	52
	21-Mar	1	Bicycle roads	Print concrete	52
	22-Mar	1	Bicycle roads	Print concrete	52
	23-Mar	1	Bicycle roads	Print concrete	52
13	26-Mar	1	Bicycle roads	Print concrete	52
	27-Mar	1	Bicycle roads	Print concrete	52
	28-Mar	1	Bicycle roads	Print concrete	52
	29-Mar	1	Bicycle roads	Print concrete	52
Good Friday	30-Mar			Print concrete	52
Easter	2-Apr				
	3-Apr	1	Bicycle roads	Curbs	6
	4-Apr	1	Bicycle roads	Curbs	6
	5-Apr	2	Curbs		
	6-Apr	2	Curbs		
15	9-Apr	2	Curbs		
	10-Apr	2	Curbs		
	11-Apr	3	Bicycle roads		
	12-Apr	4	Curbs		

	13-Apr	4	Curbs		
16	16-Apr	5	Bicycle roads		
	17-Apr	5	Bicycle roads	Curbs	4
	18-Apr	5	Bicycle roads	Curbs	4
	19-Apr	5	Bicycle roads	Curbs	2
	20-Apr	5	Bicycle roads	Curbs	2
17	23-Apr	5	Bicycle roads	Curbs	2
	24-Apr	5	Bicycle roads	Curbs	2
	25-Apr	6	Curbs	Bicycle roads	3
	26-Apr	6	Curbs		4
Kingsday	27-Apr				4
18	30-Apr	6	Curbs	Bicycle roads	5
	1-May	6	Curbs	Bicycle roads	5
	2-May	7	Print concrete	Bicycle roads	5
	3-May	7	Print concrete	Bicycle roads	5
	4-May	7	Print concrete	Bicycle roads	5
19	7-May	8	Curbs	Bicycle roads	5
	8-May	8	Curbs	Bicycle roads	5
	9-May	8	Curbs		
Ascension day	10-May				
Free	11-May				
20	14-May	8	Print concrete	Curbs	6
	15-May	9	Print concrete	Curbs	6
	16-May	8	Print concrete	Print concrete	7
	17-May	8	Curbs	Print concrete	7
	18-May	8	Curbs	Print concrete	7
Pentecost	21-May				
	22-May	8	Roundabout	Curbs	8
	23-May	8	Roundabout	Curbs	8
	24-May	8	Roundabout	Curbs	8
	25-May	8	Roundabout		
22	28-May	9	Curbs	Print concrete	8
	29-May	9	Curbs	Print concrete	9
	30-May	9	Curbs	Print concrete	8
	31-May	10	Print concrete	Curbs	8
	1-Jun	11	Print concrete	Curbs	8
23	4-Jun	11	Curbs		
	5-Jun	12	Print concrete	Roundabout	8
	6-Jun	11	Print concrete	Roundabout	8
	7-Jun	13	Roadside concrete	Roundabout	8
	8-Jun	14	Roadside concrete	Roundabout	8
24	11-Jun	14	Curbs	Print concrete	15

	12-Jun	15	Print concrete	Print concrete	15
	13-Jun	15	Print concrete	Print concrete	15
	14-Jun	15	Print concrete	Roadside concrete	13
	15-Jun	16	Print concrete	Print concrete	11
25	18-Jun	15	Print concrete	Curbs	11
	19-Jun	17	Print concrete	Print concrete	12
	20-Jun	17	Curbs	Print concrete	11
	21-Jun	17	Curbs	Print concrete	10
	22-Jun	17	Curbs	Bicycle roads	20
26	25-Jun	18	Print concrete	Bicycle roads	20
	26-Jun	19	Print concrete	Curbs	9
	27-Jun	20	Bicycle roads	Curbs	9
	28-Jun	20	Bicycle roads	Curbs	9
	29-Jun			Print concrete	16
27	2-Jul	21	Print concrete	Print concrete	15
	3-Jul	22	Print concrete	Print concrete	17
	4-Jul	22	Print concrete	Curbs	17
	5-Jul	23	Print concrete	Curbs	17
	6-Jul	23	Print concrete	Curbs	17
28	9-Jul			Print concrete	18
	10-Jul	24	Curbs	Print concrete	19
	11-Jul	25	Print concrete	Roadside concrete	14
	12-Jul	25	Print concrete	Curbs	14
	13-Jul	26	Bicycle road		
29	16-Jul	26	Bicycle road	Print concrete	21
	17-Jul	26	Bicycle road	Print concrete	22
	18-Jul	26	Roadside concrete	Print concrete	22
	19-Jul	26	Roadside concrete	Print concrete	23
	20-Jul	27	Print concrete	Print concrete	23
30	23-Jul	28	Bicycle road		
	24-Jul	28	Bicycle road	Curbs	24
	25-Jul	28	Roadside concrete	Print concrete	25
	26-Jul	28	Roadside concrete	Print concrete	25
	27-Jul			Bicycle road	26
31	30-Jul	29	Curbs	Bicycle road	26
	31-Jul	29	Curbs	Bicycle road	26
	1-Aug	30	Print concrete	Roadside concrete	26
	2-Aug			Roadside concrete	26
	3-Aug	30	Print concrete	Print concrete	27
32	6-Aug				
Construction holiday	7-Aug				
Construction holiday	8-Aug				
Construction holiday	9-Aug				

Construction holiday	10-Aug				
33	13-Aug				
Construction holiday	14-Aug				
Construction holiday	15-Aug				
Construction holiday	16-Aug				
Construction holiday	17-Aug				
34	20-Aug				
Construction holiday	21-Aug				
Construction holiday	22-Aug				
Construction holiday	23-Aug				
Construction holiday	24-Aug				
35	27-Aug	31	Print concrete	Curbs	29
	28-Aug	31	Print concrete	Curbs	29
	29-Aug	32	Print concrete		
	30-Aug	33	Curbs	Bicycle road	28
	31-Aug	33	Curbs	Bicycle road	28
36	3-Sep	34	Bicycle roads	Roadside concrete	28
	4-Sep	34	Bicycle roads	Roadside concrete	28
	5-Sep	34	Print concrete	Print concrete	30
	6-Sep	35	Curbs		
	7-Sep	35	Curbs	Print concrete	30
37	10-Sep	36	Print concrete	Curbs	33
	11-Sep	36	Print concrete	Curbs	33
	12-Sep	37	Print concrete	Print concrete	32
	13-Sep	37	Curbs	Print concrete	31
	14-Sep	37	Print concrete	Print concrete	31
38	17-Sep	38	Roadside concrete	Bicycle roads	34
	18-Sep	38	Roadside concrete	Bicycle roads	34
	19-Sep	39	Curbs	Print concrete	34
	20-Sep	39	Roadside concrete	Print concrete	36
	21-Sep	39	Curbs	Print concrete	36
39	24-Sep	40	Bicycle road	Curbs	35
	25-Sep	40	Bicycle road	Curbs	35
	26-Sep	41	Print concrete	Print concrete	37
	27-Sep	41	Print concrete	Curbs	37
	28-Sep	41	Print concrete	Print concrete	37
40	1-Oct	42	Print concrete	Roadside concrete	38
	2-Oct	42	Print concrete	Roadside concrete	38
	3-Oct	42	Print concrete	Curbs	39
	4-Oct	42	Print concrete	Roadside concrete	39
	5-Oct	42	Print concrete	Curbs	39
41	8-Oct	42	Print concrete	Bicycle road	40

	9-Oct	42	Print concrete	Bicycle road	40
	10-Oct	42	Print concrete	Print concrete	41
	11-Oct	43	Bicycle road	Print concrete	41
	12-Oct	43	Bicycle road	Print concrete	41
42	15-Oct	44	Print concrete	Print concrete	42
	16-Oct	45	Print concrete	Print concrete	42
	17-Oct	46	Print concrete	Print concrete	42
	18-Oct			Print concrete	42
	19-Oct			Print concrete	42
43	22-Oct			Print concrete	42
	23-Oct	47	Print concrete	Print concrete	42
	24-Oct	47	Print concrete	Print concrete	42
	25-Oct	48	Roadside concrete	Bicycle road	43
	26-Oct	48	Roadside concrete	Bicycle road	43
44	29-Oct	49	Bicycle roads	Print concrete	44
	30-Oct	49	Bicycle roads	Print concrete	45
	31-Oct	49	Bicycle roads	Print concrete	46
	1-Nov				
	2-Nov				
45	5-Nov	50	Bicycle roads		
	6-Nov	50	Bicycle roads	Print concrete	47
	7-Nov	50	Bicycle roads	Print concrete	47
	8-Nov	50	Bicycle roads	Roadside concrete	48
	9-Nov	50	Bicycle roads	Roadside concrete	48
46	12-Nov			Bicycle roads	49
	13-Nov			Bicycle roads	49
	14-Nov			Bicycle roads	49
	15-Nov				
	16-Nov				
47	19-Nov			Bicycle roads	50
	20-Nov			Bicycle roads	50
	21-Nov			Bicycle roads	50
	22-Nov			Bicycle roads	50
	23-Nov	51	Roadside concrete	Bicycle roads	50
48	26-Nov				
	27-Nov				
	28-Nov				
	29-Nov				
	30-Nov				
49	3-Dec				
	4-Dec				
	5-Dec				
	6-Dec				

	7-Dec			Roadside concrete	51
50	10-Dec	52	Print concrete		
	11-Dec	52	Print concrete		
	12-Dec	52	Print concrete		
	13-Dec	52	Print concrete		
	14-Dec	52	Print concrete		
51	17-Dec	52	Print concrete		
	18-Dec	52	Print concrete		
	19-Dec	52	Print concrete		
	20-Dec	52	Print concrete		
	21-Dec	52	Print concrete		

Appendix D

Week	Date	Project number	Type of work Team 1	Type of work Team 2	Project number
8	20-Feb				
	21-Feb				
	22-Feb				
	23-Feb				
	24-Feb				
9	26-Feb				
	27-Feb				
	28-Feb				
	1-Mar				
	2-Mar				
10	5-Mar				
	6-Mar			Bicycle roads	1
	7-Mar			Bicycle roads	1
	8-Mar			Bicycle roads	1
	9-Mar			Bicycle roads	1
11	12-Mar			Bicycle roads	1
	13-Mar			Bicycle roads	1
	14-Mar			Bicycle roads	1
	15-Mar			Bicycle roads	1
	16-Mar			Bicycle roads	1
12	19-Mar			Print concrete	52
	20-Mar			Print concrete	52
	21-Mar	1	Bicycle roads	Print concrete	52
	22-Mar	1	Bicycle roads	Print concrete	52
	23-Mar	1	Bicycle roads	Print concrete	52
13	26-Mar	1	Bicycle roads	Print concrete	52
	27-Mar	1	Bicycle roads	Print concrete	52
	28-Mar	1	Bicycle roads	Print concrete	52
	29-Mar	1	Bicycle roads	Print concrete	52
Good Friday	30-Mar			Print concrete	52
Easter	2-Apr				
	3-Apr	1	Bicycle roads	Curbs	6
	4-Apr	1	Bicycle roads	Curbs	6
	5-Apr	2	Curbs		
	6-Apr	2	Curbs		
15	9-Apr	2	Curbs		
	10-Apr	2	Curbs		
	11-Apr	3	Bicycle roads		
	12-Apr	4	Curbs		

	13-Apr	4	Curbs		
16	16-Apr	5	Bicycle roads		
	17-Apr	5	Bicycle roads	Curbs	4
	18-Apr	5	Bicycle roads	Curbs	4
	19-Apr	5	Bicycle roads	Curbs	2
	20-Apr	5	Bicycle roads	Curbs	2
17	23-Apr	5	Bicycle roads	Curbs	2
	24-Apr	5	Bicycle roads	Curbs	2
	25-Apr	6	Curbs	Bicycle roads	3
	26-Apr	6	Curbs		4
Kingsday	27-Apr				4
18	30-Apr	6	Curbs	Bicycle roads	5
	1-May	6	Curbs	Bicycle roads	5
	2-May	7	Print concrete	Bicycle roads	5
	3-May	7	Print concrete	Bicycle roads	5
	4-May	7	Print concrete	Bicycle roads	5
19	7-May	8	Curbs	Bicycle roads	5
	8-May	8	Curbs	Bicycle roads	5
	9-May	8	Curbs		
Ascension day	10-May				
Free	11-May				
20	14-May	8	Print concrete	Curbs	6
	15-May	9	Print concrete	Curbs	6
	16-May	8	Print concrete	Print concrete	7
	17-May	8	Curbs	Print concrete	7
	18-May	8	Curbs	Print concrete	7
Pentecost	21-May				
	22-May	8	Roundabout	Curbs	8
	23-May	8	Roundabout	Curbs	8
	24-May	8	Roundabout	Curbs	8
	25-May	8	Roundabout		
22	28-May	9	Curbs	Print concrete	8
	29-May	9	Curbs	Print concrete	9
	30-May	9	Curbs	Print concrete	8
	31-May	10	Print concrete	Curbs	8
	1-Jun	11	Print concrete	Curbs	8
23	4-Jun	11	Curbs		
	5-Jun	12	Print concrete	Roundabout	8
	6-Jun	11	Print concrete	Roundabout	8
	7-Jun	13	Roadside concrete	Roundabout	8
	8-Jun	14	Roadside concrete	Roundabout	8
24	11-Jun	14	Curbs	Print concrete	15

	12-Jun	15	Print concrete	Print concrete	15
	13-Jun	15	Print concrete	Print concrete	15
	14-Jun	15	Print concrete	Roadside concrete	13
	15-Jun	16	Print concrete	Print concrete	11
25	18-Jun	15	Print concrete	Curbs	11
	19-Jun	17	Print concrete	Print concrete	12
	20-Jun	17	Curbs	Print concrete	11
	21-Jun	17	Curbs	Print concrete	10
	22-Jun	17	Curbs	Bicycle roads	20
26	25-Jun	18	Print concrete	Bicycle roads	20
	26-Jun	19	Print concrete	Curbs	9
	27-Jun	20	Bicycle roads	Curbs	9
	28-Jun	20	Bicycle roads	Curbs	9
	29-Jun			Print concrete	16
27	2-Jul	21	Print concrete	Print concrete	15
	3-Jul	22	Print concrete	Print concrete	17
	4-Jul	22	Print concrete	Curbs	17
	5-Jul	23	Print concrete	Curbs	17
	6-Jul	23	Print concrete	Curbs	17
28	9-Jul			Print concrete	18
	10-Jul	24	Curbs	Print concrete	19
	11-Jul	25	Print concrete	Roadside concrete	14
	12-Jul	25	Print concrete	Curbs	14
	13-Jul	26	Bicycle road		
29	16-Jul	26	Bicycle road	Print concrete	21
	17-Jul	26	Bicycle road	Print concrete	22
	18-Jul	26	Roadside concrete	Print concrete	22
	19-Jul	26	Roadside concrete	Print concrete	23
	20-Jul	27	Print concrete	Print concrete	23
30	23-Jul	26	Bicycle road		
	24-Jul	26	Bicycle road	Curbs	24
	25-Jul	26	Roadside concrete	Print concrete	25
	26-Jul	26	Roadside concrete	Print concrete	25
	27-Jul			Bicycle road	26
31	30-Jul	28	Curbs	Bicycle road	26
	31-Jul	28	Curbs	Bicycle road	26
	1-Aug	29	Print concrete	Roadside concrete	26
	2-Aug			Roadside concrete	26
	3-Aug	29	Print concrete	Print concrete	27
32	6-Aug				
Construction holiday	7-Aug				
Construction holiday	8-Aug				
Construction holiday	9-Aug				

Construction holiday	10-Aug				
33	13-Aug				
Construction holiday	14-Aug				
Construction holiday	15-Aug				
Construction holiday	16-Aug				
Construction holiday	17-Aug				
34	20-Aug				
Construction holiday	21-Aug				
Construction holiday	22-Aug				
Construction holiday	23-Aug				
Construction holiday	24-Aug				
35	27-Aug	30	Print concrete	Airport	
	28-Aug	30	Print concrete	Airport	
	29-Aug	31	Print concrete	Airport	
	30-Aug	32	Curbs	Airport	
	31-Aug	32	Curbs	Airport	
36	3-Sep	33	Bicycle roads	Airport	
	4-Sep	33	Bicycle roads	Airport	
	5-Sep	33	Print concrete	Airport	
	6-Sep	34	Curbs	Airport	
	7-Sep	34	Curbs	Airport	
37	10-Sep	35	Print concrete	Airport	
	11-Sep	35	Print concrete	Airport	
	12-Sep	36	Print concrete	Airport	
	13-Sep	36	Curbs	Airport	
	14-Sep	36	Print concrete	Airport	
38	17-Sep	37	Roadside concrete	Airport	
	18-Sep	37	Roadside concrete	Airport	
	19-Sep	38	Curbs	Airport	
	20-Sep	38	Roadside concrete	Airport	
	21-Sep	38	Curbs	Airport	
39	24-Sep	39	Bicycle road	Airport	
	25-Sep	39	Bicycle road	Airport	
	26-Sep	40	Print concrete	Airport	
	27-Sep	40	Print concrete	Airport	
	28-Sep	40	Print concrete	Airport	
40	1-Oct	41	Print concrete	Roadside concrete	38
	2-Oct	41	Print concrete	Roadside concrete	38
	3-Oct	41	Print concrete	Curbs	39
	4-Oct	41	Print concrete	Roadside concrete	39
	5-Oct	41	Print concrete	Curbs	39
41	8-Oct	41	Print concrete	Bicycle road	40

	9-Oct	41	Print concrete	Bicycle road	40
	10-Oct	41	Print concrete	Print concrete	41
	11-Oct	42	Bicycle road	Print concrete	41
	12-Oct	42	Bicycle road	Print concrete	41
42	15-Oct	43	Print concrete	Print concrete	42
	16-Oct	44	Print concrete	Print concrete	42
	17-Oct	45	Print concrete	Print concrete	42
	18-Oct			Print concrete	42
	19-Oct			Print concrete	42
43	22-Oct			Print concrete	42
	23-Oct	46	Print concrete	Print concrete	42
	24-Oct	46	Print concrete	Print concrete	42
	25-Oct	47	Roadside concrete	Bicycle road	43
	26-Oct	47	Roadside concrete	Bicycle road	43
44	29-Oct	48	Bicycle roads	Print concrete	44
	30-Oct	48	Bicycle roads	Print concrete	45
	31-Oct	48	Bicycle roads	Print concrete	46
	1-Nov				
	2-Nov				
45	5-Nov	49	Bicycle roads		
	6-Nov	49	Bicycle roads	Print concrete	47
	7-Nov	49	Bicycle roads	Print concrete	47
	8-Nov	49	Bicycle roads	Roadside concrete	48
	9-Nov	49	Bicycle roads	Roadside concrete	48
46	12-Nov			Bicycle roads	49
	13-Nov			Bicycle roads	49
	14-Nov			Bicycle roads	49
	15-Nov				
	16-Nov				
47	19-Nov			Bicycle roads	50
	20-Nov			Bicycle roads	50
	21-Nov			Bicycle roads	50
	22-Nov			Bicycle roads	50
	23-Nov	50	Roadside concrete	Bicycle roads	50
48	26-Nov				
	27-Nov				
	28-Nov				
	29-Nov				
	30-Nov				
49	3-Dec				
	4-Dec				
	5-Dec				
	6-Dec				

	7-Dec			Roadside concrete	51
50	10-Dec	51	Print concrete		
	11-Dec	51	Print concrete		
	12-Dec	51	Print concrete		
	13-Dec	51	Print concrete		
	14-Dec	51	Print concrete		
51	17-Dec	51	Print concrete		
	18-Dec	51	Print concrete		
	19-Dec	51	Print concrete		
	20-Dec	51	Print concrete		
	21-Dec	51	Print concrete		

Appendix E

Week	Date	Type of work Team 1	Type of work Team 2	Nr of foremen	Nr of hand workers	Nr of engine drivers	Type of machine	Total capacity demand
8	20-Feb							0
	21-Feb							0
	22-Feb							0
	23-Feb							0
	24-Feb							0
9	26-Feb							0
	27-Feb							0
	28-Feb							0
	1-Mar							0
	2-Mar							0
10	5-Mar							0
	6-Mar		Bicycle roads	1	4	1	SMGE	6
	7-Mar		Bicycle roads	1	4	1	SMGE	6
	8-Mar		Bicycle roads	1	4	1	SMGE	6
	9-Mar		Bicycle roads	1	4	1	SMGE	6
11	12-Mar		Bicycle roads	1	4	1	SMGE	6
	13-Mar		Bicycle roads	1	4	1	SMGE	6
	14-Mar		Bicycle roads	1	4	1	SMGE	6
	15-Mar		Bicycle roads	1	4	1	SMGE	6
	16-Mar		Bicycle roads	1	4	1	SMGE	6
12	19-Mar		Handwork	1	5			6
	20-Mar		Handwork	1	5			6
	21-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
	22-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
	23-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
13	26-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
	27-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
	28-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
	29-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12

Good Friday	30-Mar		Handwork	1	5			6	
Easter	14	2-Apr						0	
		3-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
		4-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
		5-Apr	Curbs		1	4	1	SP15	6
		6-Apr	Curbs		1	4	1	SP15	6
	15	9-Apr	Curbs		1	4	1	SP15	6
		10-Apr	Curbs		1	4	1	SP15	6
		11-Apr	Bicycle roads		1	4	1	SMGE	6
		12-Apr	Curbs		1	4	1	SP15	6
		13-Apr	Curbs		1	4	1	SP15	6
	16	16-Apr	Bicycle roads						0
		17-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
		18-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
		19-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
		20-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
	17	23-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
		24-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
		25-Apr	Curbs	Bicycle roads	2	8	2	SMGE & SP15	12
		26-Apr	Curbs		1	4	1	SP15	6
Kingsday		27-Apr							0
	18	30-Apr	Curbs	Bicycle roads	2	8	2	SMGE & SP15	12
		1-May	Curbs	Bicycle roads	2	8	2	SMGE & SP15	12
		2-May	Handwork	Bicycle roads	2	9	1	SMGE	12
		3-May	Handwork	Bicycle roads	2	9	1	SMGE	12
		4-May	Handwork	Bicycle roads	2	9	1	SMGE	12
	19	7-May	Curbs	Bicycle roads	2	8	2	SMGE & SP15	12
		8-May	Curbs	Bicycle roads	2	8	2	SMGE & SP15	12
		9-May	Curbs		1	4	1	SP15	6
Ascension day		10-May							0
Free		11-May							0
	20	14-May	Handwork	Curbs	2	9	1	SP15	12
		15-May	Handwork	Curbs	2	9	1	SP15	12

	16-May	Handwork	Handwork	2	10			12
	17-May	Curbs	Handwork	2	9	1	SP15	12
	18-May	Curbs	Handwork	2	9	1	SP15	12
Pentecost	21-May							0
	22-May	Roundabout	Curbs	2	9	1	SP15	12
	23-May	Roundabout	Curbs	2	9	1	SP15	12
	24-May	Roundabout	Curbs	2	9	1	SP15	12
	25-May	Roundabout						0
22	28-May	Curbs	Handwork	2	9	1	SP15	12
	29-May	Curbs	Handwork	2	9	1	SP15	12
	30-May	Curbs	Handwork	2	9	1	SP15	12
	31-May	Handwork	Curbs	2	9	1	SP15	12
	1-Jun	Handwork	Curbs	2	9	1	SP15	12
23	4-Jun	Curbs		1	4	1	SP15	6
	5-Jun	Handwork	Roundabout	2	10			12
	6-Jun	Handwork	Roundabout	2	10			12
	7-Jun	Roadside concrete	Roundabout	2	8	1	SP15	11
	8-Jun	Roadside concrete	Roundabout	2	8	1	SP15	11
24	11-Jun	Curbs	Handwork	2	9	1	SP15	12
	12-Jun	Handwork	Handwork	2	10			12
	13-Jun	Handwork	Handwork	2	10			12
	14-Jun	Handwork	Roadside concrete	2	8	1	SP15	11
	15-Jun	Handwork	Handwork	2	10			12
25	18-Jun	Handwork	Curbs	2	9	1	SP15	12
	19-Jun	Handwork	Handwork	2	10			12
	20-Jun	Curbs	Handwork	2	9	1	SP15	12
	21-Jun	Curbs	Handwork	2	9	1	SP15	12
	22-Jun	Curbs	Bicycle roads					0
26	25-Jun	Handwork	Bicycle roads	2	9	1	SMGE	12
	26-Jun	Handwork	Curbs	2	9	1	SP15	12
	27-Jun	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
	28-Jun	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
	29-Jun		Handwork	1	5			6

27	2-Jul	Handwork	Handwork	2	10			12
	3-Jul	Handwork	Handwork	2	10			12
	4-Jul	Handwork	Curbs	2	9	1	SP15	12
	5-Jul	Handwork	Curbs	2	9	1	SP15	12
	6-Jul	Handwork	Curbs	2	9	1	SP15	12
28	9-Jul		Handwork	1	5			6
	10-Jul	Curbs	Handwork	2	9	1	SP15	12
	11-Jul	Handwork	Roadside concrete	2	8	1	SP15	11
	12-Jul	Handwork	Curbs	2	9	1	SP15	12
	13-Jul	Bicycle road		1	4	1	SMGE	6
29	16-Jul	Bicycle road	Handwork	2	9	1	SMGE	12
	17-Jul	Bicycle road	Handwork	2	9	1	SMGE	12
	18-Jul	Roadside concrete	Handwork	2	8	1	SP15	11
	19-Jul	Roadside concrete	Handwork	2	8	1	SP15	11
	20-Jul	Handwork	Handwork	2	10			12
30	23-Jul	Bicycle road		1	4	1	SMGE	6
	24-Jul	Bicycle road	Curbs	2	8	2	SMGE & SP15	12
	25-Jul	Roadside concrete	Handwork	2	8	1	SP15	11
	26-Jul	Roadside concrete	Handwork	2	8	1	SP15	11
	27-Jul		Bicycle road	1	4	1	SMGE	6
31	30-Jul	Curbs	Bicycle road	2	8	2	SMGE & SP15	12
	31-Jul	Curbs	Bicycle road	2	8	2	SMGE & SP15	12
	1-Aug	Handwork	Roadside concrete	2	8	1	SP15	11
	2-Aug		Roadside concrete	1	3	1	SP15	5
	3-Aug	Handwork	Handwork	2	10			12
32	6-Aug							0
Construction holiday	7-Aug							0
Construction holiday	8-Aug							0
Construction holiday	9-Aug							0
Construction holiday	10-Aug							0
33	13-Aug							0
Construction holiday	14-Aug							0
Construction holiday	15-Aug							0
Construction holiday	16-Aug							0

Construction holiday	17-Aug							0
34	20-Aug							0
Construction holiday	21-Aug							0
Construction holiday	22-Aug							0
Construction holiday	23-Aug							0
Construction holiday	24-Aug							0
35	27-Aug	Handwork	Curbs	2	9	1	SP15	12
	28-Aug	Handwork	Curbs	2	9	1	SP15	12
	29-Aug	Handwork		1	5			6
	30-Aug	Curbs	Bicycle road	2	8	2	SMGE & SP15	12
	31-Aug	Curbs	Bicycle road	2	8	2	SMGE & SP15	12
36	3-Sep	Bicycle roads	Roadside concrete	2	7	2	SMGE & SP15	11
	4-Sep	Bicycle roads	Roadside concrete	2	7	2	SMGE & SP15	11
	5-Sep	Handwork	Handwork	2	10			12
	6-Sep	Curbs		1	4	1	SP15	6
	7-Sep	Curbs	Handwork	2	9	1	SP15	12
37	10-Sep	Handwork	Curbs	2	9	1	SP15	12
	11-Sep	Handwork	Curbs	2	9	1	SP15	12
	12-Sep	Handwork	Handwork	2	10			12
	13-Sep	Curbs	Handwork	2	9	1	SP15	12
	14-Sep	Handwork	Handwork	2	10			12
38	17-Sep	Roadside concrete	Bicycle roads	2	7	2	SMGE & SP15	11
	18-Sep	Roadside concrete	Bicycle roads	2	7	2	SMGE & SP15	11
	19-Sep	Curbs	Handwork	2	9	1	SP15	12
	20-Sep	Roadside concrete	Handwork	2	8	1	SP15	11
	21-Sep	Curbs	Handwork	2	9	1	SP15	12
39	24-Sep	Bicycle road	Curbs	2	8	2	SMGE & SP15	12
	25-Sep	Bicycle road	Curbs	2	8	2	SMGE & SP15	12
	26-Sep	Handwork	Handwork	2	10			12
	27-Sep	Handwork	Curbs	2	9	1	SP15	12
	28-Sep	Handwork	Handwork	2	10			12

40	1-Oct	Handwork	Roadside concrete	2	8	1	SP15	11
	2-Oct	Handwork	Roadside concrete	2	8	1	SP15	11
	3-Oct	Handwork	Curbs	2	9	1	SP15	12
	4-Oct	Handwork	Roadside concrete	2	8	1	SP15	11
	5-Oct	Handwork	Curbs	2	9	1	SP15	12
41	8-Oct	Handwork	Bicycle road	2	9	1	SMGE	12
	9-Oct	Handwork	Bicycle road	2	9	1	SMGE	12
	10-Oct	Handwork	Handwork	2	10			12
	11-Oct	Bicycle road	Handwork	2	9	1	SMGE	12
	12-Oct	Bicycle road	Handwork	2	9	1	SMGE	12
42	15-Oct	Handwork	Handwork	2	10			12
	16-Oct	Handwork	Handwork	2	10			12
	17-Oct	Handwork	Handwork	2	10			12
	18-Oct		Handwork	1	5			6
	19-Oct		Handwork	1	5			6
43	22-Oct		Handwork	1	5			6
	23-Oct	Handwork	Handwork	2	10			12
	24-Oct	Handwork	Handwork	2	10			12
	25-Oct	Roadside concrete	Bicycle road	2	7	2	SMGE & SP15	11
	26-Oct	Roadside concrete	Bicycle road	2	7	2	SMGE & SP15	11
44	29-Oct	Bicycle roads	Handwork	2	9	1	SMGE	12
	30-Oct	Bicycle roads	Handwork	2	9	1	SMGE	12
	31-Oct	Bicycle roads	Handwork	2	9	1	SMGE	12
	1-Nov							0
	2-Nov							0
45	5-Nov	Bicycle roads		1	4	1	SMGE	6
	6-Nov	Bicycle roads	Handwork	2	9	1	SMGE	12
	7-Nov	Bicycle roads	Handwork	2	9	1	SMGE	12
	8-Nov	Bicycle roads	Roadside concrete	2	7	2	SMGE & SP15	11
	9-Nov	Bicycle roads	Roadside concrete	2	7	2	SMGE & SP15	11
46	12-Nov		Bicycle roads	1	4	1	SMGE	6
	13-Nov		Bicycle roads	1	4	1	SMGE	6
	14-Nov		Bicycle roads	1	4	1	SMGE	6

	15-Nov							0
	16-Nov							0
47	19-Nov		Bicycle roads	1	4	1	SMGE	6
	20-Nov		Bicycle roads	1	4	1	SMGE	6
	21-Nov		Bicycle roads	1	4	1	SMGE	6
	22-Nov		Bicycle roads	1	4	1	SMGE	6
	23-Nov	Roadside concrete	Bicycle roads	2	7	2	SMGE & SP15	11
48	26-Nov							0
	27-Nov							0
	28-Nov							0
	29-Nov							0
	30-Nov							0
49	3-Dec							0
	4-Dec							0
	5-Dec							0
	6-Dec							0
	7-Dec		Roadside concrete	1	3	1	SP15	5
50	10-Dec	Handwork		1	5			6
	11-Dec	Handwork		1	5			6
	12-Dec	Handwork		1	5			6
	13-Dec	Handwork		1	5			6
	14-Dec	Handwork		1	5			6
51	17-Dec	Handwork		1	5			6
	18-Dec	Handwork		1	5			6
	19-Dec	Handwork		1	5			6
	20-Dec	Handwork		1	5			6
	21-Dec	Handwork		1	5			6

Appendix F

Week	Date	Type of work Team 1	Type of work Team 2	Nr of foremen	Nr of hand workers	Nr of engine drivers	Type of machine	Total capacity
8	20-Feb							0
	21-Feb							0
	22-Feb							0
	23-Feb							0
	24-Feb							0
9	26-Feb							0
	27-Feb							0
	28-Feb							0
	1-Mar							0
	2-Mar							0
10	5-Mar							0
	6-Mar		Bicycle roads	1	4	1	SMGE	6
	7-Mar		Bicycle roads	1	4	1	SMGE	6
	8-Mar		Bicycle roads	1	4	1	SMGE	6
	9-Mar		Bicycle roads	1	4	1	SMGE	6
11	12-Mar		Bicycle roads	1	4	1	SMGE	6
	13-Mar		Bicycle roads	1	4	1	SMGE	6
	14-Mar		Bicycle roads	1	4	1	SMGE	6
	15-Mar		Bicycle roads	1	4	1	SMGE	6
	16-Mar		Bicycle roads	1	4	1	SMGE	6
12	19-Mar		Handwork	1	5			6
	20-Mar		Handwork	1	5			6
	21-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
	22-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
	23-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
13	26-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
	27-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
	28-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12
	29-Mar	Bicycle roads	Handwork	2	9	1	SMGE	12

Good Friday	30-Mar		Handwork	1	5			6
Easter	14	2-Apr						0
		3-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15 12
		4-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15 12
		5-Apr	Curbs		1	4	1	SP15 6
		6-Apr	Curbs		1	4	1	SP15 6
	15	9-Apr	Curbs		1	4	1	SP15 6
		10-Apr	Curbs		1	4	1	SP15 6
		11-Apr	Bicycle roads		1	4	1	SMGE 6
		12-Apr	Curbs		1	4	1	SP15 6
		13-Apr	Curbs		1	4	1	SP15 6
	16	16-Apr	Bicycle roads					0
		17-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15 12
		18-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15 12
		19-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15 12
		20-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15 12
	17	23-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15 12
		24-Apr	Bicycle roads	Curbs	2	8	2	SMGE & SP15 12
		25-Apr	Curbs	Bicycle roads	2	8	2	SMGE & SP15 12
		26-Apr	Curbs		1	4	1	SP15 6
Kingsday		27-Apr						0
	18	30-Apr	Curbs	Bicycle roads	2	8	2	SMGE & SP15 12
		1-May	Curbs	Bicycle roads	2	8	2	SMGE & SP15 12
		2-May	Handwork	Bicycle roads	2	9	1	SMGE 12
		3-May	Handwork	Bicycle roads	2	9	1	SMGE 12
		4-May	Handwork	Bicycle roads	2	9	1	SMGE 12
	19	7-May	Curbs	Bicycle roads	2	8	2	SMGE & SP15 12
		8-May	Curbs	Bicycle roads	2	8	2	SMGE & SP15 12
		9-May	Curbs		1	4	1	SP15 6
Ascension day		10-May						0
Free		11-May						0
	20	14-May	Handwork	Curbs	2	9	1	SP15 12
		15-May	Handwork	Curbs	2	9	1	SP15 12

	16-May	Handwork	Handwork	2	10			12
	17-May	Curbs	Handwork	2	9	1	SP15	12
	18-May	Curbs	Handwork	2	9	1	SP15	12
Pentecost	21-May							0
	22-May	Roundabout	Curbs	2	9	1	SP15	12
	23-May	Roundabout	Curbs	2	9	1	SP15	12
	24-May	Roundabout	Curbs	2	9	1	SP15	12
	25-May	Roundabout						0
	28-May	Curbs	Handwork	2	9	1	SP15	12
22	29-May	Curbs	Handwork	2	9	1	SP15	12
	30-May	Curbs	Handwork	2	9	1	SP15	12
	31-May	Handwork	Curbs	2	9	1	SP15	12
	1-Jun	Handwork	Curbs	2	9	1	SP15	12
	4-Jun	Curbs		1	4	1	SP15	6
	5-Jun	Handwork	Roundabout	2	10			12
	6-Jun	Handwork	Roundabout	2	10			12
	7-Jun	Roadside concrete	Roundabout	2	8	1	SP15	11
	8-Jun	Roadside concrete	Roundabout	2	8	1	SP15	11
	11-Jun	Curbs	Handwork	2	9	1	SP15	12
24	12-Jun	Handwork	Handwork	2	10			12
	13-Jun	Handwork	Handwork	2	10			12
	14-Jun	Handwork	Roadside concrete	2	8	1	SP15	11
	15-Jun	Handwork	Handwork	2	10			12
	18-Jun	Handwork	Curbs	2	9	1	SP15	12
25	19-Jun	Handwork	Handwork	2	10			12
	20-Jun	Curbs	Handwork	2	9	1	SP15	12
	21-Jun	Curbs	Handwork	2	9	1	SP15	12
	22-Jun	Curbs	Bicycle roads					0
	25-Jun	Handwork	Bicycle roads	2	9	1	SMGE	12
	26-Jun	Handwork	Curbs	2	9	1	SP15	12
	27-Jun	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
	28-Jun	Bicycle roads	Curbs	2	8	2	SMGE & SP15	12
	29-Jun		Handwork	1	5			6

27	2-Jul	Handwork	Handwork	2	10			12
	3-Jul	Handwork	Handwork	2	10			12
	4-Jul	Handwork	Curbs	2	9	1	SP15	12
	5-Jul	Handwork	Curbs	2	9	1	SP15	12
	6-Jul	Handwork	Curbs	2	9	1	SP15	12
28	9-Jul		Handwork	1	5			6
	10-Jul	Curbs	Handwork	2	9	1	SP15	12
	11-Jul	Handwork	Roadside concrete	2	8	1	SP15	11
	12-Jul	Handwork	Curbs	2	9	1	SP15	12
	13-Jul	Bicycle road		1	4	1	SMGE	6
29	16-Jul	Bicycle road	Handwork	2	9	1	SMGE	12
	17-Jul	Bicycle road	Handwork	2	9	1	SMGE	12
	18-Jul	Roadside concrete	Handwork	2	8	1	SP15	11
	19-Jul	Roadside concrete	Handwork	2	8	1	SP15	11
	20-Jul	Handwork	Handwork	2	10			12
30	23-Jul	Bicycle road		1	4	1	SMGE	6
	24-Jul	Bicycle road	Curbs	2	8	2	SMGE & SP15	12
	25-Jul	Roadside concrete	Handwork	2	8	1	SP15	11
	26-Jul	Roadside concrete	Handwork	2	8	1	SP15	11
	27-Jul		Bicycle road	1	4	1	SMGE	6
31	30-Jul	Curbs	Bicycle road	2	8	2	SMGE & SP15	12
	31-Jul	Curbs	Bicycle road	2	8	2	SMGE & SP15	12
	1-Aug	Handwork	Roadside concrete	2	8	1	SP15	11
	2-Aug		Roadside concrete	1	3	1	SP15	5
	3-Aug	Handwork	Handwork	2	10			12
32	6-Aug							0
Construction holiday	7-Aug							0
Construction holiday	8-Aug							0
Construction holiday	9-Aug							0
Construction holiday	10-Aug							0
33	13-Aug							0
Construction holiday	14-Aug							0
Construction holiday	15-Aug							0
Construction holiday	16-Aug							0

Construction holiday	17-Aug							0
34	20-Aug							0
Construction holiday	21-Aug							0
Construction holiday	22-Aug							0
Construction holiday	23-Aug							0
Construction holiday	24-Aug							0
35	27-Aug	Handwork	Airport	2	15	1	SP1500	18
	28-Aug	Handwork	Airport	2	15	1	SP1500	18
	29-Aug	Handwork	Airport	2	15	1	SP1500	18
	30-Aug	Curbs	Airport	2	14	2	SP15 & SP1500	18
	31-Aug	Curbs	Airport	2	14	2	SP15 & SP1500	18
36	3-Sep	Bicycle roads	Airport	2	14	2	SMGE & SP1500	18
	4-Sep	Bicycle roads	Airport	2	14	2	SMGE & SP1500	18
	5-Sep	Handwork	Airport	2	15	1	SP1500	18
	6-Sep	Curbs	Airport	2	14	2	SP15 & SP1500	18
	7-Sep	Curbs	Airport	2	14	2	SP15 & SP1500	18
37	10-Sep	Handwork	Airport	2	15	1	SP1500	18
	11-Sep	Handwork	Airport	2	15	1	SP1500	18
	12-Sep	Handwork	Airport	2	15	1	SP1500	18
	13-Sep	Curbs	Airport	2	14	2	SP15 & SP1500	18
	14-Sep	Handwork	Airport	2	15	1	SP1500	18
38	17-Sep	Roadside concrete	Airport	2	13	2	SP15 & SP1500	17
	18-Sep	Roadside concrete	Airport	2	13	2	SP15 & SP1500	17
	19-Sep	Curbs	Airport	2	14	2	SP15 & SP1500	18
	20-Sep	Roadside concrete	Airport	2	13	2	SP15 & SP1500	17
	21-Sep	Curbs	Airport	2	14	2	SP15 & SP1500	18
39	24-Sep	Bicycle road	Airport	2	14	2	SMGE & SP1500	18
	25-Sep	Bicycle road	Airport	2	14	2	SMGE & SP1500	18
	26-Sep	Handwork	Airport	2	15	1	SP1500	18
	27-Sep	Handwork	Airport	2	15	1	SP1500	18
	28-Sep	Handwork	Airport	2	15	1	SP1500	18

40	1-Oct	Handwork	Roadside concrete	2	8	1	SP15	11
	2-Oct	Handwork	Roadside concrete	2	8	1	SP15	11
	3-Oct	Handwork	Curbs	2	9	1	SP15	12
	4-Oct	Handwork	Roadside concrete	2	8	1	SP15	11
	5-Oct	Handwork	Curbs	2	9	1	SP15	12
41	8-Oct	Handwork	Bicycle road	2	9	1	SMGE	12
	9-Oct	Handwork	Bicycle road	2	9	1	SMGE	12
	10-Oct	Handwork	Handwork	2	10			12
	11-Oct	Bicycle road	Handwork	2	9	1	SMGE	12
	12-Oct	Bicycle road	Handwork	2	9	1	SMGE	12
42	15-Oct	Handwork	Handwork	2	10			12
	16-Oct	Handwork	Handwork	2	10			12
	17-Oct	Handwork	Handwork	2	10			12
	18-Oct		Handwork	1	5			6
	19-Oct		Handwork	1	5			6
43	22-Oct		Handwork	1	5			6
	23-Oct	Handwork	Handwork	2	10			12
	24-Oct	Handwork	Handwork	2	10			12
	25-Oct	Roadside concrete	Bicycle road	2	7	2	SMGE & SP15	11
	26-Oct	Roadside concrete	Bicycle road	2	7	2	SMGE & SP15	11
44	29-Oct	Bicycle roads	Handwork	2	9	1	SMGE	12
	30-Oct	Bicycle roads	Handwork	2	9	1	SMGE	12
	31-Oct	Bicycle roads	Handwork	2	9	1	SMGE	12
	1-Nov							0
	2-Nov							0
45	5-Nov	Bicycle roads		1	4	1	SMGE	6
	6-Nov	Bicycle roads	Handwork	2	9	1	SMGE	12
	7-Nov	Bicycle roads	Handwork	2	9	1	SMGE	12
	8-Nov	Bicycle roads	Roadside concrete	2	7	2	SMGE & SP15	11
	9-Nov	Bicycle roads	Roadside concrete	2	7	2	SMGE & SP15	11
46	12-Nov		Bicycle roads	1	4	1	SMGE	6
	13-Nov		Bicycle roads	1	4	1	SMGE	6
	14-Nov		Bicycle roads	1	4	1	SMGE	6

	15-Nov							0
	16-Nov							0
47	19-Nov		Bicycle roads	1	4	1	SMGE	6
	20-Nov		Bicycle roads	1	4	1	SMGE	6
	21-Nov		Bicycle roads	1	4	1	SMGE	6
	22-Nov		Bicycle roads	1	4	1	SMGE	6
	23-Nov	Roadside concrete	Bicycle roads	2	7	2	SMGE & SP15	11
48	26-Nov							0
	27-Nov							0
	28-Nov							0
	29-Nov							0
	30-Nov							0
49	3-Dec							0
	4-Dec							0
	5-Dec							0
	6-Dec							0
	7-Dec		Roadside concrete	1	3	1	SP15	5
50	10-Dec	Handwork		1	5			6
	11-Dec	Handwork		1	5			6
	12-Dec	Handwork		1	5			6
	13-Dec	Handwork		1	5			6
	14-Dec	Handwork		1	5			6
51	17-Dec	Handwork		1	5			6
	18-Dec	Handwork		1	5			6
	19-Dec	Handwork		1	5			6
	20-Dec	Handwork		1	5			6
	21-Dec	Handwork		1	5			6

Appendix G

```
MODEL:
SETS:
! X,          !amount of permanent workers;
DAYS:
    REQUIRED,   !required capacity for day t;
    !CAPACITY, !capacity on day t;
    Y:        !amount of flex workers on day t ;
ENDSETS

DATA:
DAYS =      1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
REQUIRED =  0   0   0   0   0   0   0   0   0   0   0   6   6   6   6   6   6   6   6   6   6   6   12  4   12
ENDDATA

!constraints:
$FOR(DAYS(t): X + Y(t) >= REQUIRED(t));      !capacity should always be equal or higher than the demand;
$FOR(DAYS(t): Y(t) <= 2);                   !not more than 2 flexworkers available;

!total labour costs of permanent and flex workers;
MIN = 125400*X + @SUM(DAYS(t): 520*Y(t));

END
```