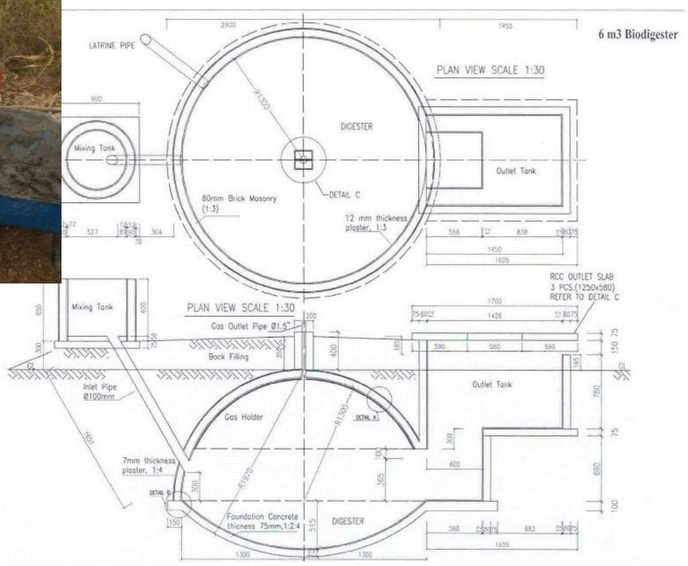

Final bachelor assignment: Constructing of biogas Digesters in South Africa

Planning and risks in building biogas digesters

Summary

Introduction, findings and recommendation

20-08-2014

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UNIVERSITEIT TWENTE.

CONSTRUCTION OF BIOGAS DIGESTERS IN SOUTH AFRICA

Final report

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Final Bachelor assignment

Civil engineering

University of Twente

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20-08-2014 **Giyani, South Africa**

Preface

This research is part of the final bachelor assignment in civil engineering education at the University of Twente. I expect to get my bachelor degree in civil engineering after completing this assignment. This assignment is done in the city Giyani and surrounding villages in South Africa and was supervised by Mpfuneko Community Support, the IDS Foundation and the University of Twente. Dr. S.H.S. Al-Jibouri will supervise and asses this report on behalf of the University of Twente. With this final bachelor assignment I hope to complete my bachelor degree at the University of Twente. The goals for this final bachelor assignment are indicated in appendix XIX.

I would like to thank Jotte van Ierland for giving me the opportunity to do this research at Mpfuneko Community Support and the helpful suggestions during the research. I would like to thank Dr. S.H.S. Al-Jibouri for the feedback on the written reports and I would like to thank Prof. Dr. Ekko van Ierland for putting me in touch with Mpfuneko Community support. I am also grateful for the fact that SANEDI gave me permission to use information from the working for energy project.

The final bachelor assignment is to be carried out based on the pre-report (Pasman, 2014).

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Summary

This research is done for Mpfuneko Community Support (MpfunekoCS) in South Africa. MpfunekoCS is a South African NGO based in Giyani. MpfunekoCS focuses on constructing and operating biogas digester in rural areas.

This reports describes the activities of MpfunekoCS regarding the construction process of the digester. First a description of the ongoing projects and the organizations is given. This is needed because this has an influence on the construction and planning process. Also the use of information within MpfunekoCS plays an important part of the research because the information within MpfunekoCS forms the data for optimizing the construction process. To understand the organisational structure and responsibilities that go with different positions within MpfunekoCS an OBS (Organizational Breakdown Structure) is made.

After carrying out the analysis of the construction process, the work starts with mapping all activities related to the construction process. Also a WBS (Work Breakdown Structure) is made. The layers of the WBS show different tasks and responsibilities for the construction process. Following the description of the current situation two variations are made based on two different approaches. The first approach is a team approach where specialization of different tasks is used. The second approach is called the single approach. With this approach the responsibility for constructing the digester lies with a single construction team that completes all the activities.

Information about the duration of the activities was collected and a risk analysis is made. This risk analysis procedure consists of different steps. Risk awareness, risk identification risk evaluation and risk management.

In this report different planning techniques are introduces. The techniques used are Network planning, PERT (Program Evaluation and Review Technique), Monte Carlo simulations, LOB (Line of Balance) and a bar chart. For the different techniques different kinds of data is needed and not all techniques will fit for the organization. Therefore a preferred technique for future planning will be selected. For all the techniques the two different approaches from the WBS will be compered.

After identifying the various risks an AON (Activity On Node) network for the construction process is constructed. This network describes an ideal situation. From this network two variations where made, one based on the team and a second based on single approach from the WBS. The networks are based on the fact that MpfunekoCS works with teams of 2 people on the construction site. An important addition to the network diagram is the critical path. The critical path shows the order of activities whereby any delay cause a delay in the total construction process. The AON network forms the basis for the PERT analysis in which delays are taken into account. Using PERT it is possible to calculate the change of obtaining a certain construction time. The last analysis that is made is using LOB. After the complete analysis a bar chart is made for MpfunekoCS.

The team approach is more difficult to plan and makes the organization more complex than the single approaches. The circumstances in the rural areas of South Africa play an important role in making the final decisions regarding to planning for project of MpfunekoCS.

Glossary

AON	Activity On Node
AOA	Activity On Arrow
WBS	Work Breakdown structure
OBS	Organizational Breakdown Structure
CPM	Critical path method
PERT	Program Evaluation and Review Technique
ICCO	Interchurch Organization for Development Cooperation (supporting organization)
WfE	Working for Energy (supporting organization)
EEP	Energy and environment partnership (supporting organization)
NGO	Non-governmental organization

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Appendix

1. Introduction

This research project is done in cooperation with Mpfuneko Community Support (MpfunekoCS). MpfunekoCS is a South African NGO that is helping with reducing poverty and implementing sustainable development in rural areas. MpfunekoCS is doing this by creating new social economic ideas on social economic topics, technical support and fundraising.

Construction biogas digesters provide an alternative for using wood as fuel. In this way both the deforestation and the emission of CO^2 can be reduced. A biogas digester uses waste materials like cow dung to produce biogas. The remaining 'slurry' can be used as a fertilizer.

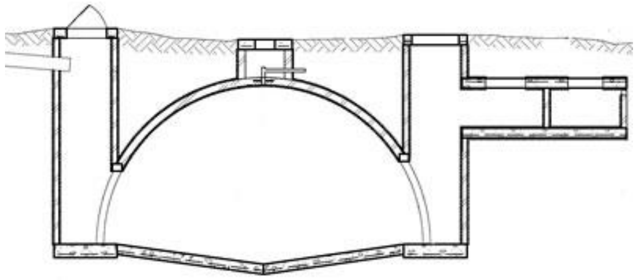


Figure 1: schematic drawing of a biogas digester

The biogas digesters will produce gas for one or more households. The gas can be used for cooking. Every household will get their own connection to the digester. The size of the digester will depend on the size and number of households and the availability of the wasted materials like cow dung.

Figure 2: Map of South Africa

In the projects related to this research, the construction process does not always run smoothly during construction of the biogas digesters. This is due to uncertainties, like the availability of building materials and water on the construction site and attendance of employees. MpfunekoCS is searching for a flexible way of planning the activities and a way to secure the construction process.

The biogas digesters projects investigated here are being built in the rural areas in South Africa around the city of Giyani in the province Limpopo, which is on the edge of the Kruger National Park. In these rural areas the living conditions are relatively primitive. Many families in small towns cook on wood or electricity. The construction of biogas installations will contribute in improving the quality of life and at the same time in the reduction of emission of CO^2.

1.1 Goals from the perspective of MpfunekoCS

MpfunekoCS wishes to have a realistic plan based on both observations from the field and the process as well as on a solid analysis of the collected data. This could be used for future planning. Therefore it is important to know that there are multiple phases in the construction of the biogas installations, which means that there are many different activities involved in the construction of biogas digesters. The most important activities are the transport of materials, digging of the pit, actual construction of the digester, connection of the digester to a household and testing and using the installation.

In the now ongoing projects there are no plans drawn for the construction of Biogas digesters and no known figures are available on how long their construction will take. MpfunekoCS thinks that an important factor in developing a good plan is by managing the inventories of building materials. In case of a shortage of building materials for certain activities work progress could be made on different activities. In case of a shortage in the number of workers contingencies should be made to have extra workers available on standby.

This research intends to develop a flexible planning or planning method that can be used for the construction of biogas digesters. With such planning or planning method the construction process should be more reliable in the future. The construction process of the biogas digester consists of many different activities. These activities need to be mapped. Also the estimated duration of each activity and the risks affecting it need to be determined after the mapping of the activities has been completed. Based on this, it will be possible to draw a plan for the construction of the biogas digesters and to optimize it with the goal of making the construction process quicker and cheaper.

1.2 Projects of MpfunekoCS

MpfunekoCS is a non-Profit organization involved in innovative developments in rural areas. Environment, economic and social sustainability are key concepts for those developments.

MpfunekoCS is working on three projects at this moment. These three projects are supported and funded by three different organizations. The type of biogas installations used in all these projects is 'fixed dome' biogas installations. The biogas digesters are being built according to the Farmer's friendly model for constructing biogas installations (NBP, 2006), which was developed in 2005. There has been a pilot project on the construction of this type of biogas digesters in South Africa in 2009. This project has been carried out in the Greater Giyani Municipality and has been supported by the Dutch organization IDS Foundation (Van Ierland, 2009).

The three projects MpfunekoCS is working on in April 2014 are:

1. ICCO: The goal of this project is to gain experience in the 'Ready-to-Cook Biogas' concept. MpfunekoCS intends to build 10 large digesters with a volume of 15 m^3 each for this project. Each digester will be connected to at least two households. For this project seven digesters still need to be built in this project. 2 digesters will be built in Gawula village and five digesters will be built in Shawela village. ICCO has paid for this project up front.
2. Working for Energy (WfE): The goals of this project are to get experience with constructing a larger number of digesters and to test the willingness of people to pay for the use of biogas. For this project there are 55 digesters built in Gawula village. At the moment the first 20 digesters are being built. WfE will pay MpfunekoCS the costs made at the end of the period.
3. Energy and Environment Partnership programme (EEP): The goal of this project is to introduce the 'Ready-to-Cook Biogas' concept in three villages. 30 biogas digesters will be built in each village. MpfunekoCS will work together with a different kind of partner organization in each village. Construction of the first three digesters has been started in Shawela. Two other villages still have to be (re)selected. EEP will pay MpfunekoCS when a milestone has been reached and completed.
4. MpfunekoCS also has a few construction sites outside the ICCO, WfE and EEP project.

2. Research question

To achieve the research goal indicated, a main research question has been formulated as follows:

How can planning for the construction of biogas installations in South Africa be improved in order to reduce delays in the construction process?

- What are the phases of the Biogas digesters construction process and what are the activities involved in these phases?
- Which activities are relevant within the scope of constructing a digester?
- What are the possible risks that can influence the duration of activities of the construction process?
- What possible measures can be taken to reduce the effects of identified risks?

In the following chapters the main research question will be answered by answering the sub-questions and a final recommendation for MpfunekoCS will be given.

Within the report different planning techniques are used. After using different techniques is possible to determine a technique that is useful for MpfunekoCS to use in future projects.

3. Progress on the Mpfuneko community support projects during the research.

During the research there has been progress within the three different projects MpfunekoCS has been working on. There has been no progress on construction sites of MpfunekoCS outside the ICCO, WfE and EEP project.

3.1.1 Global overview of the progress of the different projects

Progress of the ICCO project: The ICCO project has made a small progress in the towns Shawela and Gawula. Work on the construction sites in these towns consists of digging and constructing, but none of the 12m^3 digesters has been finished during this research.

Progress of the WfE project: The WfE in Gawula has made some progress, digging has started on new construction sites and on a site where digging already was finished, constructing of the digesters has been started. After a meeting with the supporting organization WfE the focus of this project has been shifted to the completion of the 13 digesters from which the construction process has been put on hold. Also the status reports of the projects are considered a high priority in order to get the remaining funding to finish this project.

Progress of the EEP project: The EEP project has made progress in Shawela. The progress in Shawela consists of starting constructing and digging on new constructing sites. Also, almost all the contracts in Shawela are signed. This means that it is possible to start constructing on almost all of these sites. Most of the work in Shawela has been stopped for a period of two weeks due to a problem with a local leader (indouna). None of the digesters in Shawela have been tested or finished.

The project has also started in Minginisi. The marketing in Minginisi has been started and is done by the project partner Tiforishaka. The first digesters in Minginisi are under construction but none of the digesters has been tested or finished.

This project is still looking for a third town to start constructing 30 digesters for the EEP project, but there is still no agreements for a third town to start the construction of the digesters.

4. Projects and organization

Within project planning there are different stages. MpfunekoCS divides their projects into 4 different stages: initiation, contacting, constructing and operating.

4.1 Project course

Construction is only part of the total project process. The project process consists of different phases. The initiation and contracting phases need to be completed before the construction process can be started. The project process is as shown in Figure 3.

Initiation: In this phase the location (town) is selected for the different projects (WfE ICCO and EEP). It is possible that there are more projects in one location. In the initiation phase it is important that there is a local project partner and that there is permission of the town chief.

Marketing: Marketing is done for individual households. The households need to sign a contract to get a biogas digester. It is important that there are enough households to make the project economically viable.

Contracting: This is the formal singing of the contact.

Construction: This phase is the actual construction process that is the focus of this research.

Testing and instructing: All digesters need to be tested before they become operational. Also, the persons (workers or households) who will operate the biogas digester need to be instructed about the use of the digester.

Operating: The final use of the digester

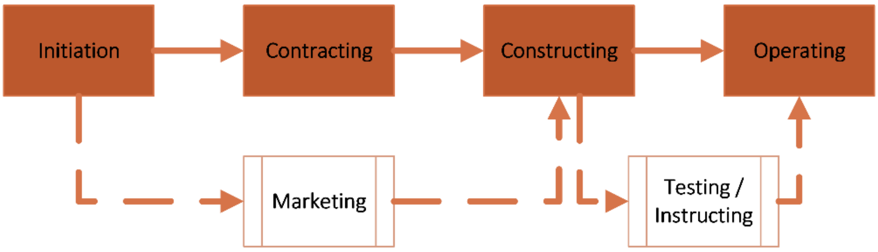


Figure 3: Project course

4.2 Project sites

The three projects where MpfunekoCS is working on are located in different towns. In each town multiple digester are being built and the stage of the digesters varies. Figure 4 shows which projects are in which town.

- Gawula
  - Marketing
  - Constructing
  - Operating
- Shawela
  - Construction
  - Marketing
- Minginisi Block 3
  - Commissioning
  - Marketing
- Shikhumba
  - Commissioning
- Other
  - Constructing

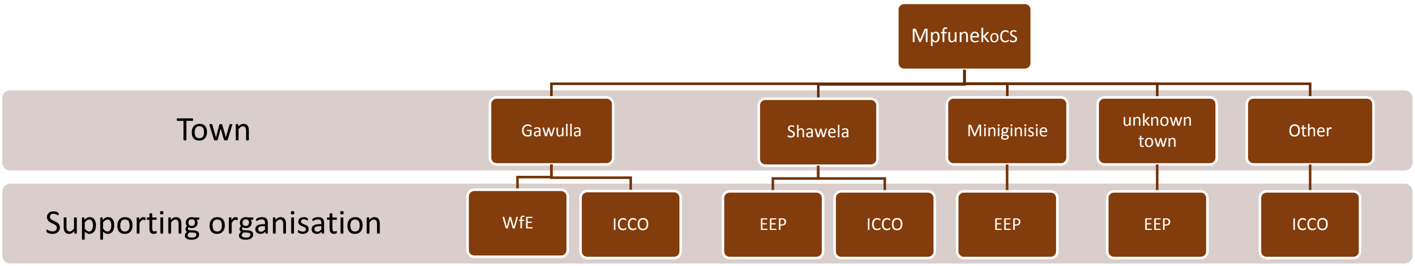


Figure 4: Towns and donors

4.3 Organizational structure

The organization that is relevant for the construction process is depicted in Figure 5. In the figure only the functions that are relevant to the building process itself are shown. Next to these functions there is also a marketing department and an office department (administration). Figure 3 is an Organizational breakdown structure (OBS) (De Marco, 2011) and depicts all the relevant tasks for the building process itself.

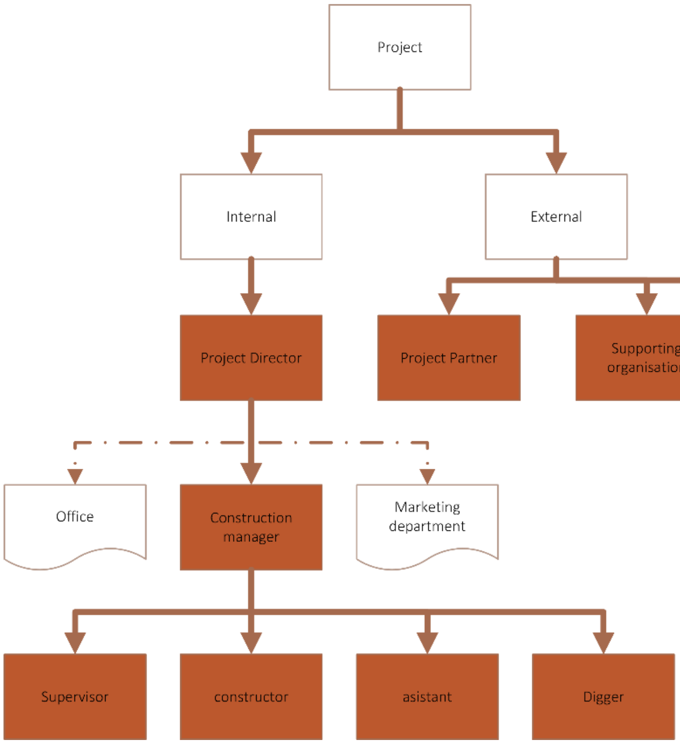


Figure 5: Organization relevant to the construction process (OBS)

Supporting organization: The organization that finances the project. The supporting organization also has specific demands for the project

Partner organisation: Responsible for the contracting agreement with the household and for operating of biogas digesters.

Managing Director: The project director is responsible for the entire project and is the person communicating with the supporting organization and the partner organization. He is also responsible for authorizing payment to the workers.

Construction manager: The construction manager is responsible for the actual building of the biogas digester. He is in charge of the constructors, the assistants and the diggers. He needs to inspect their work and make sure the right amount of materials and the proper tools are available. The construction manager is also responsible for a correct administration of the work.

Supervisor: needs to inspect the work of the constructors and diggers and reports to the construction manager or project director if mistakes are found (could be combined with another function).

Digger: Responsible for digging a pit

Constructor: Responsible for building de digester

Assistant-constructor: Helping the constructor

4.4 Project administration

Information within a project can be presented in different forms (see Figure 6: Information structure)(Wijnen & Storm, 2007). Within MpfunekoCS most of the information is not or not correctly recorded. Also the recorded information is not always up to date. The administration that is present is only used for recording the work that has been done and is not used for identifications purposes, like risk identification, and is also not used for monitoring of the process within the organisation.

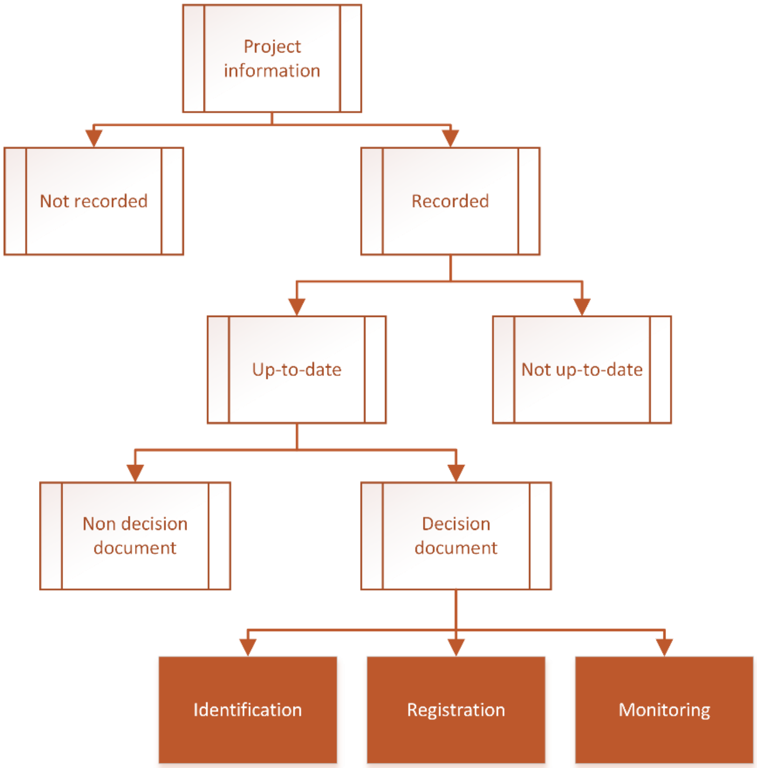


Figure 6: Information structure

4.5 Knowledge and skills of employees

A part of the work within MpfunekoCS like the digging and constructing is unschooled work. Because the workers in general are of low-skill and it is difficult to make them familiar with standard procedures, changing circumstance or responsibility. The workers have difficulties with measurements and administrations. To secure the progress, a lot of time is spent on checking the work and changes are being made to the work originally done.

MpfunekoCS provides training to new employees. This training is focused on physical constructionskills of the constructors. The constructors are not learning skills for reading drawings, making measurements or doing administration. Therefore all non-physical related work is done by the management of the MpfunekoCS.

Also within the management and in the office the skills of the employees are mostly low. This results in a poor administration of the everyday processes within MpfunekoCS. As a result of the poor administration it is hard to collect reliable data.

5. Construction activities

The digester total biogas installation, including stove and piping, consists of 9 main components (NBP, 2006). The components are:

1. Inlet (Mixing Tank)
2. Dome
3. Digging pit
4. Outlet and overflow opening
5. Main Gas Pipe and Turret
6. Main Gas Valve
7. Pipeline
8. Gas Tap
9. Gas Stove with rubber hose pipe

Figure 7 gives a schematic overview of the digester. The exact measurements could be found in the drawing in appendix V. The excavation of the digging pit has to be slightly bigger than the digesters itself to generate a workable construction site. The total excavation for a 6m^3 digester is around 13m^3. Different digesters will have slight differences in the excavation volume because the ground level may vary. The calculations for the excavation volume could be found in appendix VI.

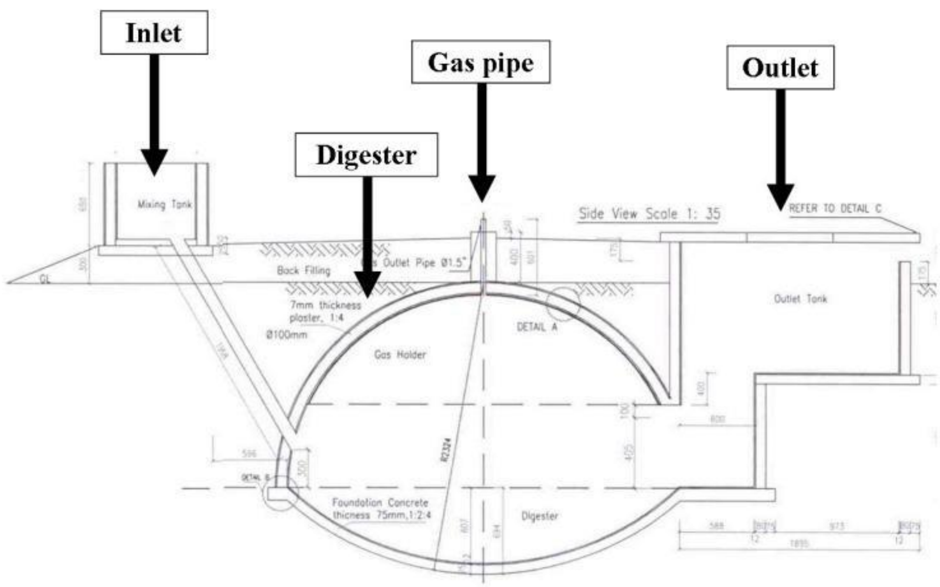


Figure 7: main parts of the digester

The activities related to the construction of these components are:

- Contract signed (starting point for the building process.
- Site assessment and selecting location on site (site assessment form).
- Demarcation: Demarcation for the digging.
- Digging pit: Digging the pit according to the demarcation and drawings.
- Demarcation and drawings.
- Pouring floor: Pouring the flour for the digesters (foundation on steel and not reinforced).
- Constructing dome: constructing the dome by laying bricks.
- Plastering dome: Plastering the inside of the dome.
- Constructing outlet: Constructing the outlet by laying bricks.
- Constructing inlet: Constructing the outlet by laying bricks.
- Constructing case: the case protects the case connection from weather conditions).
- Plastering outlet.
- Plastering inlet.
- Plastering case
- Waxing (the layer of wax makes the dome gas tight).
- Making slabs (for in, outlet and case).
- Digging trench.
- Installing pipeline.
- Backfilling.
- Testing.
- In use: The digester is ready to use.

5.1 Work breakdown structure

With the work breakdown structure (WBS) it is possible to understand the organization in relation to the different construction activities within MpfunekoCS. Also different Approaches for the organisation towards construction activities will be made to see if a different approach has a positive effect on the planning of construction activities.

Based on the activities from chapter 5 it is possible to develop a Work breakdown structure as shown in Figure 8. The WBS can be used for further steps for analysing and planning the building process like a network diagram (AL-jibouri, 1998). The WBS can be divided into 5 different levels (Ibrahim, Kaka, Aouad, & Kagioglou, 2008). The five levels are:

Level 1: Facility/physical location (the complete project)
Level 2: Elements (project sections)
Level 3: Work section (sub-sections of the project)
Level 4: Construction aids (equipment and techniques)
Level 5: Construction product (construction elements)

The level that will be used for construction is level 2: elements. Therefore the WBS will be split into elements. It is also possible to divide the WBS in different levels according to responsibilities within the organisation (AL-jibouri, Planning & control of construction projects, 2011). Figure 8 shows the WBS for a single biogas installation. Within the figure four different levels are distinguished.

- Level 1: The project director
- Level 2: The Construction manager (supported by a supervisor)
- Level 3: The Constructor (working with an assistant)
- Level 4: The digger (2 diggers working together)

The WBS has different goals these are:

1. Identifying the work that has to be done.
2. Identifying who is responsible for the work.
3. Form a basis for organisation and planning systems (AL-jibouri, Planning & control of construction projects, 2011).

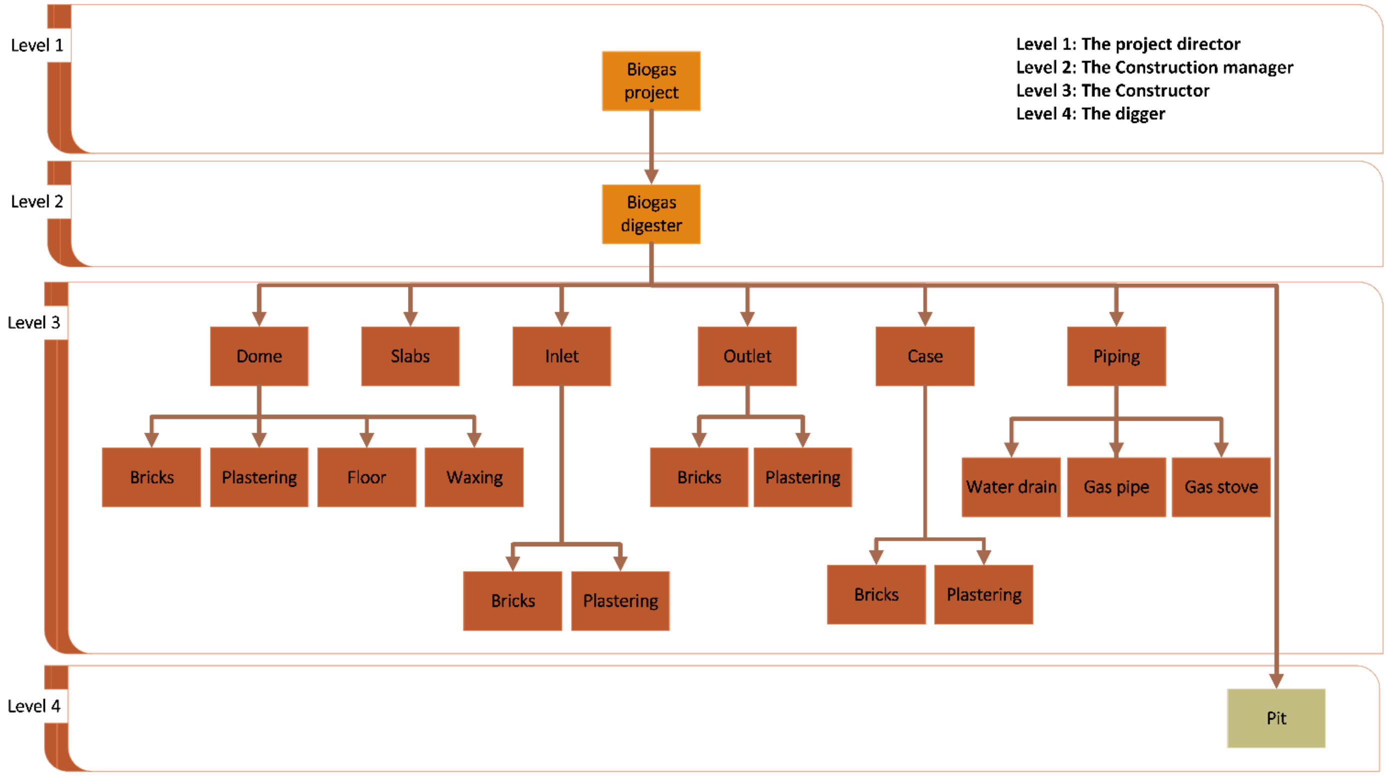


Figure 8: WBS for the current situation

The WBS can be changed if the organisation structure is changing. There are two options for changing the WBS: make a constructor completely responsible for constructing and digging. This option will be called single responsibility. The single responsibility options is shown in figure 9.

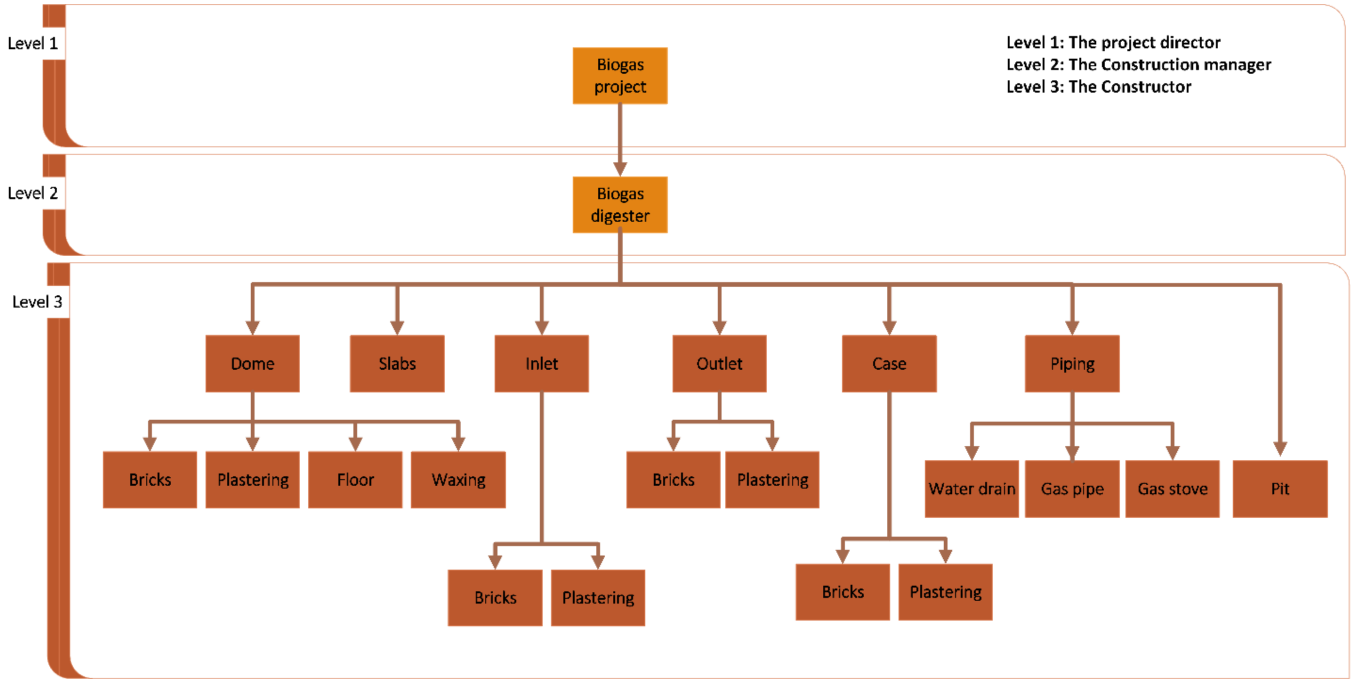


Figure 9: WBS for single responsibility

The second option is working in teams. This means that the digger is responsible for the digging. The constructor is responsible for the main construction of the digester. And there is somebody responsible for the piping. This option will be called team responsibility. The team responsibility option is shown in figure 10.

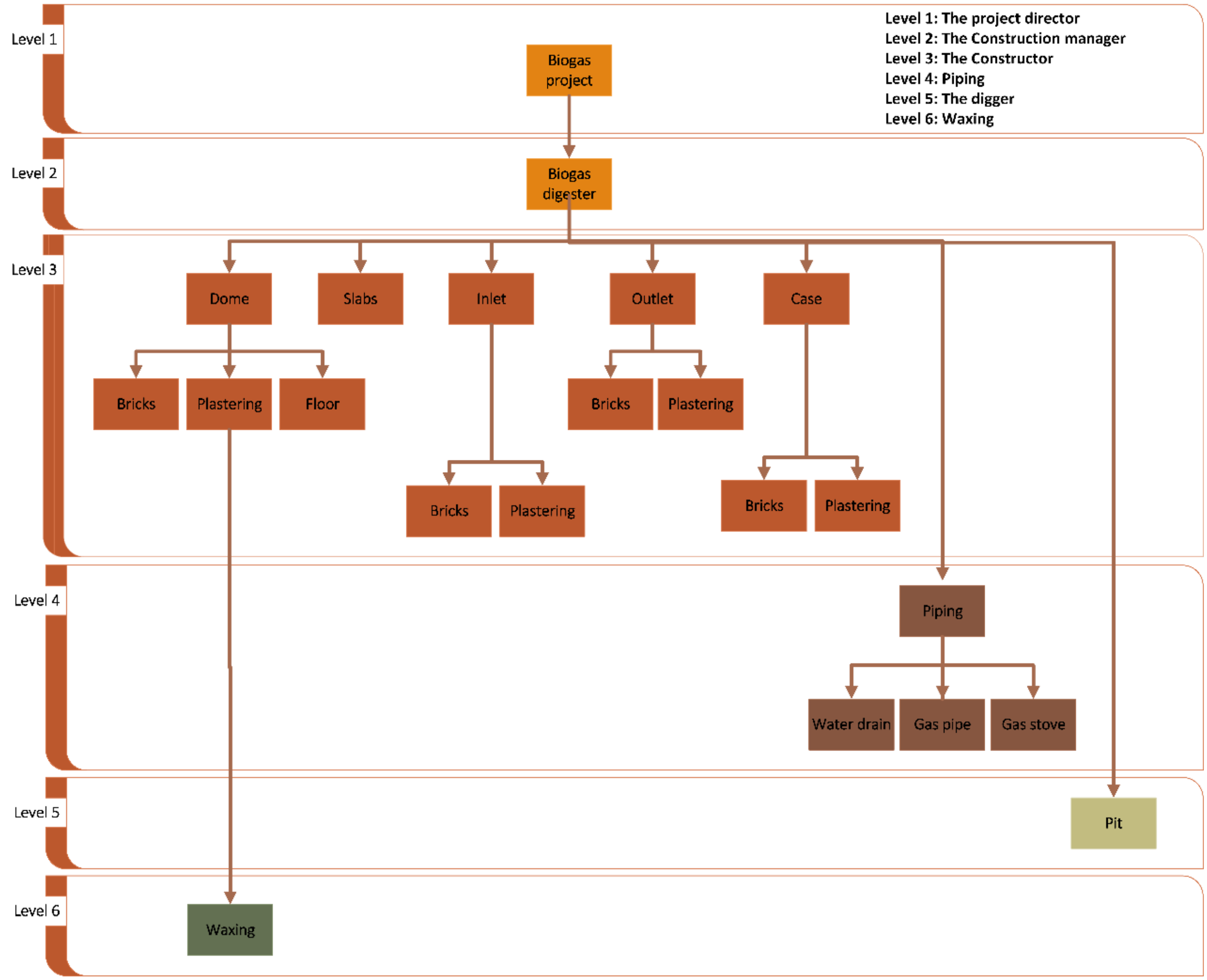


Figure 10: WBS for team responsibility

The two new variations of the WBS can be used to make to different planning scenarios. With these different planning scenarios it is possible to find the best fitting WBS structure for MpfunekoCS. In all cases MpfunekoCS likes to work with teams of two people at a construction side.

5.1.1 Teams and specialization

The WBS with the team responsibility could be used for specialization of different task like digging, construction and piping. Especially the piping is a part where specialized training is needed. Therefore the team approach could have the benefit of giving less or less extensive training to the workers.

5.2 Duration of activities

To complete the network diagram it is important to assign an estimated duration to the different activities. One way to do that is by gathering estimation of the durations of the various activities during interviews with the employees (diggers and constructors). In practice this is not a good way of measuring the duration of the activities. Due to a rapid change of employees, poor reaction on the interview and bad recollection of work done in the past it is hard to gather data.

Preliminary findings of theoretical durations of activity are shown in Appendix II: Estimation of activity duration. These findings are based on the interviews taken on 26-05-2014.

A second technique to collect reliable data is necessary. In Appendix III: digging completion form and Appendix IV: construction completion form are included. These forms could be filled in when digging or construction are completed. Using these forms it is possible to record the duration of activities more accurately. Due to the short period of research and the difficulties with the administration and the filling in of the forms, this second technique will be not be used.

Also information about the duration of activities is available via management and observations. The outcome of the interview, information from management and observations is mentioned in appendix II. The interviews and information from the management can be used to make an estimation of the theoretical durations of the activities.

Also it is important to collect data of the actual durations, including the delays in the construction process. This data can be collected by matching the time sheets and construction sheets of the past. A problem with this data is, that it is incomplete and inaccurate.

With the collected data from the administration and different methods like Network analysis, PERT Monte Carlo and LOB it is possible to make an estimations of the actual duration of the activities and the construction of the digesters as a whole.

6. Risks and uncertainties

With the implementation of a project there are always uncertainties involved. These uncertainties could be divided in three categories: uncertainties for the duration of the activities, resources and the order of the activities (AL-jibouri, 1998). In order to make a planning, the order of activities will be fixed and a shortage of resources will be considered as a course of activity delay. This means that the focus will be on uncertainties for the duration of activities

Dealing with risks can be divided in different steps (Lester, 2014). These five steps will be followed to analyse the risks involved in the construction stage of the project.

1. Risk Awareness
2. Risk Identification
3. Risk Assessment
4. Risk Evaluation
5. Risk Management

6.1.1 Risk awareness

In general there is an awareness of risks within MpfunekoCS. This means that the Project director is aware of different kind of risks within the organization. There is not always an awareness of risks in the lower ranks of the organization, for example the diggers.

6.1.2 Risk identification

The risks that are identified come from different sources. The sources used are observation, talking with management and interviews. The identified risks are classified into four groups: risks for the organisation, risks for the environment, risks in technical areas and financial risks. These risks are indicated in Appendix VII.

6.1.3 Risk evaluation

The risks found in the identification process need to be evaluated to select the most important risks for the project. The risk are evaluated by means of the probabilities of occurring and the impact of the risk. Both the chance and consequents will be rated on a scale from one to 5. Furthermore, the risk carrier is determent (the stakeholder that carries the risk). In figure 11 a risk versus impact matrix is showed. In Appendix VII is explained how the risk evaluation and the risk assessment is constructed.

The scores from one to five are based on observations and conversations with workers and managed from MpfunekoCS. This is done for the impact and chance of the risks whereby 1 is a low risk or low impact and 5 is a high risk or high impact for the projects of MpfunekoCS.

Figure 11: Risk matrix

6.1.4 Risk Management

There are several options to deal with risks, namely: avoiding the risk, sharing the risk, transferring the risk, spreading the risk, reducing the risk, insuring the risk or accepting the risk. One of the important reactions towards risks that cannot be avoided is reducing the risks. This is because it is not always possible to avoid, share or transfer risk etc. Reducing risks is possible for most of the risks identified. For MpfunekoCS there are a view measures that can be taken to reduce a number of risks.

6.1.4.1 Standardized toolsets

With the construction of the digester various tools are used. Because the tools needed for the construction are always the same, the toolset could be standardized. Therefore one of measures that could be taken is the making of standardized toolsets. These toolsets will be constructed for each specific task: digging, construction piping and demarcation. Also there should be a management and supervisor toolkit.

To avoid missing tools, the toolsets could be stored at the constructions site. The toolsets will be brought when a task starts and be removed when the task is finished. To make sure the tools will be kept on site, the workers will be made responsible for the safekeeping of the toolsets by signing a tool form. If tools are missing without a proper explanation a fine could be given to the workers who are responsible for the missing tool. Workers should not be allowed to transport the tools to other construction sites without approval of the management

Through the use of the tool forms it will be possible to ensure that all the necessary tools are on site and the risks of missing tools on site is reduced. To keep toolsets complete, all the tools could be marked to show that the tools are property of MpfunekoCS. Also, all the tools in a toolset could be numbered. With the numbers it could be possible to avoid the mixing of toolsets. Numbering is possible by painting, stickering or engraving the tools.

The composition of the different toolsets is mentioned in appendix XIV to XVIII.

Also a spare toolsets could be available to replace missing tools (sets). It is also recommended that there are spare toolsets put in stock and spare tools for tools that break more easily (like pickaxes). At least two toolsets could be hold on in stock. This could be at the storage facilities of MpfunekoCS.

6.1.4.2 Non-frequently used tools.

For constructing the digesters there are also tools available that are not always used like a jackhammer for removing rocks while digging and a water pump to pump out water in pits or digester that are flooded. For both tools there is only one tool available. This gives problems when MpfunekoCS is constructing in multiple towns. Therefore tools like a jackhammer and a water pump could be available in every town where MpfunekoCS is constructing. In this way delays due to transport of these tools are minimalized.

6.1.4.3 Quality control

Most of the mistakes made in the construction of the digesters are caused by lack of skills and insight of the constructors. This problem could be reduced by proper training and supervising Training is possible in two different ways. Training the constructors in a group or training the constructors individual. Due to a lack of interest during training in large groups it may be better to train constructors individually.

Following training, the constructors should be employed to construct multiple digesters, otherwise the

effort for the training gets lost. It should be possible to employ the same constructer in multiple towns where MpfunekoCS is constructing. Also in every town there should be at least one trainer available to give guides to constructors.

Within MpfunekoCS there is a high turnover of employees. This means that learned knowledge leaves the company and that there is a lot of time spent on instruction employees and a higher chance of mistakes to occur due to lack of skill and knowledge and following the right procedures, quality standards and safety regulation. To avoid these problems the turnover of employees could be lowered. By keeping employees longer employed, their knowledge and skills should develop more. This could be possible by paying constructors a premium on their salary after constructing a certain amount of digesters. For example if a constructor finished 5 digesters.

The quality of materials could also be a risk. The quality of sand influences the quality of the concrete, and an irregular size of bricks influences the bricklaying. These risks could be avoided by selection high quality suppliers. The selecting process for the suppliers will be al trial and error process.

6.1.4.4 Reducing chances of accidents

To reduce accidents for the workers soil and rocks always need to be removed from the edge of the digging pit. This will prevent the collapsing of the pit. In comparison with other countries the accident rate in South Africa is high (Construction Research Education and Training Enterprises, 2009). The Construction Industry Development Board (CIDB) sees training as one of the most important tools to reduce the number of accidents. Therefore every construction employee of MpfunekoCS should get a health and safety briefing before they start working for MpfunekoCS. Also, the workers should wear safety clothing and use equipment like safety boots with a steal nose and a helmet while working in the digging pits. This will reduce injuries when an accident occurs. These personal safety equipments and facilities are also mandatory throughout national regulation (Deparment of laubour, 1986). The same applies for hearing protection while working with heavy equipment like a jackhammer.

While working in confined spaces the workers of MpfunekoCS always should be with 2 persons, one person working in the confined space and one person directly near the exit of the confined space (Deparment of laubour, 1986). Also the hazardous gas, vapour, dust or fumes contemplated in confined space should not exceed 25 percent of the lower explosive limit of the gas, vapour, dust or fumes concerned.

Besides the safety of the workers also the protection of the public is important. Therefore the construction site always should be fenced off from the public. This is possible by demarcating the constructing site with pins and warning tape. This demarcation should be covering the construction site in a great extent (Deparment of labour, 2012). Also, warning signs for pedestrians are required.

6.1.4.5 Reducing financial risks

The financial risks are causing big delays for the projects of MpfunekoCS. One of the reasons is a cash flow problem. Supporting organization pay late or after work has been done. Also status reports are not frequently sent to the supporting organization. The liquidity problem can be reduced by sending status reports more frequently and complete status reports to the supporting organizations. To structure the process of making these status reports data from the administration is needed. Therefore correct and standardized administration is required.

Also MpfunekoCS should create a financial buffer. By creating a financial buffer cash flow problem could be avoided.

6.1.5 Availability of construction materials

For ordering materials two principles could be used. Keeping materials in stock or the just in time philosophy (Pheng & Chuan, 2001) could be used. Materials for piping could easily be kept in stock at the storage facilities of MpfunekoCS.

Part of the delays within MpfunekoCS is caused by shortage of construction materials. The shortage of construction materials has four reasons: there is not enough money to buy materials, the materials are not bought on time, there is no knowledge of the need for new materials and the needed materials are moved to a different site. The problem of not enough money could be solved by solving the liquidity problem. No knowledge of the need of materials and not buying materials on time could be solved by a proper administration and communication within MpfunekoCS. Also, materials for one digester should be ordered and brought to the site. After the materials arrived on the construction site they should not be moved to another site.

After reducing the causes of a shortage of materials there will still remain a risk for a shortage in materials. Therefore an emergency stock is required for activities that require materials. An emergency stock should be big enough to keep the construction teams working.

6.1.6 Risk monitoring

The risks that are identified should be monitored. This is a task for the administration. By monitoring the risks it is possible to see if the precautions that are taken have a positive effect, new risks could be identified and changes in the frequency of risks occurring could be noticed.

To monitor the risks a good administration is necessary and management should be aware when they record abnormalities in the project and construction process. It is possible for MpfunekoCS to assess the risk monitoring and the changes of risks that are detected. After detecting a change in a risk, the response to this risk could be changed. This is possible with a meeting or with a brainstorm session, if MpfunekoCS holds these meetings frequently for example every month or quarter

6.1.7 Information management

A large part of the information that is available within MpfunekoCS is not distributed through to the company and not always available on paper or digital. One of the problems already mentioned is the poor administration. The other reason is not having access to the information. Managers only have access to the data of the month that they are working in and only have access to this information on paper. Only the administration and the managing director have access to data from the past or any digitalized information. Therefore the spreading of new and changed information within the company is slow. The managing director has to collect the papers from lower management in different towns to get access to the up-to-date data and vice versa. The access to information could be made easier by installing a laptop with an internet connexion in every town where MpfunekoCS is constructing. An internet connection with a dongle and a connexion through a mobile phone network makes sending information to a central point possible. (On most places an internet connection trough the mobile phone network is possible). This will make administration and writing reports easier and quicker because information is quicker and broader available within the company. Also the loss of information could be reduced (lost forms etc.) by backing-up the information and better access for management supervision on the information and administration is easier.

7. Project planning

After the identification of all the activities, durations and risks it is possible to make a planning for the construction of the digesters. Planning is possible on three different levels.

Level 1: A summary plan
Level 2: An Intermediate level plan
level 3: A detailed level plan

The planning for MpfunekoCS will be a level three plan and fill be a detailed plan for the constructions phase of the project.

7.1 Network Diagram

With a network diagram it is possible to get an insight in the project duration activity order and relations. The network diagrams will be made with activity durations that represent good conditions for the project.

Based on the work breakdown structure of the work activities it is possible to construct a network diagram to represent the construction process. In this case an Activity On Node network has been chosen. In appendix I, Activities and dependence, the dependencies of the different activities are explained. The AON network diagram is shown in Figure 13.

The ideal network is based on an unlimited amount of resources, and would be the ideal situation (digging done by two diggers). The durations of the project based on this network will not be realistic for practice and only reflects a theoretical possibility. The network needs to be optimized in order to be used in practice. The network is filled with a combination of the forward and backward pass approach. Also the critical path is indicated in the network. The critical path is indicated by the thick orange arrows.

Within the network different times are indicated

EST: Early start time
EFT: Early finish time
D: Duration of the Activity The times between "(+*x)*" are drying times for the plastering and brickwork
LST: Late start time
LFT: Late finish time
TF: Total float

The waxing of the digester is on a separated path because the waxing is weather dependent and not possible in the rain season in September and November (Reason, Hachigonta, & Phaladi, 2005). This also means that the waxing is not taken into account for CPM.

In Appendix X an enlarged version of the AON networks is shown.

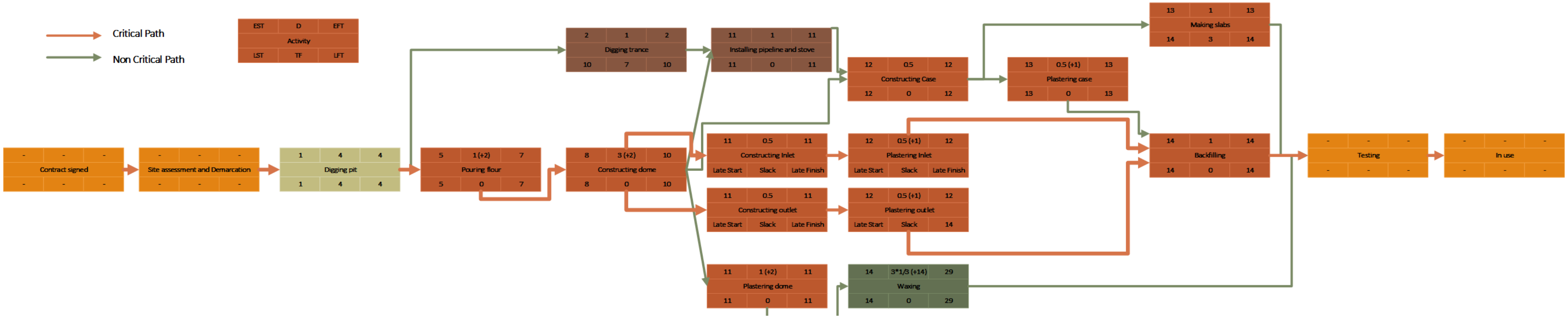
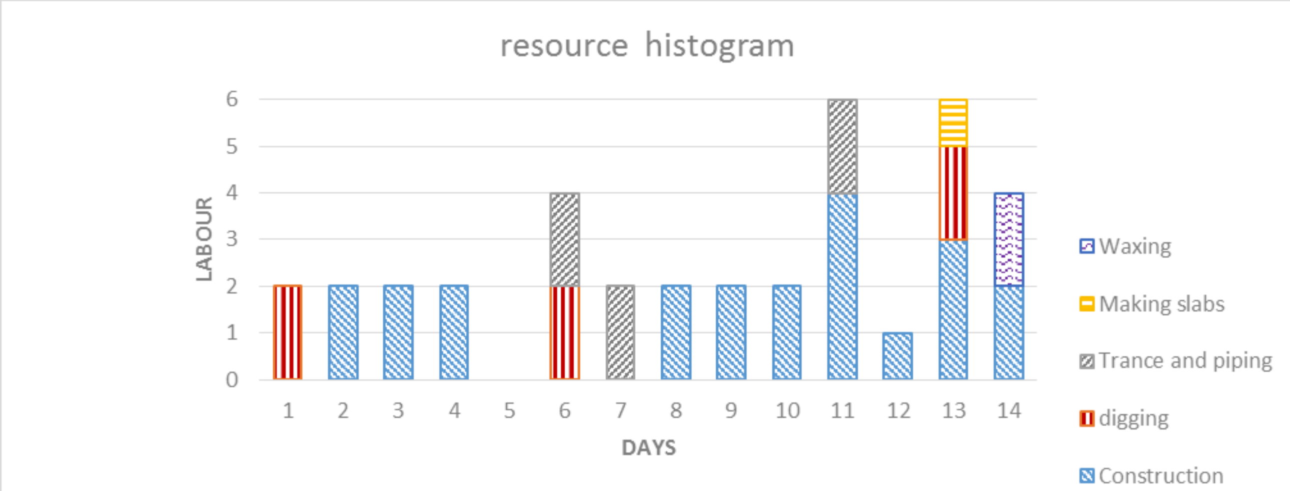


Figure 13: AON network diagram in theory

The AON network diagram in theory (the network with the shortest duration on the critical path without taking resources into account) will be optimised for the resource labour. MpfunekoCS likes to work with digging and construction teams that consists out of two people. The resource histogram for the AON network in theory is shown in Figure 14. The resources will be levelled in a way that there always will be one team (consisting of 2 people) working on a construction site. The exception on this is the waxing because the waxing is very weather depended.

In figure 17 and 18 realistic AON networks are created. These networks are based on a digging team with two diggers and a construction team with one constructor and an assistant. But also the realistic do not take risks and uncertainties into account. This means that the two realistic networks give an improved situation with taking resource labour into account situation. In the PERT analysis in chapter 7.2 risks and uncertainties are taken into account.

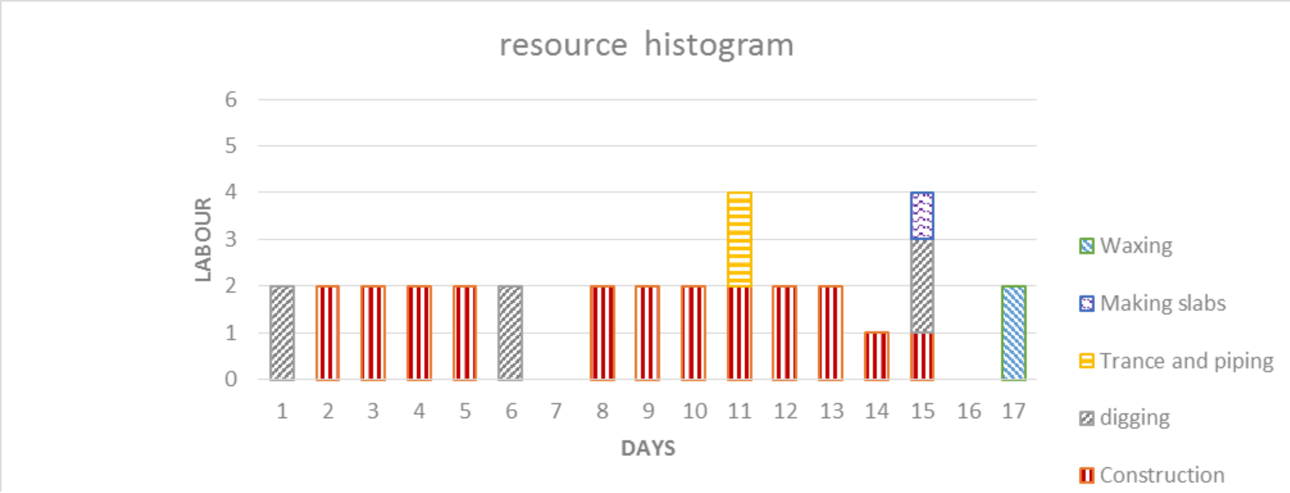


	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Waxing	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Making slabs	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Trance and piping	0	0	0	0	0	2	2	0	0	0	2	0	0	0
digging	2	0	0	0	0	2	0	0	0	0	0	0	2	0
Construction	0	2	2	2	0	0	0	2	2	2	4	1	3	2

Figure 14: Resource histogram based on early start of AON diagram in theory

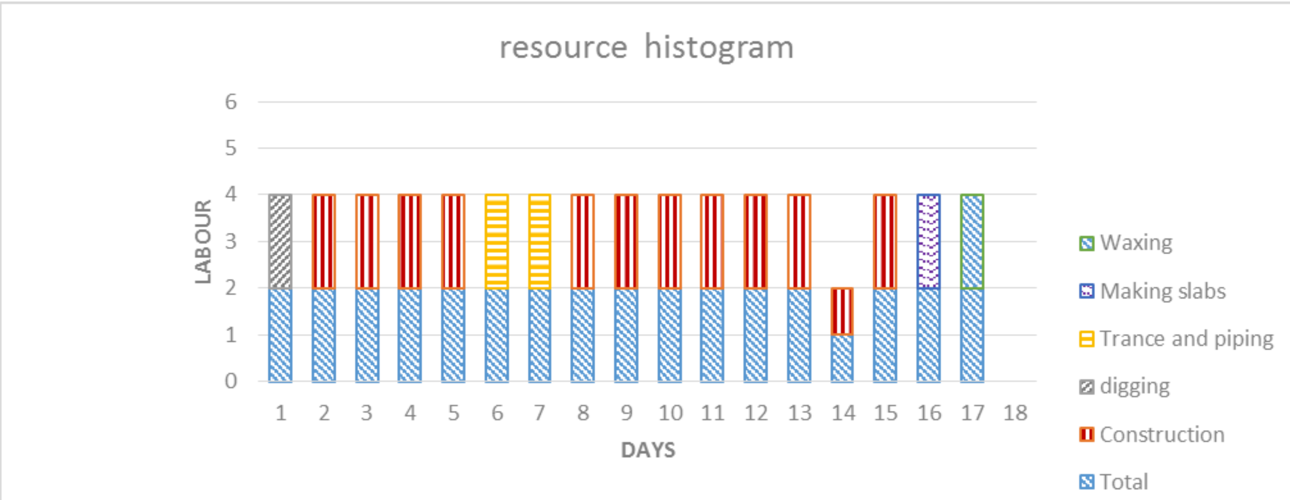
In figure 15 and 16 the resource histograms for the realistic team and single approach networks are shown.

The AON network in theory in figure 13 is not ideal for the resource labour and not in line with the habit of MpfunekoCS to always work in teams with two people on site. Therefore, based on the allocation of the recourse labour, two new networks are created. The networks are based on the two variations (team responsibility and single responsibility) of the WBS in chapter 5.1. The networks (AON network realistic team responsibility and AON network realistic single responsibility) in figure 17 and 18 have a slightly different critical path. The total duration of the construction of one single digester is in the case of the team approach one day shorter and there is more flexibility in when to do the piping and when to dig the tranche because piping and digging the trance are removed from the critical path.



Waxing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Making slabs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Trance and piping	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
digging	2	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0
Construction	0	2	2	2	2	0	0	2	2	2	2	2	2	1	1	0	0

Figure 15: Resource histogram based on early start of AON network realistic Team



Waxing																	2	
Making slabs																2		
Trance and piping						2	2											
digging	2																	
Construction		2	2	2	2	0	0	2	2	2	2	2	2	1	2	0	0	0
Total	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	0

Figure 16: Resource histogram based on early start of AON network realistic Single

Also for the two realistic AO networks applies that waxing is deliberately put on a different path.

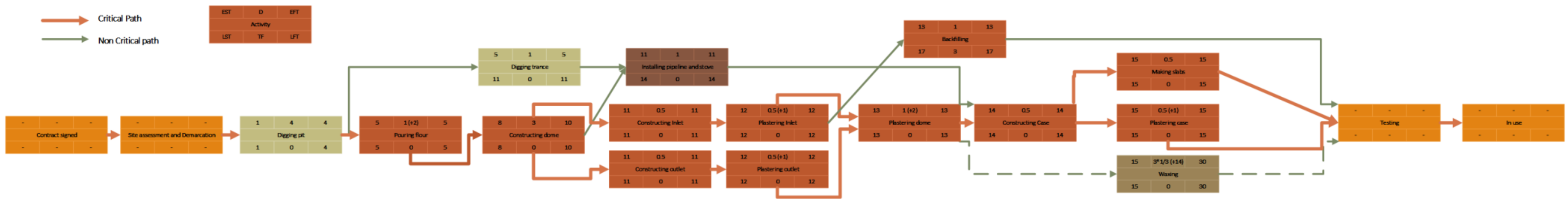


Figure 18: AON network realistic team responsibility

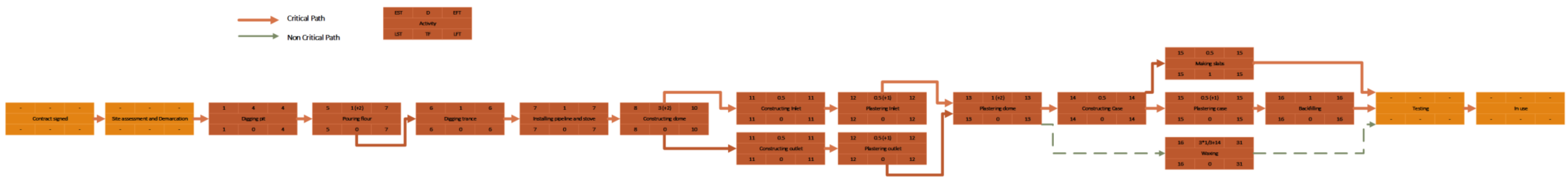


Figure 17: AON network realistic team responsibility

7.1.1 CPM

The critical paths shown in figures 17 and 18 consists of the activities shown in Table 1. This critical path shows that it is possible to do the construction of the inlet and outlet in one day, the plastering of the inlet and outlet in one day, and the plastering of the case and making slabs in one day.

Table 1: Critical path

Activity on critical path	Team	Single
	Duration in days	Duration in days
Digging pit	4	4
Pouring floor	3	3
Constructing dome	3	3
Constructing in- and outlet	1	1
Plastering in- and outlet	1	1
Plastering dome	1	1
Constructing case	1	1
Plastering Case	1	1
Backfilling		1
Total	15	16

The critical path that is suggested above is a fixed path. It is also possible to calculate which path becomes critical by executing a Monte Carlo simulation. The Monte Carlo simulation is explained in Appendix XII. The paths that are almost identical (due to activities carried out on the same day like constructing the in and outlet) are summarized. The results of the Monte Carlo analysis is shown in table 2 and 3. For the Monte Carlo Simulation a normal distribution is used.

Table 2: Critical path based on Monte Carlo simulation of realistic Team AON network

Path	Percentage
Path 1, 2*	0.2
Path 3,4,5 and 6*	96.44
Path 7 and 8*	3.36

This means that in 96.44% of the cases the critical path is equal to the fixed critical path before

Table 3: Critical path based on Monte Carlo simulation of realistic Single AON network

Path	Percentage
Path 1, 2*	73.12
Path 3 and 4*	26.88

The outcome of the Monte Carlo simulations show that the fixed critical path suggested in table 1 is truly the critical path.

7.2 PERT

By using pert it is possible to include delays into the planning. These delays are simulated by using different times for mort the most likely time, the optimistic time and the pessimistic time.

Figure 17 and 18 show the network planning for constructing a digester. In reality the different activities will have different durations due to risks and uncertainties. A real estimation of the duration of the activities can be determined with PERT (Program Evaluation and Review Technique) method. PERT is based on using different variables (durations). The pessimistic time P, the optimistic time O and the most likely time M. With these three variables it is possible to calculate the expected mean time t_e by the following equation: $t_e = \frac{O+4M+P}{6}$. In this research we base the optimistic time on the ideal situation based the network diagram showed in Figure 13. For the most likely time a small delay on the most time consuming activities is taken into account, the pessimistic time will be based on worst case examples that are found in the administration of MpfunekoCS.

The result of the PERT analysis for the different activities is shown in table 4. Also the PERT analysis will be executed for the team and the singe responsibly approach.

Table 4: result PERT

Activity	number	optimistic time (O)	most likely time (m)	pessimistic time (P)	Te	deviation te	veriation te
Contract signed	1	-	-	-	-	-	-
Site assessment and selecting location on site and demarcation	2	-	-	-	-	-	-
Digging pit	3	4	5	10	6,5	1,0	1,0
Pouring floor	4	3	4	6	4,8	0,5	0,3
Constructing the dome	5	3	4	6	4,8	0,5	0,3
Plastering dome	6	1	2	3	2,3	0,3	0,1
Constructing outlet	7	0,5	0,5	2	0,8	0,3	0,1
Constructing inlet	8	0,5	0,5	2	0,8	0,3	0,1
Constructing case	9	0,5	0,5	2	0,8	0,3	0,1
Plastering outlet	10	0,5	0,5	2	0,8	0,3	0,1
Plastering inlet	11	0,5	0,5	2	0,8	0,3	0,1
Plastering case	12	0,5	0,5	2	0,8	0,3	0,1
Waxing	13	3	5	7	5,8	0,7	0,4
Making slabs	14	0,5	1	2	1,3	0,3	0,1
Digging trench	15	1	2	3	2,3	0,3	0,1
Installing pipeline and stove	16	1	2	5	2,7	0,7	0,4
Backfilling:	17	1	2	5	2,7	0,7	0,4
Testing:	18	-	-	-	-	-	-
In use: The digester is ready to use	19	-	-	-	-	-	-
Sum		20,5	30	59	38,3	6,4	3,5

The result of PERT method would give an indication of the expected total project time, because there are no dependencies within the durations of activities (there is only a dependent in the order of activities). This means that an activity has no influence on the exact duration of the following activity, but only has an influence on when the next duration is carried out in time. The durations of the following activity will remain the same, only carried out at a different moment. The expected mean duration on the critical path can be summed. The same applies for the variances. $V_{(T_e)} = (\sigma_{(T_e)})^2 = \sum v_{(t_e)} = \sum(\sigma_{(t_e)})^2$. The results for the critical path are shown in table 5

Table 5: PERT and CPM Team and Single

Activity on critical path	Team		Single	
	Duration in days	Necessary working days	Duration in days	Necessary working days
Digging pit	6,50	7	6,50	7
Pouring floor	4,83	5	4,83	5
Constructing dome	4,83	5	4,83	5
Constructing in- and outlet	0,83	1	0,83	1
Plastering in- and outlet	0,83	1	0,83	1
Plastering dome	2,33	2	2,33	2
Constructing case	0,83	1	0,83	1
Plastering Case	0,83	1	0,83	1

Based on $\sigma_{(T_e)}$ T_e and a target duration T_s it is possible to calculate the change of the probability of achieving this target. This calculation is possible by means of the Z-score. $Z = \frac{T_s - T_e}{\sigma_{(T_e)}}$ With $\sigma_{(T_e)} = \sqrt{V_{(T_e)}}$. The distribution of the project time could be seen as a normal distribution. The combination of the Z-score and this normal distribution will give a probability of meeting the required project duration. In this case the project duration is the completion of one $6m^3$ digester.

In Table 6 and 7 the Z-score and the change of making the project deadline are given.

Table 6: changes of constructing a single digester one time Team

Ts	deviation	Te	Z-score	P	%
14	1,87	23	-4,82	7,34E-07	0,00
16	1,87	23	-3,75	9,01E-05	0,01
18	1,87	23	-2,68	3,73E-03	0,37
20	1,87	23	-1,61	5,42E-02	5,42
22	1,87	23	-0,54	2,96E-01	29,63
24	1,87	23	0,54	7,04E-01	70,37
26	1,87	23	1,61	9,46E-01	94,58
28	1,87	23	2,68	9,96E-01	99,63
30	1,87	23	3,75	1,00E+00	99,99
32	1,87	23	4,82	1,00E+00	100,00
36	1,87	23	6,96	1,00E+00	100,00
40	1,87	23	9,10	1,00E+00	100,00

Table 7: changes of constructing a single digester one time Single

Ts	deviation	Te	Z-score	P	%
14	1,868972	25	-5,89	1,98E-09	0,00
16	1,868972	25	-4,82	7,34E-07	0,00
18	1,868972	25	-3,75	9,01E-05	0,01
20	1,868972	25	-2,68	3,73E-03	0,37
22	1,868972	25	-1,61	5,42E-02	5,42
24	1,868972	25	-0,54	2,96E-01	29,63
26	1,868972	25	0,54	7,04E-01	70,37
28	1,868972	25	1,61	9,46E-01	94,58
30	1,868972	25	2,68	9,96E-01	99,63
32	1,868972	25	3,75	1,00E+00	99,99
36	1,868972	25	5,89	1,00E+00	100,00
40	1,868972	25	8,03	1,00E+00	100,00

7.3 PERT network

In figure 18 and 19 the PERT networks are filled in based on the previous discussed AON network diagrams and the PERT analysis.

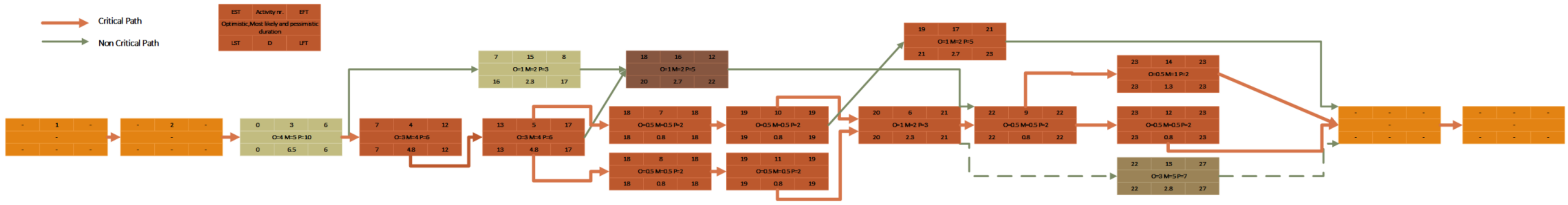


Figure 19: PERT network Team

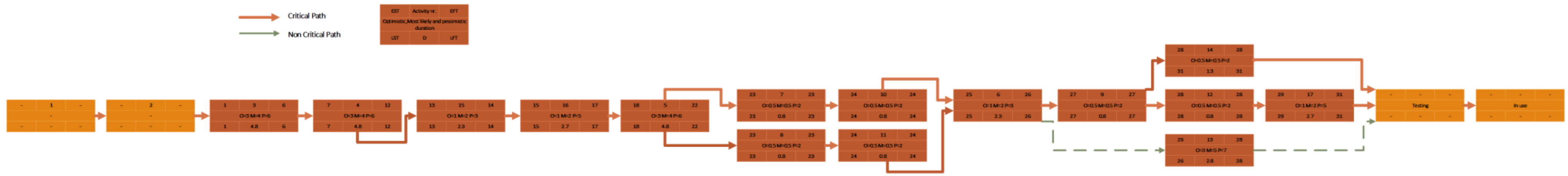


Figure 20: PERT Network Team

7.3.1 Change of critical path

After the PERT analysis there could be a differences in the critical path. Also for the PERT network a Monte Carlo simulation for the critical path has been executed.

The Monte Carlo simulations are explained in Appendix XII. The paths that are almost identical (due to activities carried out on the same day) are summarized. The result is shown in table 8 and 9.

Table 8: Critical path based on Monte Carlo simulation PERT Team

Path	Percentage
Path 1, 2*	0.04
Path 3,4,5 and 6*	99.90
Path 7 and 8*	0.06

This means that in 99.90% of the cases the critical path is equal to the fixed critical path as showed in the network

Table 9: Critical path based on Monte Carlo simulation PERT Single

Path	Percentage
Path 1, 2*	99.94
Path 3 and 4*	0.06

7.4 Line of balance method

With the line of balance method is planning technique for repeating work and could be used for the construction of mutable digesters in a town. With LOB it should be possible to plan for the different teams working on different locations

The line of the balanced method is a planning tool used in project planning. For example for repeating work within projects (AL-jibouri, Planning & control of construction projects, 2011). To implement the line of the balanced method a delivery schedule is necessary. The line of the balanced method is based on the following linear relation $Q = M * t + C$ with Q: the line of balance quantity, t: time, M: the require delivery rate and C a constant on they-axis. From this equation it is possible to subtract the following equations: Q2-Q1 = m *(t2-t1) or Q2 = m *(t2-t1) +Q1 or t2 = {(Q2 - Q1) / m} + t1.
A single digester needs to be finished within 4 weeks (this is de indication that MpfunekoCS uses to make tenders). This means within 20 working days. Based on the fact that there are 5 construction teams working at the same time the delivery rate should be 5/20 = 1/4. This means that every fourth day a digester should be delivered. Based on the fourth milestone of the EEP project (this is the fourth millstone from the EEP project contract) , where 15 digesters should be finished within 2 months in which are 42[1]. workable days[2]. Based on this information the delivery rate could be calculated. The delivery rate will be 15/(42-20) = 0.68

[1] Based on 21 workable days in a month (Tuxx, 2014)
[2] Based on 21 workable days in a month (Tuxx, 2014)

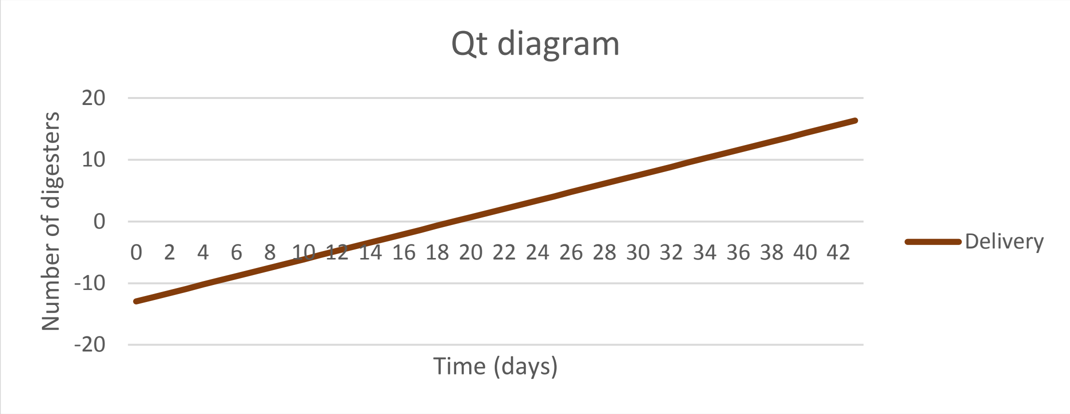


Figure 21: Qt diagram.

Based on the delivery rate of 0.36 it is possible to calculate the number of teams that are necessary to construct the digesters. Because the expected time of 20 working days, the number of teams should be 0.36*20 = 7.2. This means there is a need for at least 8 teams for the group of activities with the longest duration (activities for the constructor) to construct the digesters according to Figure 21.

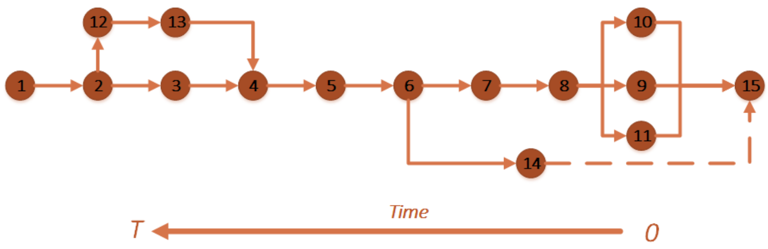


Figure 22: Delivery schedule

In Figure 22 the delivery schedule for the line of the balanced method is shown. The delivery schedule is based on the AON network showed in Figure 18. The corresponding activity durations are showed in Table 10.

Table 10: delivery schedule duration

	Activity on critical path	Duration in days
Digging pit	1-2	4
Pouring floor	2-3	3
Constructing dome	3-4	3
Constructing in- and outlet	4-5	1
Plastering dome	5-6	1
Plastering in- and outlet	6-7	1
Constructing case	7-8	1
Plastering Case	8-9	1
Backfilling	8-10	1
Making slabs	8-15	1
Digging Trance	2-12	1
Installing pipline and stove	12-13	1
waxing	6-14	3

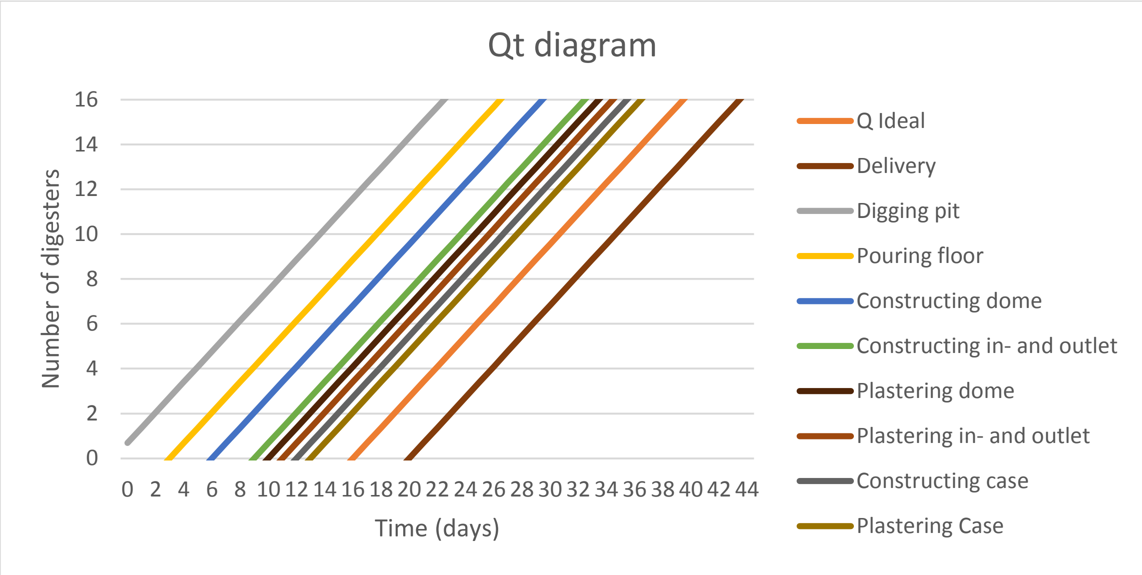


Figure 23: Qt diagram activities

Figure 23 shows the different tasks on the critical path. It is possible to read from the figure how many of the task should be completed in the schedule to meet the deadline. For example to meet the deadline for producing 15 digesters within two months (42 workable days) on day nine, six digging pits should be ready.

Based on delivering fifteen digesters within 42 working days, five constructing teams should work simultaneously. The same applies for the digging teams, where the digging teams have different tasks (digging pit, digging trance and backfilling).

Utilization = {activity duration} / {gang waiting time + activity duration} * 100 %

The Constructing activities have a duration of ten days, including two days waiting for the drying of the floor.

Utilization Constructing = 8/(8+2)*100% = 80%

Because there is a need for five constructing teams working simultaneously also five digging teams should start. In total the different digging task are spread within fourteen days of with six days are workable days.

Utilization Constructing = 6/(6+8)*100% = 42%

This means that in theory a digging team could dig at two sites, but according the PERT analysis there is a big change that the digging is delayed. Therefore it is not recommended that the digging teams are planned on working on two sites that have to be competed in a narrow time span.

This also means that a gang size problem will occur. Therefore it is not possible to use all the different teams efficiently. The gang size problem indicates that not all teams could put efficient to work. For MpfunekoCS this has no financial consequences because the workers are paid per job and not per hour.

7.5 Construction workers and teams

The workers are paid per job and per the hour. To make certain that they finish the job, they should finish a current job before starting on a new site. This will reduce the amount of half-finished digesters and will avoid problems with restarting the work on a digester.

The analysis in the previous chapters all were made with the assumption that the workers would work in teams of two people. For construction work it is necessary that the work is been done with at least two people. Digging the pit could be done with only one digger, but the time spend on the digging activities should be doubled. What means that the duration of constructing of one digester would take four days longer, because the critical path becomes four days longer.

In chapter 5.1 three possible WBS scenarios are given. Digging could be done by the diggers, because the unskilled labour is cheaper than the work of the skilled constructors. And due to the fact that it is difficult to find well skilled constructors it is better that the few well skilled constructors focus on the construction work.

The piping also could be done by a different team. This could be useful because most constructors do not have the proper skill to do the piping, but this will the efficiency of the labour due waiting teams for the teams. Piping could be done in the two days that the floor has to dry, but if the piping is done by a different team this is not possible. A gang problem will occur. This gang problem will only occur in the situation where MpfunekoCS is working with different teams.

The correct installation of the pipes is essential for a working digester and the safety. Therefore the piping needs to be done by well skilled workers. The consequence is that the piping is done by a different team.

Also, waxing the digesters gives a problem and is based on the realistic AON network. Therefore it could be helpful to do the waxing by a different team than the constructors. The waxing could be combined with the piping teams because the activities do not take place on the same time and the amount of teams used in the construction of the digesters will remain limited.

7.6 Bar chart

Figure 21 shows a bar chart for one single digester (the timescale is in days). The Bar cart is based on the AON network for the single responsibility network. This means that the bar chart shows the most ideal situation

ID	Task Number	Task Name	type of work	Duration
1	1	**Digging pit**	Digging	4 days
2	2	**Pouring floor**	Constructing	3 days
13	13	**Digging trench**	Digging	1 day
3	3	**Constructing the dome**	Constructing	3 days
5	5	**Constructing outlet**	Constructing	0,5 days
14	14	**Installing pipeline and stove**	Piping	1 day
6	6	**Constructing inlet**	Constructing	0,5 days
8	8	**Plastering outlet**	Constructing	0,5 days
9	9	**Plastering inlet**	Constructing	0,5 days
4	4	**Plastering dome**	Constructing	1 day
7	7	**Constructing case**	Constructing	0,5 days
12	12	**Making slabs**	Constructing	0,5 days
10	10	**Plastering case**	Constructing	0,5 days
15	15	**Backfilling:**	Digging	1 day
11	11	**Waxing**	Waxing	1 day

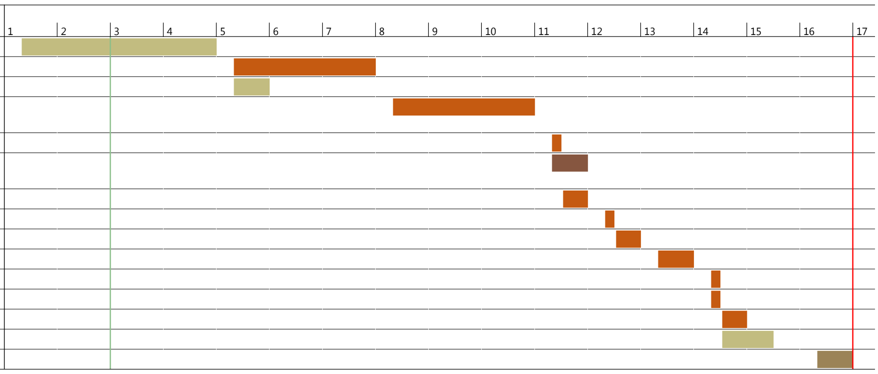


Figure 24: Bar chart single digester based on AON team network

In figure 25 a possibility for scheduling muliple digesters on a team basis is shown. The timescale is in weeks. The bar chart is based on the AON team network and the LOB method. This means that the barchart shows a situation nased on a early start.

ID	Task Name	Duration	Predecessors
1	Digging pit	4 days	
2	Constructing	10 days	1
3	Digging tranch	1 day	1
4	Piping	1 day	2SS+6 days
5	Backfilling	1 day	2SS+9 days
6	Digging pit	4 days	3
7	Constructing	10 days	2
8	Digging tranch	1 day	6
9	Piping	1 day	7SS+6 days
10	Backfilling	1 day	7SS+9 days
11	Digging pit	4 days	5
12	Constructing	10 days	7
13	Digging tranch	1 day	11
14	Piping	1 day	12SS+6 days
15	Backfilling	1 day	12SS+9 days

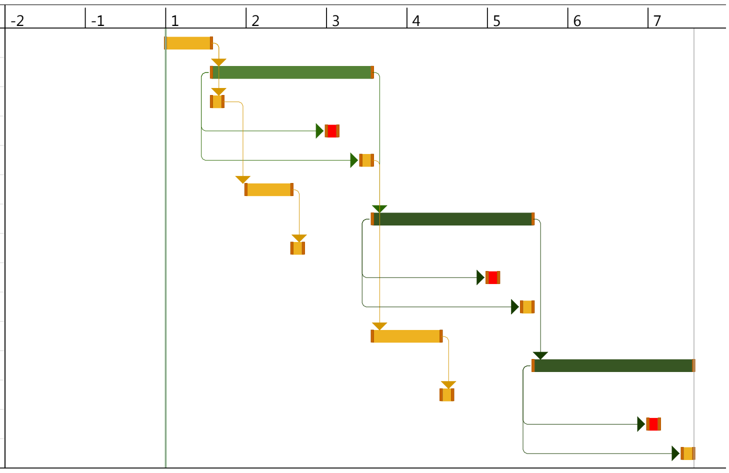


Figure 25: Bar chart

7.7 Failure of the network and long-time pause in construction.

The WfE project in Gawula is severely delayed. Part of this is due to financial problems. Also, MpfunekoCS has chosen to focus on different projects, like the EEP project in Shawela. Due to a pause in the construction of the digesters the proposed networks do not work. One of the reasons for the failure of these networks is that extra activities emerge, like cleaning the inside of the digesters before waxing or in almost all cases pumping water out of the digesters. Combined with the extra inspections that are needed due to the poor administration of the work a lot of extra time and resources are spent on these digesters.

When due to the failure of the network a project deadline or milestone is in danger there are different possibility's to soften the effects of the crashing network:

- use of more work shifts
- use of overtime
- use additional equipment
- use of bigger gang sizes
- use of alternative construction method or sequence
- use off alternative materials

In the case of MpfunekoCS only overtime, more shifts or a bigger gang size could help. For example, if the gang size is enlarged to two constructors and two assistants it is in theory possible to construct the case in and outlet in the same time. The same applies to plastering the case in and outlet or with constructing the dome faster. Of course the use of overtime and extra shift will have a similar effect, but will be limited by daylight.

Also the effects will not be significant with certain activities in the network. For example, with waxing the dome a bigger gang size will not work, because it is not possible to fit more people inside the dome. Furthermore, the use of overtime is very limited due to the amount of daylight.

8. Speeding up the construction process

There are a few possibilities to speed up the construction process. One of these possibilities is making the slabs for the digester in advance. This saves one day of work at the construction site. The slabs could be easily made in larger series at the workshop of MpfunekoCS. By making a standardized mould it should be possible to make a large amount of slabs in a day. There is one condition that has to be made to be able to make slabs in series and that is that all the outlets are made in the same size. Something that is not happening in the construct process at this moment. There is a difference of a few centimetres in the outlets of different digesters. This could be avoided by better inspection of the work in an early stage of the construction process or by employing better skilled workers.

It is also possible to change the technique to make the digesters gas tight. At this moment MpfunekoCS uses a product from concrete, called Permastop[3]. Permastop is used to waterproof the plastering layer inside the dome and then a layer of wax is used to make it gas tight. The waxing part for making the digester gas tight is very weather dependant and there is a big risk of delaying the construction of the digester. There are also different possibilities to make a digester gas tight (enerypedia, 2014) such as different layers of plastering, use of bitumen, gas tight paintings and coatings or the use of paraffin. A layer of gas tight paint could replace the Permastop and waxing layers that MpfuncoCS uses to make the digesters gas tight (Nijaguna, 2002).

There are different gas tight paints available on the market that could be applied to make the digester gas tight. Examples are Rust-Oleum Dakfill Frigo Gas & Vapour Tight Coating[4] , BOSS Gas Paint[5] and mare gastight paints.

Also, when cracks appear in the plastering layer on the inside of the dome or in the floor there are products available to fill these cracks easily. These filling products could be used for small repairs and irregularity. Products are available through a wide range of brands.

One of the reasons that the construction process is slowed down is due to constructors who lack skill or experience. MpfunekoCS should put more effort in hiring and keeping experienced constructors, to speed the construction process. Therefore it is necessary to let go of the idea of getting constructors from the local town and should MpfunekoCS look for constructors that live within travel distance from the town where MpfunekoCS is constructing.

8.1 Long-time postponing of construction activities

In the town Gawula, where some digesters are under construction,but the work has been postponed for quite some time. The result of this postponing is that extra tasks will occur, like extra inspection, pumping out water and cleaning the digesters for waxing. This means that the construction process will be extended. This also means that extra resources (labour) and costs are needed for these digesters. This could be avoided by first completing a digester and then starting with the next one.

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[3] (Cemcrete, 2012)

[4] (rawlinspaints, 2008)

[5] (The BSS group, 2014)

9. Conclusions and recommendations

9.1 Conclusions

Two scenarios for the construction work are examined in this report. A scenario where every task is done by one team (digging constructing and piping), and a scenario where different specialized teams work on a digester. According the AON network, the constructing process will be shortened with one day if a team approach is chosen. Also, some flexibility in executing the task will appear. But working in teams makes it also more difficult to plan the construction task and due to a gang size problem it is not possible to use all the teams efficiently. Although, this has no financial consequences for MpfunekoCS, because the employees are paid for the task done and not for the time worked. This is not a preferable situation. In an optimum situation the duration for the team approach is fifteen days without the waxing.

With the second scenario, the single approach one team does all the work. This means that the total construction time (excluding the waxing) in an optimum is sixteen days. A down side of the single approach is that there is almost no flexibility in the network and that all employees need to be skilled with skills for digging, constructing and piping.

There is a broad spectrum of risks for the construction process of MpfunekoCS. Some of the most important risks are financial risk. Due to a cash flow problems of MpfunekoCS, delays in the construction process arise due to the inability of buying materials and paying the workers.

To be able to manage most risks it could be useful for MpfunekoCS to work using the single responsibility approach as discussed in this report. This will make planning and controlling the project easier by on managing the risks.

For future project MpfunekoCS should use simple planning techniques like Network planning and a Bar chart. To use other techniques there is not enough reliable data within MpfunekoCS to get a benefit from those other techniques. Also a single construction team could be more useful than working with different times for different construction activities, the single teams fit better with planning techniques like a network planning and a bar chart, and the use of a single team will have lower risks than using specialized teams for different construction activities. Therefor a Bar chart planning based on the single approach from the WBS should be sufficient for panning future projects.

9.2 Recommendations

MpfunekoCS Works on a number of different sites, but not always completes a site before starting with the next site. To make planning easier MpfunekoCS could complete a digester (except waxing) before starting on another site. This will make planning and controlling easier and also make the constructing process safer. By completing a site before starting on a new site the risks of accidents on the construction site will be reduced, in particular the backfilling should be done before leaving a construction site to increase the safety.

9.2.1 Improving the estimation of activity duration

It is possible to improve the analysis of activity duration and the risks. This can be done by the MpfunekoCS office department by monitoring the durations and risks. The durations of all the activities shown in the network should be recorded. If there is a delay the reason of the delay also should be recorded.

If the durations are properly recorded it is possible to get detailed information about the construction time and it is possible to estimate the durations more accurately. The more details in the administration of the duration, the more accurately the estimations are. Mpfuneko should also record the duration of the working days. With the combination of a detailed administration of the activity duration and the working hours it should be possible to estimate the activity duration in hours instead of days. Therefore further optimization of the network is possible.

Also, by recording the reasons of the delays from the real situation it will be possible to link risks to delays. With this information the risk analysis could be more detailed and actions to manage the risks could be more effective

New estimations of the activity durations and the risks could be made based on the new data. If MpfunekoCS collects the data for two or three years an improved assessment could be possible

9.3 Possibilities for further research

To construct biogas digesters faster or with a better quality MpfunekoCS could carry out a study in using different constructing materials for constructing the fixed dome digesters, using prefab parts like a prefab dome for the digesters or constructing different types of biogas digesters like a floating dome digester.

For MpfunekoCS it may also be of value to carry out research to improve the training of the constructors. This could improve the quality of the construction work and could reduce some of the identified risks.

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Appendix I: Activities and dependents

In Table 11 the activity and their dependence are summarized. These dependencies form the basic relations for the network diagram.

Table 11: Activities and dependence

Activity	Description	Dependence
Contract signed	starting point for the building process	Non
Site assessment and selecting location on site and demarcation	Selecting location and filling in site assessment form. Demarcation for the digging	Contract signed
Digging pit	Digging the pit according to the demarcation and drawings	Demarcation
Pouring floor	Pouring de flour for de digesters (foundation on steel)	Digging pit
Constructing the dome	dome constructing the dome by laying bricks	Pouring floor
Plastering dome	Plastering the inside of the dome	Constructing dome
Constructing outlet	Constructing the outlet by laying bricks	Constructing dome
Constructing inlet	Constructing the outlet by laying bricks	Constructing dome
Constructing case	Constructing case	Installing pipeline
Plastering outlet	Plastering of the outlet	Constructing outlet
Plastering inlet	Plastering of the inlet	Constructing inlet
Plastering case	Plastering of the case	Constructing case
Waxing	Waxing of the inside of the dome	Plastering dome
Making slabs	Making fitting slabs	Constructing inlet Constructing outlet Constructing case
Digging trench	Digging the trance for the gas pipe	Site assessment
Installing pipeline and stove	Installing pipeline	Construction dome Digging trance
Backfilling:	Backfilling the excavated area around the dome	Plastering case Plastering inlet Plastering outlet Plastering dome
Testing:	Testing the digester for gas and water proofing	Backfilling waxing Making slabs
In use: The digester is ready to use	Actual use of the digester	Testing

Appendix II: Estimation of activities duration

In Table 12 the time estimation for construction a small single digester ($6m^3$) is given. The different sources of data are showed. The outcome of the table suggest an optimum possible construction site.

Table 12: Estimation of activities duration[6]

Activity	Interview	Observation/Management/ Estimation
Contract signed	Starting point	Starting point
Site assessment and selecting location on site and demarcation	-	1 hour
Digging pit	4 (3.5) days	4
Pouring floor	1 (2 day drying) day	1 (2 day drying) day
Constructing the dome	4 days	3 days
Plastering dome	1 day	1 (2 day drying) day
Constructing outlet	½ day	½ day
Constructing inlet	½ day	½ day
Constructing case	1 day	½ day
Plastering outlet	1 day	½ (1 day drying) dag
Plastering inlet	1 day	½ (1 day drying) day
Plastering case	1 day	½ (1 day drying) day
Waxing		3 days
Making slabs		1 day
Digging trench		1 days
Installing pipeline and stove		1 day
Backfilling:		1 day
Testing:		-
In use: The digester is ready to use	-	-

[6] Round up to a complete days

Appendix III: Digging completion form

BIOGAS DIGESTERS Digging completion form

SHEET INFORMATION (To be completed by administration)

Date: ______________________________ Form follow-up number: ______________________

Name Household: ___________________ Number Household: __________________________

Village: ____________________________

CHECKLIST FOR SITE (to be completed the diggers)

Working with two people: Yes / No Need for Jack Hammer Yes / No

All the tools on site Yes / No Demarcation O.K.: Yes / No

DIGGING INFORMATION (to be completed the diggers)

Name: ____

How many pits did you dig before: 0, 1, 2, 3, 4, 5, more than 5

Type of digester: Big/Small

How many day did it take to dig the pit? __________________

How many hours did you work on one day? _______________

How many day did you work in one week? ________________

What kind of problems did you encounter while digging:

____

____

____

____

____

Remarks:

____

____

____

Digging completion form Version 1.0 28-05-2013

Appendix IV: Construction completion form

BIOGAS DIGESTERS Construction completion form

SHEET INFORMATION (To be completed by administration)

Date: ______________________________ Form follow-up number: ______________________

Name Household: ____________________ Number Household: __________________________

Village: ____________________________

CHECKLIST FOR SITE (to be completed the constructor)

Working with an assistant: Yes / No Digging O.K.: Yes / No

All the tools on site Yes / No

DIGGING INFORMATION (to be completed the constructor)

Name: ____

How many pits did you Construct before: 0, 1, 2, 3, 4, 5, more than 5

Type of digester: Big/Small

How many days did it take pour the floor? _________________________

How many days did it take to construct the dome? __________________

How many days did it take to plaster the dome? ____________________

How many days did it take to wax the dome? _______________________

How many days did it take to construct the Inlet? __________________

How many days did it take to construct the outlet? _________________

Did you construct the inlet and outlet on the same day: Yes/No

How many days did it take to plaster the Inlet? _____________________

How many days did it take to plaster the outlet? ____________________

Did you plaster the inlet and outlet on the same day: Yes/No

How many days did it take to build the case? _______________________

How many days did it take to plaster the case? ______________________

How many days did it take make the slab? __________________________

How many days did it take to dig the trance? ________________________

How many days did it take to install the gas pipes? ___________________

Construction completion form Version 1.0 28-05-2014 Page **1** of **2**

How many hours did you work on one day? ________________________

How many day did you work in one week? ________________________

What kind of problems did you encounter while constructing the digester?

____

____

____

____

____

Remarks:

____

____

____

SHEET INFORMATION (To be completed by administration)

Date: ______________________________ Form follow-up number: ______________________

Construction completion form Version 1.0 28-05-2014 Page **2** of **2**

Appendix V: General information of 6m³ digester

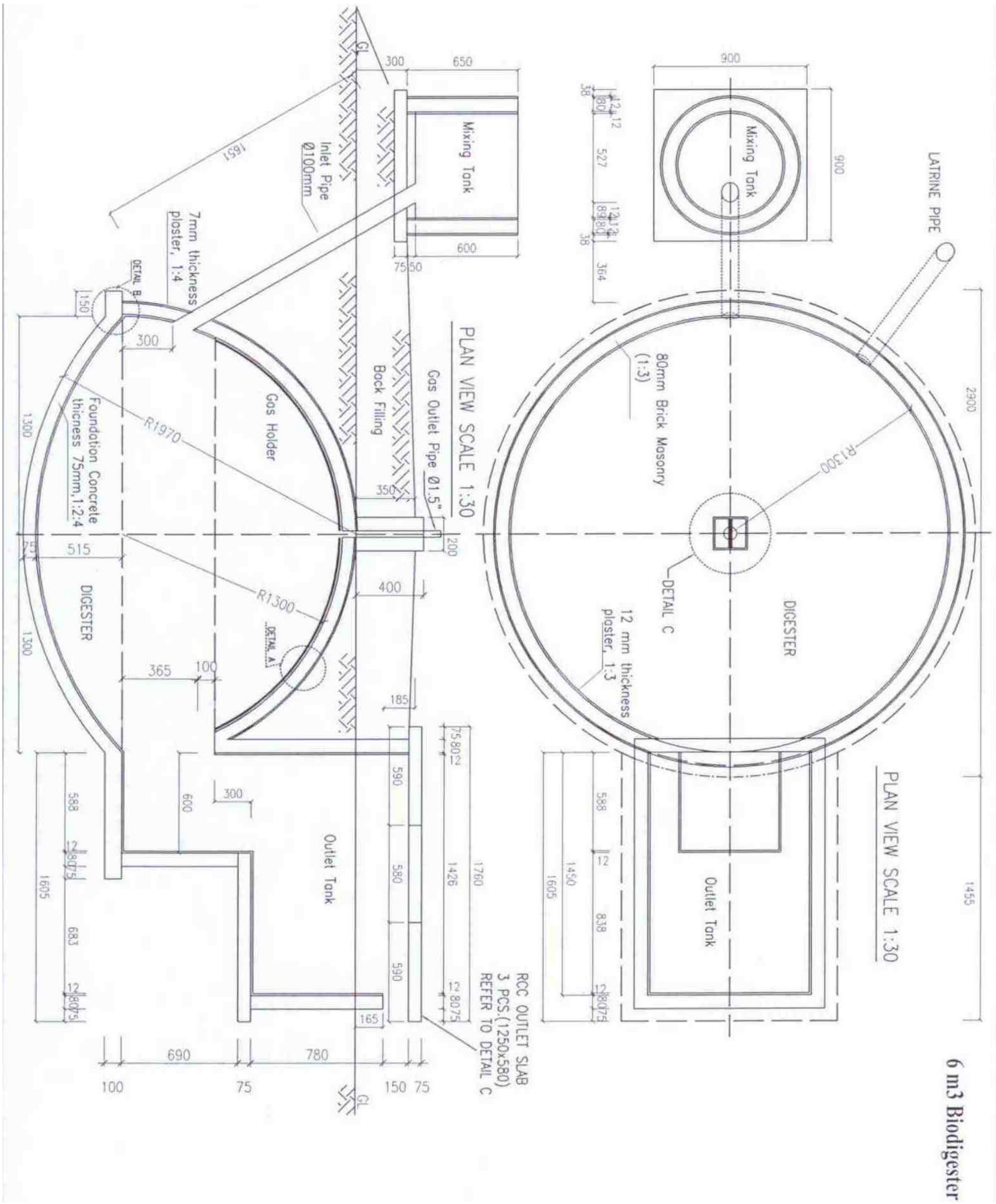

Figure 26: 6m³ digester

Table 13 indicates the materials used to construct a single digester.

Table 13: Materials

Material	$6m^3$ digester	$15m^3$ digester[7]	Possible deliverable quantity
Bousand	$3m^3$	$6m^3$	$6m^3$
Crough sand	$3m^3$	$6m^3$	$6m^3$
Cement	20 bags á 50 kg	50 bags á 50 kg	1 bag
Bricks	1100	5000	1
Weld mesh(6mm)	1/2 sheet	1 sheet	1 sheet
Gas Piping 3/4 Ginde	25	25	1
Gas Pipe Ginde Fitting	3	3	1
Stove + fittings	1	1	1
Water drains	1	1	1
Gas Piping 3/4 Galvanized	3m	3m	6m
Water proofing	25L	50L	1L
Round bar (8mm)	1	1	6m
Water	-	-	-
Electricity	On side	On side	On side

[7] Based on a connection to a single household

Appendix VI: Excavation volume

The total excavation that is needed for the digester is shown in Table 15. The excavation is calculated as a sum of different parts of the digester that are below ground level. In Figure 27 the different parts for the calculation are showed. The formulas where the calculations are based on are shown in table 14.

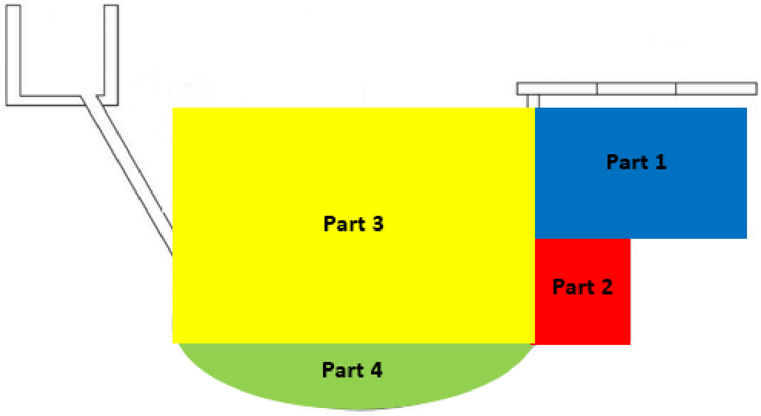

Figure 27: Parts for calculating the volume for excavating

Table 14: formulas for calculating the volume

Form	Formula
Rectangle	$h * b * d$
Cylinder	$\pi * r^2 * h$
Part of globe[8]	${}^1/_3 * \pi * h^2 * (3R - h)$

Table 15: excavation 6m^3 digester

	h (mm)	w (m)	d (mm)	r (mm)	volume mm³	Volume m³
Part 1 (rectangle)	690	1455	1500		1505925000	1,505925
Part 2 (rectangle)	790	800	700		442400000	0,4424
Part 3 (cylinder)	1400			1450	9247277976	9,247278
Part 4 Part of globe	590			1970	1939296767	1,939297
Total						13,1349

A 6m^3 digester could be excavated in four working days by a team of two diggers based on an eight hour working day. This means a worker could approximately dig 13,13 / (2*4*8) =0. 21m^3 an hour. With the excavation time an hour should be mentioned that this is an average and the digging speed declines when the pit becomes deeper.

[8] (Hofstede, n.d.)

Appendix VII: Risk identification

Table 16 shows the identified risk for constructing a digester. Also, the activity that is influenced by the risk, the source and the risk category are included in table 16.

Table 16: Risk identification

Nr.	Risk	Activity	Source	Category
1	Not enough finial means to pay the workers	General	Management	Financial
2	Not enough finial means to pay for materials	General	Management	Financial
3	Not enough finial means to pay for tools	General	Management	Financial
4	Project shutdown by the Department of Labour	General	Management	Organization
5	Demarcation wrong	General	Management	Technical
6	A lot of rocks in the ground	Digging	Interview	Environment
7	Collapsing pit	Digging	Observation	Environment
8	Digging to deep	Digging	Observation	Technical
9	Digging not right according to measurements	Digging	Observation	Technical
10	Soil to close to the edge of the pit	Digging	Observation	Technical
11	Water in the pit	Digging	Observation	Environment
12	Tools are not on site	Digging	Other	Organizational
13	Not digging from ground level	Digging	Observation	Technical
14	Not enough craft sand	Constructing floor	Observation	Organizational
15	Not enough cement	Constructing floor	Observation	Organizational
16	Floor not thick enough	Constructing floor	Observation	Technical
17	Floor is cracking	Constructing floor	Management	Technical
18	Floor not in the right shape	Constructing floor	Observation	Technical
19	The shape of the dome is not right	Constructing dome	Observation	Technical
20	Not enough brick available	Constructing general	Observation	Technical
21	Not enough masonry sand	Constructing general	Observation	Technical
22	Cracks in plastering	Plastering	Observation	Technical
23	Plastering not thick enough	Plastering	Observation	Technical
24	Walls are not strait	Inlet, outlet, case	Observation	Technical
25	Outlet on the wrong side	Outlet	Observation	Technical
26	Outlet below ground level	Outlet	Observation	Technical
27	Outlet floor not level	Constructing floor	Observation	Technical
28	No water available near the constructing site	Constructing general	Management	Organizational
29	No water supplies in town	Constructing general	Observation	Technical
30	No diggers available	digging	Observation / Management	Organizational
31	No constructors available	Constructing general	Observation / Management	Organizational
32	Contract cancelled	General	Management	Organizational
33	Workers don't understand their tasks	General	Observation	Organizational
34	Workers are striking	General	Observation	Organizational
35	Stealing of tools or materials	General	Observation	Organizational
36	Shut down by local authorities	General	Observations	Organizational
37	Accidents of non-employees at the construction side	General	Observation	Organizational

38	No support of the community	General	Observation	Organizational
39	Change of demands from supporting organization	General	Observation	Organizational
40	No supporting ground layer	General	Management	Environment
41	Settling of digester	General	Management	Technical
42	No waxing due to the humidity	Waxing dome	Management	Environment
43	Workers are intimidate other personnel	General	Observation	Organizational
44	Workers leave without any notice	General	Observation	Organizational
45	Workers leave before the work is completed	General	Observation	Organizational
46	No materials for the gas pipe and stove	Gas pipe	Observation	Organizational
47	Not correct mixing of cement	Constructing general	Observation	Technical
48	Not correct mixing of concrete	Constructing general	Observation	Technical
49	No water on constructing site	Constructing general	Observation	Organizational
50	Workers don't start on time	General	Observation	Organizational
51	Digester damaged by external party	General	Management	Organizational
52	Extra training of unskilled ore difficult workers	General	Observation	Organizational
53	Project is stopped by the supporting organization	General	Observation	Organizational

Appendix VIII: Risk evaluation

The risk evaluation is based on the risk identification, the previous step in the risk analysis. The risk evaluations will use the list of identified risks in appendix VII. The risk evaluation is expressed in a high, medium and low risk. The risk evaluation category depend on the risk value of the multiplication of the change and the consequents of the risk. The change and consequence of the risk are scaled from 1 to 5. Risk values of 5 or lower are low risks, risks with a risk value between 5 and 12 are medium risks. Risks with a value from 12 of higher are high risks. The results of the risk evaluation are shown in table 17.

Table 17: Risk evaluation

Nr.	Risk	Change	Consequence	Risk value	Category	Risk carrier	Shared risk
1	Not enough finial means to pay the workers	3	3	9	Medium	MpfunekoCS	No
2	Not enough finial means to pay for materials	3	4	12	High	MpfunekoCS	No
3	Not enough finial means to pay for tools	2	3	6	Medium	MpfunekoCS	No
4	Project shutdown by the Department of Labour	1	5	5	Low	MpfunekoCS	No
5	Demarcation wrong	2	2	4	Low	MpfunekoCS	No
6	A lot of rocks in the ground	4	3	12	High	MpfunekoCS	No
7	Collapsing pit	2	4	8	Medium	MpfunekoCS	No
8	Digging to deep	4	2	8	Medium	MpfunekoCS	No
9	Digging not right according to measurements	3	3	9	Medium	MpfunekoCS	No
10	Soil to close to the edge of the pit	4	3	12	High	MpfunekoCS	No
11	Water in the pit	2	2	4	Low	MpfunekoCS	No
12	Tools are not on site	2	2	4	Low	MpfunekoCS	No
13	Not digging from ground level	3	2	6	Medium	MpfunekoCS	No
14	Not enough craft sand	3	4	12	High	MpfunekoCS	No
15	Not enough cement	3	4	12	High	MpfunekoCS	No
16	Floor not thick enough	2	3	6	Medium	MpfunekoCS	No
17	Floor is cracking	1	4	4	Low	MpfunekoCS	No
18	Floor not in the right shape	2	2	4	Low	MpfunekoCS	No
19	The shape of the dome is not right	2	2	4	Low	MpfunekoCS	No
20	Not enough brick available	3	4	12	High	MpfunekoCS	No
21	Not enough masonry sand	3	4	12	High	MpfunekoCS	No
22	Cracks in plastering	2	3	6	Medium	MpfunekoCS	No
23	Plastering not thick enough	2	3	6	Medium	MpfunekoCS	No
24	Walls are not strait	3	2	6	Medium	MpfunekoCS	No
25	Outlet on the wrong side	1	2	2	Low	MpfunekoCS	No
26	Outlet below ground level	2	2	4	Low	MpfunekoCS	No
27	Outlet floor not level	2	2	4	Low	MpfunekoCS	No
28	No water available near the constructing site	3	3	9	Medium	MpfunekoCS	No
29	No water supplies in town	2	4	8	Medium	MpfunekoCS	No
30	No diggers available	2	4	8	Medium	MpfunekoCS	No
31	No constructors available	3	4	12	High	MpfunekoCS	No

32	Contract cancelled	2	1	2	Low	MpfunekoCS	No
33	Workers don't understand their tasks	4	2	8	Medium	MpfunekoCS	No
34	Workers are striking	4	3	12	High	MpfunekoCS	No
35	Stealing of tools or materials	2	3	6	Medium	MpfunekoCS	No
36	Shut down by local authorities	2	4	8	Medium	MpfunekoCS	No
37	Accidents of non-employees at the construction side	1	5	5	Low	External/ MpfunekoCS	Yes
38	No support of the community	3	2	6	Medium	Supporting organization / MpfunekoCS	Yes
39	Change of demands from supporting organization	3	3	9	Medium	MpfunekoCS	No
40	No supporting ground layer	1	3	3	Low	MpfunekoCS	No
41	Settling of digester	1	3	3	Low	MpfunekoCS	No
42	No waxing due to the humidity	4	4	16	High	MpfunekoCS	No
43	Workers are intimidate other personnel	2	2	4	Low	MpfunekoCS	No
44	Workers leave without any notice	3	4	12	High	MpfunekoCS	No
45	Workers leave before the work is completed	3	3	9	Medium	MpfunekoCS	No
46	No materials for the gas pipe and stove	2	3	6	Medium	MpfunekoCS	No
47	Not correct mixing of cement	3	3	9	Medium	MpfunekoCS	No
48	Not correct mixing of concrete	3	3	9	Medium	MpfunekoCS	No
49	No water on constructing site	2	5	10	Medium	MpfunekoCS	No
50	Workers don't start on time	4	2	8	Medium	Worker / MpfunekoCS	Yes
51	Digester damaged by external party	2	3	6	Medium	External/ MpfunekoCS	No
52	Extra training of unskilled ore difficult workers	3	2	6	Medium	MpfunekoCS	No
53	Project is stopped by the supporting organization	2	5	10	Medium	Supporting organization / MpfunekoCS	Yes

Appendix IX: Risk Management

The risks from the risk evaluation should be managed. Possible actions to manage the risks are shown in table 18.

Table 18: Risk Management

Nr.	Risk	Category	Action	Description of action
1	Not enough finial means to pay the workers	Medium	Reducing	Create a financial buffer
2	Not enough finial means to pay for materials	High	Reducing	Create a financial buffer
3	Not enough finial means to pay for tools	Medium	Reducing	Create a financial buffer
4	Project shutdown by the Department of Labour	Low	Accepting	Supply all the workers with the necessary safety equipment and instructions
5	Demarcation wrong	Low	Reducing	Making standardized drawings and explanation cards for demarcation
6	A lot of rocks in the ground	High	Accepting	-
7	Collapsing pit	Medium	Reducing	Remove soil from the edge of the pit
8	Digging to deep	Medium	Reducing	Make drawings and work instructions for in toolsets
9	Digging not right according to measurements	Medium	Reducing	Make drawings and work instructions for in toolsets
10	Soil to close to the edge of the pit	High	Avoiding	Put a fine on placing soil to close to the edge
11	Water in the pit	Low	Accepting	-
12	Tools are not on site	Low	Avoiding	Make standardized toolsets for each task
13	Not digging from ground level	Medium	Reducing	Make drawings and work instructions for in toolsets
14	Not enough craft sand	High	Reducing	Create safety stock
15	Not enough cement	High	Reducing	Create safety stock
16	Floor not thick enough	Medium	Reducing	Make a measuring tool for thickness of the floor
17	Floor is cracking	Low	Reducing	Spray water against fast drying
18	Floor not in the right shape	Low	Reducing	Make drawings and work instructions for in toolsets
19	The shape of the dome is not right	Low	Reducing	Make drawings and work instructions for in toolsets
20	Not enough brick available	High	Reducing	Create safety stock
21	Not enough masonry sand	High	Reducing	Create safety stock
22	Cracks in plastering	Medium	Reducing	Spray water against fast drying
23	Plastering not thick enough	Medium	Reducing	Give clear instructions and training
24	Walls are not strait	Medium	Reducing	Give clear instructions and training
25	Outlet on the wrong side	Low	Avoiding	site assessment is only done by management
26	Outlet below ground level	Low	Reducing	Make drawings and work instructions for in toolsets
27	Outlet floor not level	Low	Reducing	Make drawings and work instructions for in toolsets
28	No water available near the constructing site	Medium	Accepting	-
29	No water supplies in town	Medium	Accepting	-

30	No diggers available	Medium	Reducing	Make a backup list of possible workers
31	No constructors available	High	Reducing	Make a backup list of possible workers
32	Contract cancelled	Low	Ignoring	-
33	Workers don't understand their tasks	Medium	Reducing	Make drawings and work instructions for in toolsets
34	Workers are striking	High	Accepting	-
35	Stealing of tools or materials	Medium	Accepting	-
36	Shut down by local authorities	Medium	Reducing	Give Progress report to local authorities
37	Accidents of non-employees at the construction side	Low	Ignoring	Demarcate constructions site with warning tape and put up a warning sign
38	No support of the community	Medium	Reducing	Give progress report to local authorities
39	Change of demands from supporting organization	Medium	Sharing	Change contracts with donor organization about financial consequents
40	No supporting ground layer	Low	Ignoring	Not the case on current locations
41	Settling of digester	Low	Ignoring	Not the case on current locations
42	No waxing due to the humidity	High	Accepting	Accepting until use of different technique to make the dome air thigh
43	Workers are intimidate other personnel	Low	Ignoring	-
44	Workers leave without any notice	High	Reducing	Make a payment premium for constructing multiple digesters
45	Workers leave before the work is completed	Medium	Reducing	Reduce payments for the work done with a fine
46	No materials for the gas pipe and stove	Medium	Reducing	Create safety stock
47	Not correct mixing of cement	Medium	Reducing	Mandatory training and instructions
48	Not correct mixing of concrete	Medium	Reducing	Mandatory training and instructions
49	No water on constructing site	Medium	Reducing	Put extra buckets in the toolsets that always need to be filled for a safety stock an site
50	Workers don't start on time	Medium	Accepting	Accepting because workers are played for the work done not for the hours they work
51	Digester damaged by external party	Medium	Accepting	-
52	Extra training of unskilled ore difficult workers	Medium	Accepting	-
53	Project is stopped by the supporting organization	Medium	Reducing	Consequent reporting to supporting organization

Appendix X: Enlarged version of AON network

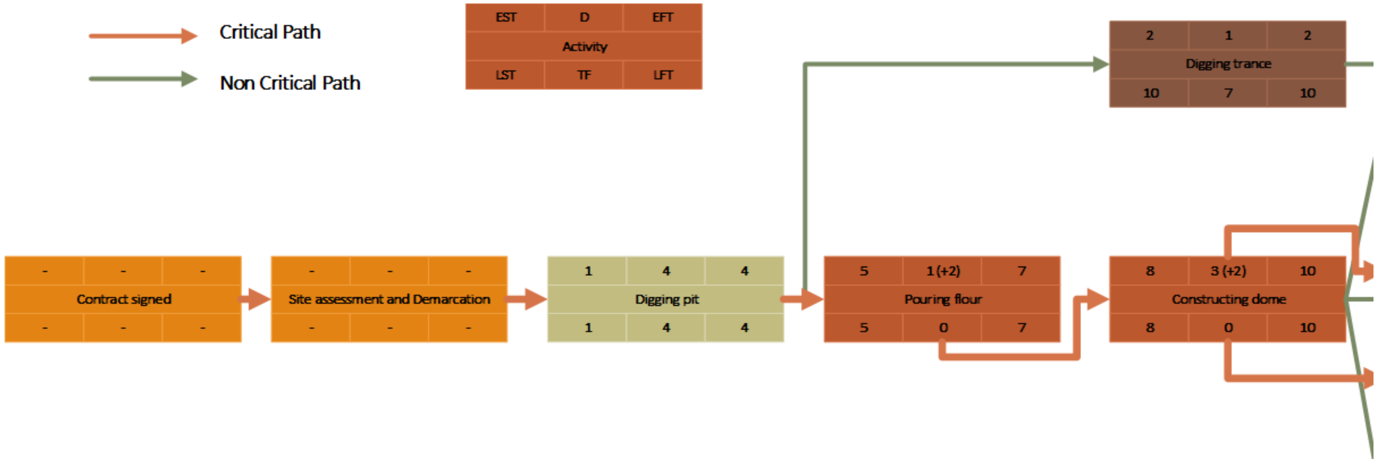

Figure 28: AON network diagram in theory part 1

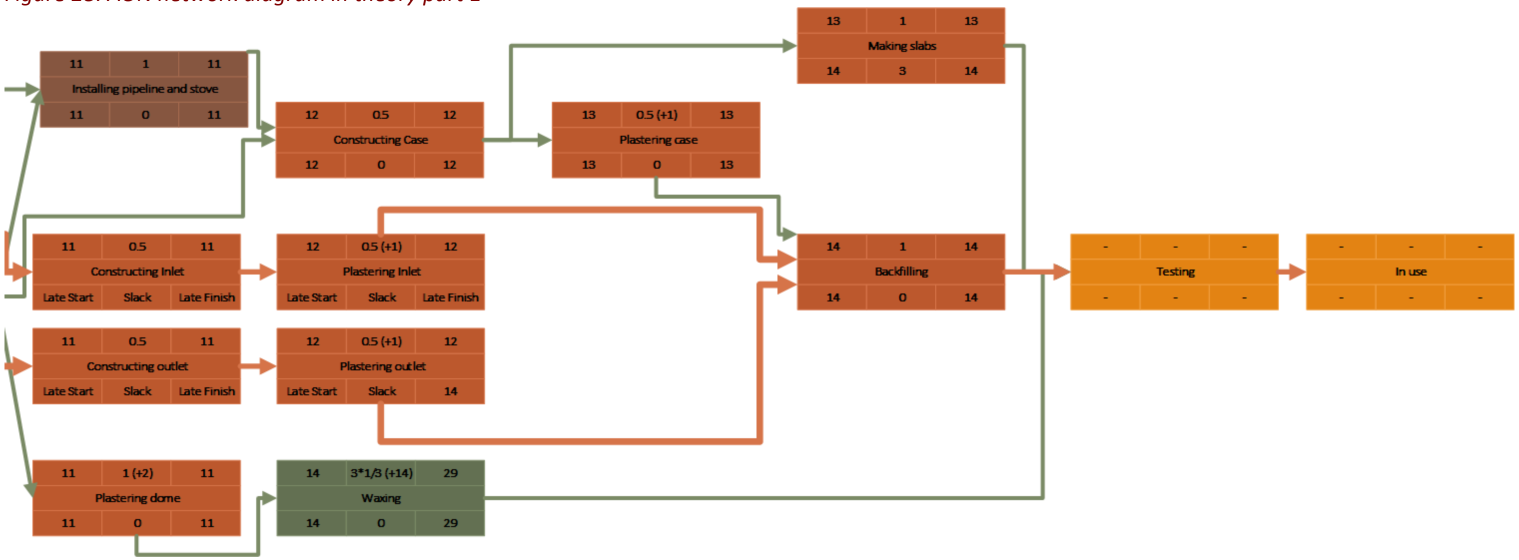

Figure 29: AON network diagram in theory part 2

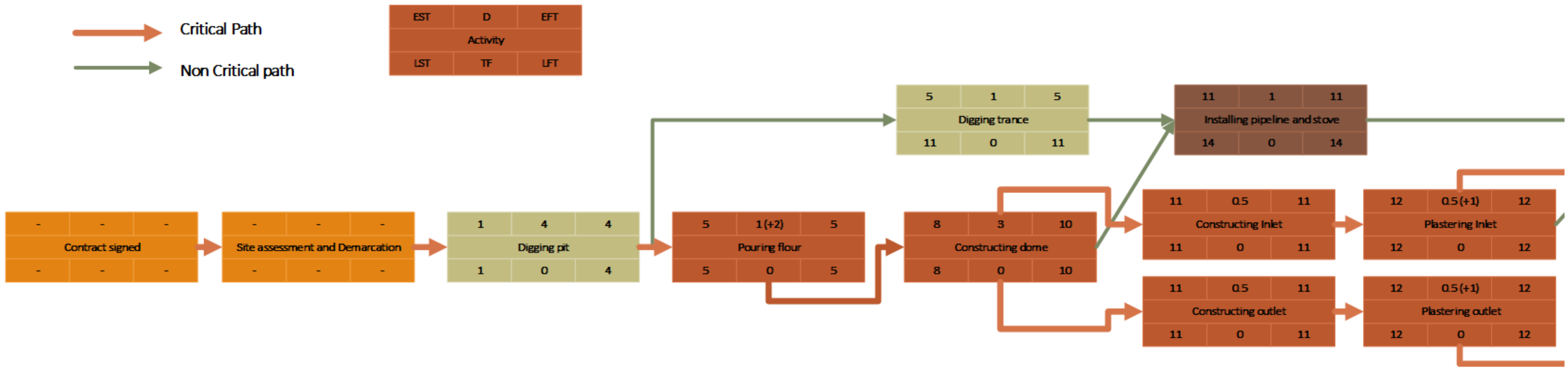

Figure 30: AON network realistic Team part 1

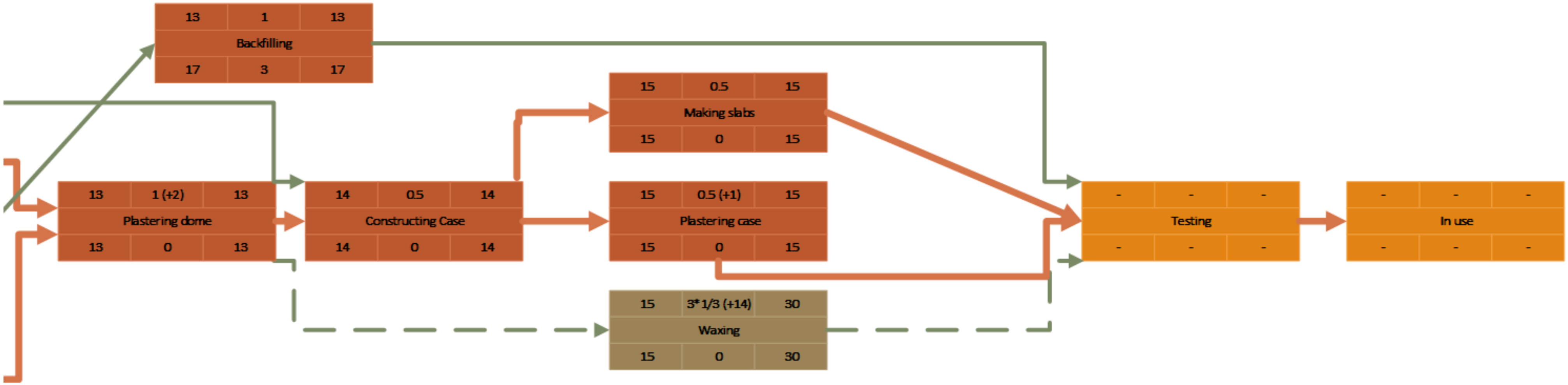

Figure 31: AON network realistic Team part 2

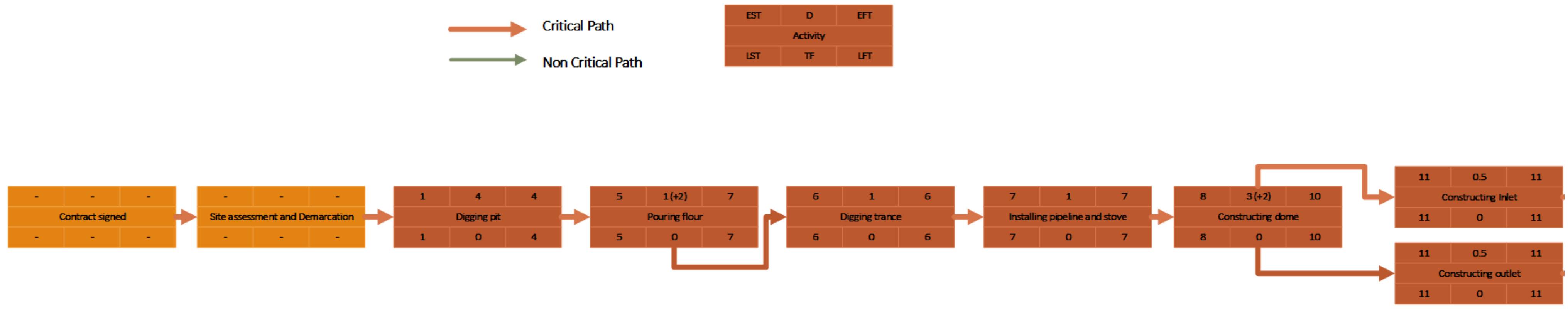

Figure 32: AON network realistic Single part 1

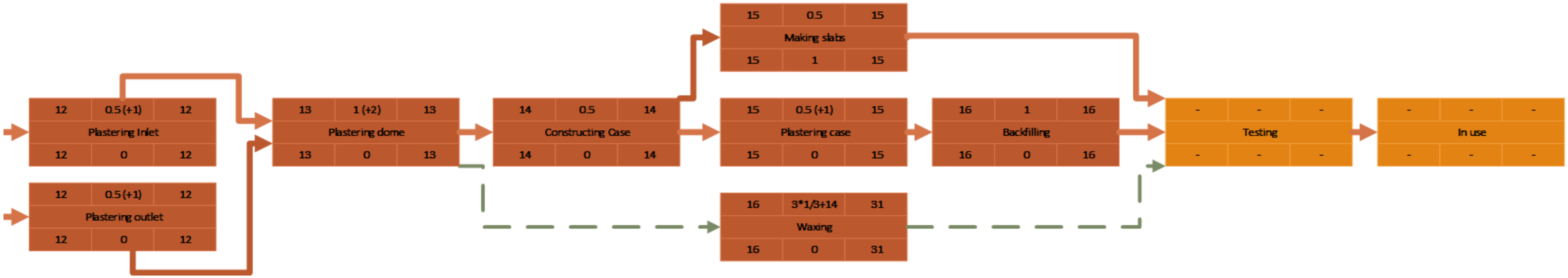

Figure 33: AON network realistic Single part 2

Appendix XI: PERT Network

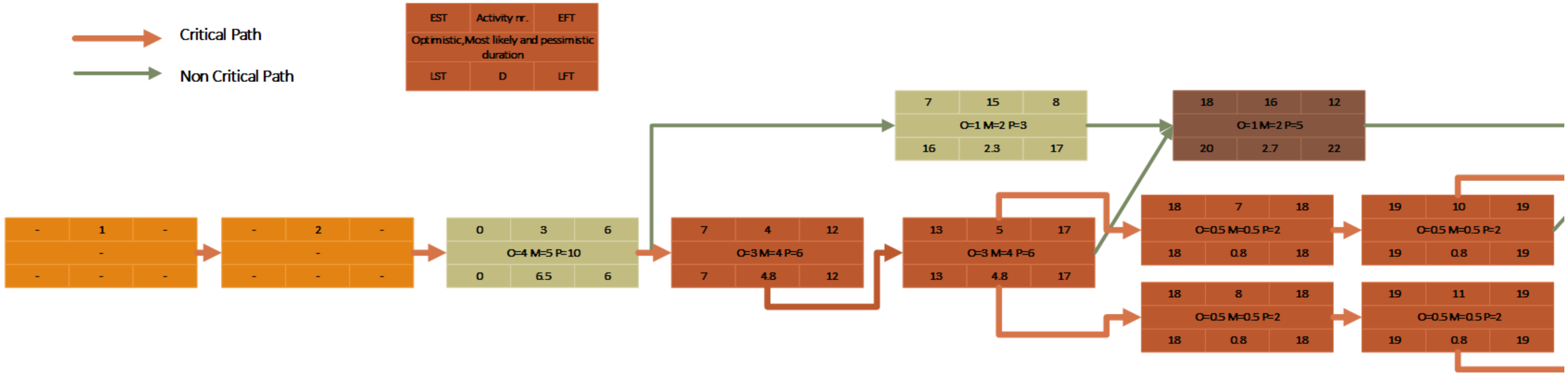

Figure 34: PERT network Team part 1

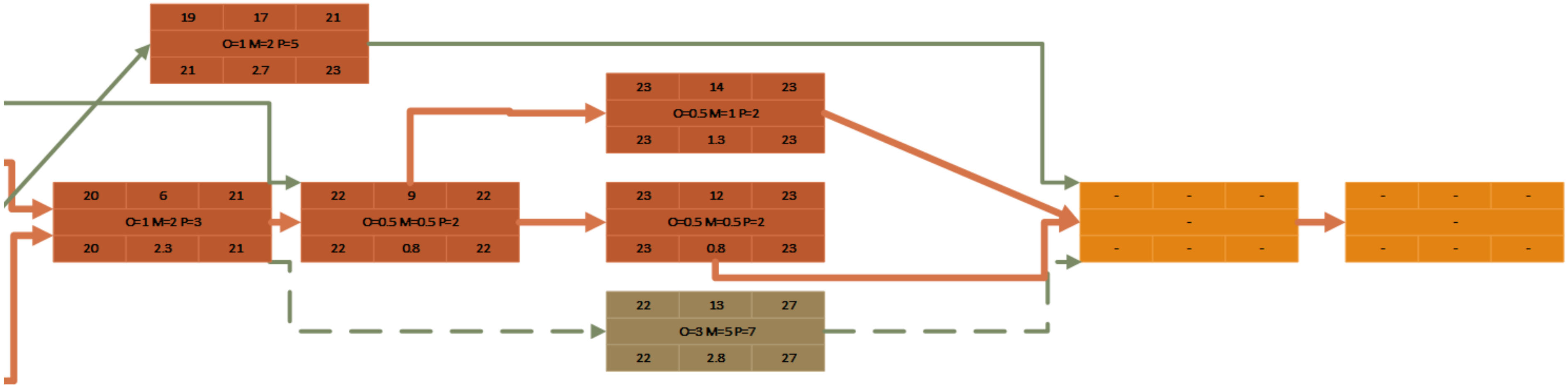

Figure 35: PERT network Team part 2

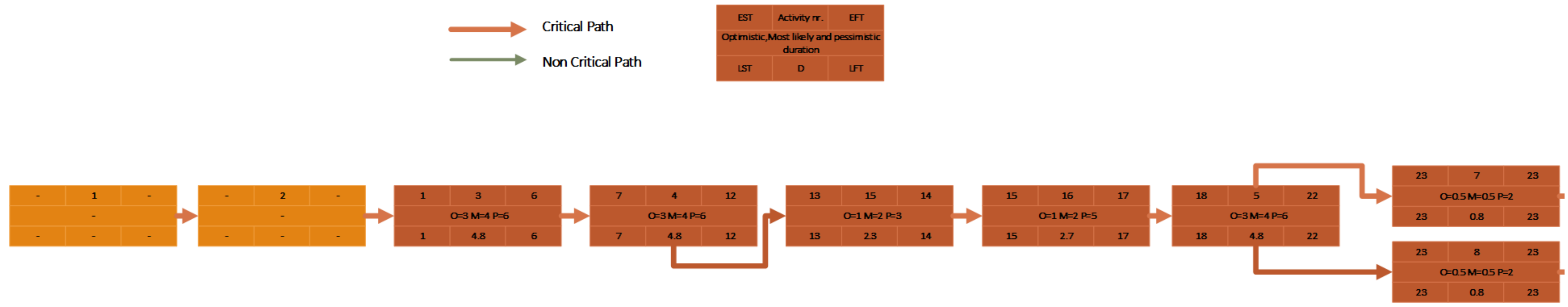

Figure 36: PERT network single part 1

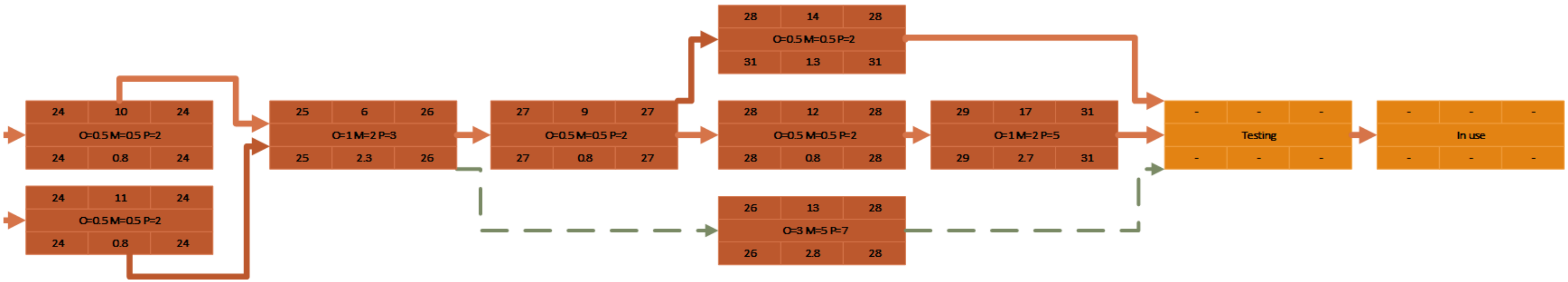

Figure 37: PERT network singe part 2

Appendix XII: Monte Carlo and critical path

There are different possible paths in the network. Not all of the paths have to be critical. With a Monte Carlo simulation it is possible to see how many times a certain paths is critical. For the realistic team AON network and the team PERT network the following paths occur.

- **Path 1**: Digging the pit → Digging the trench → installing the pipeline and stove → constructing case → Plastering case
- **Path 2**: Digging the pit → Digging the trench → installing the pipeline and stove → constructing case → Making slabs
- **Path 3:** Digging the pit → Pouring the floor → Constructing the dome → Constructing the inlet → Plastering the inlet → Plastering the dome → Constructing the case → Plastering the case
- **Path 4**: Digging the pit → Pouring the floor → Constructing the dome → Constructing the inlet → Plastering the inlet → Plastering the dome → Constructing the case → Making slabs
- **Path 5:** Digging the pit → Pouring the floor → Constructing the dome → Constructing the outlet → Plastering the outlet → Plastering the dome → Constructing the case → Plastering the case
- **Path 6:** Digging the pit → Pouring the floor → Constructing the dome → Constructing the outlet → Plastering the outlet → Plastering the dome → Constructing the case → Making slabs
- **Path 7:** Digging the pit → Constructing the dome → Constructing the inlet → Plastering the inlet → Backfilling
- **Path 8:** Digging the pit → Constructing the dome → Constructing the outlet → Plastering the outlet→ Backfilling

Because constructing the inlet and outlet could be done in one day and plastering the inlet and outlet could be done in one day, the paths 1,2, and the paths 3,4,5,6 and paths 7, 8 could be taken together be course they are nearly identical.

For the realistic single AON network and the single PERT network the following paths occur.

- **Path 1:** Digging the Pit → Pouring the floor → Digging the trance → Installing the pipeline and stove → Constructing the dome → Constructing the inlet→ Plastering the inlet → Plastering the dome → Constructing the case → Plastering case → Backfilling
- **Path 2:** Digging the Pit → Pouring the floor → Digging the trance → Installing the pipeline and stove → Constructing the dome → Constructing the inlet → Plastering the inlet → Plastering the dome → Constructing the case → Making slabs → Backfilling
- **Path 3:** Digging the Pit → Pouring the floor → Digging the trance → Installing the pipeline and stove → Constructing the dome → Constructing the outlet → Plastering the outlet → Plastering the dome → Constructing the case → Plastering case → Backfilling
- **Path 4**: Digging the Pit → Pouring the floor → Digging the trance → Installing the pipeline and stove → Constructing the dome → Constructing the outlet → Plastering the outlet → Plastering the dome → Constructing the case → Making slabs → Backfilling

Because constructing the inlet and outlet could be done in one day and plastering the inlet and outlet could be done in one day, the paths 1,2 and the paths 3,4 and could be taken together be course they are nearly identical.

With the realistic AON network from chapter 7.1 a Monte Carlo simulation is made in the computer program MATLAB. Based on the network and a simulation of 5000 runs the path that had the greatest length has been determent (the critical path). The results of this analysis is shown in table 19 and 20

Table 19: different paths becoming critical based on realistic Team AON network and PERT Team.

Path	AON		PERT	
	runs	Percentage	runs	Percentage
Path 1	4	0.08	0	0
Path 2	6	0.12	0	0
Path 3	1149	22.98	273	5.46
Path 4	1162	23.24	2190	43.8
Path 5	1187	23.74	305	6.1
Path 6	1174	23.48	2221	44.42
Path 7	152	3.04	6	0.12
Path 8	166	3.32	5	0.1
Path 1, 2*	10	0.2	0	0
Path 3,4,5 and 6*	4672	96.44	4989	99.78
Path 7 and 8*	318	3.36	11	0.22

Table 20: different paths becoming critical based on realistic Single AON network and Single Team

Path	AON		PERT	
	runs	Percentage	runs	Percentage
Path 1	1779	35.58	2468	49.36
Path 2	1827	36.54	2529	50.58
Path 3	690	12.80	1	0.02
Path 4	704	14.08	2	0.04
Path 1 and 2*	3626	73.12	4997	99.90
Path 3 and 4*	1394	26.88	3	0.06

In total the Monte Carlo simulationhas been done 3 times based on 5000, 10000 and 50000 runs. The runs are plotted in a graph. By competing the different analysis it is possible to conclude that there is no change in distribution between te different ammount of runs.

In figure 38 and 39 a visualtisationof the Monte Carlo analyzis is shown. The figures also show that the duration of the project, with taking the risks and uncertenties into acount, looks like a normal distrubaution. Also a histogram based on 5000 runs is shown.

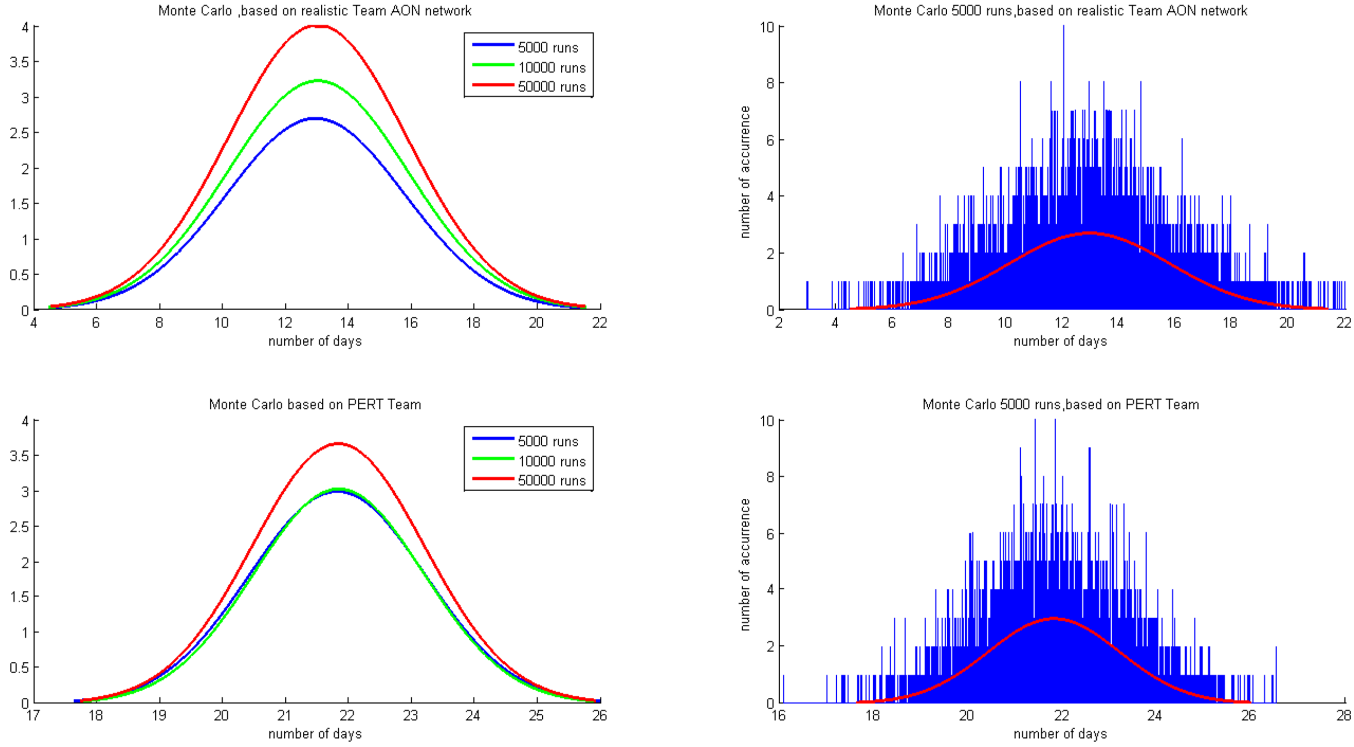

Figure 38: Monte Carlo analyses Team AON and Team PERT

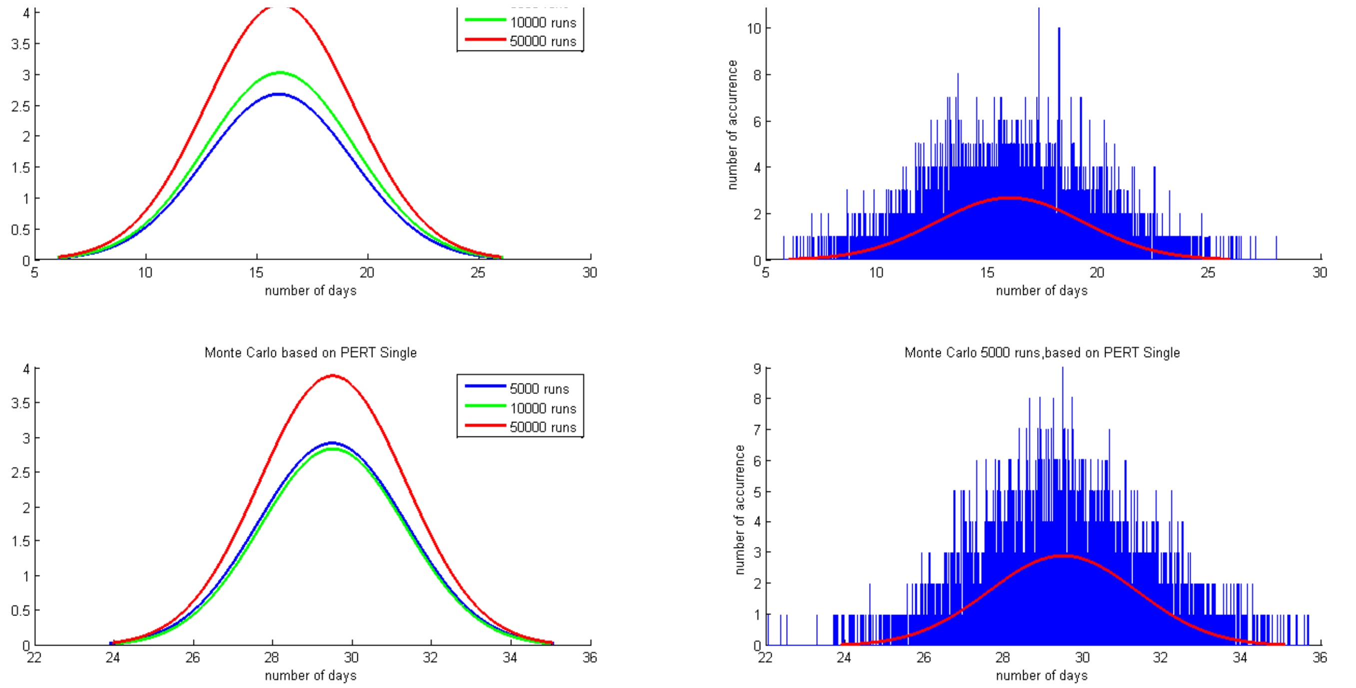

Figure 39: Monte Carlo analyses Single AON and Single PERT

Appendix XIII:Change of constructing one digester in time

In table 21 and 22 a complete overview of the changes of meeting a project deadline are shown.

Table 21: change of constructing digester in time based on PERT Team

Ts	deviation	Te	Z-score	P	%
12	1,868972	23	-5,89	1,98E-09	0,00
13	1,868972	23	-5,35	4,38E-08	0,00
14	1,868972	23	-4,82	7,34E-07	0,00
15	1,868972	23	-4,28	9,33E-06	0,00
16	1,868972	23	-3,75	9,01E-05	0,01
17	1,868972	23	-3,21	6,63E-04	0,07
18	1,868972	23	-2,68	3,73E-03	0,37
19	1,868972	23	-2,14	1,62E-02	1,62
20	1,868972	23	-1,61	5,42E-02	5,42
21	1,868972	23	-1,07	1,42E-01	14,23
22	1,868972	23	-0,54	2,96E-01	29,63
23	1,868972	23	0,00	5,00E-01	50,00
24	1,868972	23	0,54	7,04E-01	70,37
25	1,868972	23	1,07	8,58E-01	85,77
26	1,868972	23	1,61	9,46E-01	94,58
27	1,868972	23	2,14	9,84E-01	98,38
28	1,868972	23	2,68	9,96E-01	99,63
29	1,868972	23	3,21	9,99E-01	99,93
30	1,868972	23	3,75	1,00E+00	99,99
31	1,868972	23	4,28	1,00E+00	100,00
32	1,868972	23	4,82	1,00E+00	100,00
33	1,868972	23	5,35	1,00E+00	100,00
34	1,868972	23	5,89	1,00E+00	100,00
35	1,868972	23	6,42	1,00E+00	100,00
36	1,868972	23	6,96	1,00E+00	100,00
37	1,868972	23	7,49	1,00E+00	100,00
38	1,868972	23	8,03	1,00E+00	100,00
39	1,868972	23	8,56	1,00E+00	100,00
40	1,868972	23	9,10	1,00E+00	100,00

Table 22: change of constructing digester in time based on PERT Team

Ts	deviation	Te	Z-score	P	%
12	1,868972	25	-6,96	1,75E-12	0,00
13	1,868972	25	-6,42	6,79E-11	0,00
14	1,868972	25	-5,89	1,98E-09	0,00
15	1,868972	25	-5,35	4,38E-08	0,00
16	1,868972	25	-4,82	7,34E-07	0,00
17	1,868972	25	-4,28	9,33E-06	0,00
18	1,868972	25	-3,75	9,01E-05	0,01
19	1,868972	25	-3,21	6,63E-04	0,07
20	1,868972	25	-2,68	3,73E-03	0,37
21	1,868972	25	-2,14	1,62E-02	1,62
22	1,868972	25	-1,61	5,42E-02	5,42
23	1,868972	25	-1,07	1,42E-01	14,23
24	1,868972	25	-0,54	2,96E-01	29,63
25	1,868972	25	0,00	5,00E-01	50,00
26	1,868972	25	0,54	7,04E-01	70,37
27	1,868972	25	1,07	8,58E-01	85,77
28	1,868972	25	1,61	9,46E-01	94,58
29	1,868972	25	2,14	9,84E-01	98,38
30	1,868972	25	2,68	9,96E-01	99,63
31	1,868972	25	3,21	9,99E-01	99,93
32	1,868972	25	3,75	1,00E+00	99,99
33	1,868972	25	4,28	1,00E+00	100,00
34	1,868972	25	4,82	1,00E+00	100,00
35	1,868972	25	5,35	1,00E+00	100,00
36	1,868972	25	5,89	1,00E+00	100,00
37	1,868972	25	6,42	1,00E+00	100,00
38	1,868972	25	6,96	1,00E+00	100,00
39	1,868972	25	7,49	1,00E+00	100,00
40	1,868972	25	8,03	1,00E+00	100,00

Appendix XIV: Toolsets for digging

MPFUNEKOCS

Tools form

Digging

Side name: ______________________		Town: ______________	Side nr. ____________
Name diggers 1.______________________________ Name diggers 2.______________________________			Signature 1.__________ Signature 2.__________
Tools In Yes/No	Date: ______	Name manager:______________	Signature: ___________

NR	QTY	Tool	In	Out
1	2	Pics		
2	2	Spates		
3	2	shovel		
4	1	Level		
5	1	Fish line		
6	1	Measuring tape		
7	1	Drawings for digging		
8	1	Work instructions for digging		
9	1	Telephone list		
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				

Tools In Yes/No	Date: ______	Name manager:______________	Signature: ___________

Tools form digging V1.0

Figure 40: Toolset digging

Appendix XV: Toolsets for construction

MPFUNEKOCS

Tools form

Constructing

Side name: ______________		Town: ______________	Side nr. ______________
Name constructor 1.______________ Name constructor 2.______________			Signature 1.______________ Signature 2.______________
Tools In Yes/No	Date: _______	Name manager:______________	Signature: ______________

NR	QTY	Tool	In	Out
1	1	Hand saw		
2	1	Bow saw		
3	1	Level		
4	2	Block brushers		
5	1	hammer		
6	1	Fish line		
7	1	Large measuring tape		
8	1	Handhuwk		
9	2	Float		
10	1	square		
11	1	sisal		
12	1	white tape		
13	1	Extension cord		
14	1	chisel		
15	1	Paint brush		
16	2	Building trowel		
17	2	Plastering towel		
18	1	Trowel cove		
19	1	spade		
20	1	pick		
21	1	wheelbarrow		
22	1	sieve		
23	1	shovel		
24	1	Set of s hooks		
25	2	Pieces of timber		
26	1	Round metal plate		
27	2	Small measuring tape		
28	1	Set of drawings for construction		
29	2	Large buckets		
30	1	Work instructions for construction		
31	1	Telephone list		
32	1	stamper		
33				
34				
35				

Tools In Yes/No	Date: _______	Name manager:______________	Signature: ______________

Tools form constructing V1.0

Figure 41: Toolset constructing

Appendix XVI: Toolsets for Demarcation

MPFUNEKOCS

Toolset Demarcation

Side name: ______________________________		Town: ____________________	Side nr. ________________
Tools In Yes/No	Date: _______	Name manager:___________________	Signature: ______________

NR	QTY	Tool	In	Out
1	8	Big demarcation pins		
2	8	Small border pins		
3	1	Roll of warning tape		
4	1	Warning sign		
5	1	Emergency telephonist for household		
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				

Tools In Yes/No	Date: _______	Name manager:___________________	Signature: ______________

Tools form demarcation V1.0

Figure 42: Toolset demarcation

Appendix XVII: Toolsets for Piping

Tools form

Piping

MPFUNEKOCS

Side name: ___________________________	Town: __________________	Side nr. _______________
Name constructor 1.____ Name constructor 2.____		Signature 1.____________ Signature 2.____________

Tools In Yes/No	Date: _______	Name manager:_________________	Signature: _____________

NR	QTY	Tool	In	Out
1	2	shifting		
2	1	Pliers		
3	1	Teflon tape		
4	1	Level		
5	1	Cutting tool		
6	1	Pipeline file		
7	1	Spade		
8	1	Measuring tape		
9	1	Drawings for constructing		
10	1	Work instructions for piping		
11	1	Telephone list		
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				

Tools In Yes/No	Date: _______	Name manager:_________________	Signature: _____________

Tools form Piping V1.0

Appendix XVIII: Toolsets Management and supervisor

MPFUNEKOCS

Management and supervisor toolset

Side name: ______________________	Town: ______________	Side nr. ____________

Tools In Yes/No	Date: ______	Name manager:______________	Signature: ___________

NR	QTY	Tool	In	Out
1	1	Long measuring tape		
2	1	Level		
3	1	Fish line		
4	1	Messaging stick		
5	1	Fish line		
6	1	Measuring tape		
7	1	Drawings for constructing		
8	1	Drawings for digging		
9	1	Work instructions for digging		
10	1	Work instructions for construction		
11	1	Telephone list		
12	1	Drawing for demarcation		
13	1	GPS device		
14		Empty site assessment forms		
15	1	rope		
16				
17				
18				
19				
20				
21				
22				

Tools In Yes/No	Date: ______	Name manager:______________	Signature: ___________

Tools form Management and supervisor V1.0

Figure 43: Toolset management and supervisor

Appendix XIX:Goals for the final bachelor assignment

Goals for the assignment from the perspective of the University of Twente and the student

Goals in the perspective of the study program Civil Engineering

The goals of the study program civil engineering for the final bachelor assignment are:

- The student will show that he has knowledge on aspects in the field of civil engineering, like planning/ management, modelling/ designing and is able to apply them and, if necessary, is able to widen and deepen the knowledge that is necessary for the final bachelor assignment.
- The student will show that he can work in a systematic way and is able to work in strategic way. The student will also show that he is able to report in an adequate way.
- The student will show that he has the communicative and reflective skills to function in a provisional civil engineering environment.

Having experience in the professional field of civil engineering and to find a point of interest for selecting a master track, are sub-goals of the final bachelor assignment.

Personal goals

With the final bachelor assignment I hope to finish the bachelor phase at the University of Twente. This final bachelor assignment will be the last part of my bachelor education at the University of Twente. My ambition is to complete this assignment with a good result.

The second personal goal is personal development. I hope to be able to work more independently after completing the assignment in South Africa. The biggest challenge here will be working in an environment and culture that is yet unknown to me.

The third personal goal is to explore the area of professional civil engineering. I hope to find re-assurance for my preliminary decision for a master track as continuation of my education by completing this assignment. When I have finished the final bachelor assignment I hope my choice for a master track will be permanent.

Appendix XX: Research method

After listing all the activities of the construction process (by observations and interviews) a WBS can be made. To get a workable planning for the construction of the biogas digesters all activities should be known. The construction process can be analysed by using a WBS. The relatively simple construction process of the digester makes it possible to make a WBS at the lowest detailed level (i.e. elements). This level of detail will be used to make the network diagram.

It is possible to make a network diagram with the activities described in the WBS. By making a network diagram (using the AON technique) the relationship between different activities is very important. Activities that depend on each other should be placed in a specific order.

To complete the AON network there is a need for data like an early start time, late start time, free float, etc. These data will fill in the blocks in the network in which every activity exists of one block. All the blocks together will form the network. This network is a description of the construction process. Within the AON network a critical path will appear. The critical path will show the shortest possible project time. The duration of the project could be only shortened by changing the critical path. It is even possible that a different critical path will appear after changes have been made. The critical path is not always the most dangerous path for the project. The critical path is the path with the biggest project time but it is possible that there is a different path with bigger risks involved. Delays on the critical path will cause delays in the project and should always be avoided. To avoid extending the project period, delays on non-critical paths should never extend the critical path.

The time spent on the activities of the construction process should be registered to get a clear view of the time spent on these activities. Such registrations will make it possible to estimate the time spent on activities (for example by using the mean). Possible delays could be described by the standard deviation.

For each activity the most imported risks should be indicated. To get a workable amount of risks for each activity the 3 to 5 most important risks will be selected. These risks should be managed and can be used to determine and explain delays in the construction process. The identification of the risks in the organization and the construction process will be done based on interviews and observations. If gathering data does not go well, it is also possible to organize brainstorm sessions. Different risks categories will be taken into account.

The categories construction and organization will be the most important for identifying the risks. Financial risks will only be taken into account when the financial risks endanger the continuity of the construction process.

Risks can be converted into delays using the PERT method. These delays will complete the data that are needed for the AON network so that the network can be optimized. The techniques that are used to optimize the network will be the CPM method and Resource-Based Scheduling. Also the amount of stock necessary will be calculated through an EOQ analysis (Chapman, 2001). Once the network analysis has been optimized it is possible to carry out the Line of Balance method.

Within this research project the focus will be on quality of construction materials, construction activities and stock management. The Line of Balance method will be applied to situation in which several teams are working on multiple locations. All with the goal to optimize the construction process and reduce the waste time in the construction process.

Eventually the network planning will be converted to a planning that is workable for all layers in the organization. A Bar cart is a method to make a simple overview of what has to happen, when it has to happen and in which order it has to happen. It will also give the critical path and an overview of possible delays in specific activities.

Figure 44 shows a mind map of the research method.

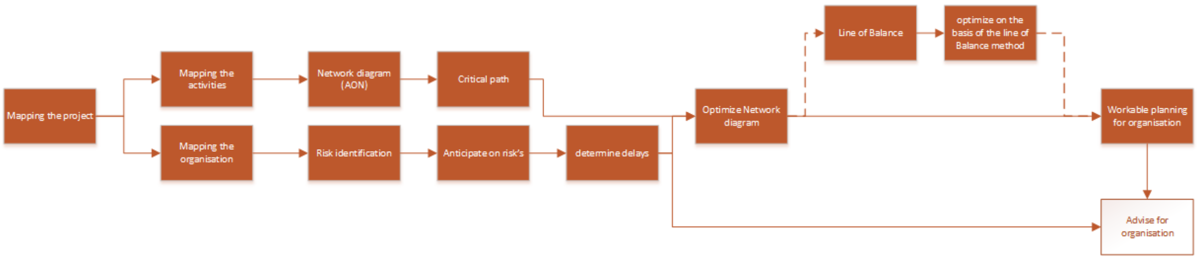

Figure 44: Mind map of research method

Appendix XXI:Theoretical background

To get a clear research method, a few useful techniques should be reviewed.

Listing the activities.

To get a clear understanding of the construction process, it is important to map all the activities of the construction process. This will include all the activities for the actual construction of the biogas digester itself, like digging, laying bricks, pouring concrete, etc. But also activities related to the construction itself like planning, ordering materials and making arrangements for permits. The activities will be analysed based on interviews and observations. After analysing the first activities a Work Breakdown Structure (WBS) can be made. It is possible that later on in the research project more activities will be identified. In that case the WBS can be changed.

Regarding the activities, there are a few important aspects, which are the duration of an activity, the type of activity, who is executing the activities, why the activity is executed, and what the relationship with other activities is.

Work breakdown structure

The first step is to disentangle the different activities. This is possible with a Work Breakdown Structure. With a WBS all the activities will be disentangled (AL-jibouri, 1998). It is possible to distinguish different levels of detail when a WBS is used. The activities will be disentangled up-to a certain level of detail depending on the characteristics of a project. A well know method for disentangling the activities is splitting the WBS into different elements (Ibrahim, Kaka, Aouad, & Kagioglou, 2008). A WBS is important for analysing a project, but even more important when projects are repeated. For projects that are repeated several times it is possible to make a standard WBS. It is possible to distinguish 5 different levels within a WBS.

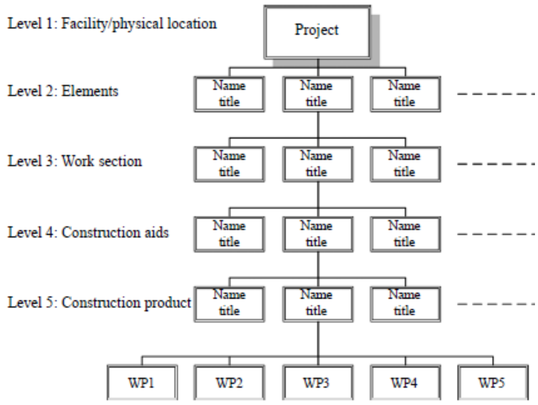

Figure 45: work Breakdown structure

Level 1: Facility/physical location (the complete project)
Level 2: Elements (project sections)
Level 3: Work section (sub-sections of the project)
Level 4: Construction aids (equipment and techniques)
Level 5: Construction product (construction elements)

The detail level of the WBS is depending on the complexity of the project.

Besides the WBS it is also possible to make an Organizational Breakdown Structure (OBS) and a Cost Breakdown Structure (CBS) (De Marco, 2011). An OBS will give an overview of the project's organization and can help by uncovering where the important decisions are made. The OBS and CBS are important by large-scale projects but less important for small simple projects.

Project planning

For making a project planning there is a variety of techniques. A couple of techniques are Matrix scheduling, Gantt Chart Scheduling (bar chart), Line-of-Balance scheduling, critical path method and Network Diagramming. For the Network Diagramming technique there are two widely spread techniques: Activity on Node and Activity on Arrow (AL-jibouri, 1998).

Activity on Arrow and Activity on Node networks

There are two well-known techniques for making a network diagram. The Activity on Arrow technique and the Activity on Node technique. Both are a form of network planning. In the Activity On Arrow (AOA) technique the arrow will represent the activities, while in the Activities On Node (AON) technique the blocks are representing the activities. (AL-jibouri, 1998). Another difference is the use of dummy activities by AOA (Kyunghwan, 2008). It is possible to create flexibility by using 'Hammock activities' in these network diagrams.

Figure 46: activity on node

There are two simple ways to fill in a network diagram, namely "the forward pass" and "the backward pass".

An important addition to a network diagram is the Critical Path Method (CPM). Delays on the critical path are very important. Delays on the critical path, like a shortage of materials, will immediately cause a project delays (Castro-Lacouture, Süer, Gonzalez-Joaqui, & Yates, 2009). The distinction between total float and free float is important when using CPM in combination with network diagramming (De Marco, 2011). Total float can be taken as the spare time on an activity, the consumption of which will affect the amount of float on both previous and subsequent jobs (AL-jibouri, 1998). Free float can be taken as the spare time on an activity which, provided that the previous activities have been carried out to plan (AL-jibouri, 1998). A more elaborated form of the CPM is the Precedence Diagramming Method (PDM). With this addition it is possible to take interactive relations into account (De Marco, 2011).

Bar chart

A bar chart is one of the most common methods used in project planning (AL-jibouri, 1998). A bar chart is a simple and clear technique to visualize a planning and is easy to understand and use in different layers of an organization.

Resource-Based Scheduling

In additions to the CPM it is necessary to find a balance between the total project time and the costs of the project. This is possible with a Time-Cost Schedule Optimization (De Marco, 2011). It is also possible to optimize for resources. But before resource-based scheduling is possible all the existing resources need to be classified. This is possible by distinguishing different types of resources such as labour, workspace, equipment, materials, sub-contractors and others (AL-jibouri, 1998). If necessary, types of resources can be further distinguished.

Line of Balance method

If there are multiple projects (i.e. construction sites), it is possible to use the Line of Balance Method. The Line of Balance Method is based on the network diagram (AON or AOA). This network diagram can be changed into a production diagram for one digester. It is also possible to make a delivery schedule for all the digesters. It is possible to check the number of activities that should have been finished by using control activities.

Risks and uncertainties

There are different uncertainties that are related to the duration of the activities, recourses and the order of the activities (AL-jibouri, 1998).

Dealing with risks can be divided in different steps (Lester, 2014).

- Risk Awareness
- Risk Identification
- Risk Assessment
- Risk Evaluation
- Risk Management

Risk Awareness: The awareness of risks in the project. The most important thing in this phase is that it is understood that there are risks involved.

Risk Identification: when searching for risks it is important that all the activities are taken into account. A WBS could be a good starting point for the risk identification. There are different methods for the identification of risks. For example brainstorm sessions, interviews, and comparisons with different projects, consulting experts or observations. The risks that are found can be divided into different categories, namely risks for the organization, risks for the environment, technical risks and financial risks.

Risk Assessment: In the assessment of risks there are two important aspects, namely the chance of the risk (high, medium or low) and the impact of the risk (big, medium or small). By processing the risks into a matrix it is possible to make a selection of risks (chance versus impact matrix). It is also possible to make an overview of risks according to a Risk Summary Chart. In addition to a description of the risk, chance and impact, it is also possible to include a risk carrier and a type of risk into a Risk Summary Chart. It is important to include all the relevant risks otherwise the risk assessment is not useful (Kutsch & Hall, 2010).

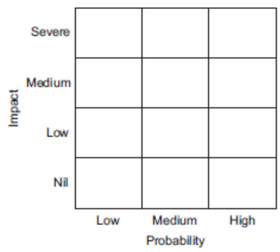

Figure 47: chance versus impact matrix

Risk Evaluation: Risk evaluation is possible with different techniques like exposure tables, matrices or diagrams. These methods will give an insight in the risks. It is also possible to combine different techniques for example by combining an exposure table with a frequency histogram.

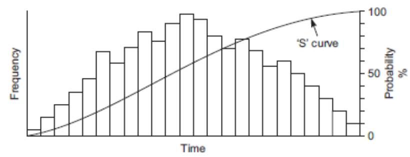

Figure 48: frequency histogram

Risk Management: Risks need to be managed after completion of the risk evaluation. A decision needs to be made about how the person exposed to a risk will deal with the risk. There are several options to deal with risks, namely avoiding the risk, sharing the risk, transferring the risk, spreading the risk, reducing the risk, insuring the risk or accepting the risk.

Risk monitoring: It is useful to make a register of the risks to keep control of the risks in future. In this way the organization will be able to discover new risks, changes in the frequency with which a risks results in an accident and changes in the consequences of accidents. Software tools like *Predict, Pandora* and *Plantrac Marshal* are available for monitoring risks. In general risks are seen as negative impacts for the project. But risks could have positive consequences like spin-off products.

A way to estimate the duration of activities is the PERT method (Program Evaluation and Review Technique) (Yum & Cho, 1997). With this method the duration of different activities can be estimated, taking the risks into account. It is also possible to use the back-forward uncertainty-estimation procedure (BFUE) method on Arrow method (Gong & Hugsted , 1993)

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Appendix XXIII: Curriculum Vitae

Personal details

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Email: r.pasman@student.utwente.nl
Date of birth: 16-03-1991
Place of birth: Utrecht
Nationality: Dutch
Linked-in: http://www.linkedin.com/profile/view?id=159309084&trk=tab_pro

Education

2011 – Current University of Twente
Bachelor of Civil Engineering
Minor Innovation and entrepreneurship

2010 – 2011 University of Twente
Mechanical Engineering

2004 – 2010 S.G. de Waerdenborch
Secondary Education: Preparatory Scientific Education
Completed in 2010

Employment

2009 – Current Company: LandalGreenparks
Position: Technical services
Responsibilities: Maintenance, projects and other activities.

2007 – 2009 Company: Mirta BV (McDonalds)
Position: Fastfood department
Responsibilities: kitchen, counter, coordinating kitchen activities.

Other activities

2010 -2011 Activities commission at W.S.G. Isaac Newton
Responsibilities: general member/public relations.

2011 -2012 Activities commission at Studievereniging Concept
Responsibilities: Chairperson.

2012 -current InterExcie, commission for research trips and lunch seminars at Studievereniging Concept
Responsibilities: general member.

2013 -current Symposium Commissie, commission for organising the event 'Innovation in management and maintenance – the future of civil engineering' on 19 March 2014.
Responsibilities: external relations.

Skills

- Being able to think and act in methodical and reflective manner Oriented at solving problems
- Social communication skills and competencies
- Aware of social responsibilities

Computer skills

- Microsoft Office: Excellent (including Visio and Projects)
- AutoCAD: Basic
- Solid works: Basic
- Photoshop: Basic

Languages

- Dutch: Excellent
- English: Good
- German: Basic