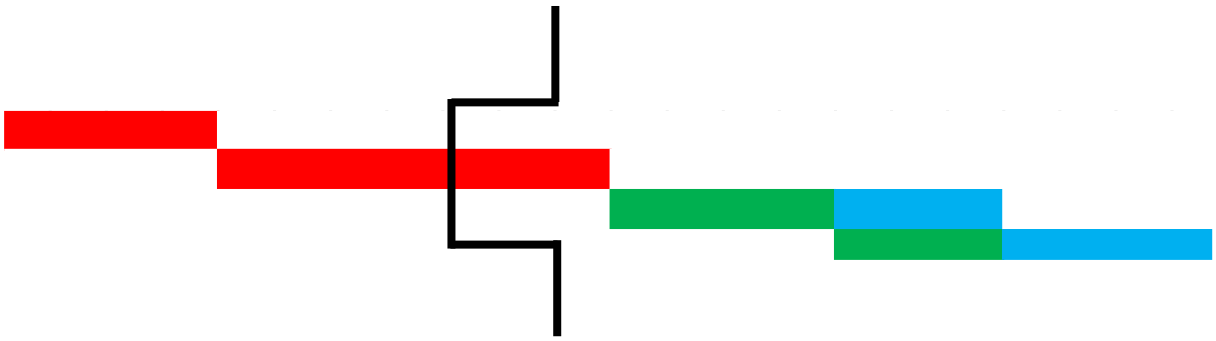
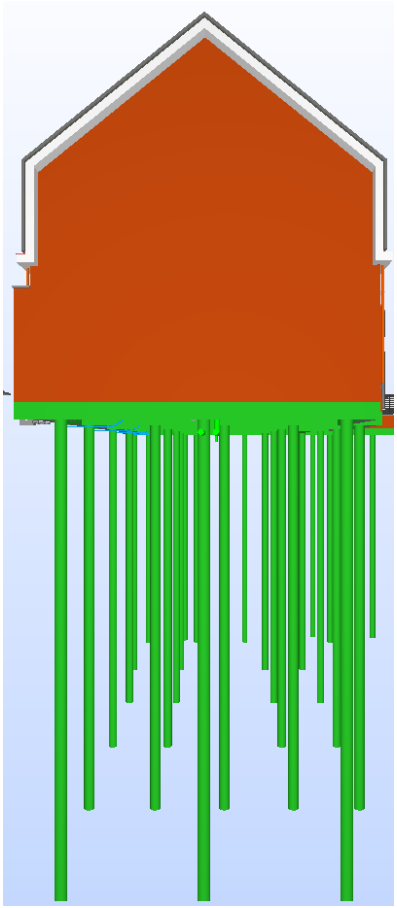
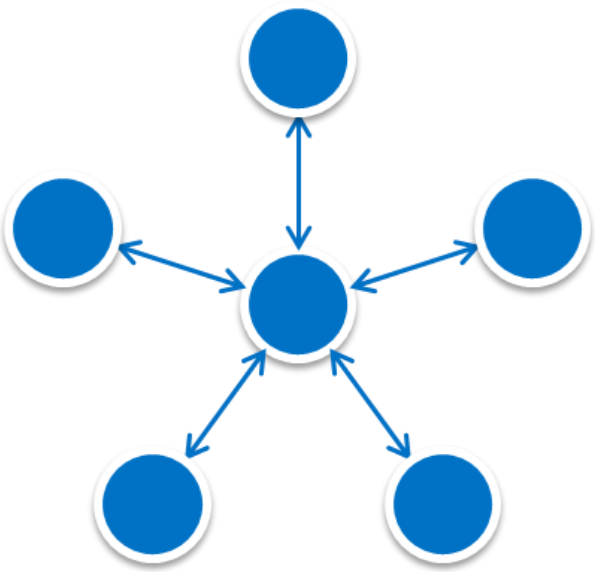
How to improve the project planning of a dwelling construction project?

Master's thesis







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Industrial Engineering and Management

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How to improve the project planning of a dwelling construction project?

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Abstract

This master thesis is about the improvement of the predictability of the planning of a dwelling construction project at Van Wijnen Arnhem. Van Wijnen Arnhem is a construction company that develops, builds, manages and maintains several types of buildings, varying from residential dwellings to business buildings. Van Wijnen Arnhem is part of the nationwide Van Wijnen network which has 24 branches in total. Van Wijnen Arnhem conducts its business in the dwelling construction, utility construction and maintenance & management industries. This research will be conducted on behalf of the dwelling construction department.

Within the dwelling construction department, the projects vary from constructing or renovating a single house up to a complete district. The emphasis of this research is on the new work construction projects, that exists of terraced dwellings which are constructed according to the prefabricated concrete assembly construction method. Van Wijnen Arnhem noticed that many dwelling construction projects aren't finished at the planned moment. To be able to plan this moment, for every dwelling construction project multiple schedules are drafted. Our research focussed on one of these schedules, the execution planning, in which all the construction activities to be performed at the construction site are planned.

The goal of this research is to propose a (partial) solution, that increases the predictability of deadlines and the delivery date of the project, with a keen eye on resources and costs. This research goal is translated into the following research question:

> **How can the predictability and structured clarity of the planning of a dwelling construction project be increased?**

To answer this question, we divide our research into three sections. First, we analyse the current situation at Van Wijnen Arnhem in a qualitative way by conducting interviews with multiple employees of Van Wijnen Arnhem. The interviewed employees are all responsible for a specific phase during the dwelling construction project. These phases are the procurement, project preparation, work preparation and execution phase, and are performed in this order. Here we want to find out how the planning within the dwelling construction department is done, and how deadlines and activity durations are determined. In the second section, we perform a more quantitative analysis using Key Performance Indicators (KPIs) and the Critical Path Method (CPM), based on real dwelling construction projects of Van Wijnen Arnhem. In the last section, a partial solution - in the form of changing the way that certain materials are supplied at the construction site - is presented.

Current situation analysis

From the current situation analysis it becomes clear that the execution planning is almost the most essential planning for each project. Delivery dates for the subcontractors and co-makers, and the planning of the work planner are all based on this planning. The difference between subcontractors and co-makers is that subcontractors perform activities at the construction site, and co-makers just supply materials. With delivery dates up to 35 weeks, for the work planner to be able to construct a decent work preparation planning this means that the execution planning must be ready at the end of the project preparation phase. Whenever the delivery dates and deadlines are incorrectly planned, the subcontractors and co-makers reserve capacity at the wrong moment. This leads to overcapacity at the planned moment that the materials are actually needed, and undercapacity at the moment that the materials are actually needed. This, in combination with an already high workload for all co-makers, leads to late delivery of the materials or manpower. Moreover, Van Wijnen Arnhem schedules just a single work planner per project. So, when a work planner falls ill unexpectedly, the whole work preparation process comes to a halt. This can also bring the work preparation of co-makers to a halt, which can also lead to late delivery of the materials.

To monitor the progress of the activities at the construction site, a so called "standlijn" is drawn in the execution planning, every end of the work week. This shows the progress of an activity in reality, relative to the planned progress. However, it doesn't show the reasons why activities are not progressing as planned because that isn't registered. It also doesn't show how an activity that is behind schedule, affects other activities, deadlines, and the delivery date of the project.

Project analysis

With the use of literature, multiple real projects of Van Wijnen Arnhem were analysed. The KPIs presented in literature study were applied to the projects. However, despite frantic attempts to gather data of completed dwelling construction projects of Van Wijnen Arnhem, we were not able to gather the required data of more than one completed project. Besides that this means that we haven't been able to compare KPIs of different completed projects, this also indicates that there is a serious lack of data when it concerns the progression of projects within Van Wijnen Arnhem.

The Critical Path Method presented in literature was applied to a project that is still in its project preparation phase. This analysis shows that: (1) the activities in the first part of the project up till the carcass assembly are always critical and (2) the carcass and roof assembly activities are always critical for the first dwelling blocks. This tells us that, if we want to let the construction activities go as planned, it is important that the focus is on these three main activities.

When we analysed the progression of one completed project and one project of which the construction started at the same moment this research started, we found that (1) at both projects the piling activities started and finished one week late, (2) at one of the projects the carcass assembly started 1 week late and finished 2 weeks late, (3) at both projects the roof assembly activities started late (1 & 5 weeks) and finished late 4 weeks at one project, and is to be expected to finish 4 weeks late at the other project.

Further research into these three activities shows that the carcass and roof elements are delivered at the construction site according to the Just-In-Time (JIT) principle. In this case this means that the materials are assembled at the moment they are delivered. This is done because there is no possibility to store these materials at the construction site due to their big dimensions. Because of using this JIT principle, any delay during the production of these materials results in a delayed delivery date.

Partial solution

By making sure that the piling, carcass assembly and roof assembly activities start at the planned moment, the predictability of the planning of a dwelling construction project will increase. VWA undertook several actions to standardise their work in each phase which should guarantee to that the execution planning is ready at the end of the project preparation phase, so we will not go further into organizational changes in that area.

To make sure that any delay of the piling activities will not affect all the succeeding activities, there is little that Van Wijnen Arnhem can do because the availability of the piling machine is the unreliable factor. Insourcing this activity may be an option, but only if it's done in cooperation with all the other Van Wijnen branches nationwide. Whether or not this is a viable option is for further research. Another option is to incorporate buffer time into the planning that serves as a buffer for any delays during the piling activities.

To tackle the problem that any late delivery of materials immediately affects the continuation of work at the construction site, we propose the so called "HUB solution". The HUB solution is: changing the way the prefabricated concrete carcass elements and roof elements are delivered to VWA. Instead of delivering straight from the production facility to the construction site, we propose to add a HUB. In this way the co-maker can deliver the materials at the HUB, and from there, the materials will be delivered Just-In-Time at the construction site. In this way the co-maker can deliver the materials on the delivery date that was established during the project preparation phase and any changes in the planning of VWA will not affect the planning of the co-maker. Calculations show that the benefits will outweigh the costs, depending on the number of projects per year, the number of dwellings for which the materials are delivered at the HUB, and under the assumption that the construction project will finish 5 week less late in comparison to the current situation. Applying this solution in practice should prove whether or not this will have the effect as assumed. To determine the number of dwellings for which materials should be delivered at the HUB, the Critical Path Method can be used in such a way that just the materials for the critical dwellings are stored.

The algorithm that applies the Critical Path Method to a planning, is developed in such a way that employees with basic knowledge of Excel are be able to use it, because the knowledge of Excel is very basic among the

employees of Van Wijnen Arnhem. This tackles the current problem of not having insight into the consequences when an activity does not progress as planned.

For Van Wijnen Arnhem to be able to apply planning improvement algorithms in the future, it is most important to start logging progression data on activity level. Therefore, we developed a program that creates an Excel sheet in which, the start & end dates, reasons for being behind or ahead of schedule, and other project specifics can be logged.

To conclude, we recommend Van Wijnen Arnhem to:

- On the short term: Implement the HUB solution in combination with the Critical Path Method.
- On the short term: Start logging the project specific progress data and use the designed tool to accommodate this.
- On the long term: apply planning improvement algorithms.

And, moreover:

- Study the possibility to insource the piling activities.
- Study the possibilities to insource other activities.

Preface

Arnhem, April, 2019

Dear reader,

With pleasure I present to you my master thesis, which is the result of my graduation project to obtain my master's degree Industrial Engineering & Management. I would like to thank my supervisors Peter Schuur and Hans Voordijk who have provided me with a lot of constructive feedback. Peter, you helped me during the whole process of setting up the research until its completion. I appreciated our meetings, it always gave me energy and new inspiration to continue the project. Hans, your keen eye helped me to improve my thesis and to give me new insights and suggestions.

I want to express my gratitude to Anton for being my supervisor at Van Wijnen Arnhem during the project. Thanks to you I was able to continue my project at Van Wijnen Arnhem after David had to leave the company. Moreover I would like to thank all the people at the Van Wijnen Arnhem dwelling construction department for your input and collaboration.

Most of all, I would like to thank my friends and family for their support, not only during the project but also in the years before.

Last but not least, I would like to thank my university colleagues. It was nice to study with you all and together we had a great time. I especially want to thank Carly, Niek and Thom for the great time and the good collaboration we had during the last years.

Sébastiaan van der Peijl

List of abbreviations

Abbreviation	Definition	Introduced on page
VWA	Van Wijnen Arnhem	2
KPI	Key Performance Indicator	6
FD	Final Design	8
TD	Technical Design	8
3D	3 Dimensional	10
CPM	Critical Path Method	15
AOA	Activity On Arc	15
AON	Activity On Node	15
PERT	Program Evaluation and Review Technique	15
PDM	Precedence Diagramming Method	15
RCPSP	Resource Constrained Project Scheduling Problem	15
NSGA	Nondominated sorting genetic algorithm	15
MRC-DTCRO	Multi-mode Resource Constrained Discrete Time-Cost-Resource Optimization	16
MRCPSP	Multi-mode Resource Constrained Project Scheduling Problem	16
LCCC	London Construction Consolidation Centre	46
VWD	Van Wijnen Deventer	52

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Content

1 Problem introduction

In the framework of completing the master study Industrial Engineering and Management at the University of Twente, this research was conducted at Van Wijnen Arnhem. The first section describes the van Wijnen organisation and the department within the organisation where the assignment takes place. The following sections are about the problem definition of the assignment. First, the research context will be given in section 1.2. Following on the research context, the problem is analysed, and the core problem will become clear in the third section, problem description, 1.3. Based on the problem description, in section 1.4 the problem approach is given which describes the strategy to be followed for solving the core problem. The subsequent sections are about the research objective and approach (section 1.5) and the scope of the research (section 1.6).

1.1 Company description

Van Wijnen started as a company that performed carpentry activities in 1907. Nowadays it's a company that develops, builds, manages and maintains several types of buildings, variating from residential houses to business buildings. With 24 offices across the country and around 1700 employees, they sold 2,700 houses in 2017. (Van Wijnen Groep, 2018) The offices are divided into five different regions, Noord, Oost, Zuid, West and Midden, each with their own head office. The regional head office of the Oost region is established in Arnhem, which is the office from where this assignment will be done.

The markets in which the company is active are dwelling construction, utility construction and maintenance & management. The research will be conducted on behalf of the dwelling construction department of Van Wijnen Arnhem (VWA). The projects of the department vary from building or renovating a single house up to a complete district. The customers of the dwelling construction (woningbouw in Dutch) department are mainly project developers that have a piece of land where they want to build residential buildings and sell them to private individuals.

1.2 Research context

During the economic recession the whole construction industry got hit hard, as can be seen in Figure 1.1 the number of bankruptcies of construction companies in the Netherlands exploded during that time (CBS, 2018). Van Wijnen Arnhem survived as a company. But to survive, a reorganization and many layoffs were necessary. Now times are better, the number of projects has dramatically increased and thus also, the annual turnover of van Wijnen woningbouw in 2018 is expected to be doubled relative to 2017. Due to this big increase of work, flaws in the organization's procedures come to light. Standard procedures are not up-to-date or aren't available at all, which causes problems in the organization.

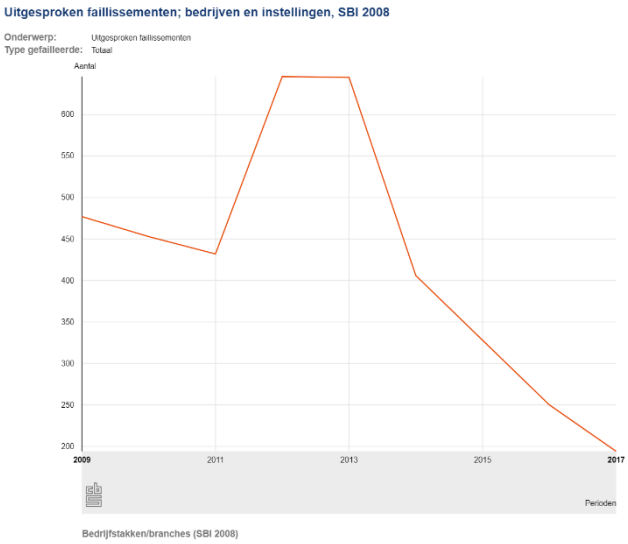


Figure 1.1; Number of bankruptcies in the construction industry over the years 2009 - 2017

In order to manage the chaos and bring clarity, rest and structure, VWA hired new employees who are concerned with updating the current standard procedures if they are there yet, and otherwise develop standard procedures. Besides that, they are also looking into automating their business processes. The main goal of this is to reduce superfluous proceedings which cost time and increase the possibility of making mistakes.

One of these standard procedures is creating a project planning. Creating a planning is quite complex, partly because VWA is a so-called multi-project organisation. Hans et al. (2005) describes a multi-project planning as an organisation that performs parallel multiple projects which require the same resources. This means that a delay of a certain activity at project A, can also delay an activity that requires the same resource at project B.

For each project VWA uses three, as we call it in this project plan, "main projects schedules". These main project schedules are 1) Purchase planning, 2) Preparation planning, and 3) Execution planning and are created in different phases during the project. The different phases of a dwelling construction project at VWA are depicted in Figure 1.2.

Figure 1.2; Dwelling construction project phases

During the first four phases, the design of the building evolves from a rough sketch to a detailed model in which all the dimensions and other specific details are available. During the fifth phase, the work preparation phase (werkvoorbereiding in Dutch), the detailed planning of the activities, personnel, and materials that are necessary to execute the project at the actual construction site is made. During the execution phase (uitvoering in Dutch) the building is actually built. When the execution phase has ended the last phase of the project is entered, this is the so-called aftercare and management phase (nazorg & beheer in Dutch). At this stage the last inconveniences are solved, and other administrative proceedings are completed.

For the sake of time we concentrate on the execution planning, but during the research we keep the other two schedules in mind. Based on these three schedules, VWA uses several more schedules on which we will not elaborate for now.

Currently it is very hard for VWA to come up with an execution project planning that is accurate. When we look at 5 randomly chosen dwelling projects that were finished in the last 2 years, 5 out of 5 of these projects were delivered later than originally planned.

Currently the execution planning for a new project is based on an old planning which is tailored to the new project and is then put into use. This takes a lot of time and mistakes that were made in an old planning are easily copied into the new one. Because of this planning problem, several other problems occur as can be seen in Figure 1.3. By solving the central problem, it is likely that these other problems will also (partly) be solved, which emphasizes the urge to solve this problem.

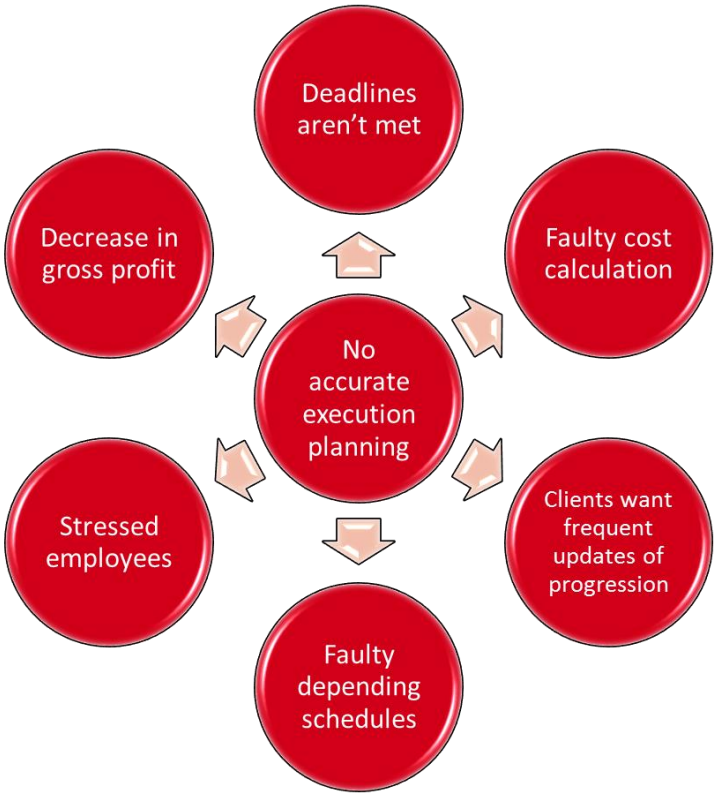


Figure 1.3; Problem cluster

VWA has already implemented some measures in order to increase the predictability of the project planning.

Standardised building
VWA developed a so called "standardised building" concept. In this concept, the dwelling is a standard, predesigned house. The dwelling is built in the same way every time they build it. In this way they try to be able to know exactly how much time every step will take and how much a dwelling will cost.

Planning software
To ensure a reliable planning, VWA makes use of the special planning software: "*Asta powerproject*". This software takes so called "non-workable days" per month into account when creating a planning. The number of these "non-workable days" depends on the time of the year the activities take place in.

Early involvement of the project leader
Another measure they have taken is to involve the project leader earlier in the project.

VWA has recently completed a project based on the "Standard building" principle, and again they failed to meet deadlines and the delivery date. The effect of these two measures, based on the feeling of project leaders, is that it has some effect on the predictability, but still not enough to be able to create an accurate project planning.

This research is therefore aimed at finding the main cause(s) that make the planning inaccurate and trying to come up with a (partial) solution, with a view to a more accurate planning. With accurate is meant that deadlines and the delivery dates are met with a more certainty.

1.3 Problem description

As the number of projects for the dwelling construction department van Wijnen Arnhem is growing over the years, it is getting more and more important to have main project schedules that can predict deadlines and delivery dates in a more reliable way. As described in the previous paragraph it is hard for VWA, despite the measures already taken, to consistently create such main project schedules. Again, this research focuses on the execution planning. So, the main problem can be described as:

> **Currently it is very hard for Van Wijnen Arnhem to consistently create an execution project planning for a dwelling construction project that can predict, with a certain level of certainty, the deadlines and the delivery dates of dwelling construction projects.**

1.4 Research goal

This research focuses on the predictability of the planning of a dwelling construction project. From the main problem we can derive the research goal which we define as follows:

> **Provide a (partial) solution that helps to create/creates a planning for a dwelling building project, that increases the predictability of deadlines and the delivery date of the project, with a keen eye on resources and costs.**

1.5 Research scope

The following is within the scope of this research:

- The execution planning (uitvoeringsplanning) of a dwelling construction project that concerns a terraced dwelling that is built according to the prefabricated concrete building concept.
- The activities that are listed on the execution planning and are performed at the construction site.
- Variability in the supply stream from subcontractors.
- A (partly) general solution to the problem that helps to create/creates the desired main project planning.

The following is not within the scope of this research:

- The activities performed in the preparation phase of the project that are not related to the execution planning.
- Integration in software used by Van Wijnen Arnhem.
- Optimization of the activities that are performed.

1.6 Research questions

The research goal is translated into the following main research question:

> **How can the predictability and structured clarity of the planning of a dwelling construction project be increased?**

By following the steps that are depicted in process flow in Figure 1.4, we want to answer the main research question.

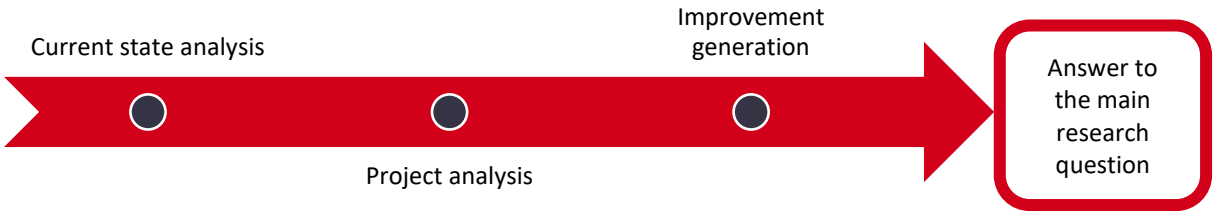


Figure 1.4; Research process flow

The following sub-questions are formulated per process step to answer the main research question:

By conducting the current state analysis, we want to get a clear view on how the activities to be performed at the construction site are planned, and how the progression is monitored. To answer these questions, semi-structured interviews will be conducted with employees of VWA, available documents and data on the servers of VWA will be reviewed and observations at the construction sites and at the dwelling construction department will be conducted.

Current state analysis

1. *How is the current state concerning the execution planning of the dwelling construction projects?*
   a. How are the activities of a dwelling construction project planned in the current situation?
   b. How is the progress of a project monitored?

By conducting project analysis, we want to analyse how the performance of the dwelling construction projects of Van Wijnen Arnhem has been in recent years. Moreover, we want to identify which activities are critical to finishing the construction activities in time. To answer these questions, a literature review on KPIs that are used for project monitoring in the construction industry and on the critical path method will be conducted. Furthermore, semi-structured interviews will be conducted with employees of VWA and available data on the servers of VWA and non-digital documentation at VWA will be reviewed.

Project analysis

2. What is the current performance of executing a dwelling construction project, in terms of the difference in time between planned activity deadlines and actual finishing an activity?
   a. Which KPIs are currently in place?
   b. Which KPIs can be used for the performance analysis?
   c. Which projects can be used to analyse?
   d. How are the selected projects performing?
   e. What activities are critical to the planning?

		In this phase we will come up with (partial) solutions that can improve the predictability of the execution planning of a dwelling construction project. A literature review on planning improvement of construction project planning and semi-structured interviews with employees of VWA will be conducted.
Improvement generation	3.	*Which method(s) is/are suitable, that can help us to improve the predictability of the execution planning of a dwelling construction project?*
	a.	Which method(s) can be used in such a way that VWA is more likely to be able to commit to the execution planning?
	b.	In which way can these method(s) help to improve the execution planning?

1.7 Deliverables

The deliverables of this research are:

- An analysis of the current situation at Van Wijnen Arnhem concerning the execution planning of dwelling construction projects.
- A partial solution to the presented problem.
- A program that can calculate the critical path.
- A program that creates an Excel sheet for the progress registration of construction projects.

2 Current situation analysis

This chapter is about the analysis of the dwelling construction department at Van Wijnen Arnhem. We elaborate on the different disciplines within the dwelling construction department and analyse how the planning and scheduling of project within the department is done.

2.1 Procurement phase

First, we look into the process at the early beginning of a project, the procurement phase. However, this discipline isn't an integral part of the dwelling construction department, we elaborate on this discipline because we want to find out what relation it has with the planning of a dwelling construction project. The information about this phase is gathered by interviewing the procurement manager of VWA.

To acquire a project VWA has two different options, we will first elaborate about these options.

One option is by tendering, here the client invites multiple parties (construction companies), often around 3 companies, for a bidding process. The competing companies all have the same timeframe to present their bid. When the bids are in/when the due date for handing in the bids is due, the client makes his decision. The party that put in the best bid, in the eyes of the client, gets the tender.

The other option to acquire a construction project, is that the client comes to VWA with the question to deliver a so called "bouwteam" for the construction project of the client. At that moment VWA is, in most cases, already sure that they will get the order to do their part of the client's construction project.

For this research it is important to know what agreements are made in relation to the planning of the project. In almost all the cases the client has already established a delivery date for the project. During the negotiations of the project this date can be adjusted when VWA has the right arguments that substantiate the change. Delivery dates are determined by the salesman by using the rule of thumb that the first dwelling should be ready after 60 workable days after the ground floor activities are finished. After the moment the first dwelling is finished every next day a dwelling should be ready. In most of the contracts a penalty clause is included which states a penalty fee must be paid by VWA to the client. An important side note is that there is a difference between the contractual finish date and the date the project is scheduled to finish. This difference is there to account for any delays. The penalty costs are between €100, - and €500, - per dwelling per day that the dwelling is delivered after the agreed contractual delivery date. (Interview Richard van Kleef – Commercial manager at VWA)

2.2 Project preparation phase

Once VWA has been contracted to perform the project, they start with the preparation of the project. The green part in Figure 2.1 indicates where in the process the preparation phase starts, and the orange part indicates where the phase ends.

Figure 2.1; Project process preparation phase

The employees involved in this phase are the project leader, calculator and the project preparer of VWA. Here the project preparer takes care of the necessary permits, maintains contact with client, architect, constructor and advisors, selects the subcontractors for the project, and creates several schedules. The schedules that are created by the project preparer are:

- FD phase planning,
- TD phase planning,
- Preparation planning,
- Execution planning.

The part of the work where the project preparer creates the different schedules is key to our research, and in particular the execution planning. Within VWA there are no guidelines that state how to perform this task, so it is up to the work preparer how this is done.

When the project preparer starts to create the execution planning, in most of the cases the starting date of the project and the date that the project must be completed are known. Sometimes these dates can be changed to a certain extent, with the right reasoning and in consultation with the client. On average it takes VWA around 100 days to build a dwelling from the moment the piling activities start.

Currently it takes relatively much time to create a "good" execution planning, which is partly caused by the lack of a standard basic planning which can be made project specific. Now every time the planning for a new project must be created from scratch, or a planning from an earlier project is adjusted.

To improve the predictability of the execution planning, every time a new planning is created one tries to incorporate the pros and cons from earlier projects. Unfortunately, these pros and cons aren't registered. So, currently the only pros and cons that are incorporated in a new execution planning, are the ones that the project preparer happens to know. Another action that is taken in order to improve the predictability, is to ask feedback from the executor (uitvoerder in Dutch). Based on this feedback some alternations, if necessary, are made. Some other variables that are considered are the so called, non-workable days due to weather influences and vacations. Other variables aren't considered.

As mentioned earlier in this paragraph, most of the subcontractors are selected in this phase of the project. Having a "good" execution planning is very important because the selected subcontractors also get a rough indication of time when they are expected to deliver goods or to perform their activities at the construction site. Based on these dates, subcontractors reserve time and capacity in their production processes. A "bad" execution planning results in big variations in the date that goods and activities are *planned to be needed* and the date that goods and activities are *needed in reality.* This big variation in time has as a consequence that subcontractors have overcapacity at the *planned* date and undercapacity at the date in *reality*. The undercapacity at the production of the subcontractors has in its turn consequences for the start and end date of the activities at the construction site. This, in combination with delivery times that in general have a delivery time of around 20 weeks, and with outliers to even 35 weeks (prognose levertijden woningbouw, 15-04-2018), can influence the actual delivery dates at the construction site. We also see that almost all the activities to be performed at the construction site, are performed by subcontractors. There are just two carpenters of Van Wijnen that perform all sorts of general and supporting activities.

Besides the subcontractors, also the calculator at VWA need the execution planning as input to calculate the general construction site costs, scaffold costs and other costs. Dates and periods that are important to the calculator are the construction time and the period that the scaffold is needed. (Personal announcement Calculator VWA, 21 November 2018)

When the preparation of the project by the project preparer is done, it is transferred to the work planner.

2.3 Work preparation phase

In the work preparation phase that the work planner starts his/her activities, the information is gathered by interviewing two work planners at VWA. The green part in Figure 2.2 indicates where in the process the phase starts, and the orange part indicates the where phase ends. This phase starts in general around 12 to 15 weeks before the activities at the construction site start. This can be a few weeks earlier or later, depending on the size of the project (number of dwellings to be build). Each project has assigned a single work planner to it, there's also a certain risk to this. The risk lies in the work continuation when the work planner isn't able to perform his/her activities, i.e. due to illness. When that happens, another work planner must (temporarily) take over the activities. But because he or she isn't familiar with the project a fast take over isn't possible, which can result in project delay.

Figure 2.2; Project process work preparation phase

The project leader is responsible for the overall continuation of all activities that must be performed and also for updating the execution planning. Updating the execution planning is necessary because the execution planning that the work preparer created, is based on a standardised dwelling without considering buyer options. These options aren't considered because these are unknown at that point of the process. Buyer options are for example, an extension of the ground floor area, an extra light switch, etc. But the most emphasis lies in this phase on the activities to be performed by the work planner. The activities that the work planner is responsible for are:

- Work preparation planning,
- Set-up the purchase contracts,
- Checking and approving the 3D models of the co-makers,
- Planning of the co-makers and the supply of materials according to the execution planning.

Key to our research is the planning of the subcontractors and the co-makers according to the updated execution planning. When the execution planning is updated in this phase, it also has to be final. The work planner communicates these start dates of the activities with the relevant parties, and they can also make their production planning final. Unfortunately, these agreed delivery dates aren't always complied with the co-makers. This has direct consequences for the execution planning and can also affect the end date of the project. The reason that co-makers can't comply with the agreements is difficult to track down because they aren't completely open about that. An often-heard excuse is that they lack capacity now that the construction industry is flourishing. VWA is under the impression that they can't do much to resolve this problem. Their hands are basically tied, and the only thing they can do, and are trying to do, is to stay in close contact with the co-makers and make sure that orders are placed in time.

When the work preparation phase ends, the work of the work planner isn't done yet. He/she is still involved in the project.

2.4 Work execution phase

When the work preparation phase is ready, the actual construction of the project starts. The green part in Figure 2.3 indicates where in the process the phase starts, and the orange part indicates where the phase ends.

Figure 2.3; Project process, execution phase

This information is gathered by interviewing two executors of VWA. Here the executor (uitvoerder in Dutch) carries out the project under supervision of the project leader. Up till now all the work that was done for the project was done at the office. From this moment on, the project takes place at the construction site. The activities to be done are all summed up in the execution planning and the executor has to make sure that all the subcontractors can perform their activities as planned. Normally the execution planning must be ready when this phase starts, but in practice it happens that the planning isn't ready, or even not created. In that case it can happen that the executor has to create the execution planning.

To have a more detailed insight on the day-to-day activities, the executor always creates a 6-week planning. This planning is based on the execution planning but is much more detailed. The way that this 6-week planning is created differs per executor. One of them creates digitally using Excel, as can be seen in the screenshot in Figure 2.4.

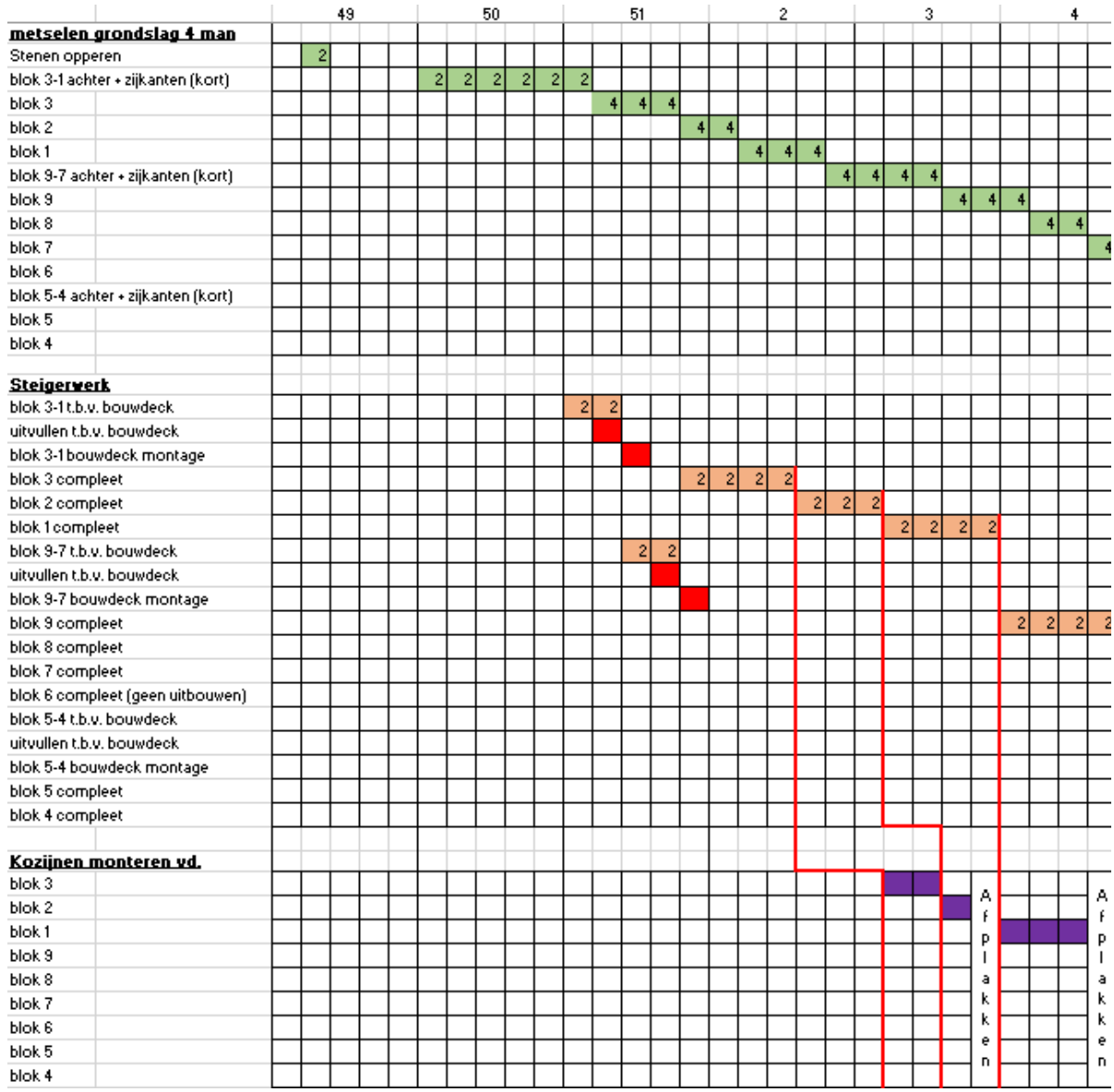


Figure 2.4; 6-week planning in Excel

Another executor creates the 6-week planning using sticky notes on a whiteboard, as can be seen in Figure 2.6; 6-week planning with sticky notes on the next page. Figure 2.5 shows an enlarged part of the sticky notes planning, to give you as a reader an idea of what information is on the notes.

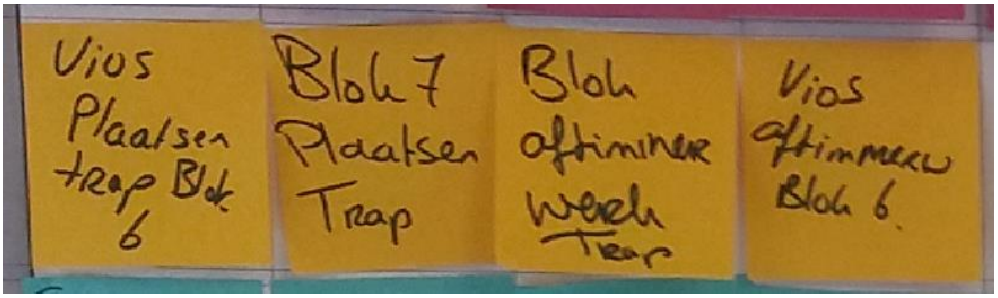


Figure 2.5; Enlargement of sticky notes planning

Figure 2.6; 6-week planning with sticky notes

A downside of the sticky note method is that the planning is only visible in the shack at the construction site. This has as a result that the project members that are not often present in the shack, have no insight in the 6-week planning. The executor invites the foreman of subcontractors, who are scheduled to perform their activities, to go through the planning. In this way he/she wants to make sure that everyone can perform their activities without being interrupted by other subcontractors. The 6-week planning also incorporates the exact moments of material delivery. Based on this planning the executor communicates with the material suppliers when he needs the material. The moment he needs the materials can, and often does, deviate from the moment that was planned in the execution planning.

To monitor the actual progression of the project in relation to the planned progression, a so called "standlijn" is drawn at the end of every workweek. This is done by the executor and it differs per person how this is done (digitally or on paper). Figure 2.7 shows a paper version of the execution planning with multiple "standlijnen" in it. Each colour represents one "standlijn". When the project is going perfectly as planned, every line should go in a straight line from top to bottom. When an activity is behind schedule the line goes to the point where the activity is completed.

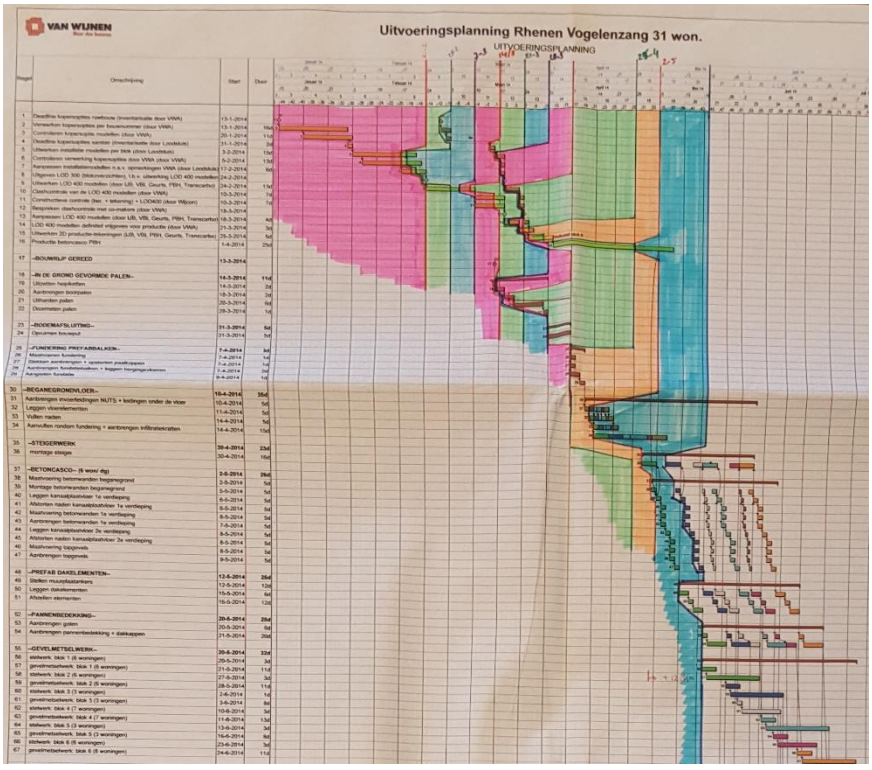


Figure 2.7; Standlijn

The digital version looks more or less the same as the paper version but has the advantage that everybody with access to the project directory on the servers of VWA can see it. Another advantage of the digital version is that it remains accessible when the project is completed, this in contradiction to the paper version that is often discarded.

Even though, the "standlijnen" shows the progression of the project over several moments in time, it doesn't show the reason why an activity is behind schedule. Moreover, this information isn't stored at another way.

2.5 Conclusion

This chapter is concluded with an answer to the first research question which reads as follows:

How is the current state concerning the execution planning of the dwelling construction projects?

At Van Wijnen Arnhem there is no standardised way of working when it concerns the execution planning. During the procurement phase the contractual delivery date of the project is set, and often there are penalties attached to it when this delivery date is not met.

In the following phase, the project preparation phase, the execution planning should be created as far as possible. However, in practice this is not always the case. In the most extreme case, the executor had to create the execution planning himself at the start of the work execution phase. When the execution planning is created, there is no standard planning template available that can be made project specific. Moreover, there are no guidelines available about how an execution planning should be created, and pros and cons from older projects aren't incorporated because these aren't documented. So, at the moment the people who create the execution planning are reinventing the wheel over and over again.

In the work preparation phase the subcontractors and co-makers are selected and informed, too. The subcontractors and co-makers receive, based on the execution planning, an indication of when their services or materials are needed. A side note is made to them that the actual data may vary a week. Based on this information they reserve time and capacity in their own (production) planning for the project of VWA. But when there is a faulty execution planning, there is a high risk of communicating data that will deviate heavily from reality. This can lead to late delivery from the co-maker or undercapacity at the subcontractor.

Then, in the work preparation phase, just a single work planner is assigned to the project to complete the necessary activities for this phase. This brings a risk to the continuation of the work, in case the assigned work planner unexpectedly can't perform his activities anymore. The key to finishing the project in time is to look closely to the delivery times of the materials, which vary from 4 to 35 weeks. To be able to do this, the work planner needs a final, and accurate execution planning and an up-to-date summary of the delivery times of the materials to be used in the project. When this information is not accurate, the work planner starts the preparation at the wrong time, which can result in delivery of materials at the construction site at the wrong time.

In the work execution phase, the influence of the executor on the delivery date of materials is at most a few days. The part that the executor can play to make sure that the project progression goes as planned, is to provide the people at the construction site with the right tools and to coordinate the subcontractors in such a way that they don't intervene with each other. The progression of the project is monitored by making use of a "standlijn" that is drawn by the executor at the end of every work week. Although it does show the progression of the project, it doesn't provide any information about the reason why an activity is behind schedule if that is the case. Moreover, this information is not documented at all, which makes it hard to analyse why activities get behind schedule afterwards.

3 Literature review

In this chapter we look into how literature can help us with our research. The first section is about literature that shows which KPIs can be used to analyse a dwelling construction project in a quantitative way. In the second section, we will elaborate on the Critical Path Method theory. In the last section, we look into which planning improvement methods for the construction industry are known in literature.

3.1 Key performance indicators

Bauer (2004) defines KPIs as quantifiable metrics which reflect the performance of an organization in achieving its goals and objectives.

We found that Chan et al. (2004) conducted a literature study in order to develop a method for measuring success of construction projects using key performance indicators. They came up with a set of KPIs including objective indicators and subjective ones. An overview of the KPIs is given in Table 3-1.

Objective measures	Subjective measures
Construction time	Quality
Speed of construction	Functionality
Time variation	End-user's satisfaction
Unit cost	Client's satisfaction
Percentage net variation over final cost	Design team's satisfaction
Net present value	Construction team's satisfaction
Accident rate	
Environment impact assessment scores	

Table 3-1; KPIs found by Chan et al. (2004)

Bassioni et al. (2004) review in their paper the main performance measurement frameworks and their application by U.K. construction firms. During their research they found a table that is developed by the construction best practice program (CBPP-KPI 2002), which shows KPIs for construction firms. The indicators are shown in Table 3-2.

Project performance	Company performance
Construction cost	Safety
Construction time	Profitability
Predictability – cost	Productivity
Predictability – time	
Defects	
Client satisfaction – product	
Client satisfaction – service	

Table 3-2; KPIs found by the CBPP-KPI (2002)

KPIs
Project performance
Time
Safety
Client satisfaction
Planning efficiency
Communication
Rework efficiency
Cost
Team performance

Table 3-3; KPIs used by Dawood et al. (2006)

Besides Bassioni et al. (2004), Dawood et al. (2006) also refers in their paper to the KPIs that were launched industry wide in the U.K. by the CBPP (CBPP-KPI-2004).

Unfortunately, there isn't any further explanation about the indicators in the paper of Bassioni et al. (2004), and the link to the webpage of the Construction Best Practice Program (CBPP), which is the original source, is no longer available.

The KPIs used by Dawood et al. (2006) are shown in Table 3-3.

When we compare the three sets of indicators, we see a lot of similarities, the difference is in the diversion of the indicators. Chan et al. (2004) split the indicators into objective and subjective measures, where the indicators were found by Bassioni et al. (2004) are divided into project and company performance. Dawood et al. (2006) has the emphasis on ranking the KPIs from important to less important to the end user of the KPIs.

3.2 Critical path analysis

To get insight in which activities are critical, in terms of having a direct impact on the delivery date when the activity takes longer to finish as planned the critical path method (CPM) can help. The critical path method is used to determine the earliest and latest possible starting time of each identified activity in a project, without affecting the end date of the project.

In the late 1950s, methods for planning and scheduling project were developed based on network models. Two different types of project networks were introduced, the *activity-on-arc* (AOA) and the *activity-on-node* (AON) network. If each activity of the project is assigned to an arc of a network (and the duration of the activity corresponds to the arc weight), we speak of an AOA network. If each activity of the project is assigned to a node of a network (and the arc weights represent minimal or maximal time lags between activities), we speak of an AON network. (Heizer & Render, 2011) The minimal and maximal time lags are needed for modelling, among other things, partial or total overlapping of activities. (Neumann & Schwindt, 1997)

According to Gabriel (2009), the AON model is frequently used in practical, non-optimization situations, and the Activity-On-Arc (AOA) model is used in optimization settings. Neumann & Schwindt (1997) state that the AOA networks have several disadvantages in comparison with the AON networks, for example:

- To model all the precedence relationships of a project in an AOA network, a large number of dummy activities have to be introduced in general, which cannot be done in a unique way and is a frequent source of error.
- Only minimal time lags between different activities can be modelled.

To determine a critical path a so-called *forward pass* and *backward pass* has to be done. In the forward pass the **earliest** possible start and finish time of each activity is calculated, and in the backward pass the **latest** possible start and finish time of each activity. By comparing the earliest possible starting moment and the latest possible starting moment, one can determine the amount of slack. The amount of slack indicates how many days an activity can start later as planned, can take longer as planned, or a combination of the two, without affecting the end date of the project. When the amount of slack of an activity is zero, it is marked as critical. (Antill & Woodhead, 1965) (Heizer & Render, 2011)

3.3 Planning improvement methods

From literature we learned that there is much research conducted into how to optimize/improve the planning of construction projects using algorithms and models.

Wang and Liu (2004) propose a factor-based model to measure the sensitivity of each factor to uncertainty by decomposing the effects of uncertainty at the level of activity, and then integrating these individual effects at the path level. Models that are used are PERT (Program Evaluation and Review Technique) and CPM. They want to try to control the project by putting more effort in the identified “critical” activities/subcontractors and less effort in the “non-critical” activities/subcontractors.

Hebert and Deckro (2009) have examined a construction project where they first prepare an initial project schedule using Microsoft Project. After that they use original linear programming to be able to resolve the time/cost trade-offs that occur when one wants to shorten the schedule. They make use of multiple scheduling methods: CPM, PERT and PDM (Precedence Diagramming Method). The linear programming formulation for the time/cost trade-off problem for projects modelled using the precedence diagramming method, is a new contribution at the time to the project management literature. So, this research is focussed on the optimization (shortening) of the project schedule with precedence relationships in it.

Das and Acharyya (2011) have done research into the Resource Constrained Project Scheduling Problem (RCPSP) and how to solve this problem by the use of different variants of Simulated Annealing. Their goal was to get optimal results with maximum hit and minimum fluctuations.

El-Abbasy et al. (2017) developed a model that has the purpose to obtain optimal trade-offs between different projects’ objectives. The paper presents the development of a multiobjective scheduling optimization model for multiple construction projects using the fast-elitist non-dominated sorting generic algorithm (NSGS-2). In the end

the model is expected to help construction industries in solving the problems of prioritizing projects under resource-conflict conditions, allocating limited resources, and optimizing all the projects' multiple objectives under certain funding limits.

Ghoddousi et al. (2012) present the multi-mode resource-constrained discrete time-cost-resource optimization (MRC-DTCRO) model. To solve multiple scheduling problems simultaneously they extended the general multi-mode resource-constrained project scheduling problem (MRCPSP) to the new multi-mode resource-constrained discrete time–cost-resource optimization (MRC-DTCRO) model. This model selects the best combination of starting rime, and execution mode for each project activity with respect to time, cost, and moment of resource histograms around its mean on the direction of X axis.

3.4 Conclusion

KPIs are quantifiable metrics which reflect the performance of an organization in achieving its goals and objectives. KPIs are split up in objective & subjective, and in company & project performance measures. The KPIs that were found will be used as input for chapter 4, where a project analysis will be conducted.

The Critical Path Method is used to determine the earliest and latest possible starting time of each identified activity in a project, without affecting the end date of the project. This model will enable us to identify the critical activities in a construction projects and will be applied in chapter 4.

The literature found about improving the project planning of a dwelling construction project addresses algorithms and models that all use historical data about dwelling construction projects. We found that these solutions can be very useful for VWA, but due to the lack of data, not on the short term.

4 Project analysis

This chapter shows a quantitative analysis of multiple real projects of VWA. Section 4.1 describes on which type of dwelling and construction method the analysis has focussed. Section 4.2 describes which Key Performance Indicators (KPIs) will be used in the case study section (section 4.3). In section 4.3 the performance of multiple dwelling construction projects is determined by calculating the KPIs. In the following section, section 4.4, the critical activities -activities that have to finish as planned to make sure the project finishes as planned- are calculated by applying the Critical Path Method. The chapter closes with a conclusion in section 4.5.

4.1 Focus of the analysis

Due to the restricted amount of time available we had to narrow down the type of dwelling and the construction method, to one dwelling type and one construction method.

Concerning the type of dwelling we had to choose from three different dwelling types, namely: terraced house, semi-detached house or detached house. We have chosen to focus on the terraced house, because this is the type of dwelling that VWA builds the most.

For the building method we had to choose from the following four different methods concerning the construction of the carcass of the dwelling.

Stacked construction (Stapelbouw in Dutch)

This building method is described by van Boom et al. (2005) as a carcass that is build out of stones, blocks or (non-storey high) elements that are stacked on top of each other and cemented or glued together.

Poured concrete carcass construction (Gietbouw in Dutch)

This building method is described by van Boom et al. (2005) as a method where the carcass of the dwelling is constructed by pouring factory-made concrete into concrete forms.

Prefabricated concrete carcass construction (Montagebouw prefab beton in Dutch)

This building method is described by van Boom et al. (2005) as a method that uses pre-fabricated concrete parts which are being assembled at the construction site to form the carcass of the dwelling.

Timber frame construction (Montagebouw houtskeletbouw in Dutch)

This building method is described by van Boom et al. (2005) as a method where the carcass is built out of standardised building timber.

We choose to focus on the “Prefabricated concrete carcass construction” method. This choice was made based on the vision of VWA and general developments in the building industry, which is that the standardised dwelling projects are to be build according to this method.

4.2 Key performance indicators

To conduct this analysis, we make use of KPIs to be able to get insight in the performance of the projects analysed, and to compare the performance of the three different projects with each other.

Based on the KPIs found in literature, and the experience of employees at VWA, we made our choice for the KPIs to be used for the analysis.

It is important to keep in mind that the KPIs in the previously mentioned research papers are used for measuring the overall performance of a project. Which is different from the goal of this analysis, which is, the performance of a project from the planning point of view. For this reason, we only use the KPIs that seems to be relevant to this research.

The KPIs that are used for the analysis of the three projects in this research, and their definitions, are shown in Table 4-1.

KPI	Definition
Construction time	Absolute time to that is calculated as the number of days/weeks from start on site to practical completion of the project
Speed of construction	The gross floor area (m^2) that is constructed in a day or week
Time variation	Percentage of increase or decrease in the estimated project duration in days/weeks
Schedule performance index	A measure of the schedule efficiency of the project. The index shows the amount of work earned, per dollar of work planned.
Hit rate percentage	The reliability of the start and end date for each activity.
Start hit rate percentage	The reliability of the start date for each activity.
Finish hit rate percentage	The reliability of the end date for each activity.
Unit cost	The final contract sum divided by the gross floor area (m^2)
Profitability performance index	A measure of how profitable the project is. The index shows the ratio between revenue earned and costs incurred.
Communication intensity	Information exchange between members using the prescribed manner and terminology.
Rework efficiency	Number of defects noted at house transfer to client/customer
Productivity performance	A measure that represents the pace of an activity. I.e. the number of piles driven per day.

Table 4-1; KPI definitions

The operationalisation per KPI is as shown in Table 4-2 on the next page.

KPI	Operationalisation
Construction time	$$Construction\ time\ = Practical\ completion\ date - Project\ commencement\ date$$ *Practical completion date = date when the last dwelling is delivered to the client/costumer. **Project commencement date = date when the piling activities start or, when there are no piling activities, the foundation activities are started.
Speed of construction	$$Speed\ of\ construction\ = \frac{Gross\ floor\ area\ (m2)}{Construction\ time\ (days)}$$
Time variation	$$Time\ variation = \frac{Construction\ time - Revised\ contract\ period}{Revised\ cotract\ period}$$ *Revised contract period = Original contract period + Extension of time
Schedule performance index	$$Schedule\ performance\ index = \frac{Budgeted\ Cost\ of\ Work\ Performed}{Budgeted\ Cost\ of\ Work\ Scheduled}$$ *BCWP = The cumulative budgeted cost for the work completed to date **BCWS = The budgeted cost for work scheduled to date
Hit rate percentage	$$Hit\ Rate\ \% = \frac{Total\ number\ of\ activities\ having\ zero\ start\ and\ finish\ variances}{Total\ number\ of\ activities\ in\ a\ package} * 100$$ *Start variance = Actual start – Scheduled start **Finish variance = Actual finish – Scheduled finish
Start hit rate percentage	$$Hit\ Rate\ \% = \frac{Total\ number\ of\ activities\ having\ zero\ start\ variance}{Total\ number\ of\ activities\ in\ a\ package} * 100$$ *Start variance = Actual start – Scheduled start
Finish hit rate percentage	$$Hit\ Rate\ \% = \frac{Total\ number\ of\ activities\ having\ zerofinish\ variance}{Total\ number\ of\ activities\ in\ a\ package} * 100$$ *Finish variance = Actual finish – Scheduled finish
Unit cost	$$Unit\ cost = \frac{Final\ contract\ sum}{Gross\ floor\ area\ (m2)}$$
Profitability performance index	$$Profitability\ performance\ index = \frac{Earned\ Revenue\ of\ Work\ Performed}{Actual\ Cost\ of\ Work\ Performed}$$ *ERWP = Cumulative revenue earned for the actual work accomplished to date **ACWP = Cumulative cost incurred to complete the accomplished work to date
Communication intensity	Number of project team meetings per week
Rework efficiency	Number of defects noted at house transfer to client/customer

Productivity performance	Number of piles driven per day

Table 4-2; KPI operationalisation

To clarify the KPIs a bit more, some of them are explained using examples which are given below.

Speed of construction

This number tells us how many square metres are built per construction day. When we have a project that consists of 10 dwellings, and every dwelling has a gross floor area of 100 m^2, the total gross floor area is 1000 m^2. The gross floor area of one dwelling is the floor area per floor summed up. With a construction time of 60 days, the speed of the construction is $\frac{1000}{60} = 16.67\ m^2/day$

Hit rate percentage

This number tells us what percentage of the activities in a construction project are started and finished in the week they were planned to start and finish. Table 4-3 shows an overview of fictional start and finish dates. Here we see that 5 of the 12 activities did hit the planned start and finish week, which is indicated with a "Yes" in the column "Hit?" This means that the hit rate percentage is:

$\frac{5}{12} * 100\% = 42\%$

	Start			Finish			
	Planned (week)	Reality (week)	Difference	Gepland (week)	Reality (week)	Difference	Hit?
Activity 1	1	1	**0**	5	5	**0**	Yes
Activity 2	4	4	**0**	11	12	**1**	No
Activity 3	12	12	**0**	16	15	**-1**	No
Activity 4	15	15	**0**	19	19	**0**	Yes
Activity 5	20	22	**2**	28	28	**0**	No
Activity 6	18	20	**2**	23	23	**0**	No
Activity 7	21	23	**2**	25	26	**1**	No
Activity 8	22	22	**0**	25	25	**0**	Yes
Activity 9	20	20	**0**	35	36	**1**	No
Activity 10	25	24	**-1**	37	37	**0**	No
Activity 11	22	22	**0**	36	36	**0**	Yes
Activity 12	34	34	**0**	37	37	**0**	Yes

Table 4-3; Fictional start and finish dates

4.3 Case study

Based on the set of KPIs that are determined in the previous section we conducted three case studies. For confidentiality reasons we refer to the projects as project 1, project 2 and project 3. The data that is required as input to the analysis, is data about the start and finish weeks of activities, financial data, and floorplans of the dwellings. Unfortunately, the registration of the progress of dwelling construction projects is relatively poor within VWA. For this reason, we were not able to conduct a case study on more than one completed project, project 1. Projects 2 and 3 are projects of which respectively the construction at the construction site, and the project preparation started in the same period as this research is conducted.

4.3.1 Data gathering

Duration data

As mentioned before, the registration of the progress of projects is very poor within VWA. This had as a result that the employees couldn't provide more information than the project's file directory. So, to gather the necessary information of project 1, we had to dive into the digital archives of VWA. We found pictures that were taken of the sticky notes 6-week planning, and two different execution schedules. The reason that there were two different execution schedules is that the first planning was created without consulting the executor. The consequence was that right before the work at the construction site had to start, he concluded that it wouldn't be possible to build according to the original schedule. Unfortunately, we're not able to track down the reasoning of the executor. Because the original planning was considered inadequate, we chose to use the latest (updated) version of the planning as input to calculate the KPIs.

By comparing the 6-week planning and the execution planning we were able, to a certain extent, to get insight into the progress of the project at the time. For the comparison we had to limit ourselves to the main activities of the project only, this because the available data wasn't detailed enough to conduct a deeper analysis. Each main activity contains several sub activities. The duration of the main activity is from the start of the first sub activity to the finish of the last sub activity. For example, Figure 4.1 shows the main activity "Heiwerk" (piling) and its sub activities.

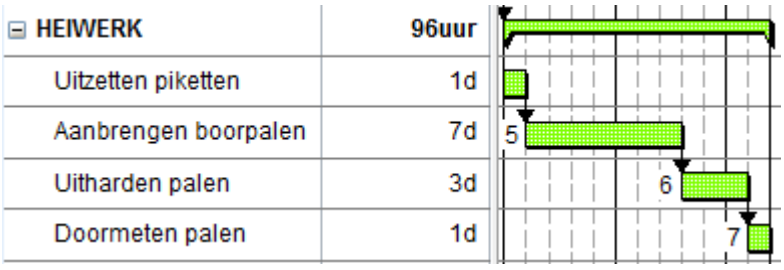


Figure 4.1; Main & sub activities example

To monitor the progress of the second project we kept close contact with the work preparer and executor. In this way we were able to keep track of the progression of both, main and sub activities.

Financial data

The contract sums of the projects can be found on the intranet page of Van Wijnen Oost.

Floorplan

The floorplans of each project can be found on the server of VWA.

4.3.2 KPI results

A summary of the general background information and the KPIs per project is given in Table 4-4. After the table, the outcomes are discussed.

	Case 1	Case 2	Case 3
General information			
Project name	Project 1	Project 2	Project 3
Nature of project	New work	New work	New work
Type of dwelling	Terraced	Terraced	Terraced + 1 detached dwelling
Building method	Prefabricated concrete carcass	Prefabricated concrete carcass	Prefabricated concrete carcass
Total no. of dwellings	50	27	25
Total no. of dwelling blocks	10	9	11
Gross floor area	5411 m^2	4127 m^2	3762 m^2
Original contract sum	€ 5,585,694. -	€ 4,293,000. -	€ 4,307,000. -
Project commencement date	16 October 2017	20 August 2018	21 May 2019 (planned)
KPIs result			
Construction time	Planned: 101 days* Real: 146 days* *Based on workable days according to prognosis calendar	Planned: 176 days*	Planned: 149 days*
Speed of construction	37.06 m^2/day** ** Based on the real construction time	23.45 m^2/day*** Based on the planned construction time	25.25 m^2/day***
Duration variation Planned vs. reality	45%	Unknown	Unknown
Schedule performance			
Hit rate percentage	8% total	30 November 2018: 49%	Unknown
Unit cost	€ 1,032. - per m^2	€ 1,040. - per m^2	€ 1,145. - per m^2
Profitability performance index	1.09	Unknown	Unknown
Communication intensity	Every 4 weeks a project team meeting	Every 2 weeks a project team meeting	Unknown
Average no. of defects at transfer to owner	0.34	Unknown	Unknown
Minimal no. of defects at transfer to owner	0	Unknown	Unknown
Maximum no. of defects at transfer to owner	2	Unknown	Unknown
Productivity performance	No. of piles driven per day: $\frac{246}{6} = 41$	No. of piles driven per day: $\frac{249}{3} = 83$	No of piles to be driven per day: $\frac{233}{5} = 46.6$

Table 4-4; Case KPIs

Dwelling blocks

It is important to keep a keen eye on the number of dwelling blocks. Because increasing the number of dwelling blocks while the number of dwellings stays the same, let also increase the total area of the masonry. This is because for each extra dwelling block, two extra side facades arise. Fortunately, there is not much difference between the total number of dwelling blocks in the projects so we don't pay attention to this difference.

Construction time

When we look at the KPIs, we see that the speed of construction of project 2 and 3 is planned to be lower than it was in reality at project 1. We tried to find an explanation for this big difference by consulting with work planners of the dwelling construction department, but failed to find one.

Table 4-5 shows the comparison that was made of project 1. It shows the planned and actual start and finish times per main activity and the difference between them.

Duration comparison	Start			Finish		
Activity description	**Planned (week)**	**Actual (week)**	**Difference**	**Planned (week)**	**Actual (week)**	**Difference**
Piling (Heiwerk)	43	44	**1**	45	46	**1**
Groundwork finishing (Bodemafsluiting)	46	46	**0**	46	48	**2**
Foundation prefabricated beams (Fundering prefab balken)	46	45	**-1**	47	47	**0**
Ground floor floring (Begane grond vloer)	47	48	**1**	49	48	**-1**
Scaffold assembly (Ruwbouwsteiger)	49	49	**0**	6	7	**1**
Carcass assembly (Cascomontage)	48	48	**0**	5	5	**0**
Prefabricated roof elements assembly (Prefab dak elementen)	50	51	**1**	7	11	**4**
Roofing (Dakbedekking)	50	2	**2**	8	15	**7**
Masonry facade (Gevelmetselwerk)	49	51	**2**	15	24	**9**
Terrain layout (Terrein inrichting)	8	16	**8**	19	21	**2**
Completion (Afbouw)	51	51	**0**	15	23	**8**
House transfer (Oplevering)	18	22	**4**	19	29	**10**

Table 4-5; Start and finish date comparison project 1

A side note must be made that the planned start and finish data that are shown in this table, come from an execution planning that was created at the moment that the work execution phase started. The first thing that we see is that of the 12 activities, only 4 of them started in the week they were planned to start. And only 2 of the 12 activities finished in the week they were planned to finish.

When we look at the hit rate of project 1, we see that it is 8%. Let us recall that this is based on an execution planning that is created while the work execution phase started, so any late deliveries that where known at that moment were already taken into account. Unfortunately, we don't have any construction projects to compare with, so we can't compare this score to other projects. Table 4-6 gives an overview of the hits of the project. We see that only the activity Carcass assembly (Casco montage in Dutch) has a full hit.

	Full hit	Start hit	End hit
Hit rate percentage	8%	33%	17%
Piling (Heiwerk)	No	No	No
Groundwork finishing (Bodemafsluiting)	No	Yes	No
Foundation prefabricated beams (Fundering prefab balken)	No	No	Yes
Ground floor flooring (Begane grond vloer)	No	No	No
Scaffold assembly (Ruwbouwsteiger)	No	Yes	No
Carcass assembly (Cascomontage)	Yes	Yes	Yes
Prefabricated roof elements assembly (Prefab dak elementen)	No	No	No
Roofing (Dakbedekking)	No	No	No
Masonry facade (Gevelmetselwerk)	No	No	No
Terrain layout (Terrein inrichting)	No	No	No
Completion (Afbouw)	No	Yes	No
House transfer (Oplevering)	No	No	No

Table 4-6; Hit rates project 1

Table 4-7 shows the start and finish date comparison of project 2. Here we see, again, that the piling activities and roof assembly activities deviate from the planning. Moreover, the carcass assembly started and finished late at this project, which, in turn led to the late start of the masonry activities.

Duration comparison	Start			Finish		
Activity description	**Planned (week)**	**Actual (week)**	**Difference**	**Planned (week)**	**Actual (week)**	**Difference**
Piling (Heiwerk)	39	39	**0**	42	43	**1**
Groundwork finishing (Bodemafsluiting)	41	42	**1**	42	42	**0**
Foundation prefabricated beams (Fundering prefab balken)	42	43	**1**	45	45	**0**
Ground floor flooring (Begane grond vloer)	46	45	**-1**	49	49	**0**
Scaffold assembly (Ruwbouwsteiger)	49	51	**2**	6	-	**-**
Carcass assembly (Cascomontage)	47	48	**1**	2	4	**2**
Prefabricated roof elements assembly (Prefab dak elementen)	50	5	**5**	7	-	**-**
Roofing (Dakbedekking)	51	5	**4**	8	-	**-**
Masonry facade (Gevelmetselwerk)	48	49	**1**	6	-	**-**
Terrain layout (Terrein inrichting)	51	51	**0**	20	-	**-**

Table 4-7; Start and finish date comparison project 2

The real and planned start and end date comparison of the two projects shows that, (1) at both projects the piling activities started and finished one week late, (2) at one of the projects the carcass assembly started 1 week late and finished two weeks late, (3) at both projects the roof assembly activities started late (1 & 5 weeks) and finished late four weeks at project 1, and is to be expected to finish four weeks late at project 2.

The reason that the piling activities started late at both projects was that the piling company was running late at another preceding project. Interviews with work planners and executors of the dwelling department learned that the piling company has a very tight schedule during the year, and that there is almost no slack in their schedule. This means that when they are running late at certain project, the piling activities at the succeeding projects can't start at the scheduled moment. Sometimes, there is the possibility of working overtime by the piling company, which was done at project 2. In this way, the piling activities are finished in time, but it still has an impact on the direct succeeding activity. Because succeeding activities cannot always speed up, and so the delay remains.

From interviews with the executor of the project 1 and the executor and work planner of the project 2, we found that the reason that the carcass and roof assembly started late had to do with the late delivery of the materials. In both cases the reason for the late delivery was undercapacity at the co-maker. And because these materials are delivered straight from the co-maker to the construction site, any delay at the co-maker immediately results in late delivery of the materials at the construction site.

From comparing the purchasing planning with the execution planning of the project that is still under construction, we found that there is a difference of 7 weeks for the carcass elements and 9 weeks for the roof elements. So, the co-makers planned their production capacity based on faulty information. We found that this is not a single mistake that happened once, when we compared the execution planning with the purchasing planning of a project that is still in its project preparation phase. Here we see that there is a difference of 11 weeks for the carcass elements and eight weeks for the roof elements. This shows that the purchasing planning is not corresponding with the execution planning.

When we take a look at the influence that VWA has on the activities to be performed in the work preparation phase and take the prefab concrete carcass process as example, we see that the role of VWA is limited. Figure 4.2 shows the activities that have to be performed during the preparation phase in the first column and the party responsible for performing the activity in the last column. It can be seen that only two activities has to be performed by VWA in this process, and all the other activities has to be performed by other parties. This shows that once the project preparation is in progress, there is little VWA itself can do to expedite the process when necessary.

PREFAB CASCO	98d	26-04-2019	07-10-2019	PBH
Te verstrekken stukken				
- Bouwkundig ifc model, situatie, bouwrouting en constructieve uitgangspunten				
Uitgangspunten				
- Vorm casco elementen uittekenen voor afstemming met installaties en vloeren				
- Details dakelementen definitief voor start tekenwerk				
Afstemming vloer met installaties & vloeren (1won/dag)	**25d**	**26-04-2019**	**03-06-2019**	**PBH**
Prefab cascomodel uitwerken (2won/dag)	14d	11-06-2019	28-06-2019	PBH
Controle prefab casco model (4won/dag)	7d	17-06-2019	01-07-2019	VWA
Opmerkingen uit clash verwerken (4won/dag)	7d	19-06-2019	02-07-2019	PBH
Opstellen 2D tekeningen wanden (2won/dag)	**14d**	**21-06-2019**	**10-07-2019**	**PBH**
Opstellen wapeningtekening en berekening (2won/dag)	**14d**	**27-06-2019**	**16-07-2019**	**PBH**
Controle berekening	15d	03-07-2019	14-08-2019	VAN MOORSEL
Prefab cascomodel definitief		14-08-2019	14-08-2019	PBH
Opstellen productietekeningen (2won/dag)	13d	15-08-2019	02-09-2019	PBH
Tekenwerk definitief		02-09-2019	02-09-2019	PBH
Definitieve stukken indienen bij de gemeente		02-09-2019	02-09-2019	VAN MOORSEL
Definitieve stukken verstrekken aan maatvoerder		02-09-2019	02-09-2019	VWA
Levering stelkozijnen		27-08-2019	27-08-2019	DELCON
Levering kozijnen		02-09-2019	02-09-2019	WENEKO
Productie wanden (1 won/dag)	25d	03-09-2019	07-10-2019	PBH

Figure 4.2; Work preparation planning prefabricated carcasses

4.4 Critical path analysis

Based on the theory presented in chapter 3, we started to apply the CPM to the execution planning of a dwelling construction project of VWA. We use the Activity-On-Node (AON) method, as the main goal is to get a clear overview of the critical activities and critical path. By using the AON network, it means that the nodes represent the activities and the arcs between the nodes indicate the precedence relationships and can have a certain weight that represents a time lag.

The time lags are needed to be able to model the activities to be performed during a dwelling construction project. Because the construction of the dwellings is done in blocks and not per dwelling, and often also these blocks are combined in the planning of a project, which means that one activity concerns multiple blocks. For example, we take the activities *mounting window frames* and *mounting windows in frames*. Say that the *mounting of the window frames* of block 1 and 2 is planned to start at day 30 and takes up to 10 days. Then, after one day of work a certain number of windows frames are mounted into the dwellings, which means that the *mounting of the windows into the frames* can start at day 31. So, this parameter indicates after how many days any direct succeeding activity is allowed to start. By giving the arrow, that graphically indicates the relations between the activities, a negative weight.

Before going deeper into how we modelled the CPM, we present a toy problem to give a better understanding of how the method works. As mentioned before, we use the AON model where each activity is represented by a node. Figure 4.3 shows such a node.

Earliest possible finishtime	Earliest possible finishtime
Activity number	
Duration (days)	
No. of days before next activity can start	
Pred. must be finished.	
Latest possible finishtime	Latest possible finishtime

Figure 4.3; Node explanation

The toy problem we present exists of 5 activities and has one critical path, as can be seen in Figure 4.4. The red arrows indicate the critical path, the green arrows indicate the path that has slack. The total duration is 32 days.

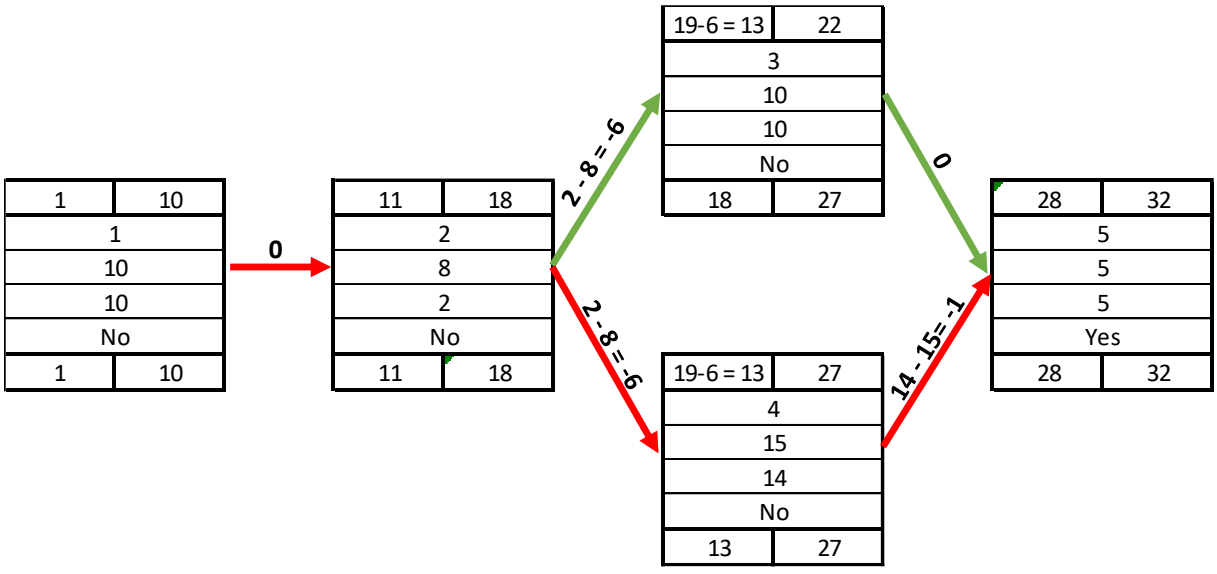


Figure 4.4; CPM toy problem

There are three arrows with a negative weight, to explain this we take activities 2 and 4 as example. The arrow weight is -6 which means that the succeeding activity (in this example activity 4) can start 6 days before activity 3 has finished.

The toy problem also shows that activity 2 has two successors, this means that both activities that have activity 2 as predecessor (activity 3 & 4) must wait for activity 2. It also shows that activity 5 has two predecessors. This has as a consequence that activity 5 can only start when both predecessors have reached the day that their succeeding activities can start. In this case, when we look just at activity 3, the succeeding activity can start at day 23. But when we look at activity 4, the succeeding activity can start no earlier than on day 27 (28-1). When we look at the succeeding activity, activity 5, we see that it starts on day 28, this is because it has the restriction that the activity can only starts when all its predecessors are finished.

The figure shows that the activities 1, 2, 4 & 5 are critical, and that activity is non-critical and has slack. The amount of slack can be calculated by subtracting the earliest finish time from the latest finish time. By doing this, we see that the amount of slack of activity 3 is 27 – 22 = 5 days.

Now we elaborate on the further modelling of the algorithm.

Input table

First, the input data, which is a table that contains all the activities that must be performed to execute the project. Each row contains one activity and per activity the input that is shown in Table 4-8, has to be entered by the user.

Parameter	Description
Activity number	A number that is unique for each activity
Activity description	A short description of the activity
Duration finish	Number of working days that it takes to finish the activity
Duration next	Minimum number of working days between the start of the activity and the start of any succeeding activity.
Pred must be finished	It happens that an activity has multiple direct successors but not all these direct successors are allowed to start before the activity has ended. So, when it happens that an activity is allowed to start only if all direct predecessors are fully finished this binary parameter is set to 1.
Predecessor(s)	The activity number of the direct predecessor(s) of the activity

Table 4-8; Input parameters CPM required to be given in by user

Based on these input variables two other input parameters (*arrow length* and *successor(s)*) are computationally determined. The formula IF(Duration_Next<>””; -Duration_finish + Duration_next;0) is used to determine the *arrow length*. This formula states that, if the parameter *Duration_next* has a value, the arrow length is calculated as follows:

$$Arrow\ length = -Duration\_finish + Duration\_Next$$

When the *Duration_next* has no value, the arrow length is set to 0.

In order to determine the successor(s) of each activity, we came up with an algorithm that does this based on the given predecessor(s). A copy of the code can be found in appendix 1. The algorithm works as follow:

1) START
2) Starting with the activity that is on top of the input table
3) Get the activity number of the activity in the current row and set the *temporary successor* value in the algorithm to this number,
4) Starting at the first predecessor column of the activity row,
5) If there is a value in the current predecessor column then;
   Get the number of the predecessor and set the *temporary predecessor* value in the algorithm to this number
   Else; Go to step 3 and go to the next row,
6) Find the row in which the *temporary predecessor* number is listed,

7) Look for an empty successor column in this row,
8) Set the value of the empty cell to the *temporary successor* value,
9) Go to step 5 and to the next row,
10) When the algorithm is at the bottom of the input table all successors are listed,
11) STOP

After running this algorithm, the input table is complete.

When we take the toy problem as an example, the input table will be as shown in Table 4-9.

Activity number	Activity description	Duration finish	Duration next	Pred must be finished?	Pred. 1	Pred. 2	Suc. 1	Suc. 2
1	Activity 1	10	10	0			2	
2	Activity 2	8	2	0	1		3	4
3	Activity 3	10	10	0	2		5	
4	Activity 4	15	14	0	2		5	
5	Activity 5	5	5	1				

Table 4-9; Input table toy problem

Now the output table can be filled by making use of the CPM heuristic algorithm. Table 4-10 shows which information is stored in the output table.

Parameter	**Description**
Activity number	A number that is unique for each activity
Activity description	A short description of the activity
Duration finish	Number of working days that it takes to finish the activity
Earliest start	Earliest moment (day) that the activity can start
Earliest finish	Earliest moment (day) that the activity can finish
Latest start	Latest moment (day) that the activity must start without delaying the project
Latest finish	Latest moment (day) that the activity must finish without delaying the project
Immediate successor	The number(s) of the direct successor(s)
Critical?	Binary variable that indicates whether an activity is critical (1 = Yes)

Table 4-10; Output table CPM

The code of the algorithm that is programmed in Excel VBA can be found in appendix 2. The code works as follows:

1. START
2. Clear the output table
3. Determine the last rows of the input and output table
4. FOR Loop through the input table from the first to the last activity
   - 4.1. Set the **earliest possible starting time** value for the current activity to 1
   - 4.2. FOR Loop through all the predecessor columns at the current row starting with the first predecessor
     - 4.2.1. IF the activity can start early THEN
       - 4.2.1.1. IF The **earliest possible starting time** (**ES**) for the current activity < the **earliest possible finish time** (adjusted for the arrow length) (**EF**) of the predecessor THEN
         - 4.2.1.1.1. Set the **ES** for the current activity to the **EF** of the predecessor
       - 4.2.1.2. END IF
     - 4.2.2. ELSE
       - 4.2.2.1. IF The **ES** for the current activity < the **EF** of the predecessor THEN
         - 4.2.2.1.1. Set the **ES** for the current activity to the **EF** of the predecessor
       - 4.2.2.2. END IF
     - 4.2.3. END IF
     - 4.2.4. Calculate the **earliest possible finish time** for the current activity
     - 4.2.5. Write the following values to the corresponding columns in the current row in the output table;
       Activity number, Activity description, Activity duration, ES, EF
   - 4.3. Next predecessor column (back to step 4.2.)
5. Next row (back to step 4.)
6. FOR Loop through the output table from the last to the first activity
   - 6.1. IF the selected row is the last row in the table THEN
     - 6.1.1. The **latest possible starting time** (**LS**) is equal to the **ES** of the activity in this row
     - 6.1.2. The **latest possible finish time** (**LF**) is equal to the **EF** of the activity in this row
     - 6.1.3. Add the following values to the corresponding columns in the current row in the output table; *LS, LF*
   - 6.2. ELSE
     - 6.2.1. Set the **LF_Temporary & LF** value equal to the **LF** of the last activity in the output table
     - 6.2.2. Lookup the current activity in the input table
     - 6.2.3. FOR Loop through all the successor columns at the current row starting with the first successor
       - 6.2.3.1. IF successor is allowed to start early* THEN
         - 6.2.3.1.1. Set the **LF_Temporary** value to; (**LS** value of the successor) – 1 – (arrow length of the current activity)
       - 6.2.3.2. ELSE
         - 6.2.3.2.1. Set the **LF_Temporary** value to; (**LS** value of the successor) – 1
       - 6.2.3.3. END IF
       - 6.2.3.4. IF **LF_Temporary < LF** THEN
         - 6.2.3.4.1. **LF = LF_Temporary**
         - 6.2.3.4.2. Set the *earliest successor* value in the output table to the activity number of the successor
       - 6.2.3.5. ELSEIF **LF_Temporary = LF** THEN
         - 6.2.3.5.1. Add the activity number of the successor to the *earliest successor* value in the output table
       - 6.2.3.6. END IF
     - 6.2.4. NEXT successor column (back to step 6.2.3.)
   - 6.3. Add the **LF** value to the corresponding column in the current row in the output table

6.4. Add the **LS** (= **LF –** (duration_finish of the current activity) + 1) value to the corresponding column in the current row in the output table

7. Next row (back to step 6.)
8. STOP

4.4.1 Project analysis

Now with the algorithm in place, we were able to determine the critical path of one of the dwelling construction projects of VWA. We chose to use the earlier mentioned project 3 as input for the analysis. This choice was made because the project was in the preparation phase at the moment of the analysis. In this way the outcome wouldn't not just be useful for this research, but also for the project preparer. It provides him with a good insight and can help him to divide the limited amount of time that he has available more efficiently, which means paying less attention to the non-critical activities and more the critical activities.

Input

To be able to enter the required data into the input table, the execution planning of the project is used. The total number of activities that are identified in the execution planning is 152 while the number of activities in the input table is 436. This difference has to do with the precedence relationships. To be able to model these relationships in the right way, we had to split up the activities into so called "construction blocks". Construction blocks contain one or more dwelling blocks and are used within VWA to be able to plan in more detail. Table 4-11 shows how, for this project, the dwelling blocks are divided into five construction blocks.

Construction block number	Dwelling block number(s)
1	5 & 6
2	3 & 4
3	7, 8 & 9
4	1 & 2
5	10 & 11

Table 4-11; Construction blocks distribution

Both the duration and predecessor(s) of each activity are based on the experience of the project preparer. The complete table with the input parameters can be found in appendix 3.

Output

When we let the algorithm run it fills the output table which can be found in appendix 4. Shortly after this analysis the execution planning was updated by the project preparer, based on the feedback of an executor. What changed was the duration of the activity "masonry". In the original planning the duration was based on a pace of 25,000 stones per week, however this turned out to be very ambitious, so it was adjusted to 15,000 stones per week. We immediately updated our input table to see how this would affect the critical path. This was done by multiplying the original duration with a factor 25000/15000 = 1.67 and by rounding this outcome to integers.

The outcomes of both the original and the updated execution schedules are shown in Table 4-12.

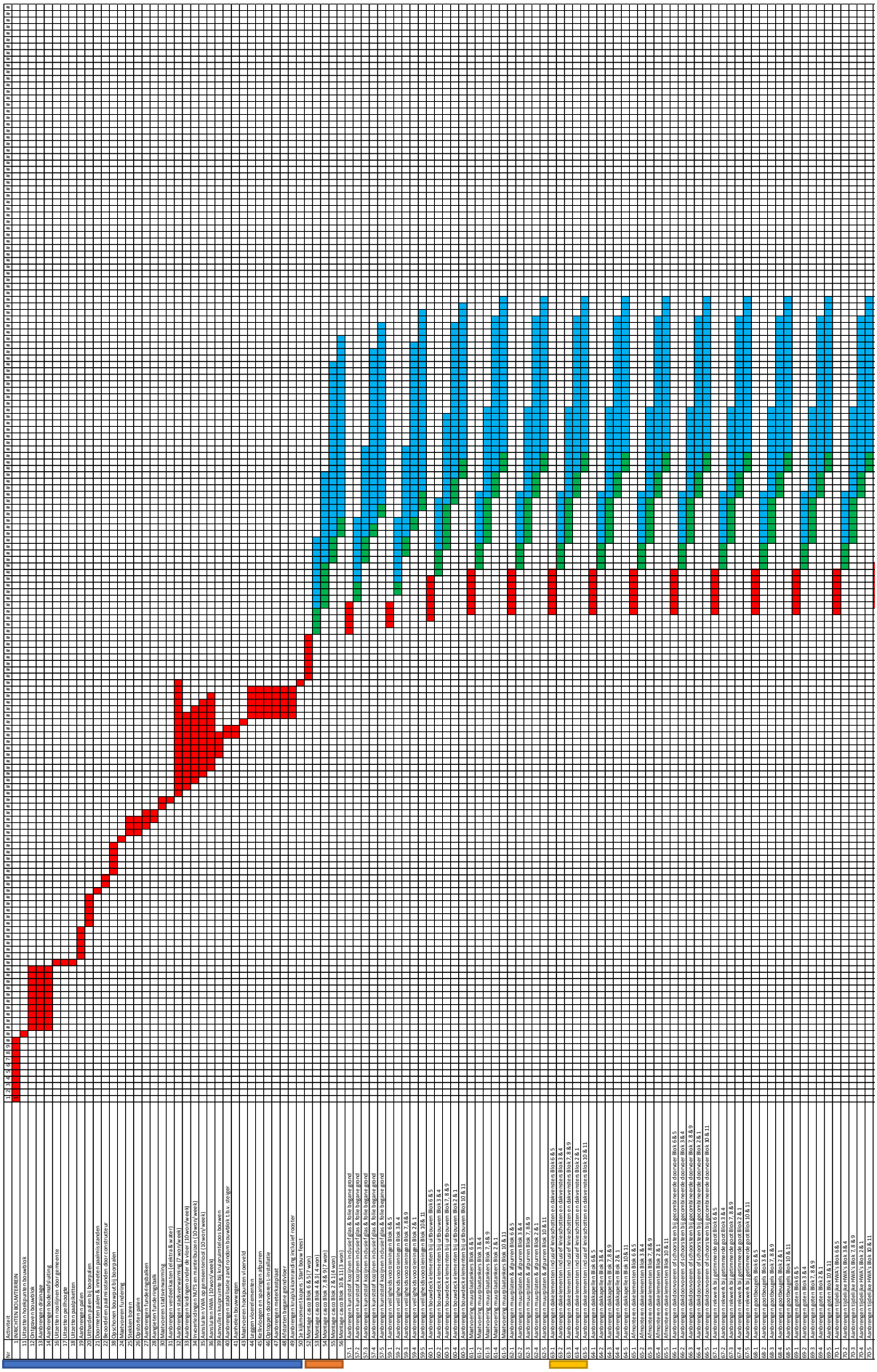
	Original planning	Updated planning
Total project duration	145 days	169 days
Number of critical activities	331	73
Number of critical paths	3888	1944

Table 4-12; CPM project analysis outcome

The number of critical paths is calculated by multiplying the number of direct succeeding critical activities per activity. To visualise the critical paths, a Gantt chart was created of both schedules which can be seen on the next pages.

The colour of the bar indicates whether an activity is critical or not. Red: the activity is critical, green: the activity is non-critical and indicates the earliest possible start and finish time, blue: amount of slack that is allowed. The first chart that is shown, is the Gant Chart based on the lower masonry pace. The activities that turned out to be the most important in relation to this research are marked by different colours.

- Blue: Construction ground preparation, piling and ground floor assembly.
- Orange: Carcass elements assembly.
- Yellow: Roof elements assembly.
- Green: Masonry.
- Grey: Filling activities.


Nr.
Activiteit
1 INRICHTEN BOUWTERREIN
11 Uitzetten hoeksputen bouwblok
12 Omtrekken bouwblok
13 Aanbrengen bouwweg
14 Aanbrengen bodemafsluiting
16 Uitzetten rooilijnen door gemeente
17 Uitzetten peilhoogte
18 Uitzetten paalassen
19 Uitzetten palen
20 Uitharden palen bij boorpalen
21 Doormeten palen & ijmeten paalmiddens
22 Bevoegdaten paalmiddens door constructeur
23 Opzoomen boorpalen bij boorpalen
24 Aanbrengen funderingsbed
25 Stekken lijnen
26 Opzoomen palen
27 Aanbrengen funderingsbalken
28 Aanleggen funderingsbalken
29 Aanbrengen vloerisolatie onderlaag
31 Aanbrengen vloerisolatie (elektra & water)
32 Aanbrengen vloerverwarming (7 werkweken)
33 Aanbrengen leidingen onder de vloer (10 werkweken)
34 Inzetten stijgers NOTS en inzetten buiten (10 werkweken)
35 Aanbrengen vloerafwerking (10 werkweken)
36 Aanleiding HWA (10 werkweken)
39 Aanvullen kruipruimte bij kruipruimtevloeren bouwen
40 Aanbrengen stabilisatie zand rondom bouwblok t.b.v. stijger
41 Aanleiden bouwwegen
42 Aanbrengen stabilisatie zand in vloerveld
43 Legen vloerelementen
45 Kelkvoegen en spuitgaten afdurven
46 Optippen doorvoeren t.i.v installatie
47 Aanbrengen metselsnoeren
48 Aanbrengen kruipluchtmondjes
49 Aanbrengen kruipluchtmondjes inclusief rooster
50 1e sijlmoment kozijnen. Start bouw fase1
52 Montage casco Blok 6 & 5 (7 won)
53 Montage casco Blok 4 & 3 (7 won)
55 Montage casco Blok 2 & 1 (4 won)
56 Montage casco blok 10 & 11(3 won)
57:1 Aanbrengen kunststof kozijnen inclusief glas & buis begane grond
57:2 Aanbrengen kunststof kozijnen inclusief glas & buis begane grond
57:3 Aanbrengen kunststof kozijnen inclusief glas & buis begane grond
57:4 Aanbrengen kunststof kozijnen inclusief glas & buis begane grond
57:5 Aanbrengen kunststof kozijnen inclusief glas & buis begane grond
59:1 Aanbrengen veiligheidsvoorzieningen blok 6& 5
59:2 Aanbrengen veiligheidsvoorzieningen blok 4 & 3
59:3 Aanbrengen veiligheidsvoorzieningen blok 7,8&9
59:4 Aanbrengen veiligheidsvoorzieningen blok 2& 1
59:5 Aanbrengen veiligheidsvoorzieningen blok 10& 11
60:1 Aanbrengen bouwdeck elementen bij uitbouwen Blok 6 & 5
60:2 Aanbrengen bouwdeck elementen bij uitbouwen Blok 4 & 3
60:3 Aanbrengen bouwdeck elementen bij uitbouwen Blok 7,8&9
60:4 Aanbrengen bouwdeck elementen bij uitbouwen Blok 2& 1
60:5 Aanbrengen bouwdeck elementen bij uitbouwen Blok 10 & 11
61:1 Metselwerk muurplaatankers Blok 6 & 5
61:2 Metselwerk muurplaatankers Blok 4 & 3
61:3 Metselwerk muurplaatankers Blok 7,8&9
61:4 Metselwerk muurplaatankers Blok 2& 1
61:5 Metselwerk muurplaatankers Blok 10 & 11
62:1 Aanbrengen muurplaten & afduren Blok 6 & 5
62:2 Aanbrengen muurplaten & afduren Blok 4 & 3
62:3 Aanbrengen muurplaten & afduren Blok 7,8& 9
62:4 Aanbrengen muurplaten & afduren Blok 2 & 1
62:5 Aanbrengen muurplaten & afduren Blok 10 & 11
63:1 Aanbrengen dakelementen inclusief wisselsohten en dakvensters Blok 6 & 5
63:2 Aanbrengen dakelementen inclusief wisselsohten en dakvensters Blok 4 & 3
63:3 Aanbrengen dakelementen inclusief wisselsohten en dakvensters Blok 7 & 8 & 9
63:4 Aanbrengen dakelementen inclusief wisselsohten en dakvensters Blok 2 & 1
63:5 Aanbrengen dakelementen inclusief wisselsohten en dakvensters Blok 10 & 11
64:1 Aanbrengen dakpannen Blok 6 & 5
64:2 Aanbrengen dakpannen Blok 4 & 3
64:3 Aanbrengen dakpannen Blok 7,8 & 9
64:4 Aanbrengen dakpannen Blok 2 & 1
64:5 Aanbrengen dakpannen Blok 10 & 11
65:1 Afmonteren dakelementen Blok 6 & 5
65:2 Afmonteren dakelementen Blok 4 & 3
65:3 Afmonteren dakelementen Blok 7,8& 9
65:4 Afmonteren dakelementen Blok 2 & 1
65:5 Afmonteren dakelementen Blok 10 & 11
66:1 Aanbrengen dakdoorvoeren of schoorstenen bij gecombineerde dooreen Blok 6 & 5
66:2 Aanbrengen dakdoorvoeren of schoorstenen bij gecombineerde dooreen Blok 4 & 3
66:3 Aanbrengen dakdoorvoeren of schoorstenen bij gecombineerde dooreen Blok 7,8& 9
66:4 Aanbrengen dakdoorvoeren of schoorstenen bij gecombineerde dooreen Blok 2 & 1
66:5 Aanbrengen dakdoorvoeren of schoorstenen bij gecombineerde dooreen Blok 10 & 11
67:1 Aanbrengen reiwerk bij gestimmerde goot Blok 6 & 5
67:2 Aanbrengen reiwerk bij gestimmerde goot Blok 4 & 3
67:3 Aanbrengen reiwerk bij gestimmerde goot Blok 7 & 8 & 9
67:4 Aanbrengen reiwerk bij gestimmerde goot Blok 2 & 1
67:5 Aanbrengen reiwerk bij gestimmerde goot Blok 10 & 11
68:1 Aanbrengen goothouten Blok 6 & 5
68:2 Aanbrengen goothouten Blok 4 & 3
68:3 Aanbrengen goothouten Blok 7 & 8 & 9
68:4 Aanbrengen goothouten Blok 2 & 1
68:5 Aanbrengen goothouten Blok 10 & 11
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69:3 Aanbrengen goten Blok 7 & 8 & 9
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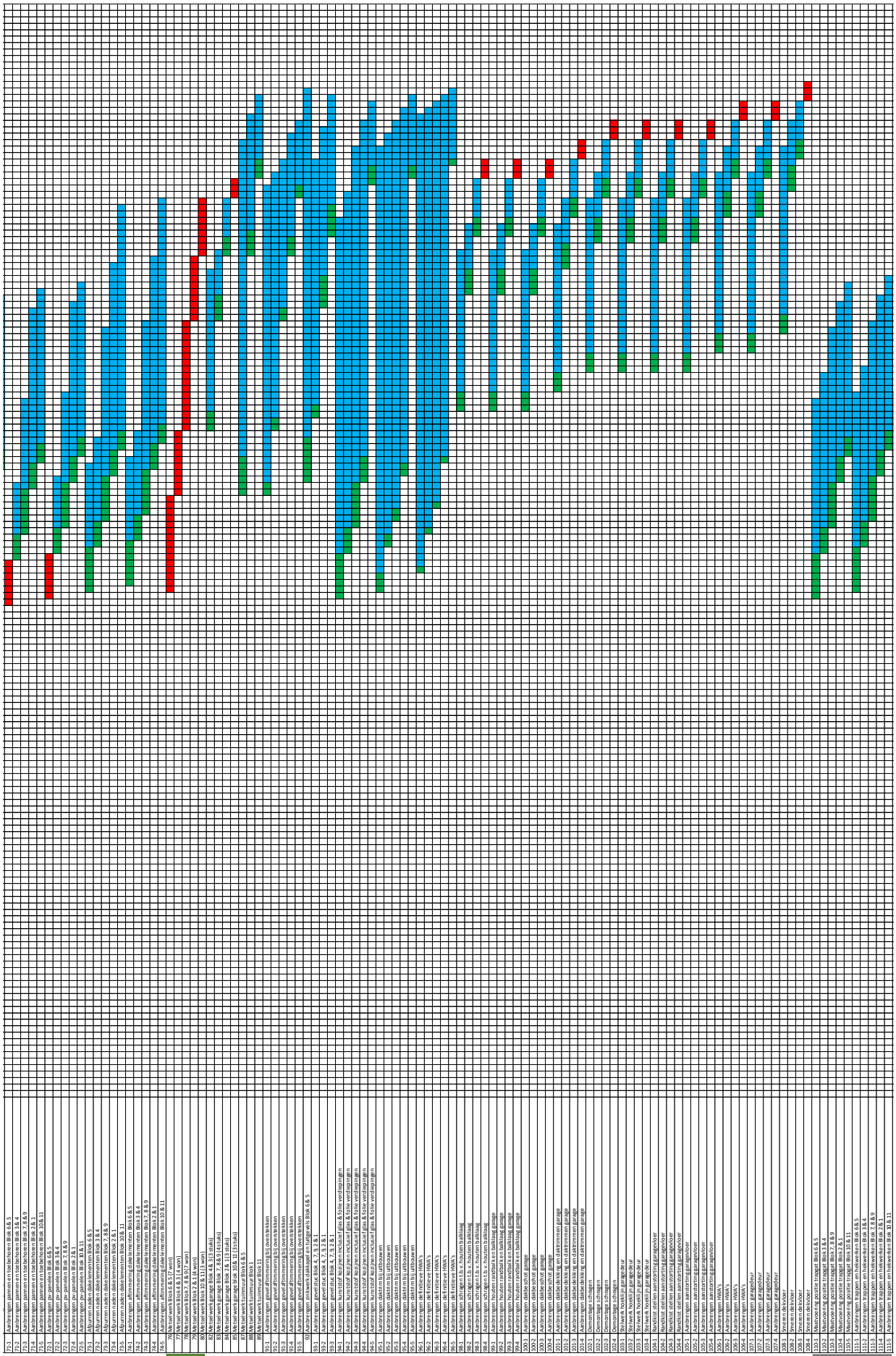
70:4 Aanbrengen tijdelijke HWA's Blok 2 & 1
70:5 Aanbrengen tijdelijke HWA's Blok 10 & 11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8.0 Metselwerk Blok 10 & 11 (5 woni)
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9.5.1 Aanbrengen dakrm bij uitbouwen
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9.9.1 Aanbrengen houten randtalk en balklaag garage
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10.0.1 Aanbrengen dakbeschot garage
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10.1.1 Aanbrengen dakbedekking en dakrimmen garage
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10.5.1 Aanbrengen aansluiting garagedeur
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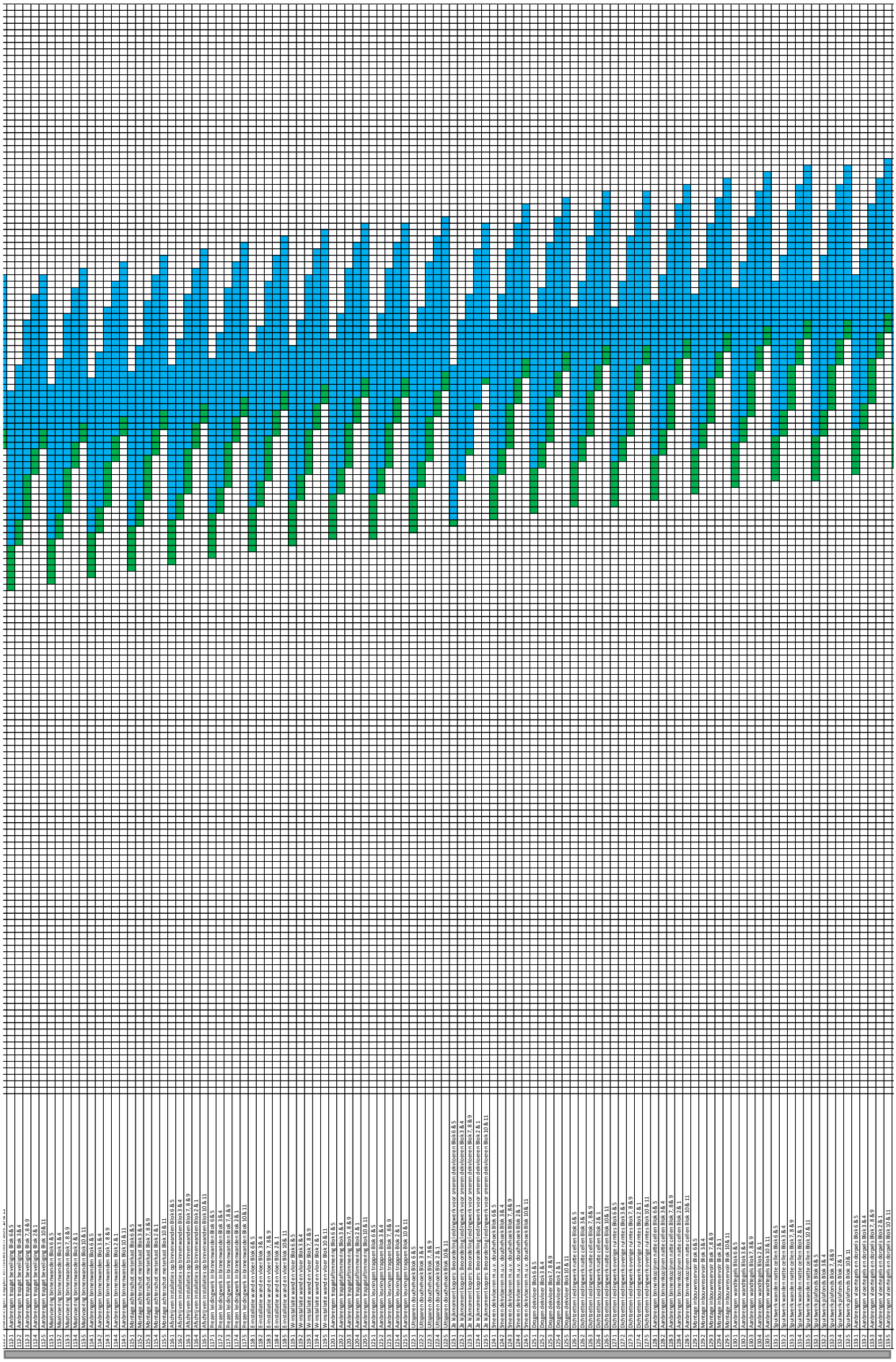

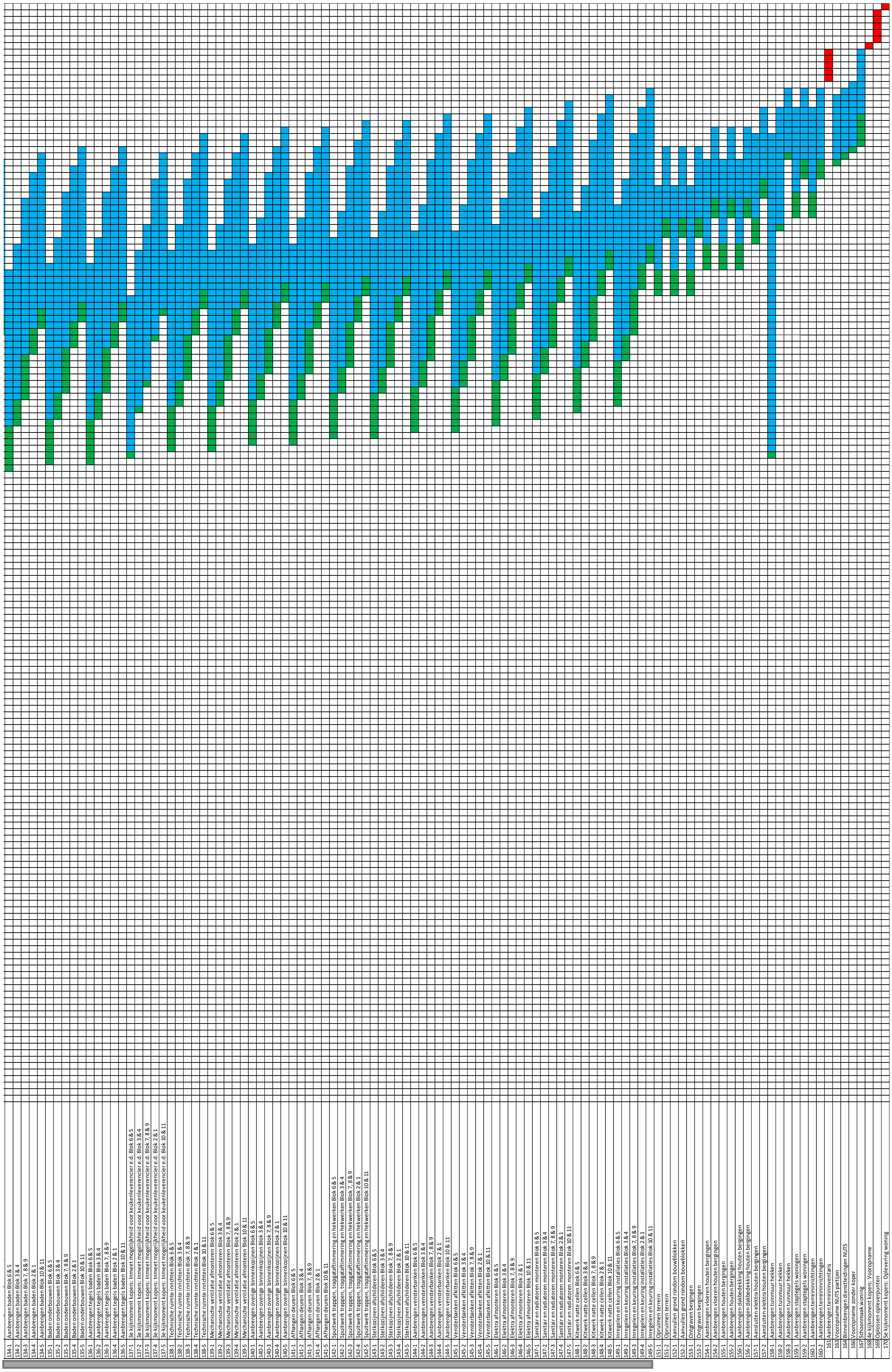
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156-1 Aanbrengen dakbedekking houten bergingen
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158-1 Aanbrengen tuinmuur hekken
158-2 Aanbrengen tuinmuur hekken
158-3 Aanbrengen tuinmuur hekken
159-1 Aanbrengen staptegels woningen
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160-1 Aanbrengen terreininrichtingen
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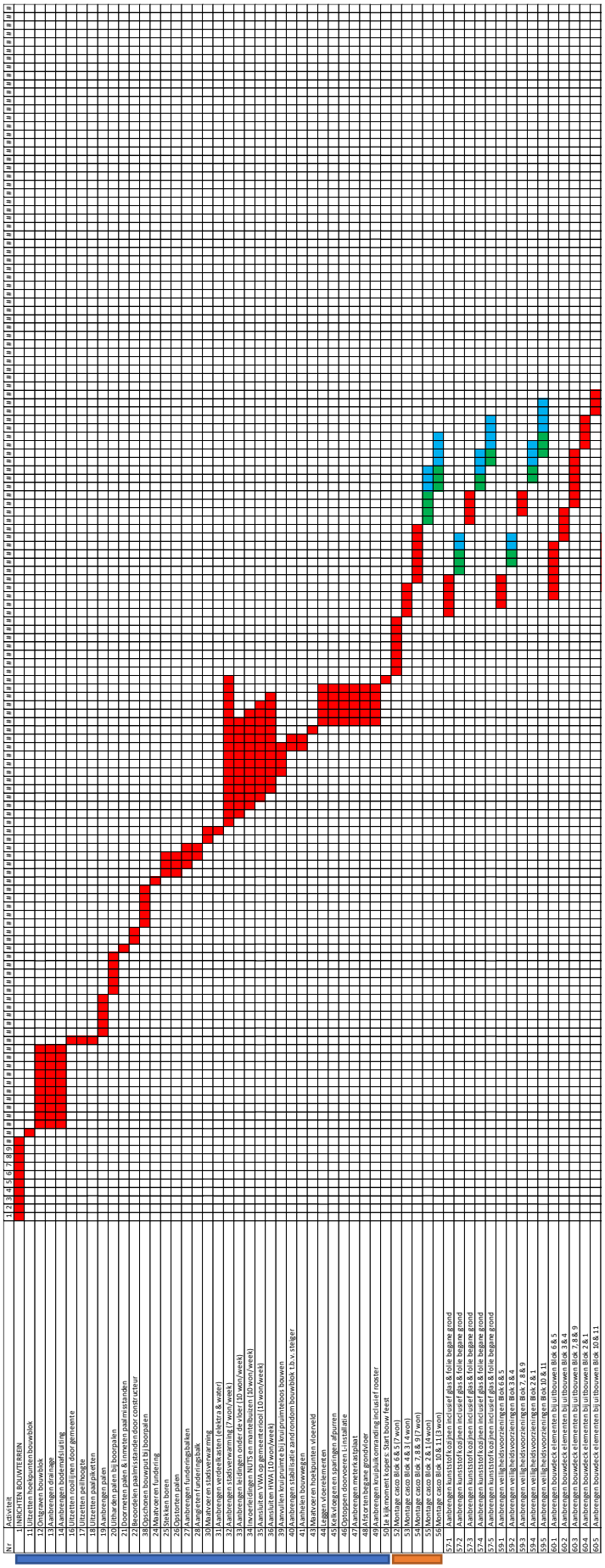
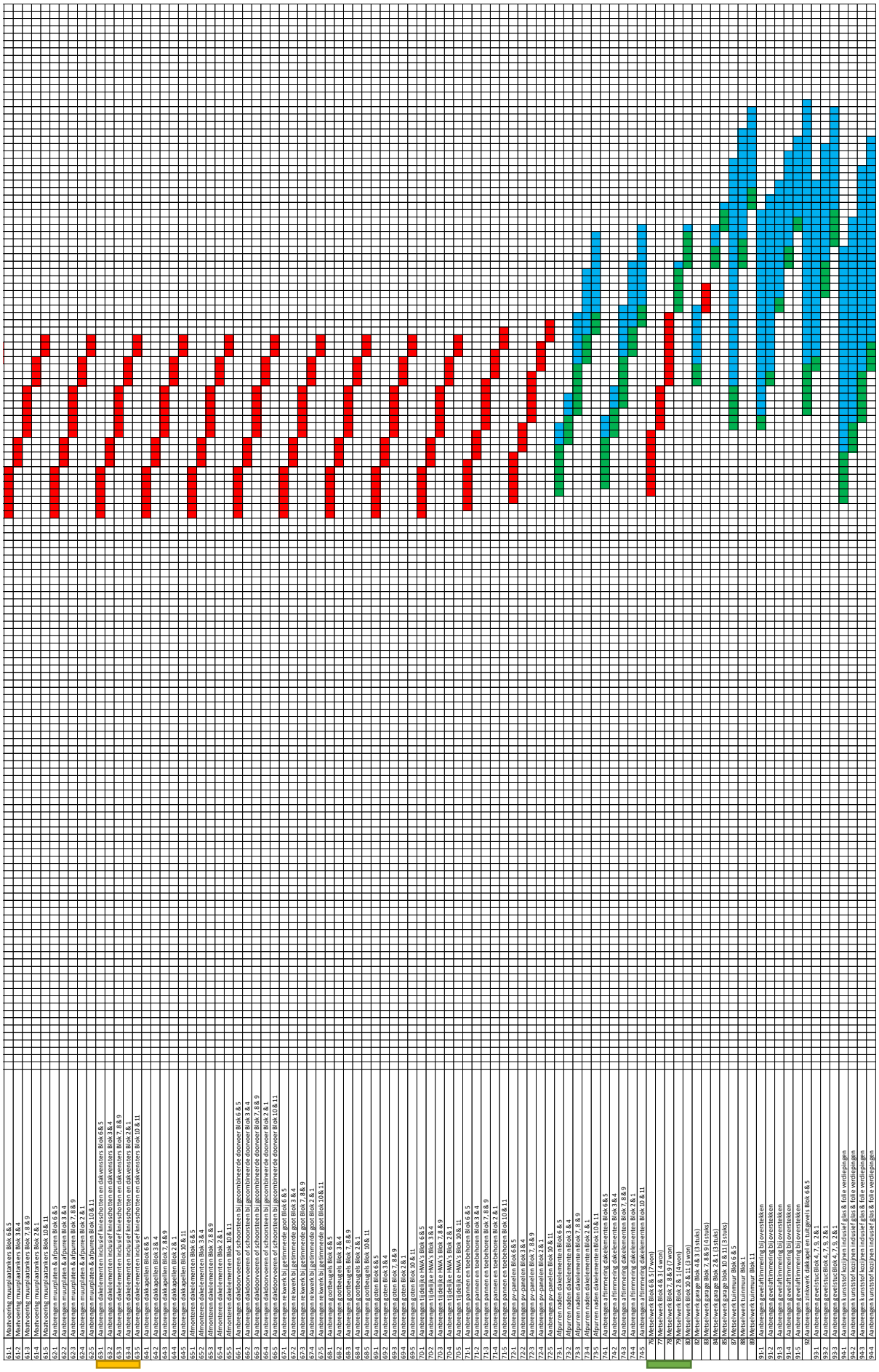
161 Aanbrengen terreininventaris
163 Vooropname NUTS partijen
164 Binnenbrengen dienstleidingen NUTS
166 Vooropname zonder koper
167 Schoonmaak woning
168 4e kijkmoment kopers: Vooropname
169 Oplossen opleverpunten
170 5e kijkmoment kopers: Oplevering woning

This second chart,
is based on the higher masonry pace.

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612 Metselwerk muurpilasters Blok 3 & 4
613 Metselwerk muurpilasters Blok 7, 8 & 9
614 Metselwerk muurpilasters Blok 2 & 1
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621 Aanbrengen muurplaten & afpuren Blok 6 & 5
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672 Aanbrengen rc kwerk bij getimmerde goot Blok 3 & 4
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675 Aanbrengen rc kwerk bij getimmerde goot Blok 10 & 11
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941 Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen
942 Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen
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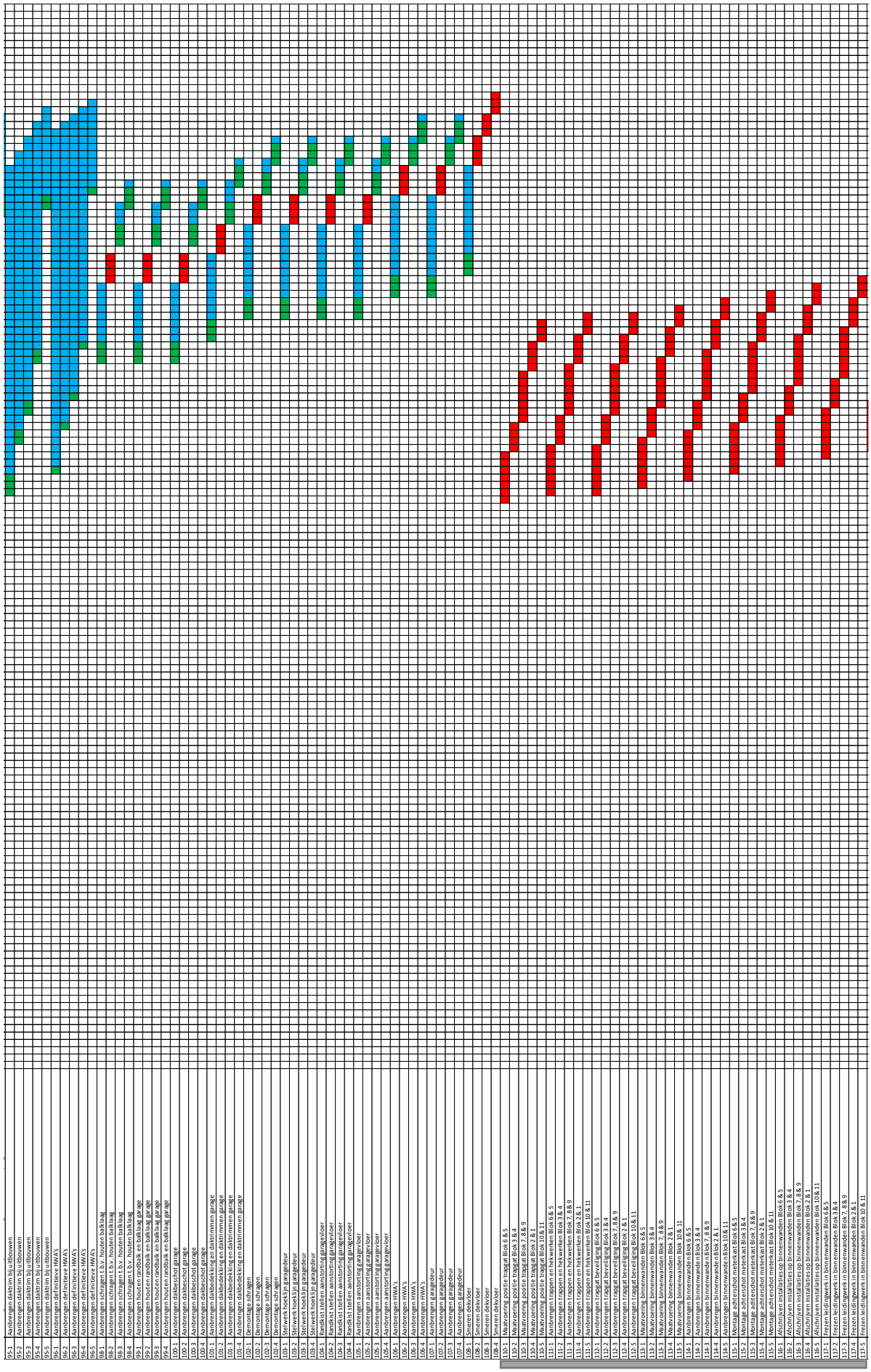
944 Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen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95-2 Aanbrengen daktrim bij uitbouwen
95-3 Aanbrengen daktrim bij uitbouwen
95-4 Aanbrengen daktrim bij uitbouwen
95-5 Aanbrengen daktrim bij uitbouwen
96-1 Aanbrengen definitieve HWA's
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98-1 Aanbrengen schragen t.b.v. houten balklaag
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98-3 Aanbrengen schragen t.b.v. houten balklaag
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99-1 Aanbrengen houten randbalk en balklaag garage
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105-1 Aanbrengen aanstorting garagevloer
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106-1 Aanbrengen HWA's
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106-4 Aanbrengen HWA's
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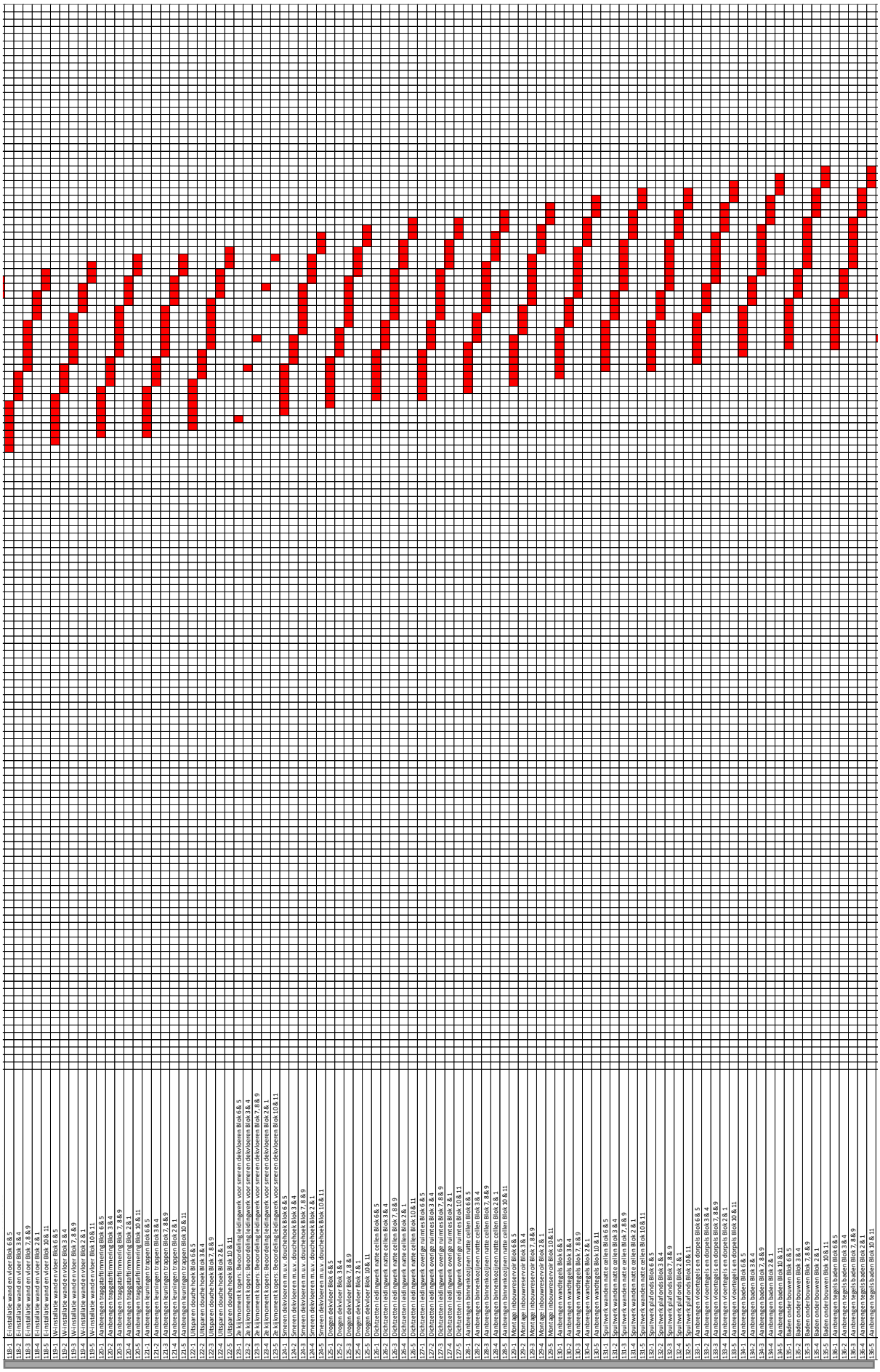
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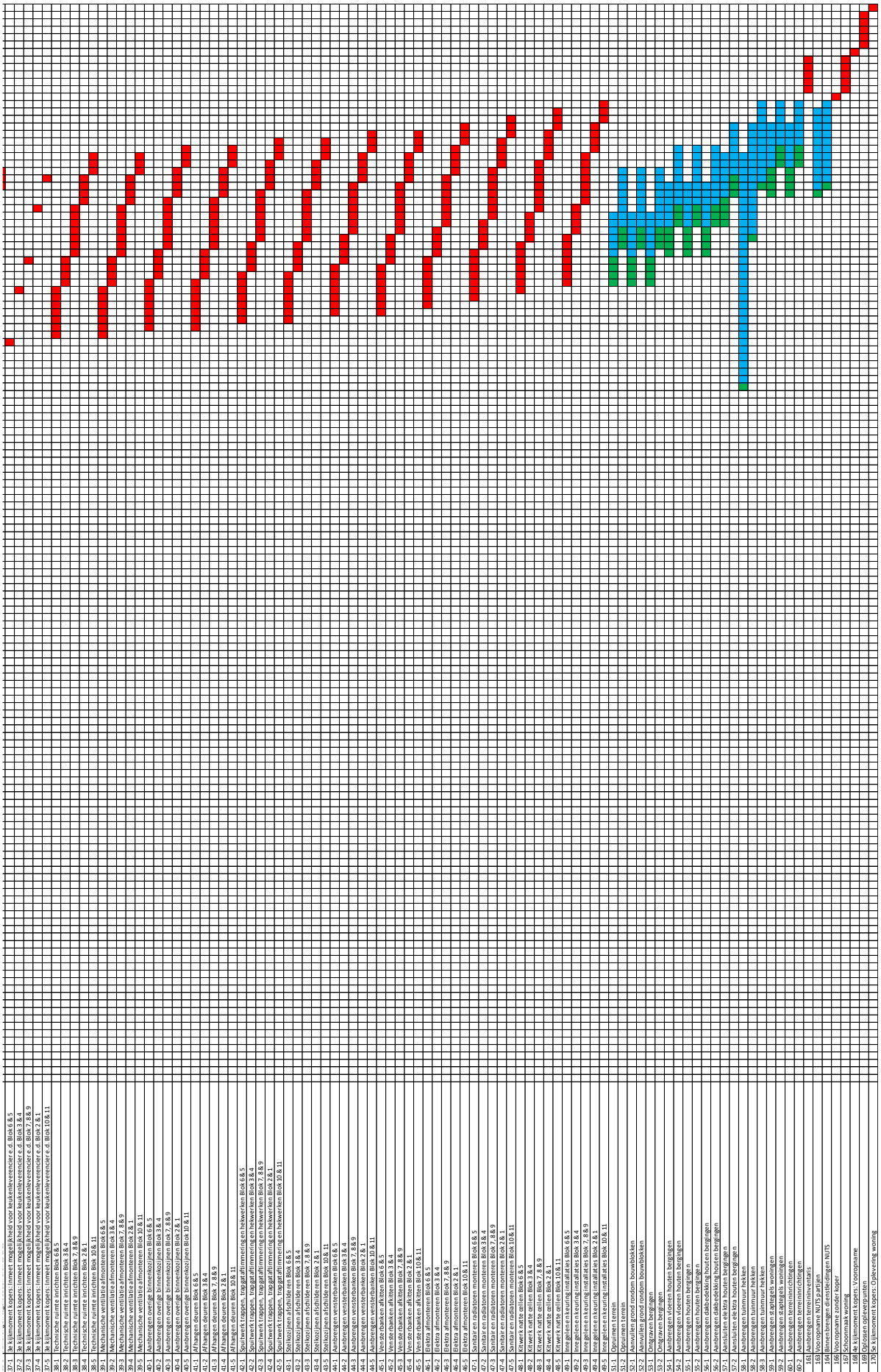
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161 Aanbrengen terreninrichtingen
163 Voorgname NUTS partijen
164 Binnenbrengen dienstbedrijven NUTS
166 Voorgname zonder koper
167 Schoonmaak woning
168 4e kijkmoment Kopers: Vooropname
169 Oplossen opleverpunten
170 5e kijkmoment Kopers: Oplevering woning

The critical path analysis shows that all the activities up to the carcass assembly (blue) are critical in both cases. Moreover, in both cases almost all the activities that are not directly related to the dwelling itself, are also not critical.

The carcass elements assembly activities (orange) are critical for first block(s) and non-critical for succeeding blocks. The first dwelling block will always be critical, but the number of succeeding blocks that are critical differs per case. In the case with the lower masonry pace, just the first dwelling block is marked as critical and the amount of slack for the succeeding blocks is at least 11 days. With the higher masonry pace, the first three blocks are marked as critical, and the succeeding blocks have a maximum slack of just 4 days.

The roof elements assembly activities (yellow) are always critical for the first block, but, just as with the carcass elements assembly, the number of succeeding activities that are critical differs per case. In the lower masonry pace case, the roof assembly activities of the first block are critical and all the succeeding blocks are non-critical and have slack that varies from 8 to 24 days. In the higher masonry pace, all the blocks are marked as critical.

The number of blocks for which the masonry activities (green) are critical depends on the pace. With the higher pace, the first three blocks are critical, and the last two blocks are non-critical, but these non-critical blocks have a slack of just one day. With the lower pace, all the blocks are critical.

Depending on the masonry pace, the filling activities (grey) are either all critical or all non-critical in these cases. In the case the filling activities are non-critical, the slack is even up to 24 days.

4.5 Conclusion

This chapter is concluded with an answer to the second research question which reads as follows:

What is the current performance of executing a dwelling construction project, in terms of the difference in time between planned activity deadlines and actual finishing an activity?

The critical path analysis shows that the following activities are always critical in a dwelling construction project:

- Piling.
- Prefabricated concrete carcass elements assembly.
- Prefabricated roof elements assembly.

Whenever one of these activities finishes late, it has a domino effect. The domino effect that finishing the piling activities late has on the carcass and roof assembly activities is shown in Figure 4.5.

Figure 4.5; Domino effect finishing piling activities late

When the piling activities finish late, the carcass assembly activities can't start at the scheduled moment. This has as a consequence that the carcass assembly activities finishes late, which causes that both the roof assembly and the masonry activities can't start at the planned moment. To conclude, when the roof assembly activities aren't finished as scheduled, the filling activities can't start as planned, which causes that also these activities will finish late. When the piling activities do finish in time, it can still happen that either the carcass or roof assembly activities finish late. When the carcass assembly activities finish late, the domino effect from that point on is the same as not finishing the piling activities as scheduled. However, when the roof assembly activities finish late, just the starting moment of the filling activities is affected.

The domino effect is amplified in multiple ways. Firstly, when the carcass assembly activities can't start at the scheduled moment, the delivery of the elements must be postponed because there is no space available at construction sites to store materials with such big dimensions. It can happen that the co-maker also lacks storage space at that moment, which means that the production of the elements must be postponed. When this happens,

there is a big chance that the production of the elements isn't finished at the moment the elements are needed at the construction site. This leads to even more delay. Delay of the starting date of the roof assembly activities can have the same effect. Secondly, when the subcontractor, that is contracted to perform the masonry activities, can't start at the planned moment, he needs to employ the planned workforce elsewhere. At the moment that the masonry activities can start, the subcontractor has no workforce available, which leads to even more delay. The same goes for the subcontractor that is contracted to perform the filling activities.

The comparison of the actual and planned start and finish times of the main activities to be performed at the construction site, showed that:

- The piling activities started and finished late at both projects.
- The carcass activities started and finished late at project 2 but were on time at project 1 (Side note has to be made that for project 1 this is based on an updated planning)
- The roof activities started and finished/are planned to finish late at both projects.

So, exactly those activities that are always critical the execution planning, seem to be hard to control for VWA.

Reasons for the late start and/or finish of the piling, carcass assembly and roof assembly activities are found to be partly due to the inadequate planning of the activities by VWA themselves, and partly due to high demand and limited capacity at the co-makers and subcontractors.

5 Improvement generation

From the analysis performed in the previous chapters we now know in which areas problems occur. This chapter shows the generation of possible improvements. The sections 5.1 to 5.5 show different possible solutions that are considered. In the last section, section 5.6, a conclusion of this chapter is given.

5.1 Improvement algorithms and models

The main problems that VWA faces are not problems that can be solved by implementing optimization algorithms, moreover, due to the almost complete lack of data it isn't even possible to apply the algorithms. That is why, for now, the solution that helps VWA to improve the predictability of their dwelling construction projects must be found in another area.

5.2 HUB

The idea of this solution is to add a HUB in the supply chain of VWA. In the following paragraphs we elaborate on HUB and Spoke, and the Gravity method theory. After that we elaborate on how this could contribute to solve the problem, and the last section is a feasibility study will show to what extent this solution is feasible.

5.2.1 Theory

Vries and Ludema (2012) conducted research into a logistical HUB for the construction industry. The logistical HUB as proposed acts as a decoupling point where the supply of materials from the supplier to the HUB is push based, and the supply of the materials from the HUB to the construction site is pull based. In this way the delivery of the materials to the HUB is more time-independent than delivery direct from the co-maker to the construction site. The results of pilot projects are very promising, however, the number of pilot projects is very low and is all subject to certain conditions, such that a logistical HUB was the only alternative to arrange the material deliveries at the construction site. The investments in a logistical HUB are high, while the results are hard to quantify and uncertain.

The London Construction Consolidation Centre (LCCC) is a logistical HUB that is used in a pilot project to serve construction sites in London. The LCCC was used to supply the construction materials to construction sites on a just-in-time basis. The LCCC was intended to reduce the number of deliveries going directly to the construction sites. Among other findings, one of the findings was that the deliveries from the LCCC to the sites achieved 97 per cent delivery reliability(i.e. 97 per cent materials of the correct type and quantity were delivered within 15 minutes of the scheduled time). The standard achieved without use of a consolidation centre (HUB) is 39 per cent. Furthermore, an increase of productivity of the work force on the construction sites was achieved up to 25 minutes per person per day, as a result of the higher delivery reliability. Besides these positive findings, there were also negative findings such as increase of the order lead time of up to six days, incorrect materials being sent from the LCCC to the construction sites, materials being misplaced at the LCCC and liability issues. The required data to determine whether or not the consolidation centre is commercial viable was not obtained during the project due to commercial sensitivity. As a result they did not achieve the aim to determine the commercial viability. (Transport for London, 2008)

To find a location for the logistical HUB, Murphy and Wood (2008) use the Centre of Gravity method for locating a single logistic facility. According to Slack et al. (2010) the centre of gravity method is used to find a location which minimizes transportation costs. It is based on the idea that all possible locations have a 'value', which is the sum of all transportation costs to and from that location. The method provides the $\bar{x}$ and $\bar{y}$ coordinates of the lowest-cost location by the use of the following two formulas:

$$\bar{x} = \frac{\sum x_i V_i}{\sum V_i} \qquad \text{and} \qquad \bar{y} = \frac{\sum y_i V_i}{\sum V_i}$$

Where

x_i = the x coordinate of source or destination i

x_i = the y coordinate of source or destination i

V_i = the amount to be shipped to or from source or destination i

5.2.2 Contribution to solving the problem

The HUB solution is conceived with the aim to increase the on-time delivery of materials which are critical for the planning. The research showed that, among other activities, the assembly of the prefabricated concrete carcasses and the roof elements are always critical. By adding a HUB to the supply chain, a buffer is created for the concrete carcass, and roof elements. This allows the subcontractors to deliver in the week as planned in the project preparation or work preparation phase, even if the materials are needed later as planned at the construction site. For the subcontractors this has the advantage that they can plan the production of the elements better, because no last moment changes to the delivery date are made. For VWA it has the advantage that the on-time delivery of the elements increases, which has as consequence that the succeeding activities can also start. In this way the domino effect that occurs when one of these two activities finish late can be tackled.

Figure 5.1 and Figure 5.2 shows the logistical structure of current situation and the situation with HUB, respectively. The logistical structures are simplified which means that certain data flows, that are considered not to be directly relevant, are omitted.

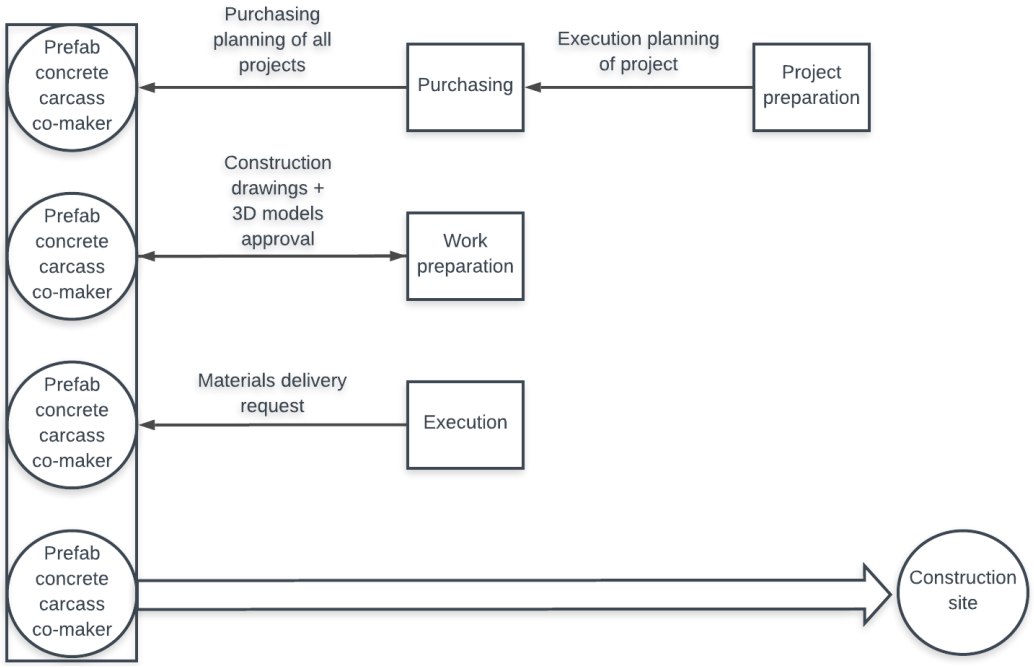


Figure 5.1; Logistical structure current situation

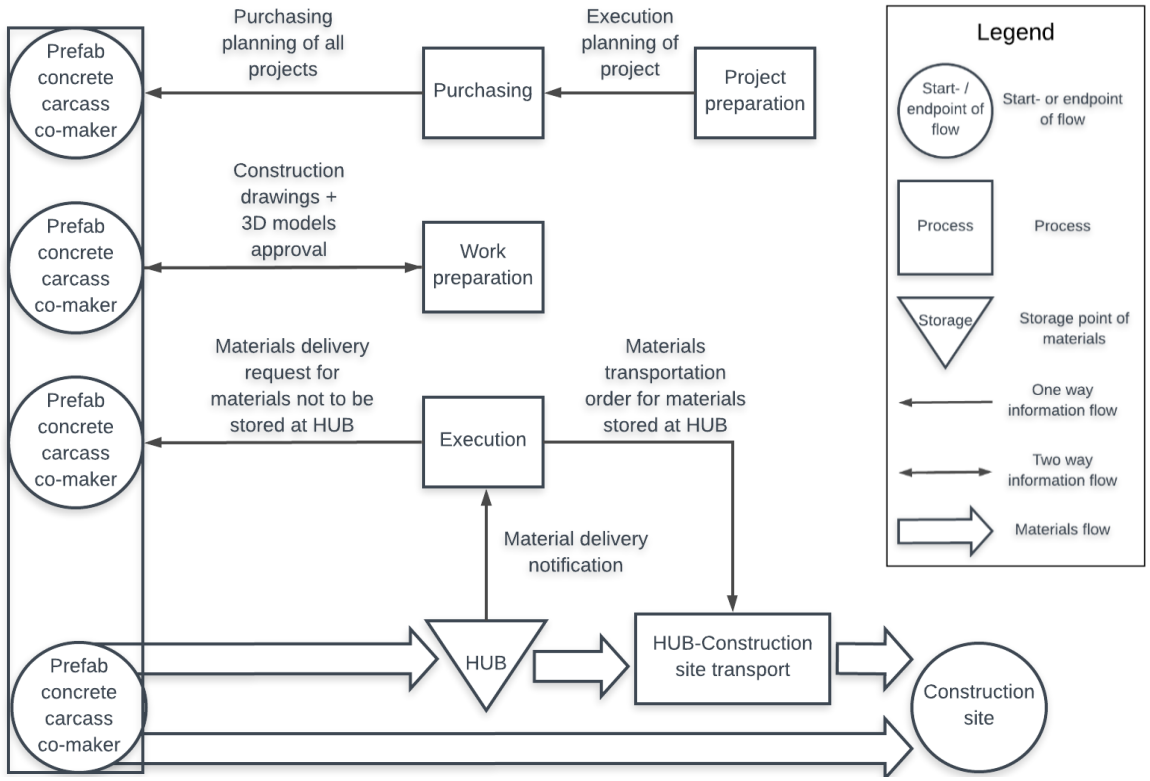


Figure 5.2; Logistical structure with HUB

5.2.3 Feasibility

To be a feasible solution for VWA, the HUB should not cost more than it brings. That is why we performed a cost-benefit analysis. The calculations are done based on a standardised dwelling construction project that consists of 25 dwellings and is constructed according to the prefabricated concrete carcass building method.

Benefits

To determine the benefit of the HUB solution, we only looked into the benefit that will come from the decrease in project duration. Any other benefits that can come along, such as a higher client satisfaction are left out of consideration.

First, we determined the costs of extending the delivery date of a project with one week (5 days). This calculation was already available within VWA. After verifying the calculation with the calculator of VWA, we determined that the costs of extending a project with one week varies from € 3,000. – to € 6,000. –. The variation is because one can argue about the costs for the carpenters (Timmerman 1 & 2). When the project faces any delays, it is sometimes possible to transfer the carpenter(s) to another project. Based on a interviews with several employees of VWA, we assume that on average one of the two carpenters can be transferred to another project. Based on this information we determined that the costs of extending the delivery date of a project with one week will be € 4,500.-. A table with specifications of the costs can be found in appendix 5.

To determine the benefit per project we had to determine how many weeks in due date overrun could be saved, in comparison to the current situation, by implementing this solution. Due to the lack of data it is not possible to come up with a statistically substantiated calculation, so we made an educated guess based on the available information of the projects the earlier mentioned projects 1 and 2. Here we see that in one project the carcass and roof activities finished respectively 3 and 8 weeks late, and the whole project finished 17 weeks late. The other project is still under construction at the moment this research is conducted. For this reason, we have to guess when the roof activities will be finished. What we do know is that the carcass activities finished 4 weeks late, and the roof activities started 4 weeks late. Based on this information and the experience of VWA, we assume that the due date overrun of projects can be reduced with 5 weeks.

With this information we are able to calculate the costs that can be saved per project. These costs are: 5 weeks * € 4,500. - = € 22,500. - per project.

Based on the years 2016-2018, VWA had on average six projects that started. This means that when this trend continues, € 135,000. - can be saved per year.

Costs

To come to the costs of the HUB solution, multiple steps had to be taken. The first step was to determine the amount of prefabricated concrete carcass elements and prefabricated roof elements each dwelling contains. The calculations are based on a terraced dwelling with the following characteristics:

- Construction method is the assembly of prefabricated storey high concrete carcass elements
- Ground floor, first floor, and second floor
- Width of the house (beukmaat in Dutch) is 6 metres
- Length of the house is 10 metre

First, we elaborate on the carcass elements.

The elements are stored and transported in a special crate as can be seen in Figure 5.3. Each crate can hold eight elements next to each other with a maximum length of 11 metres. Per standard dwelling there are in total 12 elements which we placed in three categories based on their size, Table 5-1 shows the different categories and the quantity per dwelling.

Figure 5.3; Carcass element crates

	Length	Width	Quantity
Category 1	2 metre	1 metre	2
Category 2	Between 5 & 6 metre	3 metre	4
Category 3	Between 9 & 11 metre	3 metre	6

Table 5-1; Carcass elements overview

When the two category 1 elements are placed behind two category 2 elements, a total number of 10 crate places are needed per dwelling. This means that per dwelling 1.25 crates are needed. A crate is 11 metre long and 1 metre wide and is transported by a special trailer. To be able to load and unload the crate, 0.5 metre of free space on each side of the crate is required, Figure 5.4 shows why.

Figure 5.4; Loading of a crate with carcass elements

Depending on the coverage per project, the required space for the HUB can be calculated. To store the crate in such a way that the least amount of space is required, three different options are evaluated which are shown in Figure 5.5. The black blocks represent the crates and the light grey represent the required free space between the crates. Because the trailer needs to drive backwards in alignment with the crate, the driveway in front of the crate has to be at least 20 metre wide. Calculations show that option 2 requires the least amount of space. The time that is needed to load or unload a crate is estimated to be 15 minutes, and the crate can be stored in the open air.

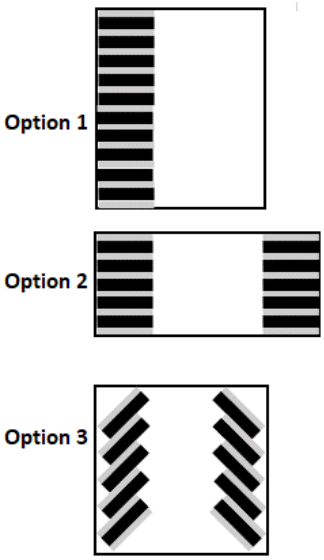


Figure 5.5; Storage options

Now we will elaborate on the storage and transportation of the prefabricated roof elements. The elements are transported on top of each other on a flatbed trailer, as can be seen in Figure 5.6. Each dwelling contains four loose elements. However, to simplify the installation of the elements they are coupled by hinges (Figure 5.7) at the factory, there are at least two elements on top of each other when transported or stored. The roof is as wide as the dwelling so one roof element has a width of 3 metres.

Figure 5.6; Roof elements transport

Figure 5.7; Roof elements

To determine the length of the roof elements, we looked into two projects and found that the length variated between 5.3 and 8.5 metre and the average length was 6.6 metre. For our calculations we used 6.6 metre as the length of a roof element. To reduce the required amount of space that is needed at the HUB, the elements can be stored on top of each other. The maximum number of elements that can be packed on a truck is 8, 2 stacks of 2 coupled elements per stack. To be able to load and unload the elements a crane is needed, and the estimated time that is required to load or unload two coupled elements is estimated to be 0.5 hour and they have to be stored indoor.

VWA has no space available for the storage of the materials so it has to be stored elsewhere. First, we looked into the possibility to store the materials at the Van Wijnen branch in Deventer (VWD). This is not only an office just like VWA, it is also the materials HUB for the region Van Wijnen East. Here the shacks that are placed at each project and some other materials are stored. This turned out not to be an option due to the lack of available space. After that, we looked into the possibility to store the materials at the co-makers but due to lack of capacity this wasn't an option. So, it is necessary to rent or buy a HUB facility.

To get an idea of what a good location would be, the weighted gravity method is used, but in a slightly different way as described in section 5.2.1. Not the amount to be shipped is used for parameter V, the number of projects in a certain city is used instead. This because we assume that the amount of materials to be shipped is equal for each project. Based on the dwelling construction projects over the last 5 years (from 2015 to 2019) a location is chosen. The x and y coordinates of the cities where are determined by the use of google maps. After that, each city was assigned a weight (V) depending on the number of construction projects performed in that city. The weighted average of the longitude and latitude is taken, which resulted in the location which is marked with the blue circle in Figure 5.8.

Figure 5.8; HUB location

Based on this location, the average travel distance from the HUB to the construction site (according to google maps) will be around 40 kilometres. We assume that the total yearly transportation costs from the supplier to the HUB will be the same as from the supplier to the construction sites. This seems to be a reasonable assumption when we look at how the location of the HUB is determined.

From the annual contract that VWA has with a transportation company the transportation cost is known to be, € 80, - per hour for both the carcass and roof elements.

The get an idea about the rental costs for both outside and inside storage, a real estate agency in Arnhem was consulted, and said that the average price for outdoor storage is € 25.- and for indoor storage € 50.-. We neglect the costs of managing the HUB, because the loading and unloading of the materials can be done by the drivers of the truck that deliver the materials.

After delivery of the materials, VWA receives the invoice of the materials that are delivered. So, when (a part of) the materials are delivered several weeks earlier at the HUB, VWA has to pay the invoice earlier. The average costs per dwelling (based on three projects) for the prefabricated concrete carcass and roof elements, are € 8,280.52 and € 9,897.15 respectively. To be able to finance the earlier payment of the invoices, VWA has to make use of a current account credit. A current account credit can be used to deal with a short-term deficit, and within a certain limit one can take out funds or pay off the credit anytime one wants to (Rabobank, 2019). The costs of such a credit are build-up out of interest, credit provision and administration costs. The interest rate is between 1.00% and 12.50% and has to be paid over the part of the credit that is actually used. The credit provision rate is between 0.10% and 2.80% and has to be paid over the maximum credit limit.

The administration costs are € 100.00 and have to be paid once. (Rabobank, 2019) Per project, the credit is needed for period that materials are stored at the HUB.

We neglect the insurance costs because these are relatively low. The costs to insure the materials for 25 dwellings in storage will be under € 300.- per month. (Rabobank, 2019)

Based on this information we were able to calculate the costs and the benefits. Figure 5.9, on the next page, shows a screenshot of the calculation sheet in Excel. After the figure, the calculations are explained in more detail.

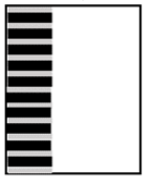
General project information	
Number of projects per year	4
Number of dwellings for which materials has to go to the HUB per project	10
Distance depot - project (km)	34
Travel time depot - project (uur)	1
Footprint tansportcrate (m2)	10
Number of elements per crate	8
Minimum space required between crates (m)	0.5
Stack height (# of coupled elements)	4
Minimum width of path between element stacks (m)	1
Number of weeks in depot	4
Total costs Depot + Transport + Financing	**€ -80,426.82**

€ 9,573.18

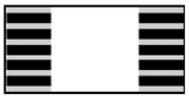
Carcass elements per dwelling	Length	Length for cal.	Width	Width for cal.	Amount
Category 1	5 - 6 meter	6	3 meter	3	4
Category 2	9 - 11.4 meter	10	3 meter	3	6
Category 3	2 meter	2	1 meter	1	2

Carcass elements storage cost calculation	
Number of crates required per project	13
Required length for crates (side by side perpendiculair) (m)	20
Required width for crates (side by side perpendiculair) (m)	11
Required area for crates (side by side perpendiculair) (m)	220
Required width for transportation path (side by side perpendiculair) (m)	20
Required area for transportation path (side by side perpendiculair) option 1 (m)	400
Total required area option 1 (m2)	620
Required area for transportation path (side by side perpendiculair) option 2 (m)	200
Total required area option 2 (m2)	420
Total required area option 3 (m2)	1229
Storage location costs (per m2)	€ 25.00
Total storage costs	€ 10,500.00

Option 1



Option 2



Carcass elements transportation cost calculation	
Number of crates per transport	1
Required number of transports	13
Load & Unload time per crate (hour)	1
Average travel distance (km)	40
Average travel time (hour)	1
Total transportation time (hour)	26
Hourly transportation rate	€ 80.00
Total transportation costs	€ 8,320.00

Option 3

Total costs carcass elements	€ -18,820.00

Roof elements per dwelling	Length	Length for cal.	Width	Width for cal.	Height	Height for cal.	Amount
Roof elements	5.3 - 8.5 meter	6	3 meter	3	0.3 meter	0.3	4

Project storage cost calculation	
Required area per 2 coupled elements (m2)	18
Heigth per 2 coupled elements(m)	0.6
Heigth of stack (number of single elements)	8
Total number of stacks	5
Number of rows broadwise	5
Number of rows longwise	1
Required length (m)	7
Required width (m)	20
Total required area (m2)	140
Storage location costs with crane included (per m2)	€ 50.00
Total storage costs	€ 7,000.00

Project berekening transport	
Number of coupled elements per transport	8
Required number of transports	3
Load & Unload time per crate (hour)	0.5
Average travel distance (km)	40
Average travel time (hour)	1
Total transportation time (hour)	15
Hourly transportation rate	€ 80.00
Total transportation costs	€ 4,800.00
Total costs roof elements	€ -11,800.00

Financing costs (Rabobank)	
Interest	6.5%
Loan provision	1.4%
Carcass costs per dwelling	€ 8,280.52
Roof element costs per dwelling	€ 9,897.15
Required credit per dwelling	€ 18,177.67
Loan costs per dwelling per month	€ -1,181.55
Total financing costs	€ -49,806.82

Figure 5.9; Calculation sheet HUB solution

Calculation example

This calculation example is based on four projects per year, with materials in storage for ten dwellings per project and with an interest rate of 1%. This is the same configuration as shown in Figure 5.9.

The storage costs of prefabricated concrete carcass elements are calculated by:

$$Required\ storage\ area\ for\ prefabricated\ concrete\ carcass\ elements\ (m2) \cdot Storage\ location\ costs\ per\ m2\ (€)$$

The length (in metres) of the prefabricated concrete carcass elements storage area is calculated by:

$$\#\ of\ crates\ per\ project * 1.5 + 0.5$$

The 0.5 metre that is added, is the width of the (un)load area along one side of the first crate (the (un)load area at the other side of the crate is incorporated in the 1.5 metre).

The number of transportation crates per project is calculated by:

$$\frac{Number\ of\ category\ 1\ \&\ 2\ prefabricated\ carcass\ elements\ to\ be\ stored\ at\ HUB}{Number\ of\ elements\ a\ crate\ can\ hold}$$

The width of the prefabricated concrete carcass elements storage area is calculated by:

$$2 \cdot length\ of\ the\ crate + width\ of\ transportation\ path$$

In this case, the prefabricated concrete carcass elements storage costs are:

$$420 \cdot € 25.00 = € 10{,}500.00$$

The transportation costs of the prefabricated concrete carcass elements from the HUB to the construction site are calculated by:

$$Total\ transportation\ time\ (hour) \cdot Hourly\ transportation\ rate$$

The total transportation time in hours, is calculated by:

$$\frac{Number\ of\ transportation\ crates}{Number\ of\ transportation\ crates\ per\ transport} \cdot (Total\ (un)load\ time\ per\ transport + travel\ time)$$

In this case, the transportation costs of the prefabricated concrete carcass elements from the HUB to the construction site are:

$$26 \cdot € 80.00 = € 2080.00$$

The storage costs of prefabricated roof elements are calculated by:

$$Required\ storage\ area\ for\ prefabricated\ roof\ elements\ (m2) \cdot Storage\ location\ costs\ per\ m2\ (€)$$

The length (in metres) of the prefabricated roof elements storage area is calculate by:

$$(Width\ of\ path\ between\ stacked\ elements + Length\ of\ an\ element) \cdot Number\ of\ element\ stacks$$

The number of element stacks is calculated by:

$$\frac{Number\ of\ coupled\ elements\ to\ be\ stored\ at\ the\ HUB}{Number\ of\ coupled\ elements\ per\ stack}$$

In this case, the prefabricated roof elements storage costs are:

$$140 \cdot € 50.00 = € 7{,}000.00$$

The transportation costs of the prefabricated roof elements from the HUB to the construction site are calculated by:

$$\frac{Total\ number\ of\ coupled\ elements}{Number\ of\ coupled\ elements\ per\ transport} \cdot (Total\ (un)load\ time\ per\ transport + travel\ time)$$

In this case, the transportation costs of the prefabricated roof elements from the HUB to the construction site are:

$$15 \cdot € 80.00 = € 1{,}200.00$$

The financing costs are calculated by:

$$Number\ of\ projects\ per\ year \cdot Number\ of\ dwellings\ for\ which\ materials\ must\ be\ stored\ at\ HUB \cdot Loan\ costs\ per\ dwelling\ per\ month + Number\ of\ dwellings\ for\ which\ materials\ must\ be\ stored\ at\ HUB \cdot Loan\ provision\ percentage\ \cdot Credit\ limit$$

The loan costs per dwelling per month are calculated by:

$$Interest\ rate(\%) * Material\ costs$$

In this case, the financing costs are:

$$4 \cdot 10 \cdot € 1{,}181.55 + 10 \cdot 1.4\% \cdot € 18{,}177.67 = € 49{,}806.82$$

The cost-benefit calculation results for multiple situations and different interest percentages are shown in Table 5-2.

Number of projects per year	Number of dwellings in storage	Benefit – Cost result (Interest 1%)	Benefit – Cost result (Interest 6.5%)	Benefit – Cost result (Interest 12%)
1	5	€ 8,423.68	€ 3,424.82	€ -1,574.04
1	10	€ -2,642.64	€ -12,640.36	€ -22,638.08
1	15	€ -15,108.96	€ -30,105.54	€ -45,102.12
1	20	€ -26,175.28	€ -46,170.72	€ -66,166.16
1	25	€ -42,789.10	€ -67,783.40	€ -92,777.71
2	5	€ 28,094.80	€ 18,097.08	€ 8,099.36
2	10	€ 14,759.59	€ -5,235.85	€ -25,231.29
2	15	€ 24.39	€ -29,968.77	€ -59,961.93
2	20	€ -13,310.82	€ -53,301.70	€ -93,292.58
2	25	€ -32,753.52	€ -82,742.12	€ -132,730.72
3	5	€ 47,765.91	€ 32,769.33	€ 17,772.75
3	10	€ 32,161.82	€ 2,168.66	€ -27,824.50
3	15	€ 15,157.74	€ -29,832.01	€ -74,821.75
3	20	€ -446.35	€ -60,432.67	€ -120,419.00
3	25	€ -22,717.94	€ -97,700.84	€ -172,683.74
4	5	€ 67,437.03	€ 47,441.59	€ 27,446.15
4	10	€ 49,564.06	€ 9,573.18	€ -30,417.71
4	15	€ 30,291.08	€ -29,695.24	€ -89,681.56
4	20	€ 12,418.11	€ -67,563.65	€ -147,545.41
4	25	€ -12,682.36	€ -112,659.56	€ -212,636.76
5	5	€ 87,108.14	€ 62,113.84	€ 37,119.54

5	10	€ 66,966.29	€ 16,977.69	€ -33,010.91
5	15	€ 45,424.43	€ -29,558.47	€ -104,541.37
5	20	€ 25,282.58	€ -74,694.62	€ -174,671.83
5	25	€ -2,646.78	€ -127,618.28	€ -252,589.78
6	5	€ 106,779.26	€ 76,786.10	€ 46,792.94
6	10	€ 84,368.52	€ 24,382.20	€ -35,604.12
6	15	€ 60,557.78	€ -29,421.70	€ -119,401.18
6	20	€ 38,147.04	€ -81,825.60	€ -201,798.24
6	25	€ 7,388.80	€ -142,577.00	€ -292,542.80

Table 5-2; Financial overview HUB solution

The cost-benefit analysis shows that the interest percentage has a big impact on the results. With an interest percentage of 1%, in most situations the benefits will outweigh the costs. However, when the interest percentage is increased to 12%, only the situations with materials in stock for 5 dwellings per project have a positive result. The instinctive feeling tells us that, when the number of dwellings in stock increases, the cost-benefit result should also increase. However, in this situation the opposite is true. To clarify this, we show how the costs increase when the number of dwellings for which materials are held in storage increase. We do this for the situation that there is 1 dwelling construction project per year, the amount of materials to be stored at the HUB increases from 5 to 10 dwellings per project and with an interest percentage of 1%. The comparison in shown in Table 5-3.

		Materials in HUB for 5 dwellings	**Materials in HUB for 10 dwellings**
Cost			
	HUB facility	€ 9,975.00	€ 17,500.00
	Transportation costs HUB > Construction site	€ 1,920.00	€ 3,280.00
	Financing costs	€ 2,181.32	€ 4,362.64
	Total cost	**€ 14,076.32**	**€ 25,142.64**
Benefit			
	Construction time overdue reduction	€ 22,500.00	€ 22,500.00
Benefit – Costs result		**€ 8,423.68**	**€ -2,642.64**

Table 5-3; Cost-Benefit comparison 5 & 10 dwellings

The HUB facility costs increase due the extra storage space that is needed. In this example the total required storage area at the HUB facility increases from 315 m^2 to 560 m^2, which leads to an increase of the HUB facility cost of € 7,525.00.

The increase of the cost of transportation from the HUB to the construction site is due the extra materials to be shipped. The number of crates, that hold the prefabricated carcass elements, that are stored at the HUB increase from 7 to 13, and with a capacity of one crate per transport, the increase in number of prefabricated concrete element transports is the same. The number prefabricated roof elements that are stored at the HUB increase from 20 to 40. With a capacity of 16 elements per transport, the number of transports increase from two to three.

The financing costs double as the number of dwellings for which materials has to be stored at the HUB doubles. The required credit doubles from € 90,888.37 to € 181,776.73.

One should keep in mind that, as soon the assumption about the number of weeks gained turns out to be too ambitious, the benefits will decrease. The same calculations with adjusted benefits can be used to find out whether or not the solution is still profitable.

Table 5-4 shows a cost-benefit comparison of the prefabricated concrete carcass and roof elements supply chain without and with HUB. The figures are based on the situation that there are 4 dwelling construction projects per year, the amount of materials to be stored at the HUB is for 10 dwellings per project and with an interest percentage of 6.5%. We decided to highlight this situation for the following two reasons. Firstly, the critical path analysis showed that not all the dwelling blocks are marked as critical. Secondly, the number of dwelling construction projects per year will be less than the last few years, due to recent organisational changes at VWA. The interest percentage of 6.5% is used because that was the average interest percentage in 2018.

		Current situation	Proposed situation with HUB
Cost			
	5 weeks construction time overdue	€ 90,000.00	€ 0.00
	HUB facility	€ 0.00	€ 17,500.00
	Transportation costs HUB > Construction site	€ 0.00	€ 13,120.00
	Financing costs	€ 0.00	€ 49,860.82
	Total cost	**€ 90,000.00**	**€ 80,426.82**
Benefit			
	Construction time overdue reduction	€ 0.00	€ 90,000.00
	Total benefit	**€ 0.00**	**€ 90,000.00**
Benefit – Costs result		**€ -90,000.00**	**€ 9,573.18**

Table 5-4; Cost-Benefit comparison supply chain without HUB versus with HUB

5.3 Buffer time

A partial solution to the problem that can be implemented on the short term is to add buffer time to a critical activity, on which VWA has little influence. A good example of such an activity is the piling. Even when the preparation is perfectly done and the piling activities can start as planned, there is still sthe risk that the piling company runs late at another project. In this case, the addition of buffer time in the execution planning to the activity can help in such a way that when this happens, the starting dates of the succeeding activities aren't affected. However, this seems a very attractive solution, one should be keep the amount of buffer time in a planning to a minimum because it is also a very costly solution. As mentioned earlier, the cost of one week construction time is € 4,500.-. So each day of buffer time added to the planning costs € 900.-.

A project preparer has done this for a project of which the work at the construction site is planned to start in May 2019. He incorporated a buffer time of 10 workable days into the planning.

5.4 Documentation of project progression

During this research we found that the documentation of the progression of the dwelling construction projects is quite poor within VWA. To be able to conduct in depth analysis in the future it is necessary to start with documenting these progression data. However, this won't help VWA to improve the execution planning on a short time basis, it can help VWA in the future. To determine the required input, literature can help.

To make sure that the required data is registered properly and in a uniform way we developed a program. The program works by entering project specific data, this is done by completing four steps. Screenshots of the input screens can be found in appendix 6. Figure 5.10 shows the outcome of the program. When this will be done for every future project, all the necessary information about the duration and relevant comments will be available in the same format.

Activiteit	Startdatum	Datum gereed	Werkelijke activiteit duur	Opmerkingen en/of bijzonderheden
Inrichten bouwterrein				
Funderingsbalken				
Installatie				
Beganegrond vloer				
Prefab casco Blok 3, 4				
Prefab casco Blok 2				
Prefab casco Blok 8, 5				
Prefab casco Blok 7, 10				
Prefab casco Blok 1, 9, 6				
Dakelementen Blok 3, 4				
Dakelementen Blok 2				
Dakelementen Blok 8, 5				
Dakelementen Blok 7, 10				
Dakelementen Blok 1, 9, 6				
Metselwerk woningen Blok 3, 4				
Metselwerk woningen Blok 2				
Metselwerk woningen Blok 8, 5				
Metselwerk woningen Blok 7, 10				
Metselwerk woningen Blok 1, 9, 6				
Afbouw Blok 3, 4				
Afbouw Blok 2				
Afbouw Blok 8, 5				
Afbouw Blok 7, 10				
Afbouw Blok 1, 9, 6				
Terreininrichting				
Nutsaansluitingen				
Opleveringen				

Figure 5.10; Progression monitoring table

5.5 KPI dashboard

During the research it became clear that the dwelling construction department doesn't use any KPIs to monitor their projects. So, during this research we developed a KPI dashboard that can be used by VWA. The dashboard doesn't only provide a nice overview of how the project is performing, it also forces the project members to update the necessary input data. In consultation with the employees that work at the office of the dwelling construction department we determined which KPIs should be on the dashboard. Based on this input the dashboard as shown in Figure 5.11 is developed.

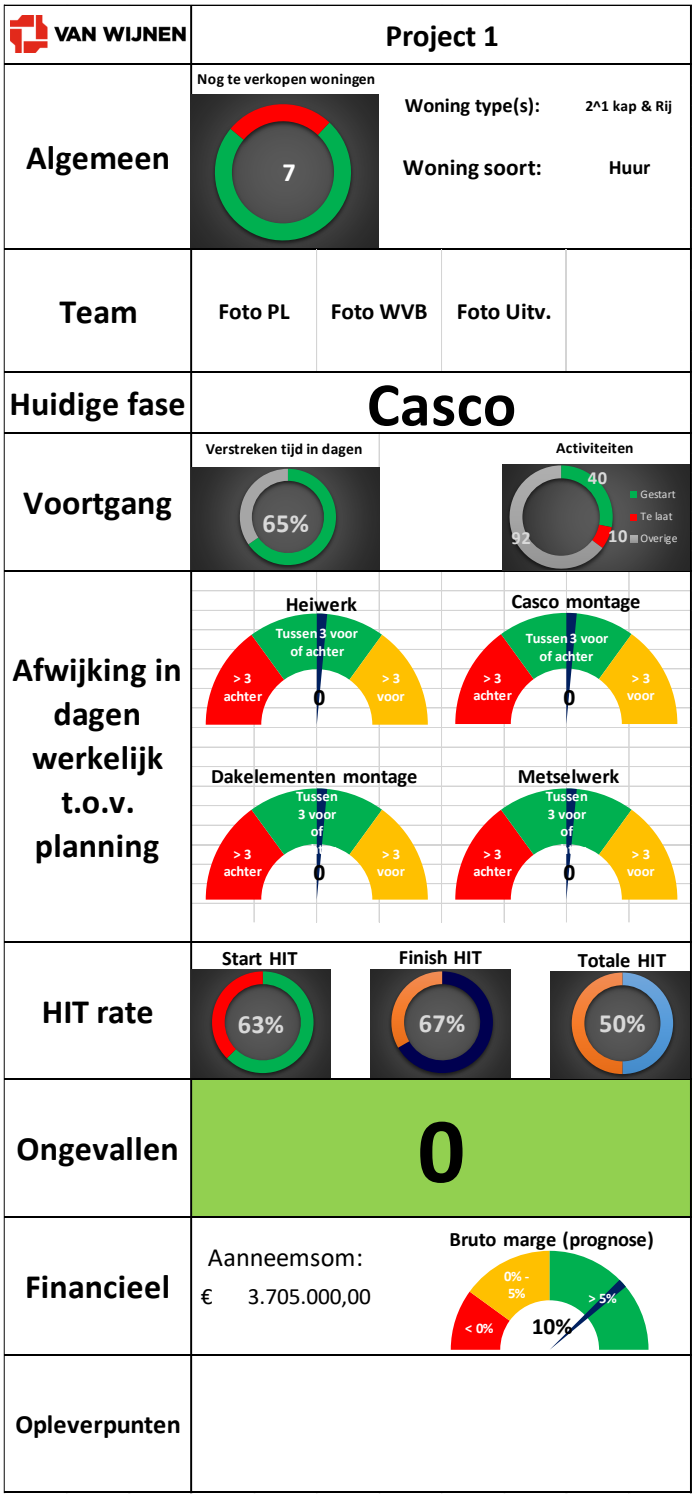


Figure 5.11; KPI dashboard (in Dutch)

From top to bottom it shows the following:

Project name

General project information (Algemeen)

- Number of houses that still has to be sold,
- Type of the dwellings in the project, terraced, semi-detached or detached houses, or a combination of the three,

Team

- Pictures of the:
  - Project leader
  - Work planner
  - Executor

Current phase (Huidige fase)

- This shows the phase that the project is currently in

Progression (Voortgang)

- The percentage of the number of days that have passed since the work at the construction site started in relation to the planned number of days that the project will take from start to finish.
- The number of activities that has started (green), the number of activities that should be started but aren't started yet (red), the number of activities that has to start in the future.

Number of days that the activity deviates from the planning (Afwijking in dagen werkelijk t.o.v. planning)

- Here the four activities that are found to be the most critical for the overall progress of the construction project are monitored. It shows the progress of the activities in relation to the planning.

HIT rate

- The start, finish and total hit rate are shown.
- The start hit shows the percentage of the activities that have started so far, have started according to the planning.
- The finish hit shows the percentage of the activities that have finished so far, have finished according to the planning.
- The total hit shows the percentage of the activities that have finished so far, that have started and finished according to the planning.

Accidents (Ongevallen)

- The number of accidents that happened at the construction site

Financial (Financieel)

- The contract sum
- The gross margin of the project

Number of defects (Opleverpunten)

- Total number of defects that were found during the transfer to the new owners.

5.6 Conclusion

This chapter is concluded with an answer to the third research question which reads as follows:

Which method(s) is/are suitable, that can help us to improve the predictability of the execution planning of a dwelling construction project?

This chapter discussed multiple options to improve the predictability of the execution planning. Some options can help on the short term, while other options are expected to improve the planning on the long term.

The first option is to incorporate buffer time into the execution planning. A buffer is created by extending the duration of an activity in the planning. In case the activity starts later as planned, this will not affect the succeeding activities, as long as it finishes within the planned period.

The second option, the HUB solution, is also an option that can be implemented on the short term. A cost-benefit analysis has shown that, depending on the number of projects per year and the number of dwellings per project for which materials should be delivered at the HUB, the benefits can outweigh the costs. It is assumed that by implementing this solution, the construction time overdue can be reduced with 5 weeks. With four projects per year and materials in storage for ten dwelling per project, this results in a benefit of € 9,573.18 in comparison with not implementing the HUB solution. A pilot should show whether or not the assumed 5 weeks of less construction time overdue reflects the reality.

The last option, documentation of project progress, is an option for the long term. To overcome the lack of data about the progress of dwelling construction projects, a program is developed that creates an excel sheet where the progress of a project can be documented. The data gathered in this way can be used in the future as input for planning optimization algorithms.

As a result of a side project during the research, a KPI dashboard is developed. The dashboard shows the performance of projects that are under construction at that moment. The dashboard creates that employees that work at the office in Arnhem are more “connected” with the projects and can easily monitor the progress of the project. The dashboard can be implemented on a very short term.

6 Conclusion and recommendation

This chapter discusses the conclusions and recommendations. The first section provides answers to the research question stated in Chapter 1. In the second section directions for implementation and guidance for future research will be provided. The final section discusses the limitations of this research.

6.1 Conclusion

After some bad years for the entire construction sector due to the economic recession, the number of dwelling construction projects dramatically increased in the past few years. Van Wijnen Arnhem also experienced that the number of projects per year increased and their annual turnover even doubled in 2018 in relation to the turnover in 2017. However, they noticed that the dwelling construction projects almost never go as planned and are not finished at the planned date. The exact reason or reasons for why this happens are not known within VWA, and that is why this research is conducted. For every dwelling construction project multiple schedules are created. Our research focussed on the execution planning, in which all the construction activities to be performed at the construction site are planned. The research question we wanted to answer by conducting this research was:

How can the predictability and structured clarity of the planning of a dwelling construction project be increased?

From the current situation analysis, we conclude the following.

We found that, due to the lack of a standardised way of working, the execution planning is not ready at the moment that it should be ready, which has far reaching consequences. This planning should be ready at the end of the project preparation phase because subcontractors and co-makers are be contracted based on the delivery dates according to this planning. This has to be done in such an early phase due to long delivery times that can be up to 35 weeks. Based on these dates, the subcontractors and co-makers reserve capacity in their production and/or workforce. Whenever these dates are not accurate, they have capacity available at the wrong moment, and no capacity available at the moment it should be available. Because almost all activities at the construction site are performed by subcontractors, this can have a huge impact on the finishing date of the project. Another risk that can affect the finishing date is that for every project just a single work planner is assigned to it. So, whenever a work planner unexpectedly cannot perform his/her activities anymore due to for example illness, the whole work preparation process comes to a halt. This means that a co-maker can't continue with his preparations which, in turn, can lead to late delivery of materials.

We also found that the registration of the project progression during the construction is very minimal. A so called "standlijn", that is drawn every end of the work week, shows the progression of the activities that are on the execution planning. It differs per person whether this is done digital, or on paper. Whenever an activity is behind schedule, it is not known how this affects the date that the project is finished. There is no clear insight into which activities are critical, and which are not. The downside of the paper versions is that they are discarded after the project is finished and so the possibility to analyse the progression afterwards with it, which we experienced during the project analysis. Even though, the digital ones stay available at the servers of VWA, the reasons that explain why activities are behind or ahead of schedule are not documented, which makes it hard to track down the reasons of any deviations from the planning. From literature know that there are several planning improvement and planning optimization methods available and are also already applied on construction projects in those studies. However, these methods are unknown to VWA and therefore the urge to gather data, about the progression of projects that is required as input for these methods, isn't there.

From the project analysis we conclude the following.

The algorithm we developed to get insight into the critical path and critical construction activities of a project, showed us that; (1) the activities in the first part of the project up till the carcass assembly are always critical and (2) the carcass and roof assembly activities are always critical for the first dwelling blocks. This tells us that, if we

want to let the construction activities go as planned, it is important that the focus should be on these three main activities.

The analysis of 2 projects, of which one is fully finished and one is still under construction, shows us that, (1) at both projects the piling activities started and finished one week late, (2) at one of the projects the carcass assembly started 1 week late and finished 2 weeks late, (3) at both projects the roof assembly activities started late (1 & 5 weeks) and finished late 4 weeks at one project, and is to be expected to finish 4 weeks late at the other project. So here we see that, at both projects, multiple activities that were found to be always critical finished late. The analysed project that is already fully completed, finished late 10 weeks in total.

Reason whys the piling activities started late was that the piling company was running out at another project. We found that the piling company has a very tight schedule during the year. This means that when they are running late at one of their projects, the following project often immediately faces the consequences.

The reason that the carcass and roof assembly started late has to do with the late delivery of the materials. In both cases the reason for the late delivery was undercapacity at the co-maker. Because these materials are delivered straight from the co-maker to the construction site, any delay at the co-maker immediately results in late delivery of the materials at the construction site. However, when we compared the purchasing planning to the execution planning of the project that is still under construction, we saw that there is a difference of 7 weeks for the carcass elements and 9 weeks for the roof elements. So, the co-makers planned their production capacity based on faulty information. That this is not a single mistake that happened once, we found out when we compared the execution planning with the purchasing planning of a project that is still in its project preparation phase. Here we see that there is a difference of 11 weeks for the carcass elements and 8 weeks for the roof elements.

By making sure that the piling, carcass assembly and roof assembly activities start at the planned moment, the predictability of the planning of a dwelling construction project will have to increase. VWA has already undertaken actions to standardise their work in each phase, so we will not go further in to organizational changes. To tackle the problem that any late delivery of materials, immediately affects the continuation of work at the construction site, we proposed the so called “HUB solution”. The HUB solution is to change the way the prefabricated concrete carcass elements and prefabricated roof elements are delivered to VWA. Instead of delivering straight from the production facility to the construction site, we propose to add a HUB. In this way the co-maker can deliver the materials at the HUB, and from there, the materials will be delivered Just In Time (JIT) at the construction site. Then, the co-maker can deliver on the delivery date that was established during the project preparation phase and any changes in the planning of VWA will not affect the planning of the co-maker. The cost-benefit analysis showed that the benefits will outweigh the costs depending on the configuration of number of projects per year, the amount of materials to be stored at the HUB and the interest percentage. Assuming that the construction project will finish 5 weeks less late in comparison with the current situation. A faster completion of the project was also one of the results of both the earlier mentioned studies in section 5.2.1. The right configuration per project can be determined by using the Critical Path Algorithm program. The program shows which dwellings or dwelling blocks are critical to the planning. From this outcome, the number of dwellings for which materials has to be stored at the HUB can be determined. In contradiction to our study, the earlier mentioned studies store almost all the materials at the HUB, and not just a part of the materials. This difference can be (partly) explained by the fact that the aim of the other studies was to reduce the number of transportation movements directly to the construction site, whereas the aim of this research was to improve the predictability of the planning. Unfortunately in neither one of the studies a financial overview of the costs and benefits is presented, which means a comparison couldn’t be made. Due to the lack of a financial analysis in those studies, the cost-benefit analysis performed in this study is a nice contribution. The cost-benefit analysis showed that interest rate has a high impact on whether or not the result of a certain configuration is positive. With an interest percentage of 1%, 20 out of 30 configurations show a positive result, and with an interest percentage of 12% just 5 out of 30 configurations remain to show a positive result. To make sure that the HUB solution will have a positive result it is most important to make sure that the interest percentage of the loan is as low as possible, or to extend the term of payment.

6.2 Implementation & Recommendations

In this section we will briefly give some guidelines concerning the implementation of the proposed solution. Furthermore, the recommendations are presented.

The HUB solution turned out to be a viable solution in certain situations. A trade-off between the benefits, in the form of number of weeks less construction time, and the costs, in the form of extra transportation, the HUB facility itself and interest, has to be made to conclude whether or not the HUB solution is viable. Based on the number of dwelling construction projects VWA has planned for the upcoming years, it can be seen in Table 6-1 that implementing the HUB solution will have a positive result. Therefore we recommend VWA to implement the HUB solution. The figures are based on the situation that there are 4 dwelling construction projects per year, the amount of materials to be stored at the HUB is for 10 dwellings per project and with an interest percentage of 6.5%.

		Current situation	Proposed situation with HUB
Cost			
	5 weeks construction time overdue	€ 90,000.00	€ 0.00
	HUB facility	€ 0.00	**€ 17,500.00**
	Transportation costs HUB > Construction site	€ 0.00	€ 3,280.00
	Financing costs	€ 0.00	€ 49,860.82
	Total cost	**€ 90,000.00**	**€ 78,138.44**
Benefit			
	Construction time overdue reduction	€ 0.00	€ 90,000.00
	Total benefit	**€ 0.00**	**€ 90,000.00**
Benefit – Costs result		**€ -90,000.00**	**€ 9,573.18**

Table 6-1; Trade-off costs HUB solution

The implementation can't be done right away because first a suitable HUB should be selected. However, this shouldn't take a very long time, given the high availability of facilities in the surroundings of the proposed location as we checked. In case the situation for VWA will change in the future, we recommend VWA to use the critical path algorithm to help to decide for how many dwellings the carcass and roof elements should be delivered and stored at the HUB. VWA should only store the materials at the HUB of the critical dwelling blocks. To lower the costs VWA can try to extend the term of payment of the materials that are delivered at the HUB, because this solution is also beneficial for the suppliers. They know for sure that they can deliver at the agreed delivery date, which mean that they can plan their own production better.

To be able to conduct in-depth analysis into the activity durations, it is wise to start with the registration of the activity duration at each dwelling construction project. This can easily be done by using the program we developed. In this way, VWA is assured that all the required data will be available and easy to access in the future.

Furthermore, we recommend VWA to look into the possibilities of insourcing certain construction activities. In this way VWA will be more in control over the available manpower.

6.3 Discussion

In this section we discuss the limitations of the research.

Lack of data

Due to the lack of data about the duration of activities of completed dwelling construction projects, it was impossible to draw conclusions that are quantitatively substantiated. To overcome this, we discussed the outcomes of the project analyses with multiple members of the dwelling construction department.

Availability of project members

During the research several employees left Van Wijnen Arnhem or were not available for a longer period of time. This made it hard or even impossible to learn the core reason for example late deliveries. To overcome this, we

again presented the findings to members of the dwelling construction department and asked them whether they could think of reasons why this could have happened.

Number of weeks gained by HUB solution

To be able to calculate the financial benefits of the HUB solution, assumptions about the number of weeks that are gained by implementing the HUB solution had to be made. So, there is a possibility that the assumed 5 weeks, will deviate in reality. When this turns out to be more weeks, then there is nothing to worry about. However, when it turns out to be many weeks less, the benefits can shrink hard, and combinations -of the number of projects per year and the number of dwelling per project for which materials have to be stored in the HUB that were thought to be beneficial, can turn out to be not beneficial at all.

6.4 Student reflection on the master thesis process

My time at Van Wijnen Arnhem hasn't been a quite ordinary time. Right from the start there was a set back because the person who attracted me to come to VWA to conduct the research and write my master's thesis got fired in my first week there. Then it also became clear that it was not possible to continue the research as it was planned, but fortunately it was possible for me to stay at VWA. The research plan had to be changed which caused some more delay at the start of the project. All in all not the start I hoped for.

After the somewhat bumpy start, the good conversations with Anton and Peter gave me new energy. A very interesting new research objective was established and I started to conduct the interviews. During the weeks that I conducted these interviews it became clear that, due to some organizational changes and other personal issues, multiple employees stopped working at VWA or wouldn't be available for a longer period of time. These were not only employees that worked for VWA just recently but also employees that have been working there for multiple years. For me, this was very frustrating because those were the people who could provide me with the most information about how construction projects were conducted at VWA.

Halfway the project, Peter came to visit VWA. I arranged that we could start the day with a construction site visit. The idea of this visit was to walk around at a construction site and in that way to get a nice insight view on how a dwelling is built. However, the executor of VWA at the construction site turned the visit into a small lecture and we never left the shack. Although we both learned from the "lecture" of the executor, it was kind of a bummer that in the end there was no time left to walk around at the construction site.

As the project continued, also the organisational changes within VWA continued and now also people higher up in the hierarchy left VWA. This caused a lot of restlessness among the employees of VWA and everyone had to work almost twice as hard to get the work done, which made it hard to make appointments with employees to interview them or discuss certain outcomes. A reorganisation of the dwelling construction office initiated by the dwelling department manager caused that, I had to move to another department. This was a pity because this caused that the people who were involved in my research were not around me anymore.

As the end of the project came closer also my second supervisor (Anton) was cleared from his duties at VWA. Fortunately, this was almost at the end of my project and Anton stayed at my disposal for any questions and feedback.

Because of the bumpy period VWA went through and is still going through, it was for me as a graduate intern hard to gather the required information and feedback of people within VWA. So besides that writing this master's thesis is a challenge on itself, it was even more a challenge to do it during the period VWA is currently in. All in all I learned a lot, not just about how to conduct research, but also about how things can go in business life and how to cope with that.

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Appendix 1: Successor determination algorithm

```
Sub DetermineSuccessors()


Dim Column3, Row5 As Integer

Dim Predecessor As String

Dim Successor As String

DetermineLastRows

Range("Q2:AB800").Select

Selection.Delete

MsgBox ("Successors bepalen")

For Row5 = 2 To LastRowInvoer                    'Loop through all the rows in the Invoer sheet

   For Column3 = 7 To 16                         'Loop through all the predecessor rows in the Invoer sheet

      If Blad9.Cells(Row5, Column3) <> "" Then     'If an activity has a predecessor then

         Predecessor = Blad9.Cells(Row5, Column3) 'Set the predecessor value

         Successor = Blad9.Cells(Row5, 1)         'Set the successor value

         AddSuccessor Predecessor, Successor      'Call the AddSuccessor sub that adds the successor to an activity
based on the given Predecessor and Successor values.

      End If

   Next Column3

Next Row5

End Sub


Sub AddSuccessor(Pred As String, Succ As String)

Dim Column2, ActivityRow3 As Integer

   ActivityRow3 = FindActivityRow(Pred, Blad9)              'Call the ActivityRow Function that determines the row
in which the predecessor is at sheet 9

  For Column2 = 17 To 26

      If Blad9.Cells(ActivityRow3, Column2) = "" Then      'If an empty successor column is found, add the successor
number.

         Blad9.Cells(ActivityRow3, Column2) = Succ

         Exit For

      End If

   Next Column2

End Sub
```

Appendix 2: Critical Path Method algorithm

```
Sub ConstructCP()

Dim RowCounter, Column4, ES, EF, LS, LF As Integer

Dim Row4 As Integer

Dim Row3 As Integer


Row3 = 2

RowCounter = 2

ClearWorksheet

MsgBox ("Worksheet wordt geleegd")

DetermineLastRows

   For Row3 = 2 To LastRowInvoer                'Loop through all the activities in in the INVOER sheet and determine the ES and EF

      If Blad9.Cells(Row3, 1) <> "" Then

         DetermineLastRows

         Blad10.Cells(RowCounter, 1) = Blad9.Cells(Row3, 1)

         Blad10.Cells(RowCounter, 2) = Blad9.Cells(Row3, 2)

         Blad10.Cells(RowCounter, 3) = Blad9.Cells(Row3, 3)

         ES = CalculateES(Row3)

         Blad10.Cells(RowCounter, 4) = ES

         Blad10.Cells(RowCounter, 5) = (ES + Blad9.Cells(Row3, 3) - 1) 'Earliest finish time calculation

         RowCounter = (RowCounter + 1)

      End If

   Next Row3

DetermineLastRows

   For Row4 = LastRowCP To 2 Step -1

      If Row4 = LastRowCP Then

         Blad10.Cells(Row4, 6) = Blad10.Cells(Row4, 4)

         Blad10.Cells(Row4, 7) = Blad10.Cells(Row4, 5)

      Else

         LF2 = DetermineLF(Row4)

         Blad10.Cells(Row4, 7) = LF2

         Blad10.Cells(Row4, 6) = (LF2 - Blad10.Cells(Row4, 3) + 1)
```

```
        End If
    Next Row4
End Sub

Sub ClearWorksheet() 'Clear the CP worksheet
    Range("A2").Select
    Range(Selection, Selection.End(xlToRight)).Select
    Range(Selection, Selection.End(xlDown)).Select
    Selection.ClearContents
    Range("A1").Select
End Sub

Sub DetermineLastRows()
Dim z As Integer
For z = 1 To 3000
    If Blad10.Cells(z, 1) = "" Then
        Exit For
    End If
Next z
LastRowCP = z - 1
For Y = 2 To 5000
    If Blad9.Cells(Y, 1) = "END" Then
        Exit For
    End If
Next Y
LastRowInvoer = (Y - 1)
End Sub

Function CalculateES(ActivityRow As Integer) As Integer
Dim Pred As String
Dim v, Row7, Row8, PredColumn, ES, ESTemp, ArrLength2 As Integer
Dim ActivityNo As String
```

```
ES = 1

ActivityNo = Blad9.Cells(ActivityRow, 1)

For PredColumn = 7 To 16

  If Blad9.Cells(ActivityRow, PredColumn) <> "" Then                    'Look for predecessors if none found, exit for loop

    Pred = Blad9.Cells(ActivityRow, PredColumn)                         'Set the predecessor number

    For Row7 = 2 To LastRowCP                                           'Get the EF time of the pred

      If Blad10.Cells(Row7, 1) = Pred Then                              'When the Precedent activity is found in the CP2 Sheet, continue

        If Blad9.Cells(ActivityRow, 5) = "" And ParallelityCheck(ActivityNo, Pred) = False Then 'Check if the activity is aloud to start early if possible

          ArrLength2 = ArrowLength(Pred)

          ESTemp = (Blad10.Cells(Row7, 5) + ArrLength2)

          If ESTemp >= ES Then                                          'Check if the finish time of the prececent activity is higher than the ES time of the activity

            ES = (ESTemp + 1)                                           'If finish time of precedent activity is higher, then update the ES of the activity

          End If

        Else

          If Blad10.Cells(Row7, 5) >= ES Then                           'Check if the finish time of the prececent activity is higher than the ES time of the activity

            ES = (Blad10.Cells(Row7, 5) + 1)                            'If finish time of precedent activity is higher, then update the ES of the activity

          End If

        End If

      End If

    Next Row7

  Else

    Exit For

  End If

Next PredColumn


CalculateES = ES


End Function
```

```
Function DetermineLF(ActivityRow2 As Integer) As Integer


Dim Succ As String

Dim ActivityNo2 As String

Dim ActivityRow5 As Integer

Dim Row1, Column1, LF, LFTemp As Integer

Dim FollowUPAc As String


DetermineLastRows

ActivityNo2 = Blad10.Cells(ActivityRow2, 1)                    'Get activity number of activity for which
the LF has to be calculated

LF = Blad10.Cells(LastRowCP, 5)                    'Set a high number for the Temp LF (in this case
the latest date in the CP sheet


For Row1 = 2 To LastRowInvoer

   If Blad9.Cells(Row1, 1) = ActivityNo2 Then                    'Search for the activity in the INVOER sheet,
when found get the successor                    'BinVar turns 1 when activity is found,
when 1 the For Row1 loop will be exitted

      For Column1 = 17 To 26

         Succ = Blad9.Cells(Row1, Column1)                    'Get the successor number

         If Succ <> "" Then

            ActivityRow5 = FindActivityRow(Succ, Blad9)

            If Blad9.Cells(ActivityRow5, 5) = "" Then                    'Check if the predecessor is allowed to
start early

               If ParallelityCheck(ActivityNo2, Succ) = False Then

                  LFTemp = (FindLSSuccessor(Succ) - 1 - ArrowLength(ActivityNo2))       'Determine LF time based on
this successor taking into account the arrowlength

               Else

                  LFTemp = (FindLSSuccessor(Succ) - 1)

               End If

            Else

               LFTemp = (FindLSSuccessor(Succ) - 1)                    'Determine LF time based on this successor

            End If


            If LFTemp < LF Then                    'Check if the LF based on this successor is earlier than
the LF calculated so far
```

```
            LF = LFTemp                                    'If LFTemp < LF then update LF
            Blad10.Cells(ActivityRow2, 8) = Succ
          ElseIf LFTemp = LF Then
            Blad10.Cells(ActivityRow2, 8) = Blad10.Cells(ActivityRow2, 8) & ", " & Succ
          End If

        ElseIf Succ = "" And Column1 = 17 Then
          MsgBox ("Let op activiteit op rij " & Row1 & " heeft geen successor")
          Exit For
        Else
          Exit For
        End If
      Next Column1
      Exit For
    End If
Next Row1

DetermineLF = LF

End Function

Function FindLSSuccessor(Succ2 As String) As Integer

Dim Row2, LS As Integer

  For Row2 = 2 To LastRowCP
    If Blad10.Cells(Row2, 1) = Succ2 Then
      LS = Blad10.Cells(Row2, 6)
      Exit For
    End If
  Next Row2

FindLSSuccessor = LS
```

```
End Function

Function ArrowLength(Activity As String) As Integer

Dim Row9 As Integer
Dim ArrLength As Integer

For Row9 = 2 To LastRowInvoer
   If Blad9.Cells(Row9, 1) = Activity Then
      ArrLength = Blad9.Cells(Row9, 6)
      Exit For
   End If
Next Row9

ArrowLength = ArrLength

End Function

Sub DetermineSuccessors()

Dim Column3, Row5 As Integer
Dim Predecessor As String
Dim Successor As String

DetermineLastRows

Range("Q2:AB800").Select
Selection.Delete
MsgBox ("Successors bepalen")

For Row5 = 2 To LastRowInvoer                'Loop through all the rows in the Invoer sheet
   For Column3 = 7 To 16                     'Loop through all the predecessor rows in the Invoer sheet
```

```
        If Blad9.Cells(Row5, Column3) <> "" Then     'If an activity has a predecessor then

            Predecessor = Blad9.Cells(Row5, Column3) 'Set the predecessor value

            Successor = Blad9.Cells(Row5, 1)         'Set the successor value

            AddSuccessor Predecessor, Successor      'Call the AddSuccessor sub that adds the successor to an activity
based on the given Predecessor and Successor values.

        End If

    Next Column3

Next Row5


End Sub


Sub AddSuccessor(Pred As String, Succ As String)


Dim Column2, ActivityRow3 As Integer


    ActivityRow3 = FindActivityRow(Pred, Blad9)              'Call the ActivityRow Function that determines the row
in which the predecessor is at sheet 9


    For Column2 = 17 To 26

        If Blad9.Cells(ActivityRow3, Column2) = "" Then      'If an empty successor column is found, add the successor
number.

            Blad9.Cells(ActivityRow3, Column2) = Succ

            Exit For

        End If

    Next Column2


End Sub


Function FindActivityRow(ActivityNo As String, WS As Worksheet) As Integer


Dim Row6, ActivityRow4 As Integer


DetermineLastRows
```

```
    For Row6 = 2 To LastRowInvoer
        If WS.Cells(Row6, 1) = ActivityNo Then              'Loop through the rows of sheet 4,
            ActivityRow4 = Row6                             'when activityno is found, update ActivityRow2 and exit for loop
            Exit For
        End If
    Next Row6

If ActivityRow4 = 0 Then
    MsgBox ("Er werd gezocht naar activiteit nummer " & ActivityNo & " maar dit nummer komt niet voor in de
INVOER lijst!")
    End
End If
    FindActivityRow = ActivityRow4

End Function

Function ParallelityCheck(ActivityNo6 As String, SuccessorNo6 As String) As Boolean

Dim TempVar As Boolean

If InStr(SuccessorNo6, "-") <> 0 Then
    Select Case Len(ActivityNo6)

    Case 3
        If Left(ActivityNo6, 1) = Left(SuccessorNo6, 1) Then
            TempVar = True
        Else
            TempVar = False
        End If
    Case 4
        If Left(ActivityNo6, 2) = Left(SuccessorNo6, 2) Then
            TempVar = True
        Else
```

```
            TempVar = False
        End If
    Case 5
        If Left(ActivityNo6, 3) = Left(SuccessorNo6, 3) Then
            TempVar = True
        Else
            TempVar = False
        End If
    End Select
Else
    TempVar = False
End If

ParallelityCheck = TempVar

End Function
```

Appendix 3: Input table CPM algorithm

Activity_No	Activity_Description	Duration_Finish	Duration_Next	Pred_Must_Be_Finished_Full	Arrow_Length	Predecessor_1	Determine successors								Predecessor_10
					0										
1	INRICHTEN BOUWTERREIN	10			0										
					0										
11	Uitzetten hoekpunten bouwblok	1			0	1									
12	Ontgraven bouwblok	10			0	11									
13	Aanbrengen drainage	10			0	11									
14	Aanbrengen bodemafsluiting	10			0	11									
					0										
16	Uitzetten rooilijnen door gemeente	1			0	12	13	14							
17	Uitzetten peilhoogte	1			0	12	13	14							
18	Uitzetten paalpiketten	1			0	12	13	14							
19	Aanbrengen palen	5			0	16	17	18							
20	Uitharden palen bij boorpalen	5			0	19									
21	Doormeten palen & inmeten paalmisstanden	1			0	20									
22	Beoordelen paalmisstanden door constructeur	2			0	21									
38	Opschonen bouwput bij boorpalen	5			0	22									
					0										
24	Maatvoeren fundering	1			0	38									
25	Stekken boren	3	1		-2	24									
26	Opstorten palen	3	1		-2	24									
27	Aanbrengen funderingsbalken	3	1		-2	25	26								
28	Aangieten funderingsbalk	2			0	27									
					0										

30	Maatvoeren stadsverwarming	2	1		-1	28									
31	Aanbrengen verdeelkasten (elektra & water)	1			0	30									
32	Aanbrengen stadsverwarming (7 won/week)	18	1		-17	31									
33	Aanbrengen leidingen onder de vloer (10 won/week)	12	1		-11	32									
34	Invoerleidingen NUTS en mantelbuizen (10 won/week)	12	1		-11	33									
35	Aansluiten VWA op gemeenteriool (10 won/week)	12	1		-11	34									
36	Aansluiten HWA (10 won/week)	12	2		-10	35									
					0										
39	Aanvullen kruipruimte bij kruipruimteloos bouwen	4	3		-1	36									
40	Aanbrengen stabilisatie zand rondom bouwblok t.b.v. steiger	2			0	39									
41	Aanhelen bouwwegen	2			0	39									
					0										
43	Maatvoeren hoekpunten vloerveld	1			0	40	41								
44	Leggen vloerelementen	5			0	32	43								
45	Kelkvloegen en sparingen afpurren	5			0	32	43								
46	Optoppen doorvoeren L-installatie	5			0	32	43								
47	Aanbrengen meterkastplaat	5			0	32	43								
48	Afstorten begane grondvloer	5			0	32	43								
49	Aanbrengen kruipluikomranding inclusief rooster	5			0	32	43								
50	1e kijkmoment kopers: Start bouw feest	1			0	44	45	46	47	48	49				
					0										

52	Montage casco Blok 6 & 5 (7 won)	7			0	50									
53	Montage casco Blok 4 & 3 (4 won)	4			0	52									
54	Montage casco Blok 7, 8 & 9 (7 won)	7			0	53									
55	Montage casco Blok 2 & 1 (4 won)	4			0	54									
56	Montage casco Blok 10 & 11 (3 won)	3			0	55									
57-1	Aanbrengen kunststof kozijnen inclusief glas & folie begane grond	5	1		-4	52									
57-2	Aanbrengen kunststof kozijnen inclusief glas & folie begane grond	3	1		-2	53	57-1								
57-3	Aanbrengen kunststof kozijnen inclusief glas & folie begane grond	4	1		-3	54	57-2								
57-4	Aanbrengen kunststof kozijnen inclusief glas & folie begane grond	2	1		-1	55	57-3								
57-5	Aanbrengen kunststof kozijnen inclusief glas & folie begane grond	2	1		-1	56	57-4								
					0										
59-1	Aanbrengen veiligheidsvoorzieningen Blok 6 & 5	4	1		-3	57-1									
59-2	Aanbrengen veiligheidsvoorzieningen Blok 3 & 4	2	1		-1	57-2									
59-3	Aanbrengen veiligheidsvoorzieningen Blok 7, 8 & 9	3	1		-2	57-3									
59-4	Aanbrengen veiligheidsvoorzieningen Blok 2 & 1	2	1		-1	57-4									
59-5	Aanbrengen veiligheidsvoorzieningen Blok 10 & 11	3	1		-2	57-5									
60-1	Aanbrengen bouwdeck elementen bij uitbouwen Blok 6 & 5	7	1		-6	59-1									
60-2	Aanbrengen bouwdeck elementen bij	4	1		-3	59-2	60-1								

	uitbouwen Blok 3 & 4														
60-3	Aanbrengen bouwdeck elementen bij uitbouwen Blok 7, 8 & 9	7	1		-6	59-3	60-2								
60-4	Aanbrengen bouwdeck elementen bij uitbouwen Blok 2 & 1	4	1		-3	59-4	60-3								
60-5	Aanbrengen bouwdeck elementen bij uitbouwen Blok 10 & 11	3	1		-2	59-5	60-4								
61-1	Maatvoering muurplaatankers Blok 6 & 5	7	1		-6	60-1									
61-2	Maatvoering muurplaatankers Blok 3 & 4	4	1		-3	60-2	61-1								
61-3	Maatvoering muurplaatankers Blok 7, 8 & 9	7	1		-6	60-3	61-2								
61-4	Maatvoering muurplaatankers Blok 2 & 1	4	1		-3	60-4	61-3								
61-5	Maatvoering muurplaatankers Blok 10 & 11	3	1		-2	60-5	61-4								
62-1	Aanbrengen muurplaten & afpurren Blok 6 & 5	7	1		-6	60-1									
62-2	Aanbrengen muurplaten & afpurren Blok 3 & 4	4	1		-3	60-2	62-1								
62-3	Aanbrengen muurplaten & afpurren Blok 7, 8 & 9	7	1		-6	60-3	62-2								
62-4	Aanbrengen muurplaten & afpurren Blok 2 & 1	4	1		-3	60-4	62-3								
62-5	Aanbrengen muurplaten & afpurren Blok 10 & 11	3	1		-2	60-5	62-4								
63-1	Aanbrengen dakelementen inclusief knieschotten en dakvensters Blok 6 & 5	7	1		-6	60-1									

6 3-2	Aanbrengen dakelementen inclusief knieschotten en dakvensters Blok 3 & 4	4	1		-3	60 -2	63 -1								
6 3-3	Aanbrengen dakelementen inclusief knieschotten en dakvensters Blok 7, 8 & 9	7	1		-6	60 -3	63 -2								
6 3-4	Aanbrengen dakelementen inclusief knieschotten en dakvensters Blok 2 & 1	4	1		-3	60 -4	63 -3								
6 3-5	Aanbrengen dakelementen inclusief knieschotten en dakvensters Blok 10 & 11	3	1		-2	60 -5	63 -4								
6 4-1	Aanbrengen dakkapellen Blok 6 & 5	7	1		-6	60 -1									
6 4-2	Aanbrengen dakkapellen Blok 3 & 4	4	1		-3	60 -2	64 -1								
6 4-3	Aanbrengen dakkapellen Blok 7, 8 & 9	7	1		-6	60 -3	64 -2								
6 4-4	Aanbrengen dakkapellen Blok 2 & 1	4	1		-3	60 -4	64 -3								
6 4-5	Aanbrengen dakkapellen Blok 10 & 11	3	1		-2	60 -5	64 -4								
6 5-1	Afmonteren dakelementen Blok 6 & 5	7	1		-6	60 -1									
6 5-2	Afmonteren dakelementen Blok 3 & 4	4	1		-3	60 -2	65 -1								
6 5-3	Afmonteren dakelementen Blok 7, 8 & 9	7	1		-6	60 -3	65 -2								
6 5-4	Afmonteren dakelementen Blok 2 & 1	4	1		-3	60 -4	65 -3								
6 5-5	Afmonteren dakelementen Blok 10 & 11	3	1		-2	60 -5	65 -4								

6 6-1	Aanbrengen dakdoorvoeren of schoorsteen bij gecombineerde doorvoer Blok 6 & 5	7	1		-6	60 -1									
6 6-2	Aanbrengen dakdoorvoeren of schoorsteen bij gecombineerde doorvoer Blok 3 & 4	4	1		-3	60 -2	66 -1								
6 6-3	Aanbrengen dakdoorvoeren of schoorsteen bij gecombineerde doorvoer Blok 7, 8 & 9	7	1		-6	60 -3	66 -2								
6 6-4	Aanbrengen dakdoorvoeren of schoorsteen bij gecombineerde doorvoer Blok 2 & 1	4	1		-3	60 -4	66 -3								
6 6-5	Aanbrengen dakdoorvoeren of schoorsteen bij gecombineerde doorvoer Blok 10 & 11	3	1		-2	60 -5	66 -4								
6 7-1	Aanbrengen rekwerk bij getimmerde goot Blok 6 & 5	7	1		-6	60 -1									
6 7-2	Aanbrengen rekwerk bij getimmerde goot Blok 3 & 4	4	1		-3	60 -2	67 -1								
6 7-3	Aanbrengen rekwerk bij getimmerde goot Blok 7, 8 & 9	7	1		-6	60 -3	67 -2								
6 7-4	Aanbrengen rekwerk bij getimmerde goot Blok 2 & 1	4	1		-3	60 -4	67 -3								
6 7-5	Aanbrengen rekwerk bij getimmerde goot Blok 10 & 11	3	1		-2	60 -5	67 -4								
6 8-1	Aanbrengen gootbeugels Blok 6 & 5	7	1		-6	60 -1									
6 8-2	Aanbrengen gootbeugels Blok 3 & 4	4	1		-3	60 -2	68 -1								
6 8-3	Aanbrengen gootbeugels Blok 7, 8 & 9	7	1		-6	60 -3	68 -2								

68-4	Aanbrengen gootbeugels Blok 2 & 1	4	1		-3	60-4	68-3								
68-5	Aanbrengen gootbeugels Blok 10 & 11	3	1		-2	60-5	68-4								
69-1	Aanbrengen goten Blok 6 & 5	7	1		-6	60-1									
69-2	Aanbrengen goten Blok 3 & 4	4	1		-3	60-2	69-1								
69-3	Aanbrengen goten Blok 7, 8 & 9	7	1		-6	60-3	69-2								
69-4	Aanbrengen goten Blok 2 & 1	4	1		-3	60-4	69-3								
69-5	Aanbrengen goten Blok 10 & 11	3	1		-2	60-5	69-4								
70-1	Aanbrengen tijdelijke HWA's Blok 6 & 5	7	1		-6	60-1									
70-2	Aanbrengen tijdelijke HWA's Blok 3 & 4	4	1		-3	60-2	70-1								
70-3	Aanbrengen tijdelijke HWA's Blok 7, 8 & 9	7	1		-6	60-3	70-2								
70-4	Aanbrengen tijdelijke HWA's Blok 2 & 1	4	1		-3	60-4	70-3								
70-5	Aanbrengen tijdelijke HWA's Blok 10 & 11	3	1		-2	60-5	70-4								
71-1	Aanbrengen pannen en toebehoren Blok 6 & 5	7	1		-6	61-1	62-1	63-1	64-1	65-1	66-1	67-1	68-1	69-1	70-1
71-2	Aanbrengen pannen en toebehoren Blok 3 & 4	4	1		-3	61-2	62-2	63-2	64-2	65-2	66-2	67-2	68-2	69-2	70-2
71-3	Aanbrengen pannen en toebehoren Blok 7, 8 & 9	7	1		-6	61-3	62-3	63-3	64-3	65-3	66-3	67-3	68-3	69-3	70-3
71-4	Aanbrengen pannen en toebehoren Blok 2 & 1	4	1		-3	61-4	62-4	63-4	64-4	65-4	66-4	67-4	68-4	69-4	70-4
71-5	Aanbrengen pannen en toebehoren Blok 10 & 11	3	1		-2	61-5	62-5	63-5	64-5	65-5	66-5	67-5	68-5	69-5	70-5

Duration next na 1 dag maar ook na 3 dagen

72-1	Aanbrengen pv-panelen Blok 6 & 5	7	1		-6	71-1									
72-2	Aanbrengen pv-panelen Blok 3 & 4	4	1		-3	71-2	72-1								
72-3	Aanbrengen pv-panelen Blok 7, 8 & 9	7	1		-6	71-3	72-2								
72-4	Aanbrengen pv-panelen Blok 2 & 1	4	1		-3	71-4	72-3								
72-5	Aanbrengen pv-panelen Blok 10 & 11	3	1		-2	71-5	72-4								
73-1	Afpurren naden dakelementen Blok 6 & 5	7	1		-6	72-1									
73-2	Afpurren naden dakelementen Blok 3 & 4	4	1		-3	72-2	73-1								
73-3	Afpurren naden dakelementen Blok 7, 8 & 9	7	1		-6	72-3	73-2								
73-4	Afpurren naden dakelementen Blok 2 & 1	4	1		-3	72-4	73-3								
73-5	Afpurren naden dakelementen Blok 10 & 11	3	1		-2	72-5	73-4								
74-1	Aanbrengen aftimmering dakelementen Blok 6 & 5	7	1		-6	73-1									
74-2	Aanbrengen aftimmering dakelementen Blok 3 & 4	4			0	73-2	74-1								
74-3	Aanbrengen aftimmering dakelementen Blok 7, 8 & 9	7			0	73-3	74-2								
74-4	Aanbrengen aftimmering dakelementen Blok 2 & 1	4			0	73-4	74-3								
74-5	Aanbrengen aftimmering dakelementen Blok 10 & 11	3			0	73-5	74-4								
					0										
76	Metselwerk Blok 6 & 5 (7 won)	9			0	72-1									
77	Metselwerk Blok 4 & 3 (4 won)	6			0	72-2	76	74-1							

78	Metselwerk Blok 7, 8 & 9 (7 won)	10			0	72-3	77	74-2							
79	Metselwerk Blok 2 & 1 (4 won)	6			0	72-4	78	74-3							
80	Metselwerk Blok 10 & 11 (3 won)	5			0	72-5	79	74-4							
					0										
82	Metselwerk garage Blok 4 & 3 (3 stuks)	3			0	77									
83	Metselwerk garage Blok 7, 8 & 9 (4 stuks)	4			0	78									
84	Metselwerk garage Blok 2 & 1 (3 stuks)	3			0	79									
85	Metselwerk garage blok 10 & 11 (3 stuks)	3			0	80	74-5								
					0										
87	Metselwerk tuinmuur Blok 6 & 5	6			0	76									
88	Metselwerk tuinmuur Blok 1	4			0	79									
89	Metselwerk tuinmuur Blok 11	3			0	85									
					0										
91-1	Aanbrengen gevelaftimmering bij overstekken	2			0	76									
91-2	Aanbrengen gevelaftimmering bij overstekken	2			0	77	91-1								
91-3	Aanbrengen gevelaftimmering bij overstekken	2			0	78	91-2								
91-4	Aanbrengen gevelaftimmering bij overstekken	3			0	79	91-3								
91-5	Aanbrengen gevelaftimmering bij overstekken	2			0	80	91-4								
92	Aanbrengen zinkwerk dakkapel en tuitgevels Blok 6 & 5	7			0	91-1									
93-1	Aanbrengen gevelstuc Blok 4, 7, 9, 2 & 1	2			0	91-2									
93-2	Aanbrengen gevelstuc Blok 4, 7, 9, 2 & 1	5			0	91-3	93-1								
93-3	Aanbrengen gevelstuc Blok 4, 7, 9, 2 & 1	5			0	91-4	93-2								

94-1	Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen	7	1	1	-6	57-1									
94-2	Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen	4	1	1	-3	57-2	94-1								
94-3	Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen	7	1	1	-6	57-3	94-2								
94-4	Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen	4	1	1	-3	57-4	94-3								
94-5	Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen	3	1	1	-2	57-5	91-5	94-4							
95-1	Aanbrengen daktrim bij uitbouwen	3			0	94-1									
95-2	Aanbrengen daktrim bij uitbouwen	2			0	94-2	95-1								
95-3	Aanbrengen daktrim bij uitbouwen	2			0	94-3	95-2								
95-4	Aanbrengen daktrim bij uitbouwen	2			0	94-4	95-3								
95-5	Aanbrengen daktrim bij uitbouwen	2			0	94-5	95-4								
96-1	Aanbrengen definitieve HWA's	1			0	95-1									
96-2	Aanbrengen definitieve HWA's	1			0	95-2	96-1								
96-3	Aanbrengen definitieve HWA's	1			0	95-3	96-2								
96-4	Aanbrengen definitieve HWA's	1			0	95-4	96-3								
96-5	Aanbrengen definitieve HWA's	1			0	93-3	95-5	96-4							
					0										
98-1	Aanbrengen schragen t.b.v. houten balklaag	3			0	82									

98-2	Aanbrengen schragen t.b.v. houten balklaag	4			0	83	98-1								
98-3	Aanbrengen schragen t.b.v. houten balklaag	3			0	84	98-2								
98-4	Aanbrengen schragen t.b.v. houten balklaag	3			0	85	98-3								
99-1	Aanbrengen houten randbalk en balklaag garage	3			0	82									
99-2	Aanbrengen houten randbalk en balklaag garage	4			0	83	99-1								
99-3	Aanbrengen houten randbalk en balklaag garage	3			0	84	99-2								
99-4	Aanbrengen houten randbalk en balklaag garage	3			0	85	99-3								
1000-1	Aanbrengen dakbeschot garage	3			0	82									
1000-2	Aanbrengen dakbeschot garage	4			0	83	1000-1								
1000-3	Aanbrengen dakbeschot garage	3			0	84	1000-2								
1000-4	Aanbrengen dakbeschot garage	3			0	85	1000-3								
1011-1	Aanbrengen dakbedekking en daktrimmen garage	3			0	98-1	99-1	1001							
1011-2	Aanbrengen dakbedekking en daktrimmen garage	4			0	98-2	99-2	1002	1011						
1011-3	Aanbrengen dakbedekking en daktrimmen garage	3			0	98-3	99-3	1003	1012						
1011-4	Aanbrengen dakbedekking en daktrimmen garage	3			0	98-4	99-4	1004	1013						
10	Demontage schragen	3			0	1011									

2-1															
102-2	Demontage schragen	4			0	101-2	102-1								
102-3	Demontage schragen	3			0	101-3	102-2								
102-4	Demontage schragen	3			0	101-4	102-3								
103-1	Stelwerk hoeklijn garagedeur	3			0	101-1									
103-2	Stelwerk hoeklijn garagedeur	4			0	101-2	103-1								
103-3	Stelwerk hoeklijn garagedeur	3			0	101-3	103-2								
103-4	Stelwerk hoeklijn garagedeur	3			0	101-4	103-3								
104-1	Randkist stellen aanstorting garagevloer	3			0	101-1									
104-2	Randkist stellen aanstorting garagevloer	4			0	101-2	104-1								
104-3	Randkist stellen aanstorting garagevloer	3			0	101-3	104-2								
104-4	Randkist stellen aanstorting garagevloer	3			0	101-4	104-3								
105-1	Aanbrengen aanstorting garagevloer	3			0	101-1									
105-2	Aanbrengen aanstorting garagevloer	4			0	101-2	105-1								

105-3	Aanbrengen aanstorting garagevloer	3			0	101-3	105-2								
105-4	Aanbrengen aanstorting garagevloer	3			0	101-4	105-3								
106-1	Aanbrengen HWA's	3			0	102-1	103-1	104-1	105-1						
106-2	Aanbrengen HWA's	4			0	102-2	103-2	104-2	105-2	106-1					
106-3	Aanbrengen HWA's	3			0	102-3	103-3	104-3	105-3	106-2					
106-4	Aanbrengen HWA's	3			0	102-4	103-4	104-4	105-4	106-3					
107-1	Aanbrengen garagedeur	3			0	102-1	103-1	104-1	105-1						
107-2	Aanbrengen garagedeur	4			0	102-2	103-2	104-2	105-2	107-1					
107-3	Aanbrengen garagedeur	3			0	102-3	103-3	104-3	105-3	107-2					
107-4	Aanbrengen garagedeur	3			0	102-4	103-4	104-4	105-4	107-3					
108-1	Smeren dekvloer	3			0	106-1	107-1								
108-2	Smeren dekvloer	4			0	106-2	107-2	108-1							
108-3	Smeren dekvloer	3			0	106-3	107-3	108-2							
108-4	Smeren dekvloer	3			0	106-4	107-4	108-3							

					0										
110-1	Maatvoering positie trapgat Blok 6 & 5	7	1		-6	71-1									
110-2	Maatvoering positie trapgat Blok 3 & 4	4	1		-3	71-2	110-1								
110-3	Maatvoering positie trapgat Blok 7, 8 & 9	7	1		-6	71-3	110-2								
110-4	Maatvoering positie trapgat Blok 2 & 1	4	1		-3	71-4	110-3								
110-5	Maatvoering positie trapgat Blok 10 & 11	3	1		-2	71-5	110-4								
111-1	Aanbrengen trappen en hekwerken Blok 6 & 5	7	1		-6	72-1	110-1								
111-2	Aanbrengen trappen en hekwerken Blok 3 & 4	4	1		-3	72-2	110-2	111-1							
111-3	Aanbrengen trappen en hekwerken Blok 7, 8 & 9	7	1		-6	72-3	110-3	111-2							
111-4	Aanbrengen trappen en hekwerken Blok 2 & 1	4	1		-3	72-4	110-4	111-3							
111-5	Aanbrengen trappen en hekwerken Blok 10 & 11	3	1		-2	72-5	110-5	111-4							
112-1	Aanbrengen trapgat beveiliging Blok 6 & 5	7	1		-6	72-1	110-1								
112-2	Aanbrengen trapgat beveiliging Blok 3 & 4	4	1		-3	72-2	110-2	112-1							
112-3	Aanbrengen trapgat beveiliging Blok 7, 8 & 9	7	1		-6	72-3	110-3	112-2							
11	Aanbrengen trapgat beveiliging Blok 2 & 1	4	1		-3	72-4	110-4	112-3							

2-4															
112-5	Aanbrengen trapgat beveiliging Blok 10 & 11	3	1		-2	72-5	110-5	112-4							
113-1	Maatvoering binnenwanden Blok 6 & 5	7	1		-6	111-1	112-1								
113-2	Maatvoering binnenwanden Blok 3 & 4	4	1		-3	111-2	112-2	113-1							
113-3	Maatvoering binnenwanden Blok 7, 8 & 9	7	1		-6	111-3	112-3	113-2							
113-4	Maatvoering binnenwanden Blok 2 & 1	4	1		-3	111-4	112-4	113-3							
113-5	Maatvoering binnenwanden Blok 10 & 11	3	1		-2	111-5	112-5	113-4							
114-1	Aanbrengen binnenwanden Blok 6 & 5	7	1		-6	113-1									
114-2	Aanbrengen binnenwanden Blok 3 & 4	4	1		-3	113-2	114-1								
114-3	Aanbrengen binnenwanden Blok 7, 8 & 9	7	1		-6	113-3	114-2								
114-4	Aanbrengen binnenwanden Blok 2 & 1	4	1		-3	113-4	114-3								
114-5	Aanbrengen binnenwanden Blok 10 & 11	3	1		-2	113-5	114-4								
115-1	Montage achterschot meterkast Blok 6 & 5	7	1		-6	114-1									
115-2	Montage achterschot meterkast Blok 3 & 4	4	1		-3	114-2	115-1								

115-3	Montage achterschot meterkast Blok 7, 8 & 9	7	1		-6	114-3	115-2								
115-4	Montage achterschot meterkast Blok 2 & 1	4	1		-3	114-4	115-3								
115-5	Montage achterschot meterkast Blok 10 & 11	3	1		-2	114-5	115-4								
116-1	Afschrijven installaties op binnenwanden Blok 6 & 5	7	1		-6	115-1									
116-2	Afschrijven installaties op binnenwanden Blok 3 & 4	4	1		-3	115-2	116-1								
116-3	Afschrijven installaties op binnenwanden Blok 7, 8 & 9	7	1		-6	115-3	116-2								
116-4	Afschrijven installaties op binnenwanden Blok 2 & 1	4	1		-3	115-4	116-3								
116-5	Afschrijven installaties op binnenwanden Blok 10 & 11	3	1		-2	115-5	116-4								
117-1	Frezen leidingwerk in binnenwanden Blok 6 & 5	7	1		-6	116-1									
117-2	Frezen leidingwerk in binnenwanden Blok 3 & 4	4	1		-3	116-2	117-1								
117-3	Frezen leidingwerk in binnenwanden Blok 7, 8 & 9	7	1		-6	116-3	117-2								
117-4	Frezen leidingwerk in binnenwanden Blok 2 & 1	4	1		-3	116-4	117-3								
117-5	Frezen leidingwerk in binnenwanden Blok 10 & 11	3	1		-2	116-5	117-4								
118-1	E-installatie wand en vloer Blok 6 & 5	7	1		-6	117-1									

118-2	E-installatie wand en vloer Blok 3 & 4	4	1		-3	117-2	118-1								
118-3	E-installatie wand en vloer Blok 7, 8 & 9	7	1		-6	117-3	118-2								
118-4	E-installatie wand en vloer Blok 2 & 1	4	1		-3	117-4	118-3								
118-5	E-installatie wand en vloer Blok 10 & 11	3	1		-2	117-5	118-4								
119-1	W-installatie wand en vloer Blok 6 & 5	7	1		-6	118-1									
119-2	W-installatie wand en vloer Blok 3 & 4	4	1		-3	118-2	119-1								
119-3	W-installatie wand en vloer Blok 7, 8 & 9	7	1		-6	118-3	119-2								
119-4	W-installatie wand en vloer Blok 2 & 1	4	1		-3	118-4	119-3								
119-5	W-installatie wand en vloer Blok 10 & 11	3	1		-2	118-5	119-4								
120-1	Aanbrengen trapgataftimmering Blok 6 & 5	7	1		-6	119-1									
120-2	Aanbrengen trapgataftimmering Blok 3 & 4	4	1		-3	119-2	120-1								
120-3	Aanbrengen trapgataftimmering Blok 7, 8 & 9	7	1		-6	119-3	120-2								
120-4	Aanbrengen trapgataftimmering Blok 2 & 1	4	1		-3	119-4	120-3								
120-5	Aanbrengen trapgataftimmering Blok 10 & 11	3	1		-2	119-5	120-4								

121-1	Aanbrengen leuningen trappen Blok 6 & 5	7	1		-6	119-1									
121-2	Aanbrengen leuningen trappen Blok 3 & 4	4	1		-3	119-2	121-1								
121-3	Aanbrengen leuningen trappen Blok 7, 8 & 9	7	1		-6	119-3	121-2								
121-4	Aanbrengen leuningen trappen Blok 2 & 1	4	1		-3	119-4	121-3								
121-5	Aanbrengen leuningen trappen Blok 10 & 11	3	1		-2	119-5	121-4								
122-1	Uitsparen douchehoek Blok 6 & 5	7	1		-6	120-1	121-1								
122-2	Uitsparen douchehoek Blok 3 & 4	4	1		-3	120-2	121-2	122-1							
122-3	Uitsparen douchehoek Blok 7, 8 & 9	7	1		-6	120-3	121-3	122-2							
122-4	Uitsparen douchehoek Blok 2 & 1	4	1		-3	120-4	121-4	122-3							
122-5	Uitsparen douchehoek Blok 10 & 11	3	1		-2	120-5	121-5	122-4							
123-1	2e kijkmoment kopers: Beoordeling leidingwerk voor smeren dekvloeren Blok 6 & 5	1			0	122-1									
123-2	2e kijkmoment kopers: Beoordeling leidingwerk voor smeren dekvloeren Blok 3 & 4	1			0	122-2									
123-3	2e kijkmoment kopers: Beoordeling leidingwerk voor	1			0	122-3									

	smeren dekvloeren Blok 7, 8 & 9														
123-4	2e kijkmoment kopers: Beoordeling leidingwerk voor smeren dekvloeren Blok 2 & 1	1			0	122-4									
123-5	2e kijkmoment kopers: Beoordeling leidingwerk voor smeren dekvloeren Blok 10 & 11	1			0	122-5									
124-1	Smeren dekvloeren m.u.v. douchehoek Blok 6 & 5	7	1		-6	123-1									
124-2	Smeren dekvloeren m.u.v. douchehoek Blok 3 & 4	4	1		-3	123-2	124-1								
124-3	Smeren dekvloeren m.u.v. douchehoek Blok 7, 8 & 9	7	1		-6	123-3	124-2								
124-4	Smeren dekvloeren m.u.v. douchehoek Blok 2 & 1	4	1		-3	123-4	124-3								
124-5	Smeren dekvloeren m.u.v. douchehoek Blok 10 & 11	3	1		-2	123-5	124-4								
125-1	Drogen dekvloer Blok 6 & 5	7	1		-6	124-1									
125-2	Drogen dekvloer Blok 3 & 4	4	1		-3	124-2	125-1								
125-3	Drogen dekvloer Blok 7, 8 & 9	7	1		-6	124-3	125-2								
125-4	Drogen dekvloer Blok 2 & 1	4	1		-3	124-4	125-3								
125-5	Drogen dekvloer Blok 10 & 11	3	1		-2	124-5	125-4								

126-1	Dichtzetten leidingwerk natte cellen Blok 6 & 5	7	1		-6	125-1									
126-2	Dichtzetten leidingwerk natte cellen Blok 3 & 4	4	1		-3	125-2	126-1								
126-3	Dichtzetten leidingwerk natte cellen Blok 7, 8 & 9	7	1		-6	125-3	126-2								
126-4	Dichtzetten leidingwerk natte cellen Blok 2 & 1	4	1		-3	125-4	126-3								
126-5	Dichtzetten leidingwerk natte cellen Blok 10 & 11	3	1		-2	125-5	126-4								
127-1	Dichtzetten leidingwerk overige ruimtes Blok 6 & 5	7	1		-6	125-1									
127-2	Dichtzetten leidingwerk overige ruimtes Blok 3 & 4	4	1		-3	125-2	127-1								
127-3	Dichtzetten leidingwerk overige ruimtes Blok 7, 8 & 9	7	1		-6	125-3	127-2								
127-4	Dichtzetten leidingwerk overige ruimtes Blok 2 & 1	4	1		-3	125-4	127-3								
127-5	Dichtzetten leidingwerk overige ruimtes Blok 10 & 11	3	1		-2	125-5	127-4								
128-1	Aanbrengen binnenkozijnen natte cellen Blok 6 & 5	7	1		-6	126-1	127-1								
128-2	Aanbrengen binnenkozijnen natte cellen Blok 3 & 4	4	1		-3	126-2	127-2	128-1							
128-3	Aanbrengen binnenkozijnen natte cellen Blok 7, 8 & 9	7	1		-6	126-3	127-3	128-2							
128-4	Aanbrengen binnenkozijnen natte cellen Blok 2 & 1	4	1		-3	126-4	127-4	128-3							

128-5	Aanbrengen binnenkozijnen natte cellen Blok 10 & 11	3	1		-2	126-5	127-5	128-4							
129-1	Montage inbouwreservoir Blok 6 & 5	7	1		-6	128-1									
129-2	Montage inbouwreservoir Blok 3 & 4	4	1		-3	128-2	129-1								
129-3	Montage inbouwreservoir Blok 7, 8 & 9	7	1		-6	128-3	129-2								
129-4	Montage inbouwreservoir Blok 2 & 1	4	1		-3	128-4	129-3								
129-5	Montage inbouwreservoir Blok 10 & 11	3	1		-2	128-5	129-4								
130-1	Aanbrengen wandtegels Blok 6 & 5	7	1		-6	129-1									
130-2	Aanbrengen wandtegels Blok 3 & 4	4	1		-3	129-2	130-1								
130-3	Aanbrengen wandtegels Blok 7, 8 & 9	7	1		-6	129-3	130-2								
130-4	Aanbrengen wandtegels Blok 2 & 1	4	1		-3	129-4	130-3								
130-5	Aanbrengen wandtegels Blok 10 & 11	3	1		-2	129-5	130-4								
131-1	Spuitwerk wanden natte cellen Blok 6 & 5	7	1		-6	130-1									
131-2	Spuitwerk wanden natte cellen Blok 3 & 4	4	1		-3	130-2	131-1								
131-3	Spuitwerk wanden natte cellen Blok 7, 8 & 9	7	1		-6	130-3	131-2								

131-4	Spuitwerk wanden natte cellen Blok 2 & 1	4	1		-3	130-4	131-3								
131-5	Spuitwerk wanden natte cellen Blok 10 & 11	3	1		-2	130-5	131-4								
132-1	Spuitwerk plafonds Blok 6 & 5	7	1		-6	130-1									
132-2	Spuitwerk plafonds Blok 3 & 4	4	1		-3	130-2	132-1								
132-3	Spuitwerk plafonds Blok 7, 8 & 9	7	1		-6	130-3	132-2								
132-4	Spuitwerk plafonds Blok 2 & 1	4	1		-3	130-4	132-3								
132-5	Spuitwerk plafonds Blok 10 & 11	3	1		-2	130-5	132-4								
133-1	Aanbrengen vloertegels en dorpels Blok 6 & 5	7	1		-6	131-1	132-1								
133-2	Aanbrengen vloertegels en dorpels Blok 3 & 4	4	1		-3	131-2	132-2	133-1							
133-3	Aanbrengen vloertegels en dorpels Blok 7, 8 & 9	7	1		-6	131-3	132-3	133-2							
133-4	Aanbrengen vloertegels en dorpels Blok 2 & 1	4	1		-3	131-4	132-4	133-3							
133-5	Aanbrengen vloertegels en dorpels Blok 10 & 11	3	1		-2	131-5	132-5	133-4							
134-1	Aanbrengen baden Blok 6 & 5	7	1		-6	133-1									
134-2	Aanbrengen baden Blok 3 & 4	4	1		-3	133-2	134-1								

134-3	Aanbrengen baden Blok 7, 8 & 9	7	1		-6	133-3	134-2								
134-4	Aanbrengen baden Blok 2 & 1	4	1		-3	133-4	134-3								
134-5	Aanbrengen baden Blok 10 & 11	3	1		-2	133-5	134-4								
135-1	Baden onderbouwen Blok 6 & 5	7	1		-6	134-1									
135-2	Baden onderbouwen Blok 3 & 4	4	1		-3	134-2	135-1								
135-3	Baden onderbouwen Blok 7, 8 & 9	7	1		-6	134-3	135-2								
135-4	Baden onderbouwen Blok 2 & 1	4	1		-3	134-4	135-3								
135-5	Baden onderbouwen Blok 10 & 11	3	1		-2	134-5	135-4								
136-1	Aanbrengen tegels baden Blok 6 & 5	7	1		-6	134-1									
136-2	Aanbrengen tegels baden Blok 3 & 4	4	1		-3	134-2	136-1								
136-3	Aanbrengen tegels baden Blok 7, 8 & 9	7	1		-6	134-3	136-2								
136-4	Aanbrengen tegels baden Blok 2 & 1	4	1		-3	134-4	136-3								
136-5	Aanbrengen tegels baden Blok 10 & 11	3	1		-2	134-5	136-4								
137-1	3e kijkmoment kopers: Inmeet mogelijkheid voor	1			0	135-1	136-1								

	keukenleverencier e.d. Blok 6 & 5														
137-2	3e kijkmoment kopers: Inmeet mogelijkheid voor keukenleverencier e.d. Blok 3 & 4	1			0	135-2	136-2								
137-3	3e kijkmoment kopers: Inmeet mogelijkheid voor keukenleverencier e.d. Blok 7, 8 & 9	1			0	135-3	136-3								
137-4	3e kijkmoment kopers: Inmeet mogelijkheid voor keukenleverencier e.d. Blok 2 & 1	1			0	135-4	136-4								
137-5	3e kijkmoment kopers: Inmeet mogelijkheid voor keukenleverencier e.d. Blok 10 & 11	1			0	135-5	136-5								
138-1	Technische ruimte inrichten Blok 6 & 5	7	1		-6	137-1									
138-2	Technische ruimte inrichten Blok 3 & 4	4	1		-3	137-2	138-1								
138-3	Technische ruimte inrichten Blok 7, 8 & 9	7	1		-6	137-3	138-2								
138-4	Technische ruimte inrichten Blok 2 & 1	4	1		-3	137-4	138-3								
138-5	Technische ruimte inrichten Blok 10 & 11	3	1		-2	137-5	138-4								
139-1	Mechanische ventilatie afmonteren Blok 6 & 5	7	1		-6	137-1									
139-2	Mechanische ventilatie afmonteren Blok 3 & 4	4	1		-3	137-2	139-1								
139-3	Mechanische ventilatie afmonteren Blok 7, 8 & 9	7	1		-6	137-3	139-2								

139-4	Mechanische ventilatie afmonteren Blok 2 & 1	4	1		-3	137-4	139-3								
139-5	Mechanische ventilatie afmonteren Blok 10 & 11	3	1		-2	137-5	139-4								
140-1	Aanbrengen overige binnenkozijnen Blok 6 & 5	7	1		-6	138-1	139-1								
140-2	Aanbrengen overige binnenkozijnen Blok 3 & 4	4	1		-3	138-2	139-2	140-1							
140-3	Aanbrengen overige binnenkozijnen Blok 7, 8 & 9	7	1		-6	138-3	139-3	140-2							
140-4	Aanbrengen overige binnenkozijnen Blok 2 & 1	4	1		-3	138-4	139-4	140-3							
140-5	Aanbrengen overige binnenkozijnen Blok 10 & 11	3	1		-2	138-5	139-5	140-4							
141-1	Afhangen deuren Blok 6 & 5	7	1		-6	138-1	139-1								
141-2	Afhangen deuren Blok 3 & 4	4	1		-3	138-2	139-2	141-1							
141-3	Afhangen deuren Blok 7, 8 & 9	7	1		-6	138-3	139-3	141-2							
141-4	Afhangen deuren Blok 2 & 1	4	1		-3	138-4	139-4	141-3							
141-5	Afhangen deuren Blok 10 & 11	3	1		-2	138-5	139-5	141-4							
142-1	Spuitwerk trappen, trapgataftimmering en hekwerken Blok 6 & 5	7	1		-6	140-1	141-1								
142-2	Spuitwerk trappen, trapgataftimmering en hekwerken Blok 3 & 4	4	1		-3	140-2	141-2	142-1							

142-3	Spuitwerk trappen, trapgataftimmering en hekwerken Blok 7, 8 & 9	7	1		-6	140-3	141-3	142-2							
142-4	Spuitwerk trappen, trapgataftimmering en hekwerken Blok 2 & 1	4	1		-3	140-4	141-4	142-3							
142-5	Spuitwerk trappen, trapgataftimmering en hekwerken Blok 10 & 11	3	1		-2	140-5	141-5	142-4							
143-1	Stelkozijnen afschilderen Blok 6 & 5	7	1		-6	140-1	141-1								
143-2	Stelkozijnen afschilderen Blok 3 & 4	4	1		-3	140-2	141-2	143-1							
143-3	Stelkozijnen afschilderen Blok 7, 8 & 9	7	1		-6	140-3	141-3	143-2							
143-4	Stelkozijnen afschilderen Blok 2 & 1	4	1		-3	140-4	141-4	143-3							
143-5	Stelkozijnen afschilderen Blok 10 & 11	3	1		-2	140-5	141-5	143-4							
144-1	Aanbrengen vensterbanken Blok 6 & 5	7	1		-6	142-1	143-1								
144-2	Aanbrengen vensterbanken Blok 3 & 4	4	1		-3	142-2	143-2	144-1							
144-3	Aanbrengen vensterbanken Blok 7, 8 & 9	7	1		-6	142-3	143-3	144-2							
144-4	Aanbrengen vensterbanken Blok 2 & 1	4	1		-3	142-4	143-4	144-3							
144-5	Aanbrengen vensterbanken Blok 10 & 11	3	1		-2	142-5	143-5	144-4							
145-1	Vensterbanken afkitten Blok 6 & 5	7	1		-6	142-1	143-1								

145-2	Vensterbanken afkitten Blok 3 & 4	4	1		-3	142-2	143-2	145-1							
145-3	Vensterbanken afkitten Blok 7, 8 & 9	7	1		-6	142-3	143-3	145-2							
145-4	Vensterbanken afkitten Blok 2 & 1	4	1		-3	142-4	143-4	145-3							
145-5	Vensterbanken afkitten Blok 10 & 11	3	1		-2	142-5	143-5	145-4							
146-1	Elektra afmonteren Blok 6 & 5	7	1		-6	144-1	145-1								
146-2	Elektra afmonteren Blok 3 & 4	4	1		-3	144-2	145-2	146-1							
146-3	Elektra afmonteren Blok 7, 8 & 9	7	1		-6	144-3	145-3	146-2							
146-4	Elektra afmonteren Blok 2 & 1	4	1		-3	144-4	145-4	146-3							
146-5	Elektra afmonteren Blok 10 & 11	3	1		-2	144-5	145-5	146-4							
147-1	Sanitair en radiatoren monteren Blok 6 & 5	7	1		-6	146-1									
147-2	Sanitair en radiatoren monteren Blok 3 & 4	4	1		-3	146-2	147-1								
147-3	Sanitair en radiatoren monteren Blok 7, 8 & 9	7	1		-6	146-3	147-2								
147-4	Sanitair en radiatoren monteren Blok 2 & 1	4	1		-3	146-4	147-3								
147-5	Sanitair en radiatoren monteren Blok 10 & 11	3	1		-2	146-5	147-4								

148-1	Kitwerk natte cellen Blok 6 & 5	7	1		-6	147-1									
148-2	Kitwerk natte cellen Blok 3 & 4	4	1		-3	147-2	148-1								
148-3	Kitwerk natte cellen Blok 7, 8 & 9	7	1		-6	147-3	148-2								
148-4	Kitwerk natte cellen Blok 2 & 1	4	1		-3	147-4	148-3								
148-5	Kitwerk natte cellen Blok 10 & 11	3	1		-2	147-5	148-4								
149-1	Inregelen en keuring installaties Blok 6 & 5	7	1		-6	148-1									
149-2	Inregelen en keuring installaties Blok 3 & 4	4	1		-3	148-2	149-1								
149-3	Inregelen en keuring installaties Blok 7, 8 & 9	7	1		-6	148-3	149-2								
149-4	Inregelen en keuring installaties Blok 2 & 1	4	1		-3	148-4	149-3								
149-5	Inregelen en keuring installaties Blok 10 & 11	3	1		-2	148-5	149-4								
					0										
151-1	Opruimen terrein	4			0	83									
151-2	Opruimen terrein	3			0	84	151-1								
152-1	Aanvullen grond rondom bouwblokken	4			0	83									
15	Aanvullen grond rondom bouwblokken	3			0	84	152-1								

2-2															
153-1	Ontgraven bergingen	4			0	83									
153-2	Ontgraven bergingen	3			0	84	153-1								
154-1	Aanbrengen vloeren houten bergingen	4			0	151-1	152-1	153-1							
154-2	Aanbrengen vloeren houten bergingen	3			0	151-2	152-2	153-2	154-1						
155-1	Aanbrengen houten bergingen	4			0	151-1	152-1	153-1							
155-2	Aanbrengen houten bergingen	3			0	151-2	152-2	153-2	155-1						
156-1	Aanbrengen dakbedekking houten bergingen	4			0	151-1	152-1	153-1							
156-2	Aanbrengen dakbedekking houten bergingen	3			0	151-2	152-2	153-2	156-1						
157-1	Aansluiten elektra houten bergingen	4			0	154-1	155-1	156-1							
157-2	Aansluiten elektra houten bergingen	3			0	154-2	155-2	156-2	157-1						
158-1	Aanbrengen tuinmuur hekken	1			0	87									
158-2	Aanbrengen tuinmuur hekken	1			0	88	158-1								
158-3	Aanbrengen tuinmuur hekken	1			0	89	158-2								

159-1	Aanbrengen staptegels woningen	4			0	157-1	158-1								
159-2	Aanbrengen staptegels woningen	3			0	157-2	158-2	159-1							
160-1	Aanbrengen terreininrichtingen	4			0	157-1	158-1								
160-2	Aanbrengen terreininrichtingen	3			0	157-2	158-2	160-1							
161	Aanbrengen terreininventaris	5			0	108-4									
					0										
163	Vooropname NUTS partijen	1		1	0	94-5									
164	Binnenbrengen dienstleidingen NUTS	1			0	163									
					0										
166	Vooropname zonder koper	1		1	0	74-5	92	96-5	149-5	158-3	159-2	160-2	164		
167	Schoonmaak woning	5			0	166									
168	4e kijkmoment kopers: Vooropname	1			0	161	167								
169	Oplossen opleverpunten	5			0	168									
170	5e kijkmoment kopers: Oplevering woning	1			0	169									
END					0										

Appendix 4: Output table CPM algorithm

Activity_No	Activity_Description	Duration_Finish	Earliest_Start	Earliest_Finish	Latest_Start	Latest_Finish	Earliest_Successor		Critical?
1	INRICHTEN BOUWTERREIN	10	1	10	1	10	11		1
11	Uitzetten hoekpunten bouwblok	1	11	11	11	11	12, 13, 14		1
12	Ontgraven bouwblok	10	12	21	12	21	16, 17, 18		1
13	Aanbrengen drainage	10	12	21	12	21	16, 17, 18		1
14	Aanbrengen bodemafsluiting	10	12	21	12	21	16, 17, 18		1
16	Uitzetten rooilijnen door gemeente	1	22	22	22	22	19		1
17	Uitzetten peilhoogte	1	22	22	22	22	19		1
18	Uitzetten paalpiketten	1	22	22	22	22	19		1
19	Aanbrengen palen	5	23	27	23	27	20		1
20	Uitharden palen bij boorpalen	5	28	32	28	32	21		1
21	Doormeten palen & inmeten paalmisstanden	1	33	33	33	33	22		1
22	Beoordelen paalmisstanden door constructeur	2	34	35	34	35	38		1
38	Opschonen bouwput bij boorpalen	5	36	40	36	40	24		1
24	Maatvoeren fundering	1	41	41	41	41	25, 26		1
25	Stekken boren	3	42	44	42	44	27		1
26	Opstorten palen	3	42	44	42	44	27		1
27	Aanbrengen funderingsbalken	3	43	45	43	45	28		1
28	Aangieten funderingsbalk	2	44	45	44	45	30		1
30	Maatvoeren stadsverwarming	2	46	47	46	47	31		1
31	Aanbrengen verdeelkasten (elektra & water)	1	47	47	47	47	32		1
32	Aanbrengen stadsverwarming (7 won/week)	18	48	65	48	65	33		1
33	Aanbrengen leidingen onder de vloer (10 won/week)	12	49	60	49	60	34		1
34	Invoerleidingen NUTS en mantelbuizen (10 won/week)	12	50	61	50	61	35		1
35	Aansluiten VWA op gemeenteriool (10 won/week)	12	51	62	51	62	36		1
36	Aansluiten HWA (10 won/week)	12	52	63	52	63	39		1
39	Aanvullen kruipruimte bij kruipruimteloos bouwen	4	54	57	54	57	40, 41		1
40	Aanbrengen stabilisatie zand rondom bouwblok t.b.v. steiger	2	57	58	57	58	43		1
41	Aanhelen bouwwegen	2	57	58	57	58	43		1
43	Maatvoeren hoekpunten vloerveld	1	59	59	59	59	44, 45, 46, 47, 48, 49		1
44	Leggen vloerelementen	5	60	64	60	64	50		1
45	Kelkvloegen en sparingen afpurren	5	60	64	60	64	50		1
46	Optoppen doorvoeren L-installatie	5	60	64	60	64	50		1

47	Aanbrengen meterkastplaat	5	60	64	60	64	50		1
48	Afstorten begane grondvloer	5	60	64	60	64	50		1
49	Aanbrengen kruipluikomranding inclusief rooster	5	60	64	60	64	50		1
50	1e kijkmoment kopers: Start bouw feest	1	65	65	65	65	52		1
52	Montage casco Blok 6 & 5 (7 won)	7	66	72	66	72	53, 57-1		1
53	Montage casco Blok 4 & 3 (4 won)	4	73	76	73	76	54		1
54	Montage casco Blok 7, 8 & 9 (7 won)	7	77	83	77	83	57-3		1
55	Montage casco Blok 2 & 1 (4 won)	4	84	87	87	90	57-4		0
56	Montage casco Blok 10 & 11 (3 won)	3	88	90	92	94	57-5		0
57-1	Aanbrengen kunststof kozijnen inclusief glas & folie begane grond	5	73	77	73	77	59-1		1
57-2	Aanbrengen kunststof kozijnen inclusief glas & folie begane grond	3	78	80	80	82	59-2		0
57-3	Aanbrengen kunststof kozijnen inclusief glas & folie begane grond	4	84	87	84	87	59-3		1
57-4	Aanbrengen kunststof kozijnen inclusief glas & folie begane grond	2	88	89	91	92	59-4		0
57-5	Aanbrengen kunststof kozijnen inclusief glas & folie begane grond	2	91	92	95	96	59-5		0
59-1	Aanbrengen veiligheidsvoorzieningen Blok 6 & 5	4	74	77	74	77	60-1		1
59-2	Aanbrengen veiligheidsvoorzieningen Blok 3 & 4	2	79	80	81	82	60-2		0
59-3	Aanbrengen veiligheidsvoorzieningen Blok 7, 8 & 9	3	85	87	85	87	60-3		1
59-4	Aanbrengen veiligheidsvoorzieningen Blok 2 & 1	2	89	90	92	93	60-4		0
59-5	Aanbrengen veiligheidsvoorzieningen Blok 10 & 11	3	92	94	96	98	60-5		0
60-1	Aanbrengen bouwdeck elementen bij uitbouwen Blok 6 & 5	7	75	81	75	81	60-2, 61-1, 62-1, 63-1, 64-1, 65-1, 66-1, 67-1, 68-1, 69-1		1
60-2	Aanbrengen bouwdeck elementen bij uitbouwen Blok 3 & 4	4	82	85	82	85	60-3, 61-2, 62-2, 63-2, 64-2, 65-2, 66-2, 67-2, 68-2, 69-2		1

60-3	Aanbrengen bouwdeck elementen bij uitbouwen Blok 7, 8 & 9	7	86	92	86	92	60-4, 61-3, 62-3, 63-3, 64-3, 65-3, 66-3, 67-3, 68-3, 69-3		1
60-4	Aanbrengen bouwdeck elementen bij uitbouwen Blok 2 & 1	4	93	96	93	96	60-5, 61-4, 62-4, 63-4, 64-4, 65-4, 66-4, 67-4, 68-4, 69-4		1
60-5	Aanbrengen bouwdeck elementen bij uitbouwen Blok 10 & 11	3	97	99	97	99	61-5, 62-5, 63-5, 64-5, 65-5, 66-5, 67-5, 68-5, 69-5, 70-5		1
61-1	Maatvoering muurplaatankers Blok 6 & 5	7	76	82	76	82	61-2, 71-1		1
61-2	Maatvoering muurplaatankers Blok 3 & 4	4	83	86	83	86	61-3, 71-2		1
61-3	Maatvoering muurplaatankers Blok 7, 8 & 9	7	87	93	87	93	61-4, 71-3		1
61-4	Maatvoering muurplaatankers Blok 2 & 1	4	94	97	94	97	61-5, 71-4		1
61-5	Maatvoering muurplaatankers Blok 10 & 11	3	98	100	98	100	71-5		1
62-1	Aanbrengen muurplaten & afpurren Blok 6 & 5	7	76	82	76	82	62-2, 71-1		1
62-2	Aanbrengen muurplaten & afpurren Blok 3 & 4	4	83	86	83	86	62-3, 71-2		1
62-3	Aanbrengen muurplaten & afpurren Blok 7, 8 & 9	7	87	93	87	93	62-4, 71-3		1
62-4	Aanbrengen muurplaten & afpurren Blok 2 & 1	4	94	97	94	97	62-5, 71-4		1
62-5	Aanbrengen muurplaten & afpurren Blok 10 & 11	3	98	100	98	100	71-5		1
63-1	Aanbrengen dakelementen inclusief knieschotten en dakvensters Blok 6 & 5	7	76	82	76	82	63-2, 71-1		1
63-2	Aanbrengen dakelementen inclusief knieschotten en dakvensters Blok 3 & 4	4	83	86	83	86	63-3, 71-2		1
63-3	Aanbrengen dakelementen inclusief knieschotten en dakvensters Blok 7, 8 & 9	7	87	93	87	93	63-4, 71-3		1
63-4	Aanbrengen dakelementen inclusief knieschotten en dakvensters Blok 2 & 1	4	94	97	94	97	63-5, 71-4		1
63-5	Aanbrengen dakelementen inclusief knieschotten en dakvensters Blok 10 & 11	3	98	100	98	100	71-5		1
64-1	Aanbrengen dakkapellen Blok 6 & 5	7	76	82	76	82	64-2, 71-1		1
64-2	Aanbrengen dakkapellen Blok 3 & 4	4	83	86	83	86	64-3, 71-2		1
64-3	Aanbrengen dakkapellen Blok 7, 8 & 9	7	87	93	87	93	64-4, 71-3		1
64-4	Aanbrengen dakkapellen Blok 2 & 1	4	94	97	94	97	64-5, 71-4		1
64-5	Aanbrengen dakkapellen Blok 10 & 11	3	98	100	98	100	71-5		1
65-1	Afmonteren dakelementen Blok 6 & 5	7	76	82	76	82	65-2, 71-1		1

65-2	Afmonteren dakelementen Blok 3 & 4	4	83	86	83	86	65-3, 71-2		1
65-3	Afmonteren dakelementen Blok 7, 8 & 9	7	87	93	87	93	65-4, 71-3		1
65-4	Afmonteren dakelementen Blok 2 & 1	4	94	97	94	97	65-5, 71-4		1
65-5	Afmonteren dakelementen Blok 10 & 11	3	98	100	98	100	71-5		1
66-1	Aanbrengen dakdoorvoeren of schoorsteen bij gecombineerde doorvoer Blok 6 & 5	7	76	82	76	82	66-2, 71-1		1
66-2	Aanbrengen dakdoorvoeren of schoorsteen bij gecombineerde doorvoer Blok 3 & 4	4	83	86	83	86	66-3, 71-2		1
66-3	Aanbrengen dakdoorvoeren of schoorsteen bij gecombineerde doorvoer Blok 7, 8 & 9	7	87	93	87	93	66-4, 71-3		1
66-4	Aanbrengen dakdoorvoeren of schoorsteen bij gecombineerde doorvoer Blok 2 & 1	4	94	97	94	97	66-5, 71-4		1
66-5	Aanbrengen dakdoorvoeren of schoorsteen bij gecombineerde doorvoer Blok 10 & 11	3	98	100	98	100	71-5		1
67-1	Aanbrengen rekwerk bij getimmerde goot Blok 6 & 5	7	76	82	76	82	67-2, 71-1		1
67-2	Aanbrengen rekwerk bij getimmerde goot Blok 3 & 4	4	83	86	83	86	67-3, 71-2		1
67-3	Aanbrengen rekwerk bij getimmerde goot Blok 7, 8 & 9	7	87	93	87	93	67-4, 71-3		1
67-4	Aanbrengen rekwerk bij getimmerde goot Blok 2 & 1	4	94	97	94	97	67-5, 71-4		1
67-5	Aanbrengen rekwerk bij getimmerde goot Blok 10 & 11	3	98	100	98	100	71-5		1
68-1	Aanbrengen gootbeugels Blok 6 & 5	7	76	82	76	82	68-2, 71-1		1
68-2	Aanbrengen gootbeugels Blok 3 & 4	4	83	86	83	86	68-3, 71-2		1
68-3	Aanbrengen gootbeugels Blok 7, 8 & 9	7	87	93	87	93	68-4, 71-3		1
68-4	Aanbrengen gootbeugels Blok 2 & 1	4	94	97	94	97	68-5, 71-4		1
68-5	Aanbrengen gootbeugels Blok 10 & 11	3	98	100	98	100	71-5		1
69-1	Aanbrengen goten Blok 6 & 5	7	76	82	76	82	69-2, 71-1		1
69-2	Aanbrengen goten Blok 3 & 4	4	83	86	83	86	69-3, 71-2		1
69-3	Aanbrengen goten Blok 7, 8 & 9	7	87	93	87	93	69-4, 71-3		1
69-4	Aanbrengen goten Blok 2 & 1	4	94	97	94	97	69-5, 71-4		1
69-5	Aanbrengen goten Blok 10 & 11	3	98	100	98	100	71-5		1
70-1	Aanbrengen tijdelijke HWA's Blok 6 & 5	7	76	82	76	82	70-2, 71-1		1

70-2	Aanbrengen tijdelijke HWA's Blok 3 & 4	4	83	86	83	86	70-3, 71-2		1
70-3	Aanbrengen tijdelijke HWA's Blok 7, 8 & 9	7	87	93	87	93	70-4, 71-3		1
70-4	Aanbrengen tijdelijke HWA's Blok 2 & 1	4	94	97	94	97	70-5, 71-4		1
70-5	Aanbrengen tijdelijke HWA's Blok 10 & 11	3	98	100	98	100	71-5		1
71-1	Aanbrengen pannen en toebehoren Blok 6 & 5	7	77	83	77	83	72-1, 110-1		1
71-2	Aanbrengen pannen en toebehoren Blok 3 & 4	4	84	87	84	87	72-2, 110-2		1
71-3	Aanbrengen pannen en toebehoren Blok 7, 8 & 9	7	88	94	88	94	72-3, 110-3		1
71-4	Aanbrengen pannen en toebehoren Blok 2 & 1	4	95	98	95	98	72-4, 110-4		1
71-5	Aanbrengen pannen en toebehoren Blok 10 & 11	3	99	101	99	101	72-5, 110-5		1
72-1	Aanbrengen pv-panelen Blok 6 & 5	7	78	84	78	84	72-2, 76, 111-1, 112-1		1
72-2	Aanbrengen pv-panelen Blok 3 & 4	4	85	88	85	88	72-3, 111-2, 112-2		1
72-3	Aanbrengen pv-panelen Blok 7, 8 & 9	7	89	95	89	95	72-4, 111-3, 112-3		1
72-4	Aanbrengen pv-panelen Blok 2 & 1	4	96	99	96	99	72-5, 111-4, 112-4		1
72-5	Aanbrengen pv-panelen Blok 10 & 11	3	100	102	100	102	111-5, 112-5		1
73-1	Afpurren naden dakelementen Blok 6 & 5	7	79	85	82	88	73-2, 74-1		0
73-2	Afpurren naden dakelementen Blok 3 & 4	4	86	89	89	92	74-2		0
73-3	Afpurren naden dakelementen Blok 7, 8 & 9	7	90	96	97	103	74-3		0
73-4	Afpurren naden dakelementen Blok 2 & 1	4	97	100	106	109	74-4		0
73-5	Afpurren naden dakelementen Blok 10 & 11	3	101	103	112	114	74-5		0
74-1	Aanbrengen aftimmering dakelementen Blok 6 & 5	7	80	86	83	89	74-2		0
74-2	Aanbrengen aftimmering dakelementen Blok 3 & 4	4	87	90	90	93	78		0
74-3	Aanbrengen aftimmering dakelementen Blok 7, 8 & 9	7	91	97	98	104	79		0
74-4	Aanbrengen aftimmering dakelementen Blok 2 & 1	4	98	101	107	110	80		0
74-5	Aanbrengen aftimmering dakelementen Blok 10 & 11	3	102	104	113	115	85		0
76	Metselwerk Blok 6 & 5 (7 won)	9	79	87	79	87	77		1
77	Metselwerk Blok 4 & 3 (4 won)	6	88	93	88	93	78		1
78	Metselwerk Blok 7, 8 & 9 (7 won)	10	94	103	94	103	83		1
79	Metselwerk Blok 2 & 1 (4 won)	6	104	109	105	110	80		0
80	Metselwerk Blok 10 & 11 (3 won)	5	110	114	111	115	85		0

82	Metselwerk garage Blok 4 & 3 (3 stuks)	3	94	96	102	104	98-1, 99-1, 100-1		0
83	Metselwerk garage Blok 7, 8 & 9 (4 stuks)	4	104	107	104	107	98-2, 99-2, 100-2		1
84	Metselwerk garage Blok 2 & 1 (3 stuks)	3	110	112	113	115	98-3, 99-3, 100-3		0
85	Metselwerk garage blok 10 & 11 (3 stuks)	3	115	117	116	118	98-4, 99-4, 100-4		0
87	Metselwerk tuinmuur Blok 6 & 5	6	88	93	119	124	158-1		0
88	Metselwerk tuinmuur Blok 1	4	110	113	125	128	158-2		0
89	Metselwerk tuinmuur Blok 11	3	118	120	129	131	158-3		0
91-1	Aanbrengen gevelaftimmering bij overstekken	2	88	89	116	117	91-2		0
91-2	Aanbrengen gevelaftimmering bij overstekken	2	94	95	118	119	91-3, 93-1		0
91-3	Aanbrengen gevelaftimmering bij overstekken	2	104	105	120	121	93-2		0
91-4	Aanbrengen gevelaftimmering bij overstekken	3	110	112	123	125	91-5		0
91-5	Aanbrengen gevelaftimmering bij overstekken	2	115	116	126	127	94-5		0
92	Aanbrengen zinkwerk dakkapel en tuitgevels Blok 6 & 5	7	90	96	126	132	166		0
93-1	Aanbrengen gevelstuc Blok 4, 7, 9, 2 & 1	2	96	97	120	121	93-2		0
93-2	Aanbrengen gevelstuc Blok 4, 7, 9, 2 & 1	5	106	110	122	126	93-3		0
93-3	Aanbrengen gevelstuc Blok 4, 7, 9, 2 & 1	5	113	117	127	131	96-5		0
94-1	Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen	7	78	84	106	112	94-2		0
94-2	Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen	4	85	88	113	116	94-3		0
94-3	Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen	7	89	95	117	123	94-4		0
94-4	Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen	4	96	99	124	127	94-5		0
94-5	Aanbrengen kunststof kozijnen inclusief glas & folie verdiepingen	3	117	119	128	130	163		0
95-1	Aanbrengen daktrim bij uitbouwen	3	79	81	121	123	95-2		0
95-2	Aanbrengen daktrim bij uitbouwen	2	86	87	124	125	95-3		0
95-3	Aanbrengen daktrim bij uitbouwen	2	90	91	126	127	95-4		0
95-4	Aanbrengen daktrim bij uitbouwen	2	97	98	128	129	95-5		0
95-5	Aanbrengen daktrim bij uitbouwen	2	118	119	130	131	96-5		0

96-1	Aanbrengen definitieve HWA's	1	82	82	128	128	96-2		0
96-2	Aanbrengen definitieve HWA's	1	88	88	129	129	96-3		0
96-3	Aanbrengen definitieve HWA's	1	92	92	130	130	96-4		0
96-4	Aanbrengen definitieve HWA's	1	99	99	131	131	96-5		0
96-5	Aanbrengen definitieve HWA's	1	120	120	132	132	166		0
98-1	Aanbrengen schragen t.b.v. houten balklaag	3	97	99	105	107	98-2		0
98-2	Aanbrengen schragen t.b.v. houten balklaag	4	108	111	108	111	101-2		1
98-3	Aanbrengen schragen t.b.v. houten balklaag	3	113	115	116	118	98-4, 101-3		0
98-4	Aanbrengen schragen t.b.v. houten balklaag	3	118	120	119	121	101-4		0
99-1	Aanbrengen houten randbalk en balklaag garage	3	97	99	105	107	99-2		0
99-2	Aanbrengen houten randbalk en balklaag garage	4	108	111	108	111	101-2		1
99-3	Aanbrengen houten randbalk en balklaag garage	3	113	115	116	118	99-4, 101-3		0
99-4	Aanbrengen houten randbalk en balklaag garage	3	118	120	119	121	101-4		0
100-1	Aanbrengen dakbeschot garage	3	97	99	105	107	100-2		0
100-2	Aanbrengen dakbeschot garage	4	108	111	108	111	101-2		1
100-3	Aanbrengen dakbeschot garage	3	113	115	116	118	100-4, 101-3		0
100-4	Aanbrengen dakbeschot garage	3	118	120	119	121	101-4		0
101-1	Aanbrengen dakbedekking en daktrimmen garage	3	100	102	109	111	101-2		0
101-2	Aanbrengen dakbedekking en daktrimmen garage	4	112	115	112	115	102-2, 103-2, 104-2, 105-2		1
101-3	Aanbrengen dakbedekking en daktrimmen garage	3	116	118	119	121	101-4, 102-3, 103-3, 104-3, 105-3		0
101-4	Aanbrengen dakbedekking en daktrimmen garage	3	121	123	122	124	102-4, 103-4, 104-4, 105-4		0
102-1	Demontage schragen	3	103	105	113	115	102-2		0
102-2	Demontage schragen	4	116	119	116	119	106-2, 107-2		1
102-3	Demontage schragen	3	120	122	122	124	102-4, 106-3, 107-3		0
102-4	Demontage schragen	3	124	126	125	127	106-4, 107-4		0
103-1	Stelwerk hoeklijn garagedeur	3	103	105	113	115	103-2		0
103-2	Stelwerk hoeklijn garagedeur	4	116	119	116	119	106-2, 107-2		1
103-3	Stelwerk hoeklijn garagedeur	3	120	122	122	124	103-4, 106-3, 107-3		0

103-4	Stelwerk hoeklijn garagedeur	3	124	126	125	127	106-4, 107-4		0
104-1	Randkist stellen aanstorting garagevloer	3	103	105	113	115	104-2		0
104-2	Randkist stellen aanstorting garagevloer	4	116	119	116	119	106-2, 107-2		1
104-3	Randkist stellen aanstorting garagevloer	3	120	122	122	124	104-4, 106-3, 107-3		0
104-4	Randkist stellen aanstorting garagevloer	3	124	126	125	127	106-4, 107-4		0
105-1	Aanbrengen aanstorting garagevloer	3	103	105	113	115	105-2		0
105-2	Aanbrengen aanstorting garagevloer	4	116	119	116	119	106-2, 107-2		1
105-3	Aanbrengen aanstorting garagevloer	3	120	122	122	124	105-4, 106-3, 107-3		0
105-4	Aanbrengen aanstorting garagevloer	3	124	126	125	127	106-4, 107-4		0
106-1	Aanbrengen HWA's	3	106	108	117	119	106-2		0
106-2	Aanbrengen HWA's	4	120	123	120	123	108-2		1
106-3	Aanbrengen HWA's	3	124	126	125	127	106-4, 108-3		0
106-4	Aanbrengen HWA's	3	127	129	128	130	108-4		0
107-1	Aanbrengen garagedeur	3	106	108	117	119	107-2		0
107-2	Aanbrengen garagedeur	4	120	123	120	123	108-2		1
107-3	Aanbrengen garagedeur	3	124	126	125	127	107-4, 108-3		0
107-4	Aanbrengen garagedeur	3	127	129	128	130	108-4		0
108-1	Smeren dekvloer	3	109	111	121	123	108-2		0
108-2	Smeren dekvloer	4	124	127	124	127	108-3		1
108-3	Smeren dekvloer	3	128	130	128	130	108-4		1
108-4	Smeren dekvloer	3	131	133	131	133	161		1
110-1	Maatvoering positie trapgat Blok 6 & 5	7	78	84	78	84	110-2, 111-1, 112-1		1
110-2	Maatvoering positie trapgat Blok 3 & 4	4	85	88	85	88	110-3, 111-2, 112-2		1
110-3	Maatvoering positie trapgat Blok 7, 8 & 9	7	89	95	89	95	110-4, 111-3, 112-3		1
110-4	Maatvoering positie trapgat Blok 2 & 1	4	96	99	96	99	110-5, 111-4, 112-4		1
110-5	Maatvoering positie trapgat Blok 10 & 11	3	100	102	100	102	111-5, 112-5		1
111-1	Aanbrengen trappen en hekwerken Blok 6 & 5	7	79	85	79	85	111-2, 113-1		1
111-2	Aanbrengen trappen en hekwerken Blok 3 & 4	4	86	89	86	89	111-3, 113-2		1

111-3	Aanbrengen trappen en hekwerken Blok 7, 8 & 9	7	90	96	90	96	111-4, 113-3		1
111-4	Aanbrengen trappen en hekwerken Blok 2 & 1	4	97	100	97	100	111-5, 113-4		1
111-5	Aanbrengen trappen en hekwerken Blok 10 & 11	3	101	103	101	103	113-5		1
112-1	Aanbrengen trapgat beveiliging Blok 6 & 5	7	79	85	79	85	112-2, 113-1		1
112-2	Aanbrengen trapgat beveiliging Blok 3 & 4	4	86	89	86	89	112-3, 113-2		1
112-3	Aanbrengen trapgat beveiliging Blok 7, 8 & 9	7	90	96	90	96	112-4, 113-3		1
112-4	Aanbrengen trapgat beveiliging Blok 2 & 1	4	97	100	97	100	112-5, 113-4		1
112-5	Aanbrengen trapgat beveiliging Blok 10 & 11	3	101	103	101	103	113-5		1
113-1	Maatvoering binnenwanden Blok 6 & 5	7	80	86	80	86	113-2, 114-1		1
113-2	Maatvoering binnenwanden Blok 3 & 4	4	87	90	87	90	113-3, 114-2		1
113-3	Maatvoering binnenwanden Blok 7, 8 & 9	7	91	97	91	97	113-4, 114-3		1
113-4	Maatvoering binnenwanden Blok 2 & 1	4	98	101	98	101	113-5, 114-4		1
113-5	Maatvoering binnenwanden Blok 10 & 11	3	102	104	102	104	114-5		1
114-1	Aanbrengen binnenwanden Blok 6 & 5	7	81	87	81	87	114-2, 115-1		1
114-2	Aanbrengen binnenwanden Blok 3 & 4	4	88	91	88	91	114-3, 115-2		1
114-3	Aanbrengen binnenwanden Blok 7, 8 & 9	7	92	98	92	98	114-4, 115-3		1
114-4	Aanbrengen binnenwanden Blok 2 & 1	4	99	102	99	102	114-5, 115-4		1
114-5	Aanbrengen binnenwanden Blok 10 & 11	3	103	105	103	105	115-5		1
115-1	Montage achterschot meterkast Blok 6 & 5	7	82	88	82	88	115-2, 116-1		1
115-2	Montage achterschot meterkast Blok 3 & 4	4	89	92	89	92	115-3, 116-2		1
115-3	Montage achterschot meterkast Blok 7, 8 & 9	7	93	99	93	99	115-4, 116-3		1
115-4	Montage achterschot meterkast Blok 2 & 1	4	100	103	100	103	115-5, 116-4		1
115-5	Montage achterschot meterkast Blok 10 & 11	3	104	106	104	106	116-5		1
116-1	Afschrijven installaties op binnenwanden Blok 6 & 5	7	83	89	83	89	116-2, 117-1		1
116-2	Afschrijven installaties op binnenwanden Blok 3 & 4	4	90	93	90	93	116-3, 117-2		1
116-3	Afschrijven installaties op binnenwanden Blok 7, 8 & 9	7	94	100	94	100	116-4, 117-3		1
116-4	Afschrijven installaties op binnenwanden Blok 2 & 1	4	101	104	101	104	116-5, 117-4		1
116-5	Afschrijven installaties op binnenwanden Blok 10 & 11	3	105	107	105	107	117-5		1

117-1	Frezen leidingwerk in binnenwanden Blok 6 & 5	7	84	90	84	90	117-2, 118-1		1
117-2	Frezen leidingwerk in binnenwanden Blok 3 & 4	4	91	94	91	94	117-3, 118-2		1
117-3	Frezen leidingwerk in binnenwanden Blok 7, 8 & 9	7	95	101	95	101	117-4, 118-3		1
117-4	Frezen leidingwerk in binnenwanden Blok 2 & 1	4	102	105	102	105	117-5, 118-4		1
117-5	Frezen leidingwerk in binnenwanden Blok 10 & 11	3	106	108	106	108	118-5		1
118-1	E-installatie wand en vloer Blok 6 & 5	7	85	91	85	91	118-2, 119-1		1
118-2	E-installatie wand en vloer Blok 3 & 4	4	92	95	92	95	118-3, 119-2		1
118-3	E-installatie wand en vloer Blok 7, 8 & 9	7	96	102	96	102	118-4, 119-3		1
118-4	E-installatie wand en vloer Blok 2 & 1	4	103	106	103	106	118-5, 119-4		1
118-5	E-installatie wand en vloer Blok 10 & 11	3	107	109	107	109	119-5		1
119-1	W-installatie wand en vloer Blok 6 & 5	7	86	92	86	92	119-2, 120-1, 121-1		1
119-2	W-installatie wand en vloer Blok 3 & 4	4	93	96	93	96	119-3, 120-2, 121-2		1
119-3	W-installatie wand en vloer Blok 7, 8 & 9	7	97	103	97	103	119-4, 120-3, 121-3		1
119-4	W-installatie wand en vloer Blok 2 & 1	4	104	107	104	107	119-5, 120-4, 121-4		1
119-5	W-installatie wand en vloer Blok 10 & 11	3	108	110	108	110	120-5, 121-5		1
120-1	Aanbrengen trapgataftimmering Blok 6 & 5	7	87	93	87	93	120-2, 122-1		1
120-2	Aanbrengen trapgataftimmering Blok 3 & 4	4	94	97	94	97	120-3, 122-2		1
120-3	Aanbrengen trapgataftimmering Blok 7, 8 & 9	7	98	104	98	104	120-4, 122-3		1
120-4	Aanbrengen trapgataftimmering Blok 2 & 1	4	105	108	105	108	120-5, 122-4		1
120-5	Aanbrengen trapgataftimmering Blok 10 & 11	3	109	111	109	111	122-5		1
121-1	Aanbrengen leuningen trappen Blok 6 & 5	7	87	93	87	93	121-2, 122-1		1
121-2	Aanbrengen leuningen trappen Blok 3 & 4	4	94	97	94	97	121-3, 122-2		1
121-3	Aanbrengen leuningen trappen Blok 7, 8 & 9	7	98	104	98	104	121-4, 122-3		1
121-4	Aanbrengen leuningen trappen Blok 2 & 1	4	105	108	105	108	121-5, 122-4		1
121-5	Aanbrengen leuningen trappen Blok 10 & 11	3	109	111	109	111	122-5		1
122-1	Uitsparen douchehoek Blok 6 & 5	7	88	94	88	94	122-2, 123-1		1
122-2	Uitsparen douchehoek Blok 3 & 4	4	95	98	95	98	122-3, 123-2		1

122-3	Uitsparen douchehoek Blok 7, 8 & 9	7	99	105	99	105	122-4, 123-3		1
122-4	Uitsparen douchehoek Blok 2 & 1	4	106	109	106	109	122-5, 123-4		1
122-5	Uitsparen douchehoek Blok 10 & 11	3	110	112	110	112	123-5		1
123-1	2e kijkmoment kopers: Beoordeling leidingwerk voor smeren dekvloeren Blok 6 & 5	1	89	89	89	89	124-1		1
123-2	2e kijkmoment kopers: Beoordeling leidingwerk voor smeren dekvloeren Blok 3 & 4	1	96	96	96	96	124-2		1
123-3	2e kijkmoment kopers: Beoordeling leidingwerk voor smeren dekvloeren Blok 7, 8 & 9	1	100	100	100	100	124-3		1
123-4	2e kijkmoment kopers: Beoordeling leidingwerk voor smeren dekvloeren Blok 2 & 1	1	107	107	107	107	124-4		1
123-5	2e kijkmoment kopers: Beoordeling leidingwerk voor smeren dekvloeren Blok 10 & 11	1	111	111	111	111	124-5		1
124-1	Smeren dekvloeren m.u.v. douchehoek Blok 6 & 5	7	90	96	90	96	124-2, 125-1		1
124-2	Smeren dekvloeren m.u.v. douchehoek Blok 3 & 4	4	97	100	97	100	124-3, 125-2		1
124-3	Smeren dekvloeren m.u.v. douchehoek Blok 7, 8 & 9	7	101	107	101	107	124-4, 125-3		1
124-4	Smeren dekvloeren m.u.v. douchehoek Blok 2 & 1	4	108	111	108	111	124-5, 125-4		1
124-5	Smeren dekvloeren m.u.v. douchehoek Blok 10 & 11	3	112	114	112	114	125-5		1
125-1	Drogen dekvloer Blok 6 & 5	7	91	97	91	97	125-2, 126-1, 127-1		1
125-2	Drogen dekvloer Blok 3 & 4	4	98	101	98	101	125-3, 126-2, 127-2		1
125-3	Drogen dekvloer Blok 7, 8 & 9	7	102	108	102	108	125-4, 126-3, 127-3		1
125-4	Drogen dekvloer Blok 2 & 1	4	109	112	109	112	125-5, 126-4, 127-4		1
125-5	Drogen dekvloer Blok 10 & 11	3	113	115	113	115	126-5, 127-5		1
126-1	Dichtzetten leidingwerk natte cellen Blok 6 & 5	7	92	98	92	98	126-2, 128-1		1
126-2	Dichtzetten leidingwerk natte cellen Blok 3 & 4	4	99	102	99	102	126-3, 128-2		1
126-3	Dichtzetten leidingwerk natte cellen Blok 7, 8 & 9	7	103	109	103	109	126-4, 128-3		1
126-4	Dichtzetten leidingwerk natte cellen Blok 2 & 1	4	110	113	110	113	126-5, 128-4		1
126-5	Dichtzetten leidingwerk natte cellen Blok 10 & 11	3	114	116	114	116	128-5		1
127-1	Dichtzetten leidingwerk overige ruimtes Blok 6 & 5	7	92	98	92	98	127-2, 128-1		1
127-2	Dichtzetten leidingwerk overige ruimtes Blok 3 & 4	4	99	102	99	102	127-3, 128-2		1

127-3	Dichtzetten leidingwerk overige ruimtes Blok 7, 8 & 9	7	103	109	103	109	127-4, 128-3		1
127-4	Dichtzetten leidingwerk overige ruimtes Blok 2 & 1	4	110	113	110	113	127-5, 128-4		1
127-5	Dichtzetten leidingwerk overige ruimtes Blok 10 & 11	3	114	116	114	116	128-5		1
128-1	Aanbrengen binnenkozijnen natte cellen Blok 6 & 5	7	93	99	93	99	128-2, 129-1		1
128-2	Aanbrengen binnenkozijnen natte cellen Blok 3 & 4	4	100	103	100	103	128-3, 129-2		1
128-3	Aanbrengen binnenkozijnen natte cellen Blok 7, 8 & 9	7	104	110	104	110	128-4, 129-3		1
128-4	Aanbrengen binnenkozijnen natte cellen Blok 2 & 1	4	111	114	111	114	128-5, 129-4		1
128-5	Aanbrengen binnenkozijnen natte cellen Blok 10 & 11	3	115	117	115	117	129-5		1
129-1	Montage inbouwreservoir Blok 6 & 5	7	94	100	94	100	129-2, 130-1		1
129-2	Montage inbouwreservoir Blok 3 & 4	4	101	104	101	104	129-3, 130-2		1
129-3	Montage inbouwreservoir Blok 7, 8 & 9	7	105	111	105	111	129-4, 130-3		1
129-4	Montage inbouwreservoir Blok 2 & 1	4	112	115	112	115	129-5, 130-4		1
129-5	Montage inbouwreservoir Blok 10 & 11	3	116	118	116	118	130-5		1
130-1	Aanbrengen wandtegels Blok 6 & 5	7	95	101	95	101	130-2, 131-1, 132-1		1
130-2	Aanbrengen wandtegels Blok 3 & 4	4	102	105	102	105	130-3, 131-2, 132-2		1
130-3	Aanbrengen wandtegels Blok 7, 8 & 9	7	106	112	106	112	130-4, 131-3, 132-3		1
130-4	Aanbrengen wandtegels Blok 2 & 1	4	113	116	113	116	130-5, 131-4, 132-4		1
130-5	Aanbrengen wandtegels Blok 10 & 11	3	117	119	117	119	131-5, 132-5		1
131-1	Spuitwerk wanden natte cellen Blok 6 & 5	7	96	102	96	102	131-2, 133-1		1
131-2	Spuitwerk wanden natte cellen Blok 3 & 4	4	103	106	103	106	131-3, 133-2		1
131-3	Spuitwerk wanden natte cellen Blok 7, 8 & 9	7	107	113	107	113	131-4, 133-3		1
131-4	Spuitwerk wanden natte cellen Blok 2 & 1	4	114	117	114	117	131-5, 133-4		1
131-5	Spuitwerk wanden natte cellen Blok 10 & 11	3	118	120	118	120	133-5		1
132-1	Spuitwerk plafonds Blok 6 & 5	7	96	102	96	102	132-2, 133-1		1
132-2	Spuitwerk plafonds Blok 3 & 4	4	103	106	103	106	132-3, 133-2		1
132-3	Spuitwerk plafonds Blok 7, 8 & 9	7	107	113	107	113	132-4, 133-3		1
132-4	Spuitwerk plafonds Blok 2 & 1	4	114	117	114	117	132-5, 133-4		1
132-5	Spuitwerk plafonds Blok 10 & 11	3	118	120	118	120	133-5		1

133-1	Aanbrengen vloertegels en dorpels Blok 6 & 5	7	97	103	97	103	133-2, 134-1		1
133-2	Aanbrengen vloertegels en dorpels Blok 3 & 4	4	104	107	104	107	133-3, 134-2		1
133-3	Aanbrengen vloertegels en dorpels Blok 7, 8 & 9	7	108	114	108	114	133-4, 134-3		1
133-4	Aanbrengen vloertegels en dorpels Blok 2 & 1	4	115	118	115	118	133-5, 134-4		1
133-5	Aanbrengen vloertegels en dorpels Blok 10 & 11	3	119	121	119	121	134-5		1
134-1	Aanbrengen baden Blok 6 & 5	7	98	104	98	104	134-2, 135-1, 136-1		1
134-2	Aanbrengen baden Blok 3 & 4	4	105	108	105	108	134-3, 135-2, 136-2		1
134-3	Aanbrengen baden Blok 7, 8 & 9	7	109	115	109	115	134-4, 135-3, 136-3		1
134-4	Aanbrengen baden Blok 2 & 1	4	116	119	116	119	134-5, 135-4, 136-4		1
134-5	Aanbrengen baden Blok 10 & 11	3	120	122	120	122	135-5, 136-5		1
135-1	Baden onderbouwen Blok 6 & 5	7	99	105	99	105	135-2, 137-1		1
135-2	Baden onderbouwen Blok 3 & 4	4	106	109	106	109	135-3, 137-2		1
135-3	Baden onderbouwen Blok 7, 8 & 9	7	110	116	110	116	135-4, 137-3		1
135-4	Baden onderbouwen Blok 2 & 1	4	117	120	117	120	135-5, 137-4		1
135-5	Baden onderbouwen Blok 10 & 11	3	121	123	121	123	137-5		1
136-1	Aanbrengen tegels baden Blok 6 & 5	7	99	105	99	105	136-2, 137-1		1
136-2	Aanbrengen tegels baden Blok 3 & 4	4	106	109	106	109	136-3, 137-2		1
136-3	Aanbrengen tegels baden Blok 7, 8 & 9	7	110	116	110	116	136-4, 137-3		1
136-4	Aanbrengen tegels baden Blok 2 & 1	4	117	120	117	120	136-5, 137-4		1
136-5	Aanbrengen tegels baden Blok 10 & 11	3	121	123	121	123	137-5		1
137-1	3e kijkmoment kopers: Inmeet mogelijkheid voor keukenleverencier e.d. Blok 6 & 5	1	100	100	100	100	138-1, 139-1		1
137-2	3e kijkmoment kopers: Inmeet mogelijkheid voor keukenleverencier e.d. Blok 3 & 4	1	107	107	107	107	138-2, 139-2		1
137-3	3e kijkmoment kopers: Inmeet mogelijkheid voor keukenleverencier e.d. Blok 7, 8 & 9	1	111	111	111	111	138-3, 139-3		1
137-4	3e kijkmoment kopers: Inmeet mogelijkheid voor keukenleverencier e.d. Blok 2 & 1	1	118	118	118	118	138-4, 139-4		1

137-5	3e kijkmoment kopers: Inmeet mogelijkheid voor keukenleverencier e.d. Blok 10 & 11	1	122	122	122	122	138-5, 139-5		1
138-1	Technische ruimte inrichten Blok 6 & 5	7	101	107	101	107	138-2, 140-1, 141-1		1
138-2	Technische ruimte inrichten Blok 3 & 4	4	108	111	108	111	138-3, 140-2, 141-2		1
138-3	Technische ruimte inrichten Blok 7, 8 & 9	7	112	118	112	118	138-4, 140-3, 141-3		1
138-4	Technische ruimte inrichten Blok 2 & 1	4	119	122	119	122	138-5, 140-4, 141-4		1
138-5	Technische ruimte inrichten Blok 10 & 11	3	123	125	123	125	140-5, 141-5		1
139-1	Mechanische ventilatie afmonteren Blok 6 & 5	7	101	107	101	107	139-2, 140-1, 141-1		1
139-2	Mechanische ventilatie afmonteren Blok 3 & 4	4	108	111	108	111	139-3, 140-2, 141-2		1
139-3	Mechanische ventilatie afmonteren Blok 7, 8 & 9	7	112	118	112	118	139-4, 140-3, 141-3		1
139-4	Mechanische ventilatie afmonteren Blok 2 & 1	4	119	122	119	122	139-5, 140-4, 141-4		1
139-5	Mechanische ventilatie afmonteren Blok 10 & 11	3	123	125	123	125	140-5, 141-5		1
140-1	Aanbrengen overige binnenkozijnen Blok 6 & 5	7	102	108	102	108	140-2, 142-1, 143-1		1
140-2	Aanbrengen overige binnenkozijnen Blok 3 & 4	4	109	112	109	112	140-3, 142-2, 143-2		1
140-3	Aanbrengen overige binnenkozijnen Blok 7, 8 & 9	7	113	119	113	119	140-4, 142-3, 143-3		1
140-4	Aanbrengen overige binnenkozijnen Blok 2 & 1	4	120	123	120	123	140-5, 142-4, 143-4		1
140-5	Aanbrengen overige binnenkozijnen Blok 10 & 11	3	124	126	124	126	142-5, 143-5		1
141-1	Afhangen deuren Blok 6 & 5	7	102	108	102	108	141-2, 142-1, 143-1		1
141-2	Afhangen deuren Blok 3 & 4	4	109	112	109	112	141-3, 142-2, 143-2		1
141-3	Afhangen deuren Blok 7, 8 & 9	7	113	119	113	119	141-4, 142-3, 143-3		1
141-4	Afhangen deuren Blok 2 & 1	4	120	123	120	123	141-5, 142-4, 143-4		1
141-5	Afhangen deuren Blok 10 & 11	3	124	126	124	126	142-5, 143-5		1
142-1	Spuitwerk trappen, trapgataftimmering en hekwerken Blok 6 & 5	7	103	109	103	109	142-2, 144-1, 145-1		1
142-2	Spuitwerk trappen, trapgataftimmering en hekwerken Blok 3 & 4	4	110	113	110	113	142-3, 144-2, 145-2		1
142-3	Spuitwerk trappen, trapgataftimmering en hekwerken Blok 7, 8 & 9	7	114	120	114	120	142-4, 144-3, 145-3		1
142-4	Spuitwerk trappen, trapgataftimmering en hekwerken Blok 2 & 1	4	121	124	121	124	142-5, 144-4, 145-4		1

142-5	Spuitwerk trappen, trapgataftimmering en hekwerken Blok 10 & 11	3	125	127	125	127	144-5, 145-5		1
143-1	Stelkozijnen afschilderen Blok 6 & 5	7	103	109	103	109	143-2, 144-1, 145-1		1
143-2	Stelkozijnen afschilderen Blok 3 & 4	4	110	113	110	113	143-3, 144-2, 145-2		1
143-3	Stelkozijnen afschilderen Blok 7, 8 & 9	7	114	120	114	120	143-4, 144-3, 145-3		1
143-4	Stelkozijnen afschilderen Blok 2 & 1	4	121	124	121	124	143-5, 144-4, 145-4		1
143-5	Stelkozijnen afschilderen Blok 10 & 11	3	125	127	125	127	144-5, 145-5		1
144-1	Aanbrengen vensterbanken Blok 6 & 5	7	104	110	104	110	144-2, 146-1		1
144-2	Aanbrengen vensterbanken Blok 3 & 4	4	111	114	111	114	144-3, 146-2		1
144-3	Aanbrengen vensterbanken Blok 7, 8 & 9	7	115	121	115	121	144-4, 146-3		1
144-4	Aanbrengen vensterbanken Blok 2 & 1	4	122	125	122	125	144-5, 146-4		1
144-5	Aanbrengen vensterbanken Blok 10 & 11	3	126	128	126	128	146-5		1
145-1	Vensterbanken afkitten Blok 6 & 5	7	104	110	104	110	145-2, 146-1		1
145-2	Vensterbanken afkitten Blok 3 & 4	4	111	114	111	114	145-3, 146-2		1
145-3	Vensterbanken afkitten Blok 7, 8 & 9	7	115	121	115	121	145-4, 146-3		1
145-4	Vensterbanken afkitten Blok 2 & 1	4	122	125	122	125	145-5, 146-4		1
145-5	Vensterbanken afkitten Blok 10 & 11	3	126	128	126	128	146-5		1
146-1	Elektra afmonteren Blok 6 & 5	7	105	111	105	111	146-2, 147-1		1
146-2	Elektra afmonteren Blok 3 & 4	4	112	115	112	115	146-3, 147-2		1
146-3	Elektra afmonteren Blok 7, 8 & 9	7	116	122	116	122	146-4, 147-3		1
146-4	Elektra afmonteren Blok 2 & 1	4	123	126	123	126	146-5, 147-4		1
146-5	Elektra afmonteren Blok 10 & 11	3	127	129	127	129	147-5		1
147-1	Sanitair en radiatoren monteren Blok 6 & 5	7	106	112	106	112	147-2, 148-1		1
147-2	Sanitair en radiatoren monteren Blok 3 & 4	4	113	116	113	116	147-3, 148-2		1
147-3	Sanitair en radiatoren monteren Blok 7, 8 & 9	7	117	123	117	123	147-4, 148-3		1
147-4	Sanitair en radiatoren monteren Blok 2 & 1	4	124	127	124	127	147-5, 148-4		1
147-5	Sanitair en radiatoren monteren Blok 10 & 11	3	128	130	128	130	148-5		1
148-1	Kitwerk natte cellen Blok 6 & 5	7	107	113	107	113	148-2, 149-1		1

148-2	Kitwerk natte cellen Blok 3 & 4	4	114	117	114	117	148-3, 149-2		1
148-3	Kitwerk natte cellen Blok 7, 8 & 9	7	118	124	118	124	148-4, 149-3		1
148-4	Kitwerk natte cellen Blok 2 & 1	4	125	128	125	128	148-5, 149-4		1
148-5	Kitwerk natte cellen Blok 10 & 11	3	129	131	129	131	149-5		1
149-1	Inregelen en keuring installaties Blok 6 & 5	7	108	114	108	114	149-2		1
149-2	Inregelen en keuring installaties Blok 3 & 4	4	115	118	115	118	149-3		1
149-3	Inregelen en keuring installaties Blok 7, 8 & 9	7	119	125	119	125	149-4		1
149-4	Inregelen en keuring installaties Blok 2 & 1	4	126	129	126	129	149-5		1
149-5	Inregelen en keuring installaties Blok 10 & 11	3	130	132	130	132	166		1
151-1	Opruimen terrein	4	108	111	114	117	154-1, 155-1, 156-1		0
151-2	Opruimen terrein	3	113	115	121	123	154-2, 155-2, 156-2		0
152-1	Aanvullen grond rondom bouwblokken	4	108	111	114	117	154-1, 155-1, 156-1		0
152-2	Aanvullen grond rondom bouwblokken	3	113	115	121	123	154-2, 155-2, 156-2		0
153-1	Ontgraven bergingen	4	108	111	114	117	154-1, 155-1, 156-1		0
153-2	Ontgraven bergingen	3	113	115	121	123	154-2, 155-2, 156-2		0
154-1	Aanbrengen vloeren houten bergingen	4	112	115	118	121	157-1		0
154-2	Aanbrengen vloeren houten bergingen	3	116	118	124	126	157-2		0
155-1	Aanbrengen houten bergingen	4	112	115	118	121	157-1		0
155-2	Aanbrengen houten bergingen	3	116	118	124	126	157-2		0
156-1	Aanbrengen dakbedekking houten bergingen	4	112	115	118	121	157-1		0
156-2	Aanbrengen dakbedekking houten bergingen	3	116	118	124	126	157-2		0
157-1	Aansluiten elektra houten bergingen	4	116	119	122	125	159-1, 160-1		0
157-2	Aansluiten elektra houten bergingen	3	120	122	127	129	159-2, 160-2		0
158-1	Aanbrengen tuinmuur hekken	1	94	94	125	125	159-1, 160-1		0
158-2	Aanbrengen tuinmuur hekken	1	114	114	129	129	159-2, 160-2		0
158-3	Aanbrengen tuinmuur hekken	1	121	121	132	132	166		0
159-1	Aanbrengen staptegels woningen	4	120	123	126	129	159-2		0
159-2	Aanbrengen staptegels woningen	3	124	126	130	132	166		0

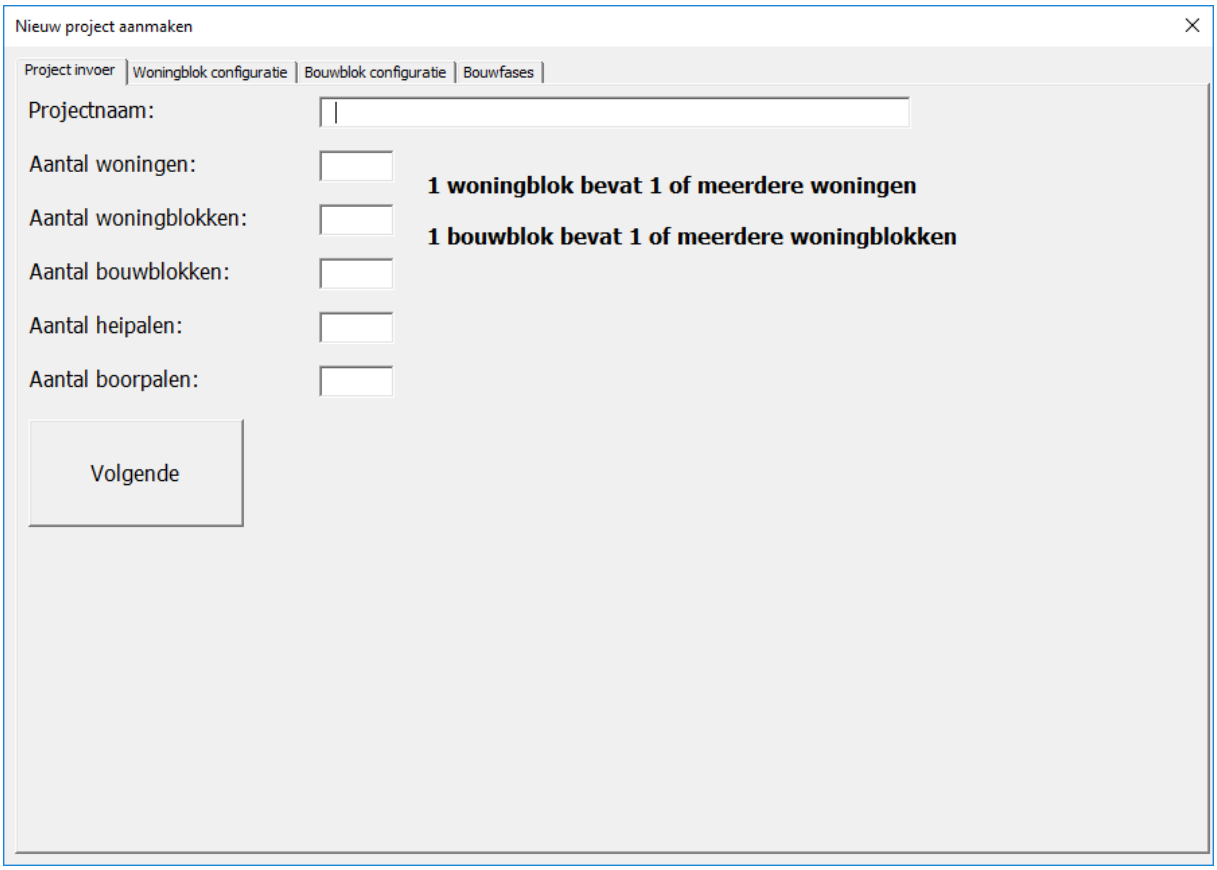
160-1	Aanbrengen terreininrichtingen	4	120	123	126	129	160-2		0
160-2	Aanbrengen terreininrichtingen	3	124	126	130	132	166		0
161	Aanbrengen terreininventaris	5	134	138	134	138	168		1
163	Vooropname NUTS partijen	1	120	120	131	131	164		0
164	Binnenbrengen dienstleidingen NUTS	1	121	121	132	132	166		0
166	Vooropname zonder koper	1	133	133	133	133	167		1
167	Schoonmaak woning	5	134	138	134	138	168		1
168	4e kijkmoment kopers: Vooropname	1	139	139	139	139	169		1
169	Oplossen opleverpunten	5	140	144	140	144	170		1
170	5e kijkmoment kopers: Oplevering woning	1	145	145	145	145			1

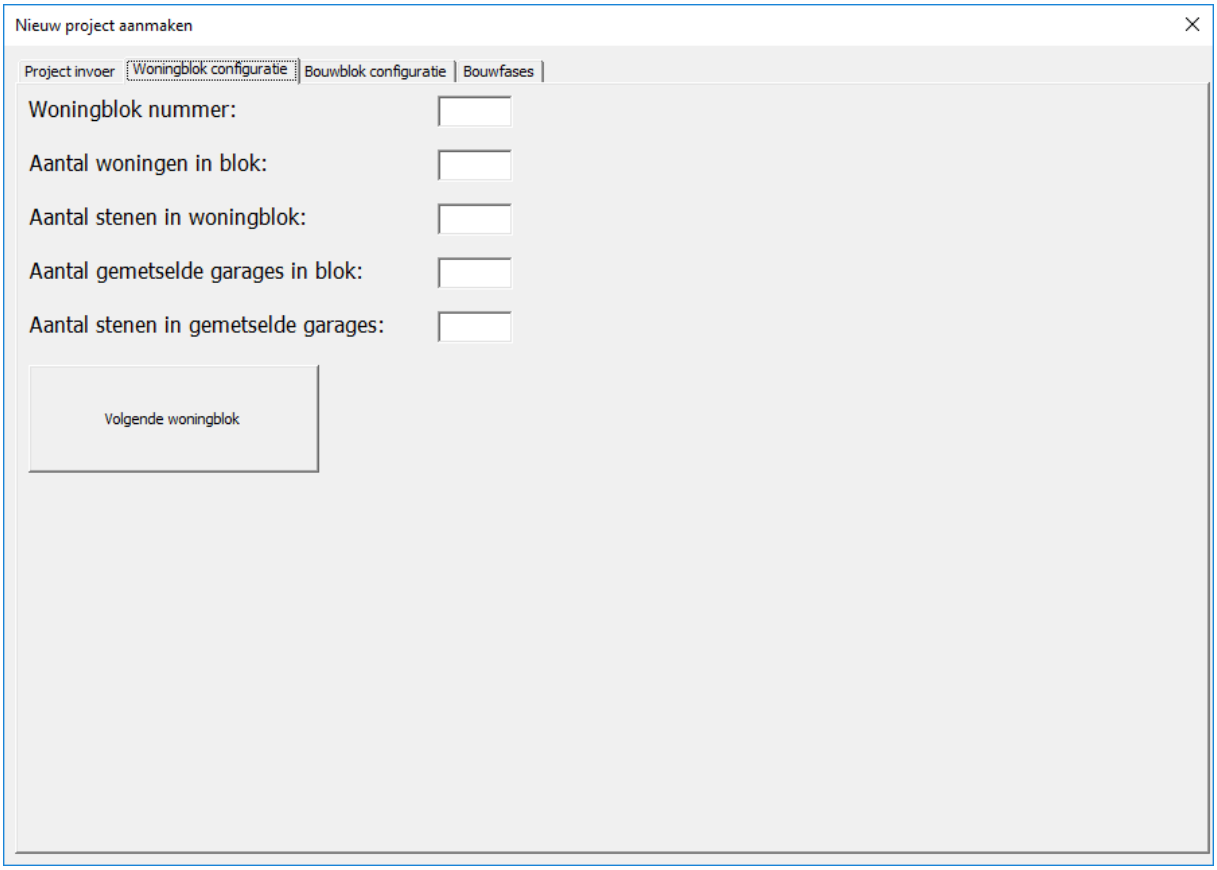
Appendix 5: Weekly construction site costs

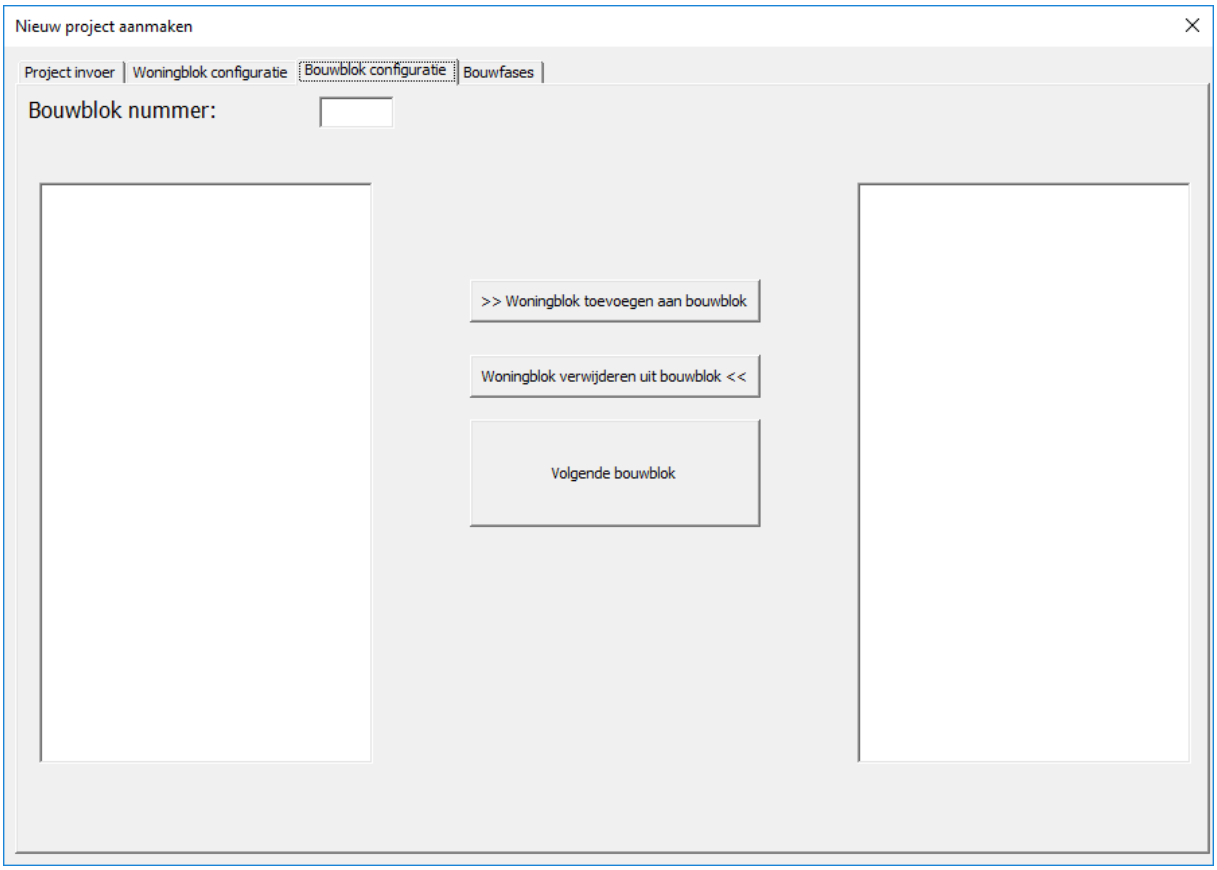
Cost specification

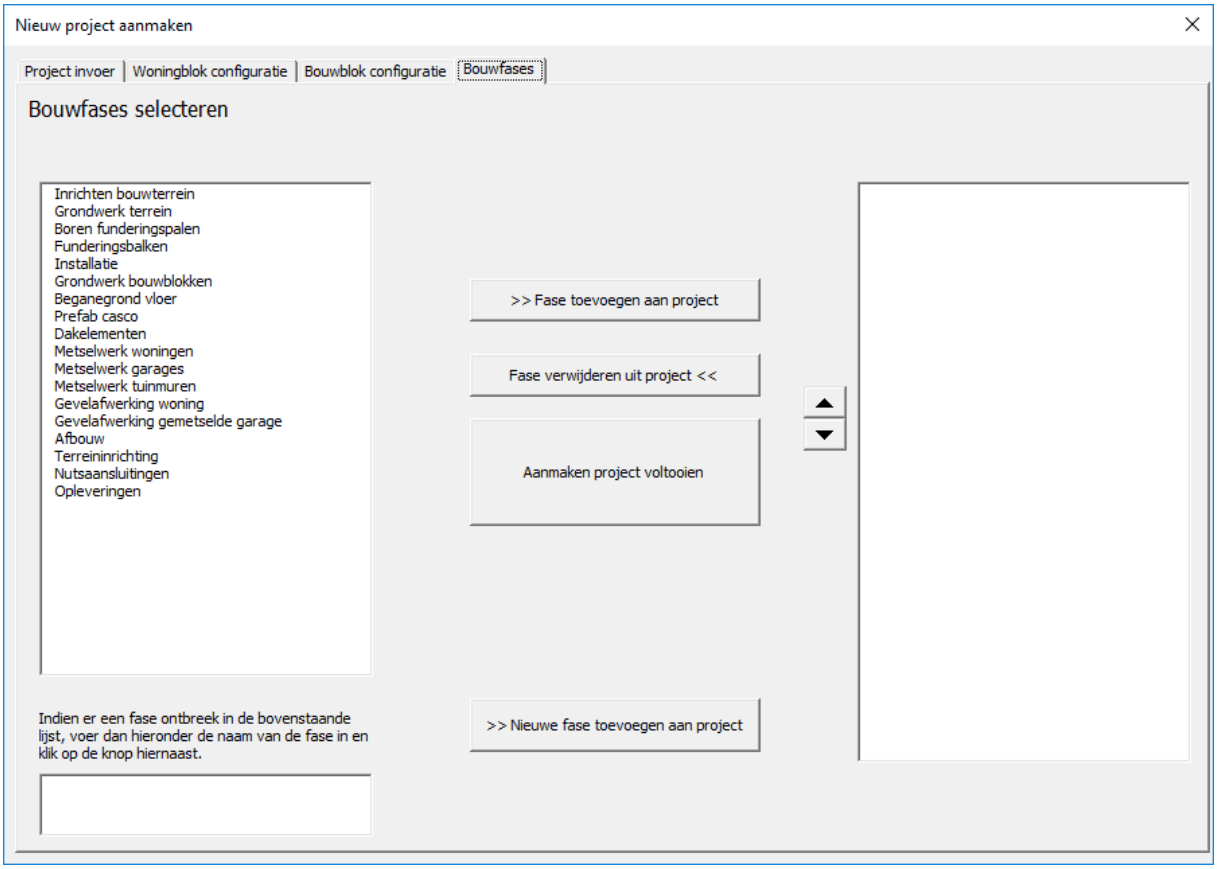
Onderdeel	**€/week**
Kantoor-tekenbehoeften	€ 12,50
Huur uitvoerderscontainer	€ 104,39
Schoonmaak keten	€ 66,19
Huur schaftcontainer	€ 72,35
Huur sanitaire unit	€ 36,62
Huur zeecontainer	€ 12,78
Huur gereedschapscontainer	€ 20,78
Stroomverbruik	€ 77,00
Waterverbruik	€ 15,00
Telefoonkosten	€ 34,00
Huur verdeelkast 125 amp	€ 17,07
Huur verdeelkast 63 amp	€ 14,88
Huur verdeelkast 32 amp	€ 5,17
Elektrakabel	€ 39,00
Huur lichtmast	€ 19,92
Huur watermeterput	€ 4,60
Verwarming container	€ 20,50
Verwarming toiletunits	€ 10,00
Huur multifunctional	€ 31,15
Huur thin client	€ 7,50
ED control	€ 39,36
Huur zaagmachine	€ 14,75
Toegangscontrole	€ 80,00
Omheining	€ 79,05
Huur camerabewaking	€ 150,00
Uitvoerder	€ 1.950,00
Timmerman 1	€ 1.600,00
Timmerman 2	€ 1.600,00
Totale kosten per week	**€ 6.134,56**

Appendix 6: Input screens motitoring program






Nieuw project aanmaken
Project invoer
Woningblok configuratie
Bouwblok configuratie
Bouwfases
Bouwblok nummer:
>> Woningblok toevoegen aan bouwblok
Woningblok verwijderen uit bouwblok <<
Volgende bouwblok


Nieuw project aanmaken
Project invoer
Woningblok configuratie
Bouwblok configuratie
Bouwfases
Bouwfases selecteren
Inrichten bouwterrein
Grondwerk terrein
Boren funderingspalen
Funderingsbalken
Installatie
Grondwerk bouwblokken
Beganegrond vloer
Prefab casco
Dakelementen
Metselwerk woningen
Metselwerk garages
Metselwerk tuinmuren
Gevelafwerking woning
Gevelafwerking gemetselde garage
Afbouw
Terreininrichting
Nutsaansluitingen
Opleveringen
>> Fase toevoegen aan project
Fase verwijderen uit project <<
Aanmaken project voltooien
Indien er een fase ontbreek in de bovenstaande lijst, voer dan hieronder de naam van de fase in en klik op de knop hiernaast.
>> Nieuwe fase toevoegen aan project