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IMPROVING CROSS-DISCIPLINARY INFORMATION EXCHANGE USING A CENTRAL PROJECT DATABASE

BACHELOR THESIS INDUSTRIAL ENGINEERING & MANAGEMENT

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Preface

This report is about my bachelor thesis, performed at ANT at Witteveen+Bos. This thesis completes my bachelor's study Industrial Engineering & Management at the University of Twente.

I want to thank Maarten Visser, my supervisor at Witteveen+Bos, for giving me this opportunity to develop myself in such an interesting project and providing me with such enthusiastic guidance.

I would also like to thank my University of Twente supervisor, Ipek Seyran Topan, for being such an involved supervisor who always went above and beyond to help me with my project.

Thomas Gielbert, 6-9-19

Management Summary

Introduction
Witteveen+Bos is a large international design and consultancy firm which aims to design large infrastructure, such as dikes, bridges and tunnels. The design process of such large products requires a multi-disciplinary approach, in which different teams use apply their specialized knowledge and perspectives to solve certain problems. These teams need to combine their knowledge to make optimal decisions and design a high-quality product.

ANT is a start-up within Witteveen+Bos which started a few years ago, after some employees realized that the information exchange between the teams is sub-optimal. This sub-optimal information exchange is caused by a lack of structure and method, which leads to miscommunications, ill-informed stakeholders and sub-optimal decisions. ANT thinks this problem can be solved with a central project database, which allows for more central and transparent information exchange and storage.

The aim of this study is to provide evidence that there are structural inefficiencies in the design process at Witteveen+Bos and that these problems can be solved with a central project database.

Approach
This study uses interviews with team members and team leaders to understand how the current design process functions. This analysis investigates what tasks the 4 main teams perform, the interaction with other teams & the client, and the communication channels used to exchange information. This analysis is visualized using a Business Process Model and Notation (BPMN) flowchart.

A literature study is performed on how Lean philosophy can be used for information management and minimizing information waste. Lean information management is applied to the design process at Witteveen+Bos, which identifies sources of information waste in the design process.

An analysis is done on how a central project database can help the design process at Witteveen+Bos, and what the requirements for such a database are, using a literature study and interviews. The improved process using a central project database is visualised using a BPMN flowchart. Additionally, the structure of the database is given.

The current process
Currently the design process experiences inefficiencies because there is a lack of structure in information exchange and storage. Team members use different communication channels that often do not allow for synchronous communication. This leads to ill-informed team members and makes it difficult to keep an overview on whether all stakeholders are well informed.

The improved process
A central project database will help centralize communication, which in turn makes communication more coordinated and transparent. This coordination makes it easier to make sure that everyone is well-informed and allows for project progress tracking.

The main requirement for the database is the use of active building components. These active building components will communicate design changes themselves, so that team members do not have to do this. This reduces the chance of miscommunications occurring. Active building components are established by determining links between different components and designers.

This study shows that the improved process has 25 data objects, compared to 61 data objects in the current process. This indicates a reduction in the number of files being shared and stored, reducing the chance of miscommunications occurring. Additionally, the message flows between teams is reduced from 61 to 43. This shows that a database will help centralize the communication channels being used, reducing miscommunication and creating more transparency.

Conclusions and recommendations

This study concludes that there are inefficiencies in the design-process at Witteveen+Bos. Most of these inefficiencies are caused by a lack of information-management, resulting in miscommunications between teams and loss of information value.

Information-management, in this case a database, will bring structure to the design-process at Witteveen+Bos and minimize efficiencies that are currently present. A big aspect of this database is active building components, which will mean that components themselves will communicate value changes, instead of designers having to do this. This reduces the chance of miscommunications occurring.

An important recommendation for Witteveen+Bos is to investigate how to properly implement such a central project database. This study focuses on the design and feasibility of the database, and shows that a database can help solve problems within the design-process. The implementation is however incredibly important, and still a relatively unknown area, which should be studied before taking action.

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Chapter 1: Introduction

This first chapter will discuss the problem that the company is experiencing and explains the approach of this study.

1.1 – Company description

ANT is a young start-up within Witteveen+Bos, a design and consultancy firm located in Deventer. 1.5 years ago ANT saw problems within the design process of Witteveen+Bos. The current design process uses reports and emails to exchange information. This can cause miscommunications and long waiting times. Through the use of a central database ANT wants to reduce the number of miscommunications, and the lead times of individual teams and the entire process.

1.2 – Problem description

Witteveen+Bos' design process consists of several different teams. These teams all have their own specialization. For example, the construction team's job is to make sure the constructions built are structurally sound: structures need to be strong enough to withstand certain requirements. All these teams have their own job in the entire process, but since these jobs are related to each other, communication between teams is required. The quality of the process is based on the quality of the individual teams, but just as much on the communication between these teams.

Proper cross-disciplinary communication is important for several reasons. The first reason is that since all teams work on the same final product, changes in one team affect other teams. For example, if the construction team decides to make the roof of the tunnel thicker for safety reasons, this changes the design of the tunnel itself, which is something the design team needs to know. Almost every decision or alteration made in the design process affects other teams. For this reason, clear communication on changes and decisions is vital for the efficiency of the process.

The second reason is that the decision making in the process is an iterative process. All teams must try to find the best solutions to their problems, but these solutions must work together as well. For example, the optimal solution for the construction team might be to make the road in a tunnel 4 meters wide. The road-design team might however consider 4.5 meters to be optimal. These 2 teams will then have to communicate to find a balance between these values. To make it more complicated, this also affects other aspects of the tunnel, such as the poles underground that support the road. The optimal dimensions for these poles are determined by another team, who then also needs to communicate what road dimensions would be best for them. Every decision and alteration made in the design process affects a lot of different teams. Since the optimal solutions for individual teams is not always the overall optimal solution, proper communication between teams is required.

The design process at Witteveen+Bos is designed in a "right on the first time" way. This means that, in an ideal world, every team individually does their research and then publishes their reports so that other teams can use the reports for their research, and in the end deliver the final product. The problem with this is that in reality, constant cross-disciplinary communication is required to make decisions, and to make sure that all teams are using the same, up-to-date, data. The design process is not a one-way street: there are constant loops of information exchange. The problem with this is that it makes the process prone to miscommunications. The constant changes of values, which are used by different teams, in combination with unclear communication can lead to different teams working with different values.

Another problem is that these communication loops can slow down decision making, and the design process as a whole. There are situations where the general solution might not be the optimal solution for individual teams. In these situations, teams can keep iterating, to try to reach the optimal solution that satisfies all teams. This does however increase the length of the design process, which is costly and inefficient. In these situations, it might be better to decide on a sub-optimal solution, to make sure the process does not get “stuck”. Overall, a balance needs to be found between the quality of the solution, and the speed of the decision making.

The problem with the current process is that there is no clear communication management. The ways of communications are different per teams, and the “amount” of communication that occurs is dependent on the individuals. This can result in miscommunications, use of incorrect information, information overload and a lengthy design process. Overall, the process is inefficient. With increasing external pressure from clients to design more complex products in shorter periods of time, the results of these inefficiencies are magnified.

Another inefficiency in the current process is that certain basic tasks need to be repeated for each project. The design for each product, for example tunnels, is different since each tunnel has different dimensions and requirements. There are however certain basic tasks in the design process of a tunnel that are present in the design of each tunnel. The specific dimensions of the tunnel might differ, but some tasks and calculations are done each time a tunnel is designed. The problem here is that these types of tasks can take up quite some time, even though they have already been done before with slightly different values. This means that some people in the current process spend quite some time doing tasks that could potentially be partially automated. This time could be spent more productively.

ANT wants to tackle these inefficiencies through the use of a central database, to which all teams have access. An advantage of this is that communication is clearer and more efficient. It is defined what information teams require of each other. Once a team has finished some calculations, they can publish their values in the database, where all other teams can see the available, up-to-date, values and use it as input for their work. This makes communication more transparent, since it is done through one central channel.

Another advantage of a database is that it allows for more parametric designs. This can reduce the amount of repetitive work. For example, in the design of a tunnel, it is expected that in the future the designers might want to experiment with the width of the tunnel. The tunnel width is then turned into a parameter, so that it can easily be altered in the future. Since it is a parameter, altering the width of the tunnel also affects the calculations done with this parameter. On top of this, parameters can be connected in the database. When the width of the tunnel is altered, the width of the roads on this tunnel needs to change too, as well as the calculations done with this parameter. This parametric design has multiple advantages. First of all, a parametric design allows for easier alterations of certain values and calculations. Secondly, it allows for re-use of certain calculations, reducing the amount of work spend on repetitive tasks. Another advantage is that through connecting parameters across teams, the amount of communication is reduced. As mentioned before, this can reduce miscommunications and information overload.

ANT has developed a database prototype and experimented with it in a project, which proved to be successful. This means that there are inefficiencies in the design process which can be improved. The problem is that ANT does not have “proof” of these inefficiencies. They know that they are present, but they do not know the specific causes. They want me to investigate the current process to determine the source of these inefficiencies and improve the process using a central database structure.

1.3 – Problem cluster

There are multiple causes that lead to the problem of the process being inefficient. These causes and their relations have been visualized in a problem cluster, which can be seen in figure 1. From this problem cluster, the core problem becomes clear: the design process is inefficient.

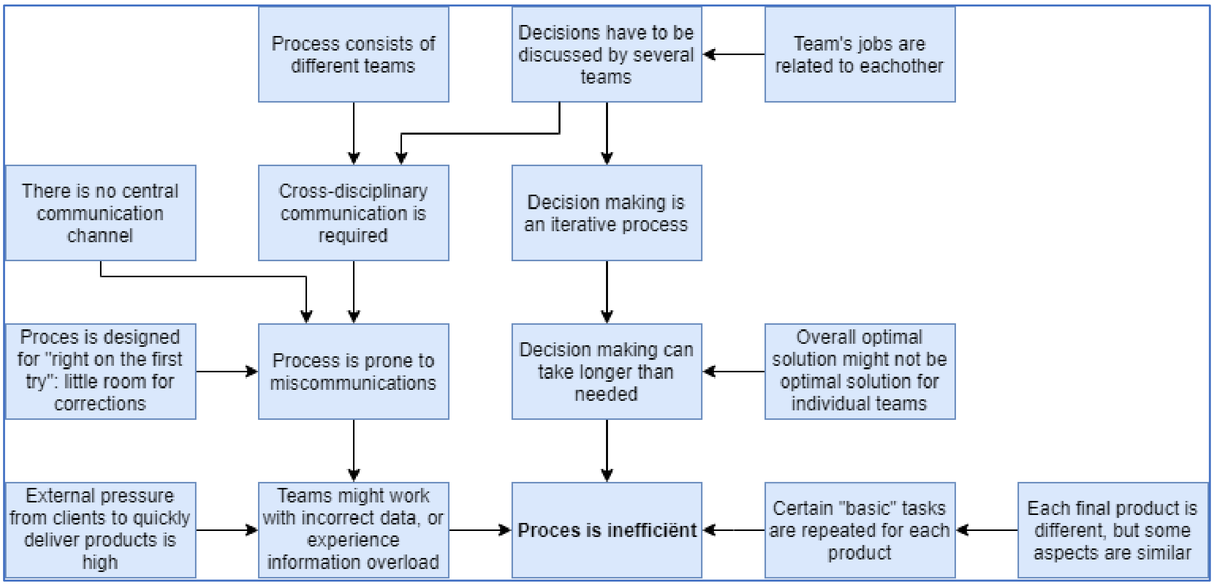

Figure 1: Problem cluster Witteveen+Bos

1.4 – Research objective

The goal of this research is to make the design process in Witteveen+Bos more efficient. This will be done by investigating the current process with focus on the teams involved, their tasks, and the relations between these teams. Additionally, it will be investigated how a database can bring improvements to the information exchange between teams, since this is the improvement to the design process proposed by ANT.

1.5 – Research motivation

ANT thinks that the design process can be made more efficient. The design process is quite traditional, but it works. The information exchange through reports and models is not very fast, but it guarantees quality, since they are checked by several actors in the process. However, because of growing external pressures and the technology becoming more accessible easier to use and, ANT believes it is time to innovate this process. The prototype has proven to be successful, which proves there is room for improvement in the current design process by restructuring the way information is exchanged between disciplines. This will lead to less miscommunication, which results in more productive labour. This can lead to the following advantages for Witteveen+Bos:

- Shorter lead times; since less time is spend waiting and correcting mistakes.
- Higher quality final products; less time is spent on tasks such as correcting mistakes and can be spend in a more productive way.

1.6 – Research questions

1) *How does the design process currently function?*
    a. *What teams are involved?*
    b. *What tasks are performed by each team?*
    c. *What are the interactions between the teams?*
    d. *How is information exchanged between the teams?*

This question will be solved by interviewing team members and team leaders. Through these interviews, a better insight is gained into how the design process functions, and why things are done the way they are done. The findings of these interviews will be analysed and visualised using a BPMN flowchart.

2) *What are the inefficiencies in the current process?*
    a. *What literature is available on information management?*
    b. *Can this literature be applied to the situation at Witteveen+Bos?*
    c. *How can these inefficiencies be observed in the current design process?*
    d. *What are the causes of these inefficiencies?*

Through literature study on lean philosophy applied to information management this question will be answered. Lean information management will give more insight into how waste occurs in information management and what the causes of these wastes are.

3) *How can the design process be improved?*
    a. *What are the advantages of a central project database?*
    b. *What literature is available on this subject?*
    c. *What are the requirements for such a central project database?*

This question will be answered using a combination of literature study and interviews. The literature study will help to determine what the advantages of a database are, as well as how it has been implemented in other cases and the requirements for such a database. Interviews will help determine what team members and team leaders within Witteveen+Bos require and expect of such a database.

4) *What will the new process look like?*
    a. *What changes will be caused by a database in the process?*
    b. *What are the results of these changes?*
    c. *What improvements do these changes bring?*

This will be answered by using the previous analyses to visualise the new process in a BPMN flowchart. This way, the current process can be compared to the new process. Using expert opinion, literature and the flowcharts, an indication of improvements can be established.

1.7 – Research scope

While investigating the current process, limitations have to be set. If I don't do this, I can spend months on determining all individuals involved in the process, and the tasks they perform. Additionally, the design process at Witteveen+Bos is highly flexible and differs for every project. For these reasons, I will look at the design process of a specific case, namely the design of a basic tunnels. The reason for this is that the design process of tunnels requires quite a lot of communication between teams, which is interesting for this study.

The complexity of the overall process is limited by looking at teams, instead of individual employees. These teams are employees with the same specialization or function. This study will only focus on the "main" teams at Witteveen+Bos in the design process of tunnels, which are the teams that require most interaction. This limitation is set because the design process of a tunnel requires a lot of different teams, some of which belong to external parties. As this study is mainly focused on investigating the information exchange between teams within Witteveen+Bos, only these internal main teams will be analysed.

A limitation of this study is that the process is difficult to measure. As the aim of this study is to improve the process through minimizing miscommunication, miscommunication needs to be measured. This is however very difficult as it is a very broad term, and communication intangible. Communication, such as the amount of emails and phone-calls could be measured, to indicate how much information exchange occurs within the design process. However, as stated before, this is highly personal, and not an objective indicator. Overall, as we are dealing with both human behaviour, which is very hard to objectively measure, and with information, which is intangible, the process is incredibly difficult to measure. For this reason, most of the proposed improvements will be based on literature and expert opinion from team members.

The current process will be analysed and the information exchange between teams will be improved using a database structure. This study will focus on the information exchange aspect of this database. A database can bring many more improvements into the process, such as automation, or possibly even artificial intelligence. This study will however focus on the information exchange aspect of the database.

This study will propose certain improvements to the design process at Witteveen+Bos, such as the use of a central project database. These proposed improvements are substantiated using literature and expert opinions. However, as the implementation of ICT (Information and Communication Technologies) can often be incredibly difficult as they can drastically affect the way employees perform their daily work, this study will leave the implementation up to the management of Witteveen+Bos, as they know best how the findings of this study can be applied to the organization. For this reason, the conclusions of this study will mainly be recommendations.

1.8 – Stakeholders

There are multiple parties involved that can benefit from an improved design process, or would be affected by it.

First of all, an improved process leads to more efficient use of company resources and thus a more productive company. This is beneficial towards Witteveen+Bos as a whole, and especially management.

Secondly, if the design process of Witteveen+Bos can be improved, it directly affects the internal employees that play a role in the design process. It will require them to adapt the way they work to the database

As mentioned before, Witteveen+Bos is not a "secluded" company. The design of infrastructure often involves multiple external parties that interact with each other a lot. Through this, changes within Witteveen+Bos might indirectly affect external parties involved in the design or execution of the design.

Lastly, an improvement within Witteveen+Bos directly affects their clients. If Witteveen+Bos manages to use their workforce more efficiently, this is beneficial for the quality of their final products, which of course is beneficial to their customers.

1.9 – Plan of approach

The current design process needs to be investigated. The teams involved need to be determined. Per team, the required inputs, the performed tasks, and the generated outputs need to be made clear. This will be done through interviews with team members that have overall knowledge on their team.

Once interviews have been performed with all relevant teams, the information gathered from these interviews needs to be analysed. As the goal of these interviews is to get more insight into how the current-design process functions, the information gained from the interviews will be turned into a flowchart. This flowchart will help visualize, and thus better understand, the current design process, the tasks per team, and the interaction between teams.

Once the current design process has been investigated and been visualized, the process needs to be optimized. A literature study on lean information management will be performed, to better understand the inefficiencies that are present in the current design process. Once the inefficiencies and their causes are made clear, a literature study on the concept of a central project database will be done, to better understand what the requirements for such a database are.

When the requirements of the central project database are made clear from the literature study, the design of the database will be discussed, and the new process will be visualized in a flowchart. This way, the new process can be compared to the current process in a simple, yet detailed way.

Finally, recommendations need to be done. The aim of this research is to optimize the design process at Witteveen+Bos using a database structure. Findings need to be presented to Witteveen+Bos in a clear way, so that they can see where problems lie, and potential improvements can be made. As previously mentioned, the implementation of the database is up to Witteveen+Bos' management, as they know better how such a database will affect their organization.

1.10 – Deliverables

Overview of the current process:

- What teams are involved?
- What tasks are performed per team?
- What are the relations between the teams?

Problems in the current process

- What is lean information management
- What types of waste occur in the design process at Witteveen+Bos?

Central project database

- What literature is available on central project databases
- What are the advantages of a central project database?
- What are the requirements for a central project database?

Improved process:

- What teams are involved?
- What tasks are performed per team?
- What are the relations between the teams?
- What are the changes compared to the current process?
- What improvements do these changes lead to?
- How much improvements do these changes lead to?

Conclusion and recommendations

- What are the problems in the current design process?
- How can these problems be solved?

1.11 – Thesis structure

This thesis will start with an analysis of the current design process within Witteveen+Bos in chapter 2. This analysis will look at what tasks the different teams perform, as well as the interaction between the teams. This analysis is visualised using a BPMN flowchart.

The third chapter will discuss the literature available on Lean Information Management, and how it can be used in the design process at Witteveen+Bos. The goal of this literature study is to find relevant theories and apply them to our specific situation.

In the fourth chapter, the proposed improvement to the design process will be explained. The choice for a central project database will be substantiated and some steps in designing the database will be discussed. On top of this, the new process using a central project database is visualised using a BPMN flowchart, so that it can be compared to the current design process.

The last chapter, chapter 5, will conclude the findings of this study. Additionally, limitations of this study will be discussed, as well as recommendations for future research.

Chapter 2: Analysis design process

This chapter will analyse how the design process is currently functioning. In section 2.1, the "full" design process will be discussed. The tasks performed by the 4 main teams will be analysed more in-depth in section 2.2. Section 2.3 will analyse the required inputs and produced outputs for per task for each team. In the next section, 2.4, the iterative design-cycle will be analysed. In the last section, 2.5, the communication channels used to exchange information between teams will be discussed.

2.1 – Process description

The analysis of the process is based on interviews. 4 team members from the Construction, Design, Road-Design and Geotechnics team were interviewed, and asked specific questions to get more insight into what tasks they perform and how these tasks are related to other disciplines. The questions asked in these interviews and a summary of the answers of the participants can be found in the appendices A, B, C & D.

The design process of Witteveen+Bos is highly variable and differs a lot depending on the final product. The reason for this is that each product designed is different. First, products can vary from tunnels to dikes. As these different products have different properties, they require different experts and specializations. Additionally, each client has specific requirements, the surrounding environments require a specific approach, and the design process itself involves several different external parties. Because of this, Witteveen+Bos is a project-based firm, defined as an organizational form "*that involves the creation of temporary systems for the performance of projects"* (Costa & Sobek Ii, 2003; Invernizzi, Locatelli, & Brookes, 2018, p. 729). This means that each project, or product, requires a different system or approach. In this specific case, this different system is a specific "composition" of experts.

To deal with these temporary systems, or compositions, Witteveen+Bos is built up from different teams, each with their own specialization. All these teams have their own responsibilities and expertise. Through the collaboration of these specialized teams, a proper final product is designed. This structure allows for more flexibility and customizability in the design process, as each project has a composition of teams best fit to the situation.

An example of a project is the design of a relatively basic tunnel. The sketch for this tunnel can be found in figure 2. A tunnel like this requires a specific composition of teams, as tunnels have different requirements than for example bridges. Some teams involved in the design of this basic tunnel are:

- The design team, who is responsible for the overall design of the model and drawings of the tunnel.
- The construction team, who is responsible for making sure the tunnel and road are solid and strong enough to support certain forces.
- The road-design team, who is responsible for determining the exact axes of the tunnel and road.
- The geotechnics team, who is responsible for determining the forces the ground exert on the tunnel & road, and the tunnel & road on the ground.

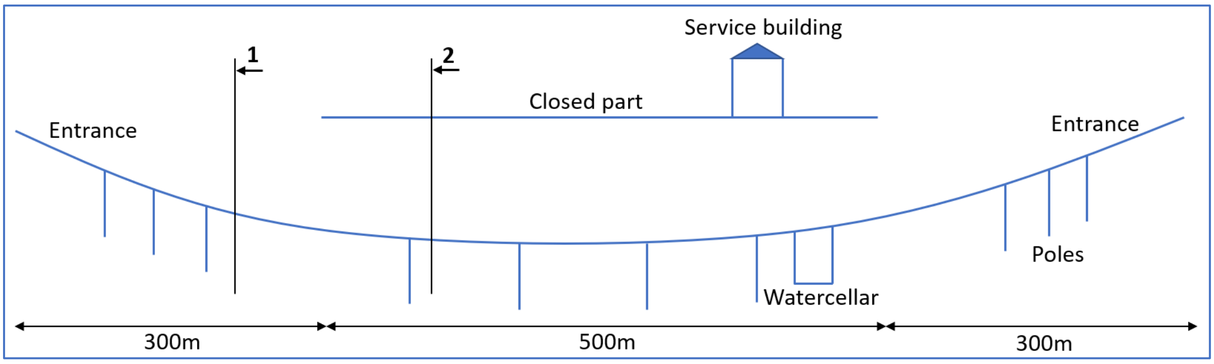

Figure 2: Basic tunnel sketch

Witteveen+Bos is a relatively large company with 20 offices in 11 different countries such as The Netherlands, Belgium, Singapore and Russia. Witteveen+Bos employs around 1.100 engineers and advisors. As projects are performed in offices and at worksites all around the Netherlands and abroad, geographic distances between teams are common. Additionally, teams are often working on several projects at the time, meaning there are temporal differences between teams as well.

Because of this, the teams can be considered, to a certain extent, to be virtual teams. Virtual teams are teams where *"one or more members of the team make some or all of their contributions from a different location and/or a different time zone and/or a different national culture than other members of the team"* (M. White, 2014, p. 111). These spatial and temporal boundaries are bridged using Information and Communication Technologies (ICT). However, teams within Witteveen+Bos do not only communicate using ICT: there are also occasions where teams are in the same office or at the same location. In these situations, teams can exchange information face-to-face in project meetings. For this reason, teams within Witteveen+Bos are best described as *hybrid* teams: a mix between virtual teams and face-to-face teams.

As each project requires the coordination of multiple teams to reach a high-quality final product, cooperation and coordination between these teams is vital. In the current design process, this information exchange is performed through different types of communication channels, mostly based on expertise and personal preference.

As mentioned before, the design process within Witteveen+Bos is highly volatile, and every project is different. To analyse the design process a specific case has been chosen, namely the design of a "basic" tunnel. The sketch for this basic tunnel can be found in figure 2. In this sketch 2 cross-sections are made, indicated with a 1 and a 2, which can be found in figures 3 and 4**.** This specific tunnel case was chosen after discussion with my supervisor and a team-leader on a large tunnel project near Rotterdam. With them the sketch for the tunnel was made, and the main teams to analyse were identified. Choosing a specific case instead of approaching the "general" design process allows for better analysis, as it gives us specific teams to work with, as well as a specific execution of the design process. Additionally, the design of tunnels often requires quite a lot of interaction between teams, which makes a tunnel case interesting for this study.

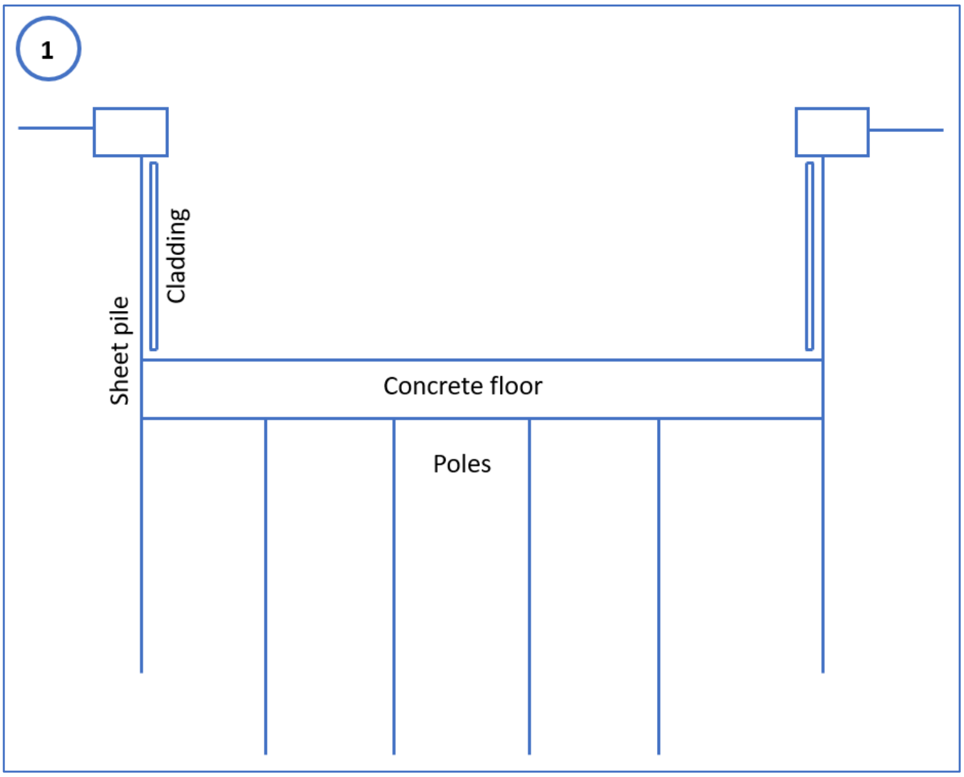

Figure 3: Tunnel cross-section 1

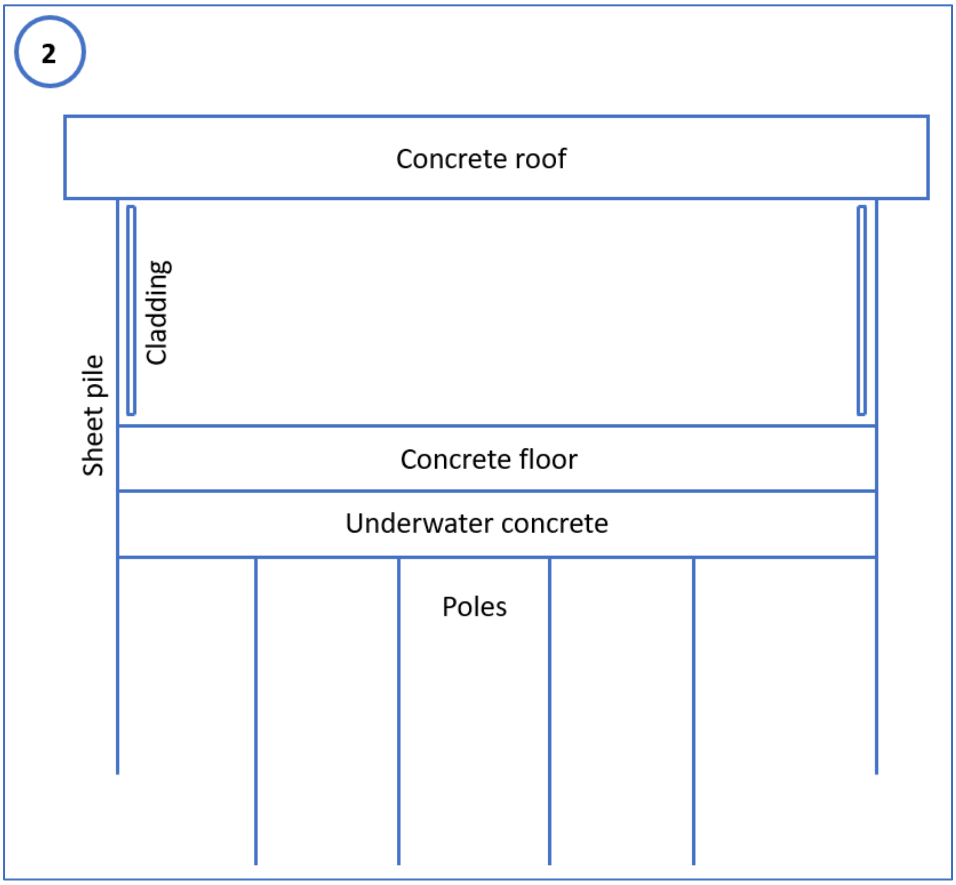

Figure 4: Tunnel cross-section 2

2.2 – Main teams

The design process at Witteveen+Bos involves multiple teams. As stated before this research will focus on internal teams who are active in most projects, and whose tasks require interactions with other internal teams. From discussion with my supervisor and a team leader on a large tunnel project, this led to the following teams: Design, Construction, Road-design and Geotechnics.

In the following section the tasks performed by each separate team will be explained. For more detail, see the flowcharts in appendix J, which visualize these steps taken by the different teams and shows the interaction between the teams and client. An overview of this flowchart can be seen in figure 6. To read the flowchart and see it in more detail, see appendix J. A more simplified flowchart, which focuses on the internal tasks per team, and less on the relations between the teams, can be found in appendix K. An overview of this flowchart is given in figure 5. These flowcharts use the BPMN notation, which is used to visualize business processes in a way which is understandable for all users, from managers to engineers. The goal of the BPMN notation is to "*create a simple mechanism for creating business process models, while at the same time being able to handle the complexity inherent to business processes"* (S. A. White, 2004, p. 1). This is a useful tool for this study, as its goal is to emphasize the inefficiencies occurring within the design process at Witteveen+Bos, without being too complex.

The BPMN flowcharts focus on both the internal tasks of the teams, as well as the interaction between these teams. The flowcharts show what specific tasks are performed by each team and the order they are performed in, and what cross-disciplinary information exchange and interaction is required between teams to perform these tasks.

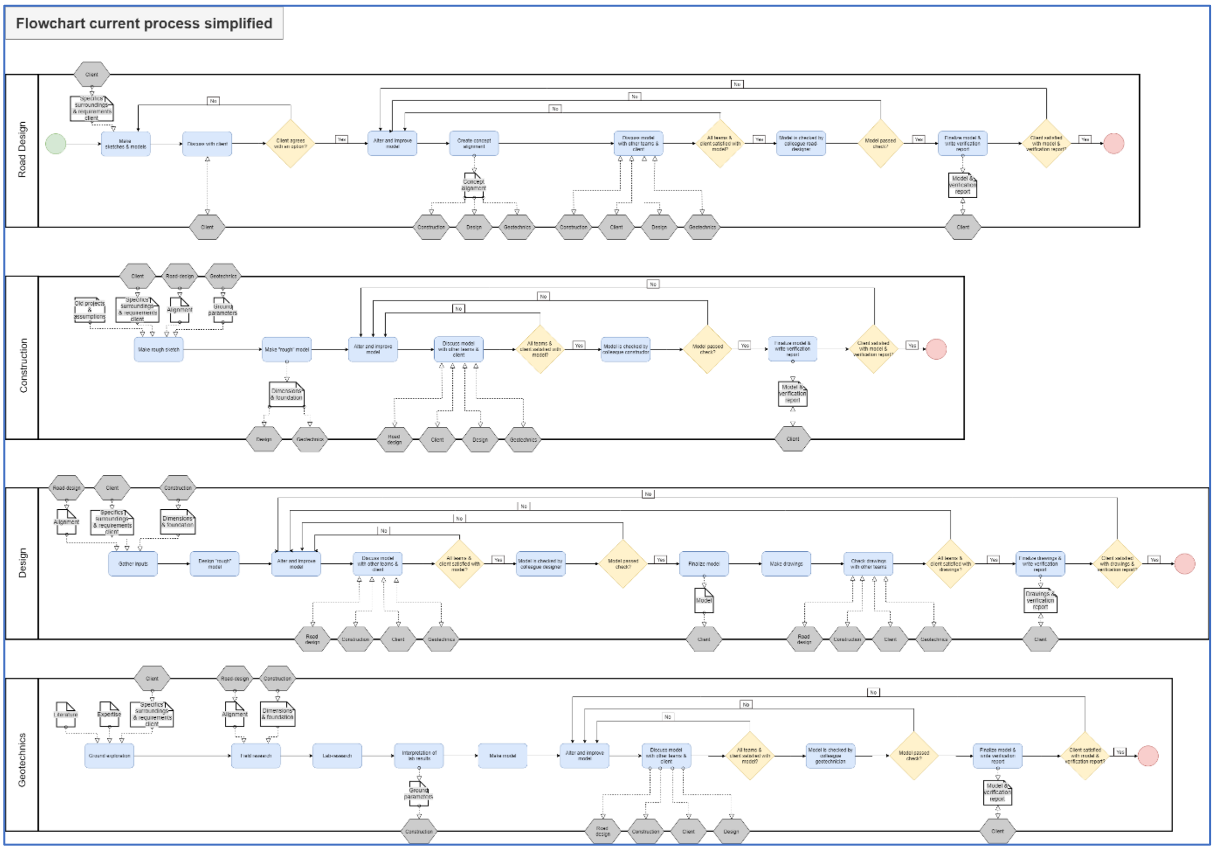

Figure 5: Flowchart current process simplified

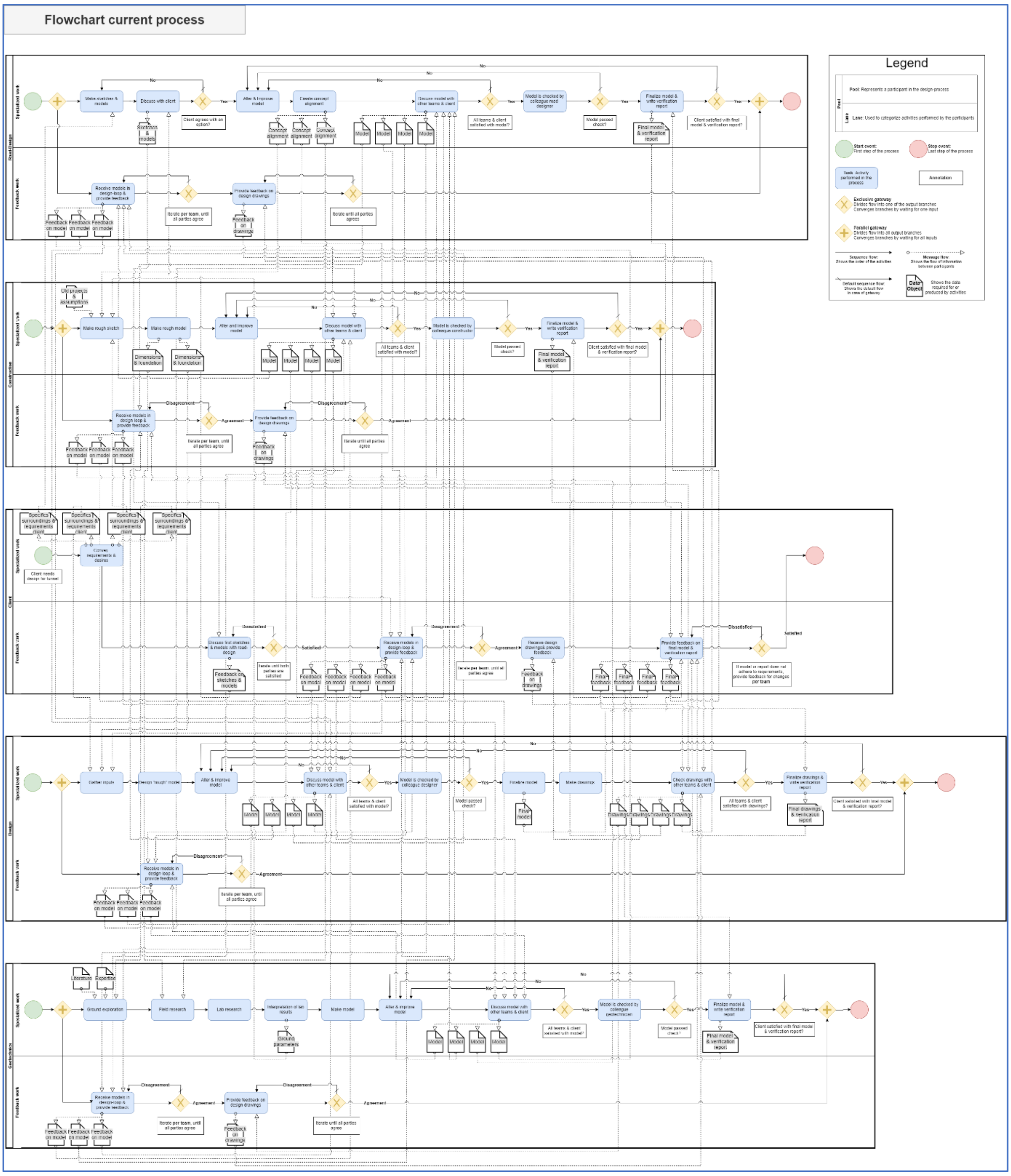

Figure 6: Flowchart current process

2.2.1 – Road-Design team

It is road-design's job to determine the position of the road and the tunnel in the environment. They discuss the several possibilities with the client, based on their requirements and the surroundings. Once the client agrees, the road-design team describes, amongst others, the axes of the road and tunnel.

The job that the road-design team performs can be broken down into the following steps:

1. Make sketches and models of different alternatives.
2. Discuss these sketches and models with the client.
3. Return to step 1 until the client is satisfied with an alternative.
4. Alter and improve the model.
5. Create the "concept" alignment which indicates the position of the road and tunnel and share it with the other teams.
6. Discuss the model with other teams and client.
7. Return to step 4 until all teams are satisfied.
8. Get the model tested by a colleague road-designer: are the right methods used and are the correct values used for these methods? In case the model does not pass the test, return to step 4.
9. Finalize the model and verification report. The verification report explains the choices made in the designing of the model and drawings, and it checks whether the requirements of the client have been met.
10. Send the final model and verification report to the client
11. Check whether client is satisfied with the final model and verification report. If not, return to step 4.

2.2.2 – Construction team

The construction team's job is to make sure that the construction itself is strong enough and adheres to the requirements determined by the customer and the law. For example, in the design of a tunnel, it is the job of the construction team to determine the thickness of the floor and the roof so that it is strong enough to support itself, the ground above it, the weight determined by the client, etc.

The construction team's job can be broken down into the following steps:

1. Make "rough" sketch with dimensions of the construction.
2. Make a "rough" model based on this sketch.
3. Alter & improve the model
4. Discuss this model with other teams and client.
5. Return to step 3 until all teams are satisfied.
6. Get the model tested by a colleague constructor: are the right methods used and are the correct values used for these methods? In case the model does not pass the test, return to step 4.
7. Finalize the model and verification report. The verification report explains the choices made in the designing of the model and drawings, and it checks whether the requirements of the client have been met.
8. Send the final model and verification report to the client
9. Check whether client is satisfied with the final model and verification report. If not, return to step 3.

2.2.3 – Design team

The overall task of the design team is quite broad. Their biggest task is designing the model of the entire tunnel, and the drawings that come with this. The model itself shows the entire tunnel and road, while the drawings show certain cross sections aspects of the tunnel and road in more detail. The design team is quite a "central" team: most information is assembled here and combined into one central model. On top of this, a lot of information is distributed through the design team, as they have a good overview of the project, since they have a lot of information from different teams.

The tasks performed by the design-team can be broken down into the following steps:

1. Gather main inputs.
2. Translate these inputs into a "rough" model.
3. Alter & improve the model
4. Discuss this model with other teams and client.
5. Return to step 3 until all teams are satisfied.
6. Get the model tested by a colleague designer: are the right methods used and are the correct values used for these methods? In case the model does not pass the test, return to step 3.
7. Finalize the model and send it to the client.
8. Make drawings based on the final model.
9. Discuss these drawings with other teams and client.
10. Return to step 3 if a team or the client is not satisfied.
11. Finalize the drawings and verification report. The verification report explains the choices made in the designing of the model and drawings, and it checks whether the requirements of the client have been met.
12. Send the final drawings and verification report to the client
13. Check whether client is satisfied with the final drawings and verification report. If not, return to step 3.

2.2.4 – Geotechnics team

The geotechnics team is responsible for determining the properties of the ground at the location of the road and tunnel. The team determines what type of ground is present at the location and the parameters linked to that ground. These parameters are then used for, amongst others, determining the forces that the ground exert on the tunnel and road, and vice-versa.

The job that the road-design team performs can be broken down into the following steps:

1. Perform ground exploration, where information on the location and the requirements of the client is gathered.
2. Perform field research, where samples are taken from the ground in the specific location.
3. Analyse the ground-samples in the lab
4. Interpret the lab results and turn them into ground parameters.
5. Make a model based on these parameters.
6. Alter and improve the model
7. Discuss the model with other teams
8. Return to step 6 until all teams are satisfied.
9. Get the model tested by a colleague geotechnician: are the right methods used and are the correct values used for these methods? In case the model does not pass the test, return to step 4.

10. Finalize the model and verification report. The verification report explains the choices made in the designing of the model and drawings, and it checks whether the requirements of the client have been met.
11. Send the final model and verification report to the client
12. Check whether client is satisfied with the final model and verification report. If not, return to step 6.

The description of the tasks performed by the 4 different teams seems very sequential. However, in reality these tasks are often performed at the same time. For example, in all teams, the verification report can be written during the creation of the model. For the purpose of clarity and to allow analysis of the process, the task performance by the different teams is seen as a sequential process.

2.3 – SIPOC analysis

The beforementioned tasks performed per team often require inputs and produce outputs. In this section the inputs and outputs required and produced per step per team will be described using a SIPOC analysis.

SIPOC stands for Supplier, Input, Process, Output and Customer. The SIPOC tool is a simple way to give more insight into the process, as it shows per step what comes in from whom, and what goes out to whom. In this study it is useful, as it shows for every step performed by teams what interaction with which team is required.

2.3.1 – Road-design SIPOC

Table 1 describes the SIPOC for the road-design team. An important thing that can be observed from this table is that an essential task of the road-design team is creating the concept alignment. This task is of importance, as it provides the concept alignment to the 3 teams, who need it for their work. Another task which is different than most other teams is discussing the sketches & models with the client. The goal of this task is to supply the client with different alternatives for the placement of the tunnel and road in the environment. This step can be repeated multiple times until the client is satisfied with an option.

Table 1: SIPOC for road-design team

Supplier	***Input***	***Process***	***Output***	***Customer***
Client	Specifics surroundings & requirements client	Make sketches & models		
Client	Feedback	Discuss sketches & models with client	Sketches & models	Client
Construction	Feedback	Alter & optimize model	Model	Construction
Design	Feedback		Model	Design
Geotechnics	Feedback		Model	Geotechnics
Client	Feedback		Model	Client
		Create concept alignment	Concept alignment	Construction
			Concept alignment	Design
			Concept alignment	Geotechnics
		Model is checked by colleague		
Client	Feedback	Finalize model & write verification report	Final model & verification report	Client

2.3.2 – Construction SIPOC

In table 2 the SIPOC for the construction team can be found. Here it becomes clear that most interaction with other parties occurs at making the sketch, as a lot of inputs are needed, and when the model needs to be altered and improved. Here, the model is supplied to the other parties, who then provide feedback on the model.

Table 2: SIPOC for construction team

Supplier	***Input***	***Process***	***Output***	***Customer***
Construction	Old projects & assumptions	Make rough sketch		
Road-design	Concept alignment			
Client	Specifics surroundings & requirements client			
Geotechnics	Ground parameters			
		Make rough model	Dimensions & foundation	Geotechnics
			Dimensions & foundation	Design
Design	Feedback	Alter & Improve model	Model	Design
Road-design	Feedback		Model	Road-design
Geotechnics	Feedback		Model	Geotechnics
Client	Feedback		Model	Client
		Model is checked by colleague		
Client	Feedback	Finalize model & write verification report	Final model & verification report	Client

2.3.3 – Design SIPOC

As the design team works on creating a “full” model on the tunnel and road, it is important that they are properly informed by all teams and the client. From table 3 it can be seen that most tasks performed by the design team require interaction with different teams or the client. For example, the design team has 2 different tasks that require interaction with all teams and the client: both the design of the model and the drawings. The outputs in these tasks are the model and the drawings, and the inputs required are the feedback from the other parties.

Table 3: SIPOC for design team

Supplier	***Input***	***Process***	***Output***	***Customer***
Road-design	Concept alignment	Gathering main inputs		
Construction	Dimensions & foundation			
Client	Specifics surroundings & requirements client			
		Make rough model		
Construction	Feedback	Alter & Improve model	Model	Construction
Road-design	Feedback		Model	Road-design
Geotechnics	Feedback		Model	Geotechnics
Client	Feedback		Model	Client
		Model is checked by colleague		
		Finalize model	Model	Client
		Make drawings		
Construction	Feedback	Check drawings	Drawings	Construction
Road-design	Feedback		Drawings	Road-design
Geotechnics	Feedback		Drawings	Geotechnics
Client	Feedback		Drawings	Client
Client	Feedback	Finalize drawings & write verification report	Final drawings & verification report	Client

2.3.4 – Geotechnics SIPOC

The SIPOC analysis of the geotechnics team can be found in table 4. From this it can be seen that most tasks performed by the geotechnics do not require a lot of inputs. The reason for this is that geotechnics' tasks are quite early in the design process, as the ground parameters are needed to determine the exact values for the construction. Some inputs such as the alignment, the requirements from the client, and basic information on the construction are required, but the lab research and interpretation of the results itself is mostly performed without any inputs.

Table 4: SIPOC for geotechnics team

Supplier	***Input***	***Process***	***Output***	***Customer***
Client	Specifics surroundings & requirements client	Ground exploration		
Geotechnics	Literature			
Geotechnics	Expertise			
Road-design	Concept alignment	Field research		
Construction	Dimensions & foundation			
		Lab research		
		Interpretation of lab results	Ground parameters	Construction
		Make rough model		
Construction	Feedback	Alter & optimize model	Model	Construction
Design	Feedback		Model	Design
Road-design	Feedback		Model	Road-design
Client	Feedback		Model	Client
		Model is checked by colleague		
Client	Feedback	Finalize model & write verification report	Final model & verification report	Client

2.4 – Iterative communication

The tasks performed by the different teams stated in section 2.3 are performed simultaneously. Different teams work on the same project at the same time, as decisions need to be made based on the expertise from different teams. For this simultaneous work structure, proper information exchange between the teams is vital. The quality of the final product is dependent on both the work of individual teams, as well as the coordination between these teams.

To incorporate both these aspects, the design process uses an iterative approach. This iterative process shall be called the *"design-loop*"; all teams work on their own specialized work for a period of time. Once they are ready with a "concept" version, the work from different teams is compared. Since different teams have different perspectives on problems, their solutions and values will differ. These values are compared and discussed between the teams. This feedback is then used by all teams to alter and improve their own specialized work. This design-loop continues until the teams find a solution that satisfies all teams and the client. A simplified visualisation of this design-loop can be found in figure 7.

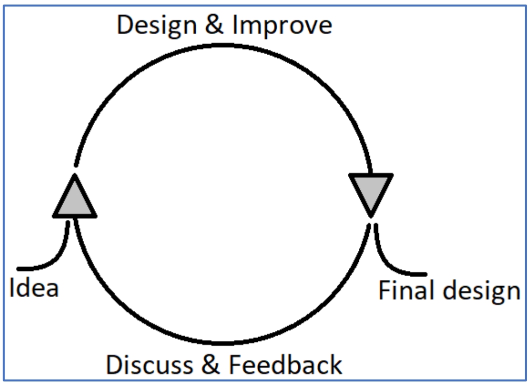

Figure 7: Design-loop

According to (*Costa & Sobek*) there are 3 types of iterations:

1. Design iteration: Repeating an activity with a different abstraction level, using the same scope.
2. Behavioural iteration: Repeating an activity with the same abstraction level, using a different scope.
3. Rework iteration: Repeating an activity at the same abstraction level and using the same scope.

Designing in iterations has multiple advantages. The main advantage of using an iterative approach, mainly focusing on design and behavioural iterations, is that it allows teams to handle information overload. It is impossible for designers to incorporate all relevant information into their design in one try, as "*cognitive limitations do not allow human designers to process all relevant information at all abstraction levels…"* (Costa & Sobek Ii, 2003, p. 4). Design iterations allow designers to "zoom in" on a problem: first the problem is looked at from a general abstraction level, and each iteration this abstraction level becomes more focused. Behavioural iterations allow designers to break down the design scope into sub-problems, and then performing behavioural iterations on each of them (Costa & Sobek Ii, 2003), which allows designers to look at the problems and possible solutions from different scopes, promoting creativity.

The third type of iteration, rework iteration, does not approach the problem using a different abstraction level or scope. Because of this "*reworks iterations do not help the design evolve towards the intended goal because it focuses on recovering from previous design errors*" (Costa & Sobek Ii, 2003, p. 5). The goal of rework iterations is thus to repeat the same activity with the same scope and abstraction level, to verify and correct information. Rework iterations are required in the design process at Witteveen+Bos for multiple reasons. Teams sometimes start their work based on assumptions, because information required might not be available yet. These assumptions need to be corrected, using rework iterations. Rework iterations also allow for the correction of mistakes caused by miscommunications. Such iterations are often performed in later stages of the design, as a final check.

Overall, iterations are highly beneficial to the design process at Witteveen+Bos. Iterative design allows creativity, promotes discussion, ensures that feedback is provided at every stage, helps mistakes to be found early in the process, and much more. The iterative design process at Witteveen+Bos does however have its inefficiencies, as the communication between the teams, which is vital to these iterative cycles, is not optimal.

2.5 – Communication channels

Communication is important in the design process. Information exchange between teams is vital, so that all teams can make well-informed decisions to reach an optimal solution and final product. In the current process, information exchange between teams is done through different channels. The main communication channels used are:

1. Email
2. Phone
3. Skype
4. Walking by desk
5. Project meetings

The first 3 of these are ICT communication channels. As mentioned before, ICT can be incredibly helpful in (hybrid) virtual teams, as it bridges temporal and geographical distances. They can however affect the quality of communication, because certain aspects such as body language are not possible through ICT. This can lead to sender and receiver interpreting each other differently, without realising so. As projects become larger and clients push for faster lead times, temporal and spatial gaps will increase. This will in turn probably lead to an increase in the use of ICT communication, as these gaps need to be bridged.

These first 3 channels are one-to-one or one-to-many communication channels, meaning that one person can address one or multiple individuals, but it does not allow for synchronous communication between several individuals or teams. For example, if road-design needs to share their concept-alignment with the other 3 teams, this concept alignment is shared through 3 different emails. This communication between the 4 teams is visualised in figure 8.

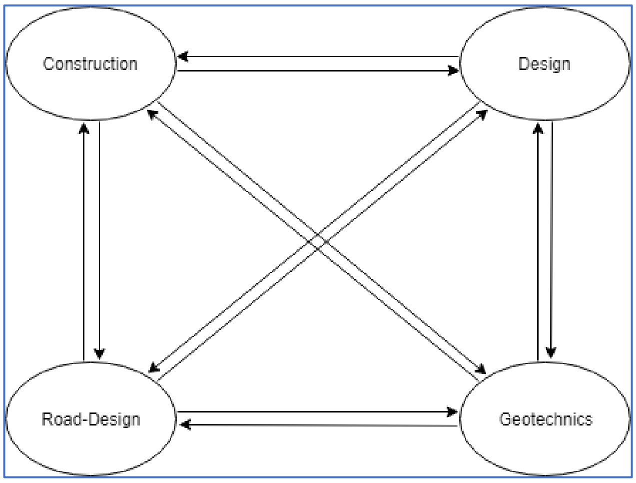

Figure 8: One-to-one and one-to-many communication

2.6 – Summary chapter 2

The design-process of a standard tunnel is investigated, based on the design, construction, road-design and geotechnics team. These teams can to a certain extent be considered virtual, or hybrid teams. Information is exchanged between teams mostly through one-to-one and one-to-many communication channels, mainly email. This communication between teams is essential, as the design-process is based on an iterative approach. These iterative cycles require all stakeholders to be properly involved with the latest information. The design-process is visualized and analysed using a BPMN flowchart.

Chapter 3: Literature Study – Lean philosophy

In this chapter a literature study on lean information management will be discussed. Section 3.1 will explain the value of information in the design process at Witteveen+Bos. Section 3.2 will discuss the available literature on the topic of lean information management. The next section, 3.3, applies this lean information management to the design process and analyses the different types of waste prevalent. Section 3.4 investigates what the causes of these information wastes are. The last section, 3.5, will discuss the results of the information wastes.

3.1 – Value of information

In project-based companies with different specialized teams, such as Witteveen+Bos, the efficiency and productivity of individual teams are vital to the quality of the final product and the overall performance of the company. However, proper collaboration and coordination between these teams is just as important. Information exchange between teams is vital, as "*the early and timely sharing of information can provide sustainable competitive advantage, especially to companies involved in interorganizational relationships"* (per Oliver 1990, Invernizzi et al., 2018, p. 729). Inefficiencies in communication within and between teams can lead to improper management of time, activities and resources (Bevilacqua, Ciarapica, & Paciarotti, 2015, p. 757), which negatively affect productivity.

Since Witteveen+Bos has multiple offices in different locations, nationally and internationally, and the fact that certain projects require on-site workers, teams are often geographically separated. This makes some, if not all teams in Witteveen+Bos virtual teams, as previously mentioned in section 2.1. This virtual team structure makes face-to-face meetings with different teams difficult, and thus requires different ways of communication. Information technologies such as e-mails, Skype, phone calls, etc., allow for better information exchange in these situations, as they can help bridge temporal and geographical gaps.

However, even with these information communication technologies (ICT) available, "*many organizations find it challenging to manage their information resources and records*" (Redeker, Kessler, & Kipper, 2019, p. 31). The reason for this is that digital communication channels have disadvantages not seen in traditional face-to-face communication. *"Digital collaboration raises new issues such as keeping track of versions, ownership and ensuring that decisions made are recorded and transmitted to the necessary participants."* (Rosenman, Smith, Ding, Marchant, & Maher, 2005, p. 433).

Information technologies have the advantage that they can facilitate information exchange across location and time. They may however weaken certain communication elements, such as nonverbal communication. A study has shown that "*face-to-face teams exhibited a stronger relationship between communication and performance than virtual teams*" (Marlow, Lacerenza, Paoletti, Burke, & Salas, 2018, p. 154). This goes to show that ICT can facilitate information exchange for virtual teams, but that these types of information exchange can affect performance and should thus be implemented wisely.

Overall, ICT has big advantages, if implemented and used correctly. If used improperly and implemented without structure, ICT can lead to large problems. Some of these problems are experienced in the design process at Witteveen+Bos.

3.2 – Lean information management

Lean philosophy focuses on maximizing value through the minimization of waste and redundant activities. Here, waste is defined as activities that consume resources, often space and time, without adding value to the product. Lean philosophy is commonly practiced in manufacturing environments such as production systems. In production processes, several different types of waste can be identified. Some of these waste-types can be removed or minimized, to improve efficiency and productivity.

Since lean philosophy is quite broad, it "*has the potential to be applied to any system or process in order to identify critical areas of improvement and ultimately bring about such improvements*" (Hicks, 2007). In the case of Witteveen+Bos, lean philosophy can be applied to the information exchange in the design process. Lean philosophy is a useful tool in this situation, as the problems with information exchange in the design process seem to be caused by information waste.

The difference in lean philosophy when applied to information exchange is that waste in information systems is intangible. In production systems, common causes of waste are Work in Progress (WIP) and product inventories. These sources of waste are often visible and tangible. With information this is slightly different. In information exchange waste can occur as well, for example in the form of information not flowing properly, or incorrect information being used. These activities are waste, as they consume resources without adding value to the product. They are however more difficult to identify, as they are not tangible or visible.

Lean manufacturing has 8 categories of waste. Since the concept of waste is different in information systems compared to manufacturing systems, these categories are not applicable. Hicks (2007) has applied lean philosophy to information systems and identified 4 different categories of information waste. *"Within the context of information management, waste can be considered to include the additional actions and any inactivity that arise as a consequence of not providing the information consumer immediate access to an adequate amount of appropriate, accurate and up-to-date information.*" (Hicks, 2007, p. 238).

Hicks has identified the 4 following categories of information waste:

1. *Failure demand*: Includes the resources and activities that are necessary to overcome a lack of information. This may include generating new information and/or acquiring additional information.
2. *Flow demand*: Concerns the time and resources spent trying to identify the information elements that need to flow.
3. *Flow excess*: Relates to the time and resources that are necessary to overcome excessive information i.e. information overload.
4. *Flawed flow*: Includes the resources and activities that are necessary to correct or verify information. It also includes the unnecessary or inappropriate activities that result from its use.

3.3 – Information waste

All of the beforementioned types of information waste occur within the design process, albeit some more than others. These types of waste can have different causes and appear in different "forms", as the information exchange, and thus the information waste, differs per project. In this section some examples of waste occurring in the design process at Witteveen+Bos are discussed, which became apparent in the interviews conducted with team members.

Failure demand can occur when a person or a team misses a deadline. As the design process requires different teams to work together this leads to other teams having to wait for their inputs, and thus not being able to start their work because of a lack of information. This is often solved by either asking the responsible team or individual for an estimation of the input, or starting the work based on assumptions.

Flow demand occurs when information is available, but not flowing properly, and thus not arriving at the right teams or individuals. This can occur when it is unclear what the interaction between different teams is, so when different teams do not know what information other teams need from them. This can lead to teams having to ask other teams for information, which is wasteful.

Flow excess happens when individuals or teams have access to so much information, that it can become difficult to distinguish what information is relevant. This occurs when all teams publish their findings in a central project folder which contains all information on the project, without properly and clearly structuring or managing this information. Another cause of flow excess can be an unstructured way of sending e-mails. This can result in people "drowning" in e-mails, making it difficult to determine whether information is relevant and up to date.

Flawed flow occurs when information needs to be verified. As the design process requires different teams to work together, it requires teams to work with the same information. To make sure that this is happening, information is often verified through tests. Sometimes, later in the process, it turns out that teams have been working with different information, which then needs to be corrected. This is a waste of resources. Another occurrence of such waste is when teams are working with assumptions and need to correct their calculations based on these assumptions when the actual data arrives.

In reality these different types of waste often go hand-in-hand or result in one another. For example, a lack of information requires the spending of resources on overcoming this lack of information, which is categorized as failure demand. Such a lack of information does however first require resources spend on identifying what information is lacking in the first place, which can be categorized as flow demand. A lack of information in the design process is sometimes solved by working with assumptions, which often leads to extra work required to verify and correct these assumptions, which is categorized as flawed flow.

3.4 – Causes of waste

A large source of waste in the design process is the unstructured way of exchanging information. There is little to no information management focused on the interactions between teams. Since there is no clear method of information exchange, communication is based on personal preference. This leads to different individuals and teams using different forms of communication. There is no common medium or communication channel connecting all teams.

In the current system information is mostly exchanged through e-mails, phone calls, Skype or walking by someone's desk. These forms of communication are quite unilateral and do not allow for synchronous communication, as mentioned in section 2.5. There are multiple "workarounds" implemented in the current process to deal with the waste caused by these one-to-many communication channels.

First of all, project meetings are a solution. In these project meetings members from different teams sit together in a room to work on and discuss the project. Here, many-to-many communication is possible, as these meetings allow for synchronous discussion. This makes information exchange clearer, and if there is a clear agenda, more structured. However, since projects often involve a large number of virtual teams situated in different locations, setting up weekly or monthly project meetings is difficult.

Secondly, a project folder is used to deal with this one-to-many communication. This is a central project folder to which all project members have access. This folder is filled with all relevant information on the project, so that all teams and team members have access to all the information they need. However, according to multiple interviews, team members have difficulties with finding relevant information in this folder. The reason for this is that this folder is unstructured. It is up to personal preference as to how information is shared in this folder. Some individuals prefer to use a lot of sub-folders, while others upload all their files directly into the main folder. This makes finding information in this folder incredibly difficult. If team members want to find information in this folder, they often use phone-calls or emails to contact the person "responsible" for this information. The idea behind this folder is that all team members have access to all the project-relevant information. This idea is good, but because of the unstructured execution, the project folder often leads to more unclear information and thus information waste.

Another cause of waste in the current process is the way information is stored. Within the team-based structure of Witteveen+Bos decisions involve multiple stakeholders. All these stakeholders have a different view based on their specialization on certain situations. To be able to make proper and well-informed decisions, all these stakeholders need to have access to all relevant, up-to-date information on the subject. In the current process the storage of this information is local; as information is mostly exchanged through one-to-many channels such as emails, these files are stored on individuals' computers or in email inboxes. This storage in multiple locations is wasteful, as it leads to data redundancy: the storage of the same piece of information in multiple places. This storage in multiple places makes it very difficult to keep an overview of whether all stakeholders have all relevant and up-to-date information, as there is no overview of all these local storages. Through this lack of overview, problems caused by stakeholders being ill-informed are often overlooked, or only noticed later in the process when the effects of these problems become clear.

Overall; Witteveen+Bos' environment requires proper coordination and information exchange between teams to allow for well-informed, fast decision making. Projects require continuous iterations between different teams to reach optimal solutions and make good decisions. These decisions require the involvement of multiple teams, as different teams have different perspectives on the situation. The communication channels currently used do not allow for such coordination, which leads to stakeholders being ill-informed by either not having all relevant information, or not having information that is up to date. This negatively affects decision making.

3.5 – Results of waste

These wastes occurring in the information exchange in the design process Witteveen+Bos have different results.

First of all, a result of this waste is that there is no clear overview. As mentioned before, information is intangible and thus difficult to locate. Because of the one-to-many communication channels and local storage used, it is difficult to determine whether all stakeholders are properly informed. Because of this, not the miscommunications themselves, but their results are noticed, often late in the process. In the design process, it is often the rule that the later the miscommunication is noticed, the more resources will be required to verify and correct information. This is because decisions are based on earlier decisions; they stack up. If one of the earlier decisions turns out to be incorrect, it can affect many decisions made later in the process, as they are based on that specific decision. The earlier a mistake resulting from miscommunication is noticed and corrected, the smaller the impact. There is currently no structured system in place that helps findings these miscommunication mistakes as soon as possible.

Secondly, the waste in the design process negatively affects decision making. As previously mentioned, all stakeholders need to be properly informed with up-to-date information. Because of the previously mentioned reasons, it is possible for stakeholders to not have all information, or to be working with incorrect information, without them realizing it. This can negatively impact decision making, which can result in a lower quality final product, longer lead times, and extra work required to correct mistakes.

Thirdly, the reliance on personal preference and habits makes the system unstructured. This unstructured way of doing things leads to mistakes being made. Making mistakes is not necessarily a bad thing, it might even be desirable in some cases, as long as these mistakes lead to new discoveries being made which can lead to improvements. However, in the current situation the lack of a method leads to the same mistakes being repeated, without learning anything from it, and thus not improving oneself. If a proper method were to be used, making mistakes would lead to learning new things and improving the method, as structured procedures "*encourages individuals and organisations to enter the cyclic learning process which involves a combination of experience, reflection concept formation and experimentation*" (per Bessant 2004, Adamides, Karacapilidis, Pylarinou, & Koumanakos, 2008, p. 37).

3.6 – Summary chapter 3

This chapter analysed literature on the topic Lean Information Management, and applied it to the design-process at Witteveen+Bos to identify the inefficiencies present in the design-process. These inefficiencies are mostly information waste. This information waste is analysed to identify its causes and results. Additionally, the value of information has been made clear based on this literature.

Chapter 4: Improved process

This chapter will explain the proposed improvements to the design process. The first section, 4.1, will explain the choice of a central project database. Section 4.2 discusses the steps required to design a database. The next section, 4.3, investigates the concept of active building components. The last section, 4.4, analyses how a central project database will function in the design process at Witteveen+Bos.

4.1 – Central project database

As discussed in chapter 3, most problems arising in the communication between teams can be attributed to the unstructured way of both exchanging and storing information. In the current design process, most information is exchanged through one-to-one or one-to-many communication channels, which allows for miscommunications. Storage of information is mostly local, which allows for stakeholders to be misinformed, and decisions to be sub-optimal.

The intervention proposed by this study is the implementation of a central project database. There are several advantages to such a central database. The following are the main advantages relevant for this study:

1. A central project database functions as a central communication channel: information exchange goes through one channel, allowing for coordination and transparency, reducing the chance of miscommunication.
2. Storage of data is central: this reduces data redundancy and allows for easier access to relevant and up-to-date information.
3. Centralization helps keep a better overview of the current state of projects: progress can be tracked, and possible problems can be anticipated sooner.
4. Database allows for synchronous information exchange. This allows for faster decision-making, which speeds up projects, and thus increases the quality of projects and their final products.
5. Bringing structure into information exchange and storage allows for improvement of oneself, as mistakes lead to learning new things.

Another reason the proposed solution is a central project database, is that has been done before according to literature. In 1998 a Ph.D. thesis "*An information model for managing design changes in a collaborative multi-disciplinary design environment"* was published by Ahmed H.M. Mohktar. This thesis states that "*failure to propagate design changes among the design team is a principal cause of problems*" (Mokhtar, 1998, p. I). The study states that information exchange on design changes is so difficult in multi-disciplinary organizations because of the large amount of information, and spatial and educational gaps between teams. This is very much in line with the problems observed within the design process at Witteveen+Bos.

The thesis develops an information model to tackle this problem. This is done using a "*central database that functions as a repository of active building components*" (Mokhtar, 1998, p. I). What Mohktar's thesis calls "*propagation of design changes"* is similar to what this study calls information exchange between teams, as this information exchange is mostly about changes in models, drawings, and values, and thus design changes. The goal of the database in Mohktar's thesis is that it "*assigns the responsibility of propagating design changes to the building components themselves*" (Mokhtar, 1998, p. 41), meaning that the building components themselves become responsible for exchanging information about value changes, instead of the designer.

This thesis developed an information model that uses information technology to better manage the communication of design changes. This information model was validated through hypothetical scenario's, as well as a case study in which the database proved a proper tool to communicate design changes between disciplines.

From this literature we see that a central project database can indeed be a proper tool to deal with the problems in the design process at Witteveen+Bos. One thing to keep in mind is that this thesis has 2 limitations. The first being that this thesis is focused on the design of buildings, while our study is focused on the design of tunnels. There are of course differences between these 2 types of infrastructure. However, the general discipline-based design is similar, making the thesis relevant to our study.

A second large limitation is that this thesis used a client-server network, which did not use the internet. The thesis states that the designers who are going to use the database should be in the same location, because the database did not use the internet. A recommendation given by the author of the thesis is "*exploring the use of the internet as a carrier of the central project-database and as the medium for automated messages propagation*". This is a vital limitation to this thesis, as Witteveen+Bos' potential database model would require the internet to bridge spatial gaps between team members.

Since the publishing of this thesis in 1998, 21 years have passed. Technology has advanced immensely and become more accessible and convenient to use. The limitation that was experienced in 1998 of using internet as a carrier for a central project database might not be such a large limitation anymore.

4.2 – Database design steps

The process of designing a database consists of multiple steps, as can be seen in figure 9. These steps are the following (Sumathi, 2007, p. 284):

1. **Feasibility study**
   The purpose for which the database is being designed must be clearly defined.
2. **Requirement collection and analysis**
   Here it is decided what data are to be stored, and to some extent how that data will be used. This information is gathered through interviews with the people that will use the database.
3. **Prototyping and design**
   In this step, the data is organized so that it supports business requirements.
4. **Implementation**
   Here code for the database is developed, and new database contents are installed.
5. **Operation**
   The database is "executed" in the organization.

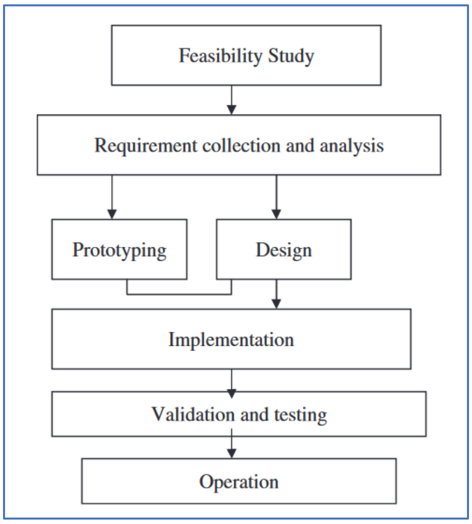

Figure 9: Database design steps

The feasibility of this database has been made clear in the previous chapters; the current way of exchanging information in the design process is unstructured and prone to miscommunication. A database will help bring structure into the information exchange, providing better coordination and collaboration between teams.

The requirement collection and analysis has been performed through interviews with a team members of each of the 4 beforementioned teams. In this interview questions were asked about whether the interviewees thought a database would be helpful, and what information they would insert into the database, and take from the database. From this, a list of inputs and outputs could be formed per team. On top of this, a literature study has been performed into what would be required from a database in a similar situation, which is discussed in the next section.

4.3 – Literature Study: Active building components

The database will have to adhere to certain requirements to be able to properly function as a central project database. These requirements are based on the literature (Mohktar, 1998). The main requirement from this thesis is that the database needs to employ active building components, as this will place the responsibility of communicating changes on the objects themselves, instead of the designers. This will reduce the chance of miscommunication, and thus improve the efficiency of the entire design process.

"*For building components to be active and perform their assigned task, they need to be equipped with the necessary "linking" knowledge. Linking knowledge identifies the disciplines that are affected by a specific design change and how they are affected"* (Mokhtar, Bédard, & Fazio, 1998, p. 86). So, links need to be established between components and disciplines. This way, when a component is changed, these changes can be communicated to the affected disciplines. These links allow for the components themselves to communicate changes, instead of the designers. Mohktar establishes these links through the use of rules. An example of such a rule is: "*If a change of 15% occurs to the following attribute: height (…) then the discipline STRU needs to be notified because it may affect 'the design of the beam that carries the wall'"*. (Mokhtar et al., 1998, p. 87). By defining these links between components and disciplines in rules, the relations between components and disciplines are set, which allows for the activation of the building components.

Since building projects are very complex and require a (slightly) different approach each project, there are 2 different types of rules:

1. Prebuilt rules
2. Dynamically built rules

Prebuilt rules are set before the project is started. Most prebuilt rules are the basic links between components and disciplines. For example in our case, if the alignment is modified, the teams that use the alignment as their input, such as the construction team, need to be notified.

Dynamically built rules are usually determined during the design process. They are often very specific to a situation in the project. According to Mokhar's study: "*an example of a dynamically built rule would be the design decision to make the height of a wall in a one-story building equal to the clear height of the floor space plus 1,000 mm.*" (Mokhtar et al., 1998, p. 86) . Such rules are often implemented during the design process, as they are used to deal with specific situations that might not have been expected in the preparation of the project.

From the interviews with team members from the beforementioned 4 teams in our study, the prebuilt rules in the design of our basic tunnel have been determined. The questions asked in these interviews, and a summary of the participants' answers can be found in appendices E, F, G & H. These prebuilt rules have been visualized in figure 10, which shows the inputs and outputs per team, and the relations between these inputs and outputs. This figure of the prebuilt rules can be found in more detail in appendix I.

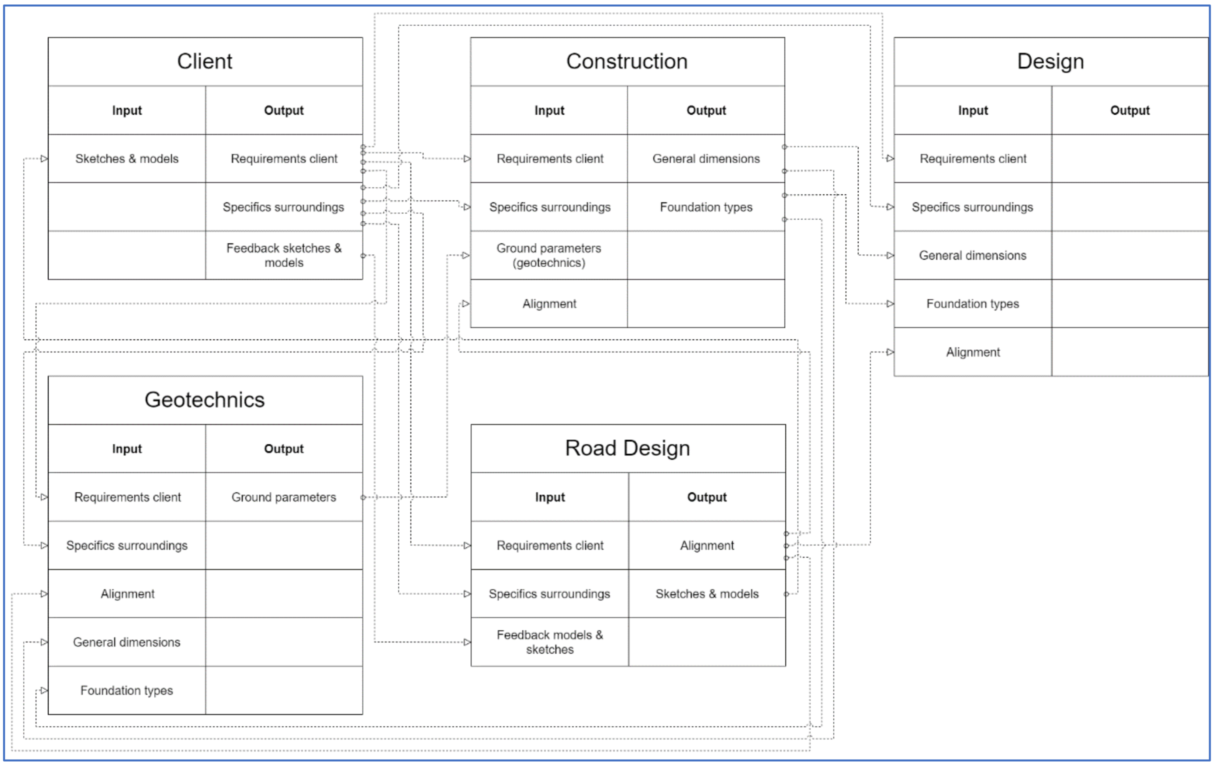

Figure 10: Prebuilt rules

4.4 – New process.

The new process will look quite different than the current process, as most information exchange will go through the central database. The internal tasks per team will remain mostly the same, but the communication between teams will differ. These changes can be seen in the flowchart describing the new database process. This flowchart depicts the design process with a properly implemented central project database with active building components, which can be found in figure 12. The more detailed version can be found in appendix L.

From this flowchart we can see the following improvements and differences:

The first difference is that there are fewer data objects in the process. Data objects show the amount of files in the flowchart, meaning there is a reduction in number of files being shared and stored. In the flowchart of the current situation, there are 61 data-objects that are exchanged with other teams or the client. In the improved process flowchart, this number is reduced to 25 data objects. This is due to the fact that teams only require 1 data object when sharing their models, drawings or values with other teams and the client. In comparison, in the current process, if there is information exchange with 3 different teams, 3 different data objects are shared, because of the use of one-to-one and one-to-many communication channel. This reduction in number of data objects is positive as it reduces data redundancy, which reduces the chance of miscommunication occurring. Another advantage of this is that all these data objects are stored in the same location: the central database, and are thus easier to verify and coordinate. It allows for easier overview of whether all stakeholders are properly informed and can help track the progress of the entire project. This central storage also allows for better archiving, which can help in future projects when information on older projects is necessary.

The second difference, as can clearly be seen from the flowcharts, is that there are fewer message flows between teams. In the current design process flowchart, there are 61 message flows between teams and the client. In the improved process flowchart, this is reduced to 43 message flows. This is due to the fact that the database allows for many-to-many information exchange between the different teams, as can be seen in figure 11. This type of communication uses one central channel, instead of a separate channel between each team, as can be seen when comparing this figure to the previous figure 8 in section 2.5.

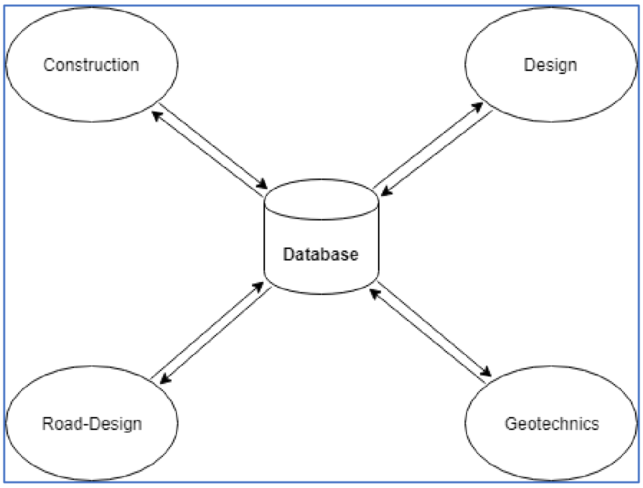

Figure 11: Many-to-many communication

Another reason that there are fewer message flows between teams is because of the active building components. The improved process flowchart shows a reduction in the amount of feedback that is exchanged between teams, since this task is taken over by the active building components. This leads to a reduction in message flows between teams. This is positive, as each message flow has a chance of miscommunication.

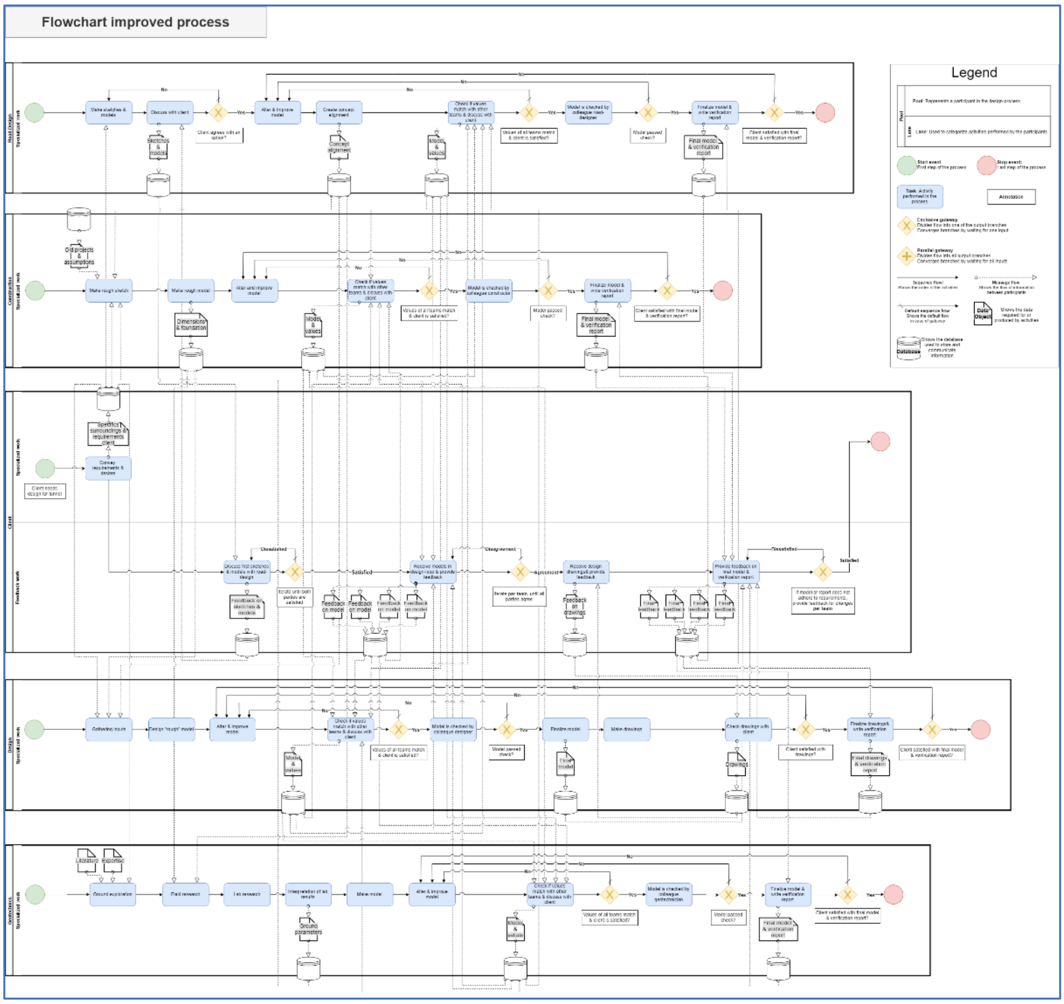

Figure 12: Flowchart improved process

Thirdly, the task of providing feedback is removed for each team. This is due to active building components, as the components themselves communicate changes to the affected disciplines, so the designers do not have to do this themselves anymore. It is not guaranteed that this will result in a reduced amount of work for the designers, as more work will go into creating the models, determining the rules and links between disciplines, and uploading the model and values into the database. It will however reduce the amount of communication performed by team members, which in turn lowers the chance of miscommunications occurring. In the improved process flowchart this can be observed in multiple ways. First of all, the task changed from "*discuss model with other teams & client*" to "*check if values match with other teams & discuss with client*". This is due to the active building components; teams don't have to check each other's models anymore and provide feedback, they simply enter their models and values into the database, and the active building components themselves communicate these changes to the affected teams. This way, providing feedback is not required anymore, but only a check to see whether all values are in line between all teams.

The final difference is that teams will not provide feedback on the drawings of the design-team anymore either, as these drawings are made from the models. Once the model of the design-team has gone through the design-loop and is in line with all teams, the drawings can simply be generated from the models which have already been checked. These drawings do go to the client one final time for a final check.

4.5 – Summary chapter 4

Chapter 4 described how the inefficiencies in the design-process can be removed or reduced using a central project database. The argumentation behind this database is based on literature and interviews. The steps taken, and yet to be taken, in the design of a database are discussed. Several requirements for this database, mainly active building components, are explained. The rules behind the active building components are analysed, and the prebuilt rules for a basic tunnel case are shown. Lastly, the new process is visualized and analysed using a BPMN flowchart.

Chapter 5 – Conclusion, discussion & recommendations

In this last chapter conclusions will be drawn in section 5.1. The findings of this study will be discussed in section 5.2 In the last section, 5.3, recommendations for future research will be explained.

5.1 – Conclusion

From the findings of this study we can conclude that there are inefficiencies in the design process at Witteveen+Bos. Some of these inefficiencies are caused by the fact that the teams at Witteveen+Bos are virtual, or hybrid teams, and therefore use ICT to bridge spatial and temporal gaps. This use of ICT can cause problems, such as keeping track of versions, storage of information and making sure all stakeholders are properly informed. Information waste is present in the current design process at Witteveen+Bos. This leads to miscommunications and sub-optimal decisions.

This study found that most information waste in the design process at Witteveen+Bos is caused by the absence of a proper communication structure. Information exchange between teams is based on personal preference instead of a structured method. This leads to mistakes being made, without learning and improving from these mistakes. The current communication channels are mostly one-to-one or one-to-many, and therefore do not allow for synchronous communication and decision making. These communication channels make it difficult to keep an overview of whether all stakeholders are well-informed with up-to-date information. This leads to teams either having not enough information, or teams experiencing information overload.

A central project database is proposed by this study as a solution for the problems experienced in the design process. The choice for such a central project database is based on literature and expert opinion. A central project database will "centralize" the communication channels, and will apply structure to the information exchange in the design process. The database will minimize the use of emails and phone calls, which are one-to-one and one-to-many communication channels. This central communication channel will allow for more synchronous communication and decision-making, and will lead to more transparency so that it is easier to determine whether all stakeholders are properly informed. Additionally, a central project database will centralize storage of project related information. This reduces the data redundancy that is currently prevalent in the design process due to the use of local storage. This central storage can allow for better analysis of project progress, and it allows for more structured archiving of project information, which can help with future projects.

An important aspect of this central project database is the concept of active building components. These active building components are established through prebuilt and dynamically built rules. These rules determine the links between different components and teams. Through these links, the active building components themselves become responsible for communicating changes in values. This way, team members do not have to communicate changes in models, drawings or values anymore, as the active building components will do this themselves. This will help reduce miscommunications in the design process.

5.2 – Discussion & limitations

As this study was exploratory in nature and only took around 10 weeks, limitations had to be set to allow for proper research.

The first limitation is that the analysis of the process was done using a basic tunnel case. On top of this, 4 important teams were identified that would be analysed further. The findings of this study are therefore applicable to this specific basic tunnel case with its 4 teams, but it might be different in other design processes, such as bridges. As it was too in-depth to analyse the entire design process with all its involved teams, a limitation has been set on the type of project, and the teams involved.

Secondly, a large limitation of this study is that a lot of information used was gathered from interviews. Because of this, a lot of information is qualitative, and prone to subjectivity of the interviewees. During the interview, such subjectivity was minimized as much as possible, but it is still qualitative data. Because of this, it is difficult to draw conclusions that are 100% valid, and applicable to Witteveen+Bos as a whole. However, as there was no quantitative data on how information exchange occurs between teams in Witteveen+Bos, gathering data through interviews was the best option available.

The third limitation is that the analysis of the design process focused on internal teams at Witteveen+Bos. This was done because this study looked at inefficiencies occurring in information exchange in the design process within Witteveen+Bos. However, the design process of such large infrastructure projects involves multiple external parties. These external parties can have large effects on the internal performance of Witteveen+Bos. For example, if an external party uses a very different way of communication, this can affect the performance within Witteveen+Bos.

Fourthly, as this study focused on the theoretical aspects of the central project database, and not on the practical aspects of the real-life implementation, the analysis was done using a best-case scenario. For example, this study discussed that all information exchange would be done using the central database, and thus lead to a more efficient design process. However, in real-life, probably not 100% of communication will go through this database. Employees will still walk by others' desks to ask questions, send emails, call each other, etc. Because of this, the situation depicted in figure 13 is probably the most realistic version of what the communication with a database would look like in real-life. This study did focus on the best-case scenario because it allowed for better analysis, as the "hybrid" realistic version is very dependent on how well the database is implemented.

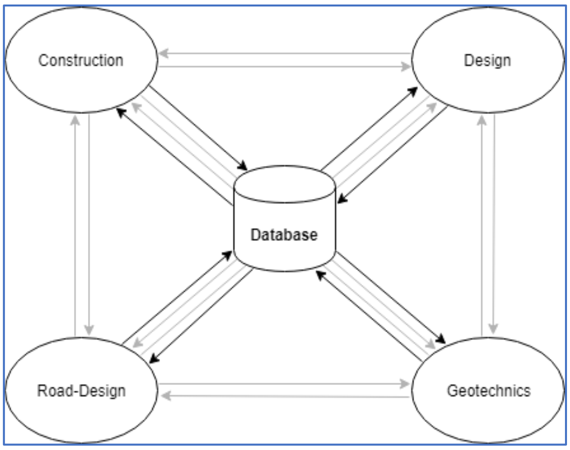

Figure 13: Real life communication

A fifth discussion point is that in the new process flowchart, the "feedback tasks" of all teams were removed due to the active building components. This did however bring the problem that in the current process, the drawings made by the design-team also require feedback. Removing this feedback task in the improved process did not only remove the feedback on the models, but also the feedback on these drawings. This feedback might be made possible with active building components. However, an assumption made in this study is that a properly implemented central project database, with well-established active building components, will allow for easy generation of 2D-drawings from the models. Therefore, no feedback from other teams is required.

Lastly, a limitation of this study is that it focused on the first steps of database design. The feasibility study, and requirement collection were performed, and the design was partially performed and explained. However, the implementation and operation of the database is not discussed. This was done because, as stated before, this study was exploratory, and its goal was to explain what the problems in the current design process at Witteveen+Bos are and how a central project database can solve them. The implementation of this database is however a very important step as well, as it will drastically alter the way people work and communicate. This change needs to be embraced by all employees, as the central project database will only function properly if everyone is involved. Since this database will impact the way people work, it is important to note that the implementation can be quite difficult.

5.3 – Recommendations for Witteveen+Bos

This study lead to some interesting findings that can help Witteveen+Bos to make the design-process more efficient. These are the main recommendations concluded from this study.

First of all, management of Witteveen+Bos should consider applying more structure to the information management between teams. This study has shown that this lack of structure, or information-management, leads to information being wasted. Through the interviews it became clear that most internal tasks in the teams were properly structured and managed, which lead to valuable specialized information being created. However, when it came to the information-exchange between these disciplines, some of this value was lost because of a lack of information-management. An information-management system, for example a database, could help reduce this loss of value in information. This could benefit the design-process and therefore the quality of projects, and Witteveen+Bos as a whole.

Secondly, this study proposes the use of a database to make the information exchange between teams more efficient. However, as this study focuses mainly on the feasibility and design of the database, and not on the implementation. As the implementation will affect the way people exchange information, and therefore the way people do their work, it is very important to study how to implement the database. The database can be beneficial to Witteveen+Bos, as long as it is implemented correctly. An incorrect implementation could lead to a lot of problems, and even lead to more inefficiencies. It is therefore important to study how the database could potentially affect the way people work, and try to minimize these effects. On top of this, the opinions of the people that will work with the database, in this case the team members, should be gathered and analysed, to ensure that the database fits the desires and requirements of the employees.

Lastly, in this study it became apparent that the database will use active building components to enable components to communicate value changes themselves, instead of designers having to do this. This is a large advantage which can reduce inefficiencies through miscommunications in the design-process. These active building components do however set certain requirements on the database and its design. In this study we saw that active building components are based on prebuilt rules and dynamically built rules. As prebuilt rules are determined before the project begins, and might even be general rules that can be applied in similar projects, the database will need to allow for these rules to be made in the first place, but also to be reusable and slightly adjustable, so that they can be used in other projects as well. Dynamically built rules are determined during the project, often to deal with unforeseen changes. This requires the database to be very flexible: it needs to be able to incorporate and adapt to these new rules. As the technical aspects of the database are not in the scope of this study, the exact technical requirements for this are still unclear. It is therefore advised to

Witteveen+Bos, and more specifically ANT, to study what kind of requirements these dynamically built rules put on the database.

5.4 – Recommendations for future research

During this study, multiple interesting topics came up. It was however not possible to investigate all these topics. Some of these topics that have not been researched but can be very interesting to study. These topics are the following.

Automation through the database. A properly implemented database can bring more than just information exchange between disciplines. A database can help with planning, cost-calculation, optimize the process through automation, etc. Research into possible other advantageous IT functions of a central project database would therefore be an interesting study.

The focus of this study was on cross-disciplinary information exchange. However, the database can also help with communication within teams, between team members. It might be interesting to investigate what the effects of this database are on the internal communication in teams, as this internal communication is often different, and maybe more "friendly", than communication between teams.

This study was based on a lot of qualitative data, as there was no quantitative data available. If quantitative data could be gathered, a simulation could possibly be very beneficial for this situation, as it could help measure the process. A simulation could help show where problems occur, how these problems are solved by the database, and exactly how much of an improvement is made.

As mentioned before, a study into the implementation of this database would be beneficial, as the database will affect the way people do their work. It is not recommended to design the database, and implement it based on a theoretical study without investigating the results in reality. It is therefore recommended to, once the database is designed and a prototype is ready, investigate the effects the database will have on people's work, and what their opinion on this new way of working is.

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Appendices

Appendix A: Questions & Answers design interview 1

Vragen Ontwerp (29-4-19)

Toerit:

INPUT

- Wat heb je nodig om te beginnen aan de taak?

  Wegontwerp, Alignement, globale afmetingen (wanden daken), funderingstype geotechnisch, estetica (architect), slagbomen etc (Tunnel Technische Installaties), verkeers technische installaties

- Van wie komt deze input?

  Alignement: Wegontwerp Afmetingen: Constructeur Funderingstype: Constructeur + via Geo technisch

  Slagbomen en verkeerstechnische installaties: VTTI

- Welk specifiek deel van deze input heb je ook echt daadwerkelijk nodig om te beginnen?

  Alignement is richtlijn: wordt wel eens invulling aangegeven. Rapporten van constructeur zijn vrij groot, moet er en toe nog wel zoeken

  VTTI uitsinformeler: vaak via overlay, of 2D tekening/bouwaanzicht aanleveren en, iets meer mondeling, of meer uitwisseling van bestanden

- Komt het voor dat deze input een aantal keer heen en weer gaat, omdat er aanpassingen worden gedaan en deze moeten worden doorgevoerd in andere specialisaties?

  Check en terugkoppeling gebeurt altijd bij elke input

- Zou jij de aangeleverde input graag anders zien: sluit de input en de vorm waarin hij aankomt aan op hoe jouw specialisatie hem nodig heeft?

  Vrij persoonlijk: vindt volledige rapporten wel fijn. VTTI komt en klare tekening is ook fijn.

TAAK

- Wat is de taak "globaal": dus niet te specifiek, hoe zou je het omschrijven?

- Uit welke stappen bestaat deze taak: gedetailleerder, wat zijn de sub-taken?

  input vergaren (met name wegontwerp & constructeur) alignment en algehele constructie nodig, dan grove contouren in model zetten, terugkoppelen met constructeur wegontwerp en TTI, dan komt vaak input terug met aanpassingen, dit is continue, klaar als iedereen akkoord gaat.

  Aannemer zit ook in deze loop, aannemer komt bij UO kijken in praktijk

1

- Bij welke stap heb je welke input nodig?

- Hoe lang duurt de globale/gehele taak normaal?

  ~~2 weken voor eerste~~ tek

- Best case: Al je inputs staan goed en op tijd klaar, hoe snel kan je het dan af hebben?

  2 weken voor 1e tekening

- Worst case: Als het een keer flink tegen zit, hoe lang kan het dan duren?

  3 à 4 voor 1e tekening

- Wat zijn de "ratio's" van de sub-taken qua tijdsbesteding, dus hoe lang ben je relatief bezig met elke sub-taak?

  4 weken: 1e 2 weken modeleren & opstellen tekening (globaal)
  3e week toetsing
  4e week toetsing verwerken
  } 1e opzet tracé

  Definitief en af zou dan 2x zo lang duren ongeveer.

OUTPUT

- Wat voor algemene/globale output wordt er geproduceerd door het uitvoeren van jouw algehele taak.

  Tekeningen: bijna op zwart wit, 3D modellen, Building Information Management BIM model, verificatie rapport (Aantonen dat eisen zijn gehaald)
  BIM is 3D model met gekoppelde waardes (model, volume, etc.)

- Wat voor outputs ontstaan er uit de sub-taken.

- Waar gaan deze outputs heen?

  Tekeningen eigenlijk overal, voornamelijk kostenberekening & werkvoorbereider, degene die gaat bouwen, vormgeving
  3D modellen vaker gebruikt door kostenberamers, ook eventueel door omgevingsmanagers die het dan op bewonersavond presenteren.
  Eventueel brandweer en hulpdiensten.
  Verkeerstunneltechnisch ook 3D model voor rooksimulatie

2

- Stuur je outputs individueel weg, of alles in 1x (of in "bulk")

Kan of in bulk, of individueel, verschilt per keer. Bij tunnel vaak per onderdeel.

- Zit er tijd tussen het af hebben van de output en het wegsturen van de output?

Wanneer af eerst toetsen, mensen die input leveren ook toetsen, dan nog verantwoordelijke (projectleider) die toetst, dan pas weg

- Weet je welk delen van jouw output worden gebruikt door andere specialisaties?

Veel communicatie met "klant" van de output

- Weet je of de manier waarin jij je output publiceert aansluit op de manier waarop de andere specialisaties hun input graag zien, heb je hier inzicht in?

Af en toe verkeerde extensie, iets kleins. CAD handboek: project huisstijl, regels afspraken, moet wel aan gehouden worden, alle teams. Huisstijl

Gesloten gedeelte

INPUT

- Wat heb je nodig om te beginnen aan de taak?

- Van wie komt deze input?

- Welk specifiek deel van deze input heb je ook echt daadwerkelijk nodig om te beginnen?

- Komt het voor dat deze input een aantal keer heen en weer gaat, omdat er aanpassingen worden gedaan en deze moeten worden doorgevoerd in andere specialisaties?

3

- Zit er tijd tussen het af hebben van de output en het wegsturen van de output?

- Weet je welk delen van jouw output worden gebruikt door andere specialisaties?

- Weet je of de manier waarin jij je output publiceert aansluit op de manier waarop de andere specialisaties hun input graag zien, heb je hier inzicht in?

- Heb je zelf nog taken waarvan je denkt dat deze belangrijke raakvlakken hebben met andere specialisaties, en ook "algemene" ontwerp taken zijn, als in die voorkomen in elk ontwerpproces, ongeacht het eindproces? (Als ja, lijstje doornemen)

Ecologie zou nog voorkomen bij bruggen etc (sociale impact), dat komt niet voor bij tunnels

- Ben je tevreden met de snelheid waarop informatie wordt uitgewisseld met andere teams, met name de snelheid waarop jij dingen binnen krijgt. (Zit je vaak te wachten op bepaalde informatie die je nodig hebt om ergens aan te werken)?

Tunnels meestal niet want planning is vrij crucial. Met buitenland komt input wel eens verkeerd aan, door miscommunicatie.
Komt wel eens voor dat input laat is, maar dan kan er voorbereid worden, omdat je weet wat voor input je gaat krijgen

- Ben je tevreden met de kwaliteit van de inputs die je krijgt: Is de informatie die je nodig hebt makkelijk te vinden in rapporten, en is deze informatie concreet, of zorgt het rapport voor "ruis"?

Is persoonsspecifiek, soms staat het in verhaalvorm, soms verhaal en raw data. Liefst ook informatie erbij om redenering te zien. Liefst onderbouwing met concrete samenvatting

- Hoeveel interactie is er met Bouwkundig en Geohydrologie, hebben jullie te maken met deze disciplines.

Bij DO Bij beslissingen t.o.v geohydrologie vaak al gemaakt
Bij riviertunnel is meer interactie met geohydrologie

Appendix B: Questions & Answers construction interview 1

Vragen — Constructie (29-4-19)

DO-Berekening vloer (met rapport)

INPUT

- Wat heb je nodig om te beginnen aan de taak?

Geometrie: bovenkant vloer welk NAP niveau: komt van wegontwerp
Breedte rijstroken + breedte: wegontwerp
Hoogte maaiveld: komt van ontwerp, die weten maaiveld van de klante ← hoogte van de grond
Eigenschappen grond: gewicht grond: geotechniek
Grondwaterstanden: Geohydrologie

- Van wie komt deze input?

- Welk specifiek deel van deze input heb je ook echt daadwerkelijk nodig om te beginnen?

- Komt het voor dat deze input een aantal keer heen en weer gaat, omdat er aanpassingen worden gedaan en deze moeten worden doorgevoerd in andere specialisaties?

Is al onderlinge communicatie voordat rapporten etc worden gedaan
Doel DO: afmetingen vast, materialen etc kunnen nog veranderen

- Zou jij de aangeleverde input graag anders zien: sluit de input en de vorm waarin hij aankomt aan op hoe jouw specialisatie hem nodig heeft?

Wordt al veel gecommuniceerd voordat de input binnenkomt

TAAK

- Wat is de taak "globaal": dus niet te specifiek, hoe zou je het omschrijven?

- Uit welke stappen bestaat deze taak: gedetailleerder, wat zijn de sub-taken?

Schets met afmetingen (gokken of oude projecten), modeleren, dan proberen met bijv. vloerdikte, dan palen, etc. totdat je model voldoet. Dan optimaliseren en aanpassen. Dan gaat iemand toetsen & checken (senior constructeur), dan aanpassen gebaseert op die toetsing (collegiale toets).
Toets op juiste waardes en of juiste berekeningen voor de situatie zijn gedaan.

1

- Bij welke stap heb je welke input nodig?

Schets met afmeting meeste inputs, maar je doet hier wel schattingen. Je weet dat sommige dingen gaan veranderen, dan doe je an conservatieve gok.

an
...
20
,2,3
...
hoe
lang
een
hummel
duurt

- Hoe lang duurt de globale/gehele taak normaal?

12 weken (12 x 40 uur)

- Best case: Al je inputs staan goed en op tijd klaar, hoe snel kan je het dan af hebben?

8 weken (8 x 40 uur)

- Worst case: Als het een keer flink tegen zit, hoe lang kan het dan duren?

16 weken (16 x 40 uur)

- Wat zijn de "ratio's" van de sub-taken qua tijdsbesteding, dus hoe lang ben je relatief bezig met elke sub-taak?

Doorlooptijd tekenen = 1 week, tekenen zelf duurt 2 dagen.
Aanpassingen = 1 week, 1 à 2 dagen bezig afhankelijk van hoeveelheid aanpassingen
Rapport schrijven = 1 week
4 weken rekenen
1 week uitgangspunten verzamelen

OUTPUT

- Wat voor algemene/globale output wordt er geproduceerd door het uitvoeren van jouw algehele taak.

Rapport 40 pagina's + 200 pagina's bijlagen.

- Wat voor outputs ontstaan er uit de sub-taken.

Belangrijkste output is de tekening van het ontwerp, rapporten zijn om de tekeningen uit te leggen aan de hand van berekeningen.

- Waar gaan deze outputs heen?

Ontwerpleider verzamelt documenten, dan naar aannemer

2

- Stuur je outputs individueel weg, of alles in 1x (of in "bulk")

In principe zsm, maar ligt aan contract & afspraken met bijv. aannemer

- Zit er tijd tussen het af hebben van de output en het wegsturen van de output?

- Weet je welk delen van jouw output worden gebruikt door andere specialisaties?

- Weet je of de manier waarin jij je output publiceert aansluit op de manier waarop de andere specialisaties hun input graag zien, heb je hier inzicht in?

Goed rapport sluit goed aan op de volgende spele, gebeurt niet altijd.

DO-berekening dak (met rapport)

INPUT

- Wat heb je nodig om te beginnen aan de taak?

- Van wie komt deze input?

- Welk specifiek deel van deze input heb je ook echt daadwerkelijk nodig om te beginnen?

- Komt het voor dat deze input een aantal keer heen en weer gaat, omdat er aanpassingen worden gedaan en deze moeten worden doorgevoerd in andere specialisaties?

3

- Zit er tijd tussen het af hebben van de output en het wegsturen van de output?

- Weet je welk delen van jouw output worden gebruikt door andere specialisaties?

- Weet je of de manier waarin jij je output publiceert aansluit op de manier waarop de andere specialisaties hun input graag zien, heb je hier inzicht in?

- Heb je zelf nog taken waarvan je denkt dat deze belangrijke raakvlakken hebben met andere specialisaties, en ook "algemene" Constructie taken zijn, als in die voorkomen in elk ontwerpproces, ongeacht het eindproces? (Als ja, lijstje doornemen)

- Ben je tevreden met de snelheid waarop informatie wordt uitgewisseld met andere teams, met name de snelheid waarop jij dingen binnen krijgt. (Zit je vaak te wachten op bepaalde informatie die je nodig hebt om ergens aan te werken)?

vaak te wachten op bijvoorbeeld sterkte en draagkracht geotechnische ~~ondert~~ onderdelen, maar zij wachten ook weer op inputs van grondonderzoek. Dan wordt er begonnen met aanpassen, wordt later aangepast

- Ben je tevreden met de kwaliteit van de inputs die je krijgt: Is de informatie die je nodig hebt makkelijk te vinden in rapporten, en is deze informatie concreet, of zorgt het rapport voor "ruis"?

2 disciplines weten niet altijd goed wat ze van elkaar nodig hebben, dan moet je echt bij elkaar gaan zitten en het goed afspreken en doornemen.

- Hoeveel interactie is er met Bouwkundig en Geohydrologie, hebben jullie te maken met deze disciplines.

Geohydrologie niet: je wil alleen grond(water)stand zien

Bouwkundig (dienstgebouw) niet.

Appendix B.1: Sidenotes meeting Construction

Team Design "beheert" alle informatie; komt vaak bij hen binnen, zij spelen het door aan de teams die het nodig hebben.

Wegontwerp bepaalt het alignement: belangrijk team, zij bepalen de as & bochtstralen van de weg.

Wegontwerp is een hele belangrijke partij: die moet je toevoegen

Vindt de opzet vreemd, zou zelf de taken van constructie onderscheiden in:
- DO open-deel (toerit)
- DO gesloten deel
- DO gesloten deel + waterkelder

ANT kan heel erg gaan helpen bij de iteratieve loop: Komt 1000 kN kracht in de palen, daarmee gaan we allemaal beginnen. 3 weken later zegt constructie dat er 1200 kN kracht op komt te staan, dan zegt de geotechneut nee ik denk dat ik maar 900 kN op kan nemen, dan ga je het dichter bij elkaar brengen stapje voor stapje. ANT kan die loop zelf gaan doen: het enige wat de constructeur en de geotechneut doen is de regels invoeren, hoe alles in elkaar grijpt, en dan gaat het programma het optimaliseren. Daarvoor moet je wel alle raakvlakken weten.

Je kijkt nu erg zwart-wit naar het proces: in het echt doet iedereen iets: wegontwerp gaat over de breedte van de rijkstrook, maar de constructeur weet ook heel goed hoe die breedte van de rijkstrook moet zijn. De breedte van de weg komt namelijk uit een norm, of dat heeft de klant bepaald. Als wegontwerp iets doet wat er raar uit, zegt de constructeur vraagt dan uit zichzelf al waarom die rijstrook 4 meter is, normaal is hij 3,5m. Er zit heel veel overlap in. Ik snap dat dit het lastig maakt voor je onderzoek, maar zo is het proces.

Deel van de eisen voor bijvoorbeeld een tunnel komen van de vraagspecificaties van de klant. De klant heeft vaak al met een andere partij gekeken, die partij levert hen adviezen, waarop zij hun specificaties baseren.

Doel van DO is dat de afmetingen vastliggen, dus dat de afmetingen in de volgende fase niet meer gaan veranderen. Het kan wel zijn dat de wapening gaat veranderen. Het kan zijn dat het beton een andere betonklasse krijgt, maar de dikte verandert niet meer.

Afweging: Communicatie leidt tot beter product, maar zorgt er ook voor dat mensen constant bezig blijven en heen en weer blijven communiceren: dit is niet altijd belangrijk, op een gegeven moment is het goed genoeg. Vooral als iedereen wat te zeggen heeft, kan dit leiden tot een veel te hoog detail niveau, het is kijken naar wat je wil onderzoeken en wat niet.

De input data die nodig is om te beginnen met zo'n DO berekening en rapport is te complex om gewoon aangeleverd te krijgen via de mail en te zeggen "hey doe mij even die waarde".

ANT zou ook heel erg kunnen helpen met automatiseren: geautomatiseerd kan heel veel verschillende varianten berekenen om zo de uiteindelijk de goedkoopste oplossing te vinden.

Nu gaat de ontwerpleider met andere mensen zitten en brainstormen over hoe het goedkoper kan. Maar ik geloof niet dat dit altijd op de goede manier gaat: er is niemand die alles beheerst, niemand weet hoe het nog goedkoper kan omdat je hiervoor alle kennis nodig hebt.

Intern lopen dingen soms niet goed en duur het wat langer, maar soms maakt de klant dan een aanpassing, en dan is er een soort opluchting intern omdat er meer tijd is om dingen af te maken die eigenlijk nog niet af waren.

Nadeel ANT is dat het menselijke er een beetje uit wordt gehaald: bijvoorbeeld 1 collega is altijd vrij optimistisch met zijn aannames, hier kan je dan op inspelen omdat je die persoon kent. Dit wordt er door ANT een beetje uitgehaald.

Appendix C: Questions & Answers road-design interview 1

Vragen Wegontwerp (3-5-19)

- Wat ziet u als de hoofdtaken van Wegontwerp in het geval van zo'n basis tunnel?

Vastleggen horizontale & verticale alignement in samenspraak met een dwarsprofiel

TAAK

- verschillende Uit welke stappen bestaat deze taak: gedetailleerd, wat zijn de sub-taken?

Vaak ook met rapport met beredeneringen

→ Schets maken. afbakenen waar weg komt te liggen, kern van alignement
→ kan nieuw zijn, of aanpassing van wat er ligt.
Dan overleggen met opdrachtgever of het goede richting in zit & bespreken varianten.
Digitaliseren naar VO, digitaal model. VO kijken naar ruimtebeslag
DO detailleren: dikte afvalk, materialisatie
UO model, gaat naar aannemer blijft communicatie met de aannemer

- Jantstudie Per sub taak: Wat voor inputs heeft u nodig om te beginnen?

Schets: wensen van de opdrachtgever & specificaties omgeving (wettelijk bepaald)
Bespreken varianten: opdrachtgever, maar soms ook bij specifieke wensen klant al langs disciplines WB
VO Digitaal model: Inputs constructie (breedte, hoogte, lengte), Inputs geotechniek (specificaties bodem), ontwerp, eisenpakket (kan opdrachtgever maar ook) kan ik VO al ruimtebeslag bepalen
DO digitaal model: Alles vastleggen: VO model invullen

- Per input: Van welke discipline/team komt deze input?

- Welk specifiek deel van deze input heeft u ook echt daadwerkelijk nodig om te beginnen aan de taak?

1

- Komt het voor dat deze input een aantal keer heen en weer gaat, omdat er aanpassingen worden gedaan en deze moeten worden doorgevoerd in andere specialisaties?

- Zou u de aangeleverde input graag anders zien: sluit de input en de vorm waarin hij aankomt aan op hoe uw specialisatie hem nodig heeft?

Op dit moment zit het op een goed niveau: zit nu meer structuur in. Communicatie loopt vaak wel via een centraal persoon.

- Per sub-taak, wat voor output wordt er geproduceerd, waar gaat deze output heen, en met welke disciplines wordt er informatie uitgewisseld?

Per stap alles archiveren: op slot, dan ga je verder.

VO → toets → DO

toets binnen discipline & inter-disciplinaire toets door senioren

- Worden de outputs van wegontwerp individueel weggestuurd, of als bulk?

Afhankelijk van de opdrachtgever. Meestal bulk

- Zit er tijd tussen het af hebben van de output en het wegsturen van de output?

- Weet je welke delen van uw output worden gebruikt door andere specialisaties?

Is wel afstemming onderling

- Weet u of de manier waarop u uw output publiceert aansluit op de manier waarop de andere specialisaties hun input graag zien, heeft u hier inzicht in?

- Hoe lang duurt de globale/gehele taak normaal?

Schets: 10%
Variant: 20%
VO model: 30%
DO Model: 40%
UO Model: 50%

Loopt op door o.a. meer communicatie

- Best case: Al je inputs staan goed en op tijd klaar, hoe snel kan je het dan af hebben?

- Worst case: Als het een keer flink tegen zit, hoe lang kan het dan duren?

- Wat zijn de "ratio's" van de sub-taken qua tijdsbesteding, dus hoe lang ben je relatief bezig met elke sub-taak?

- Bent u tevreden met de snelheid waarop informatie wordt uitgewisseld met andere teams, met name de snelheid waarop u dingen binnen krijgt. (Zit u vaak te wachten op bepaalde informatie die u nodig heeft om ergens aan te werken)?

Wel tevreden, beter dan bij de overheid bijvoorbeeld.

Beslissingen nemen gaat hier snel, verschilt per projectleider

- Bent u tevreden met de kwaliteit van de inputs die u krijgt: Is de informatie die u nodig heeft makkelijk te vinden in rapporten, en is deze informatie concreet, of zorgt het rapport voor "ruis"?

- Hoe vaak kunt u informatie verkrijgen via het Ontwerpteam? Heb nu het idee dat zij een centraal punt zijn waar alles informatie samen komt.

Binnen het ontwerpteam ook nog wel specialisten

- Welke vorm van communicatie vindt u het fijnst?

Als 1 maat nodig heb, het liefst niet een heel rapport, maar even langs lopen of direct mailtje

Zit wel eens te wachten op input, maar dan beginnen aan ander project

5

- Welke vorm van communicatie komt het meest voor?

Via mail, informele mailtjes. Werkt tot nu toe goed.

- Vindt u dat er te veel, genoeg, of te weinig wordt gecommuniceerd?

Kan wel meer samen zijn met het projectteam, zou meer "projectdagen" erk willen zien.

Appendix D: Questions & Answers geotechnics interview 1

Vragen Geotechniek [...] 7-5-19)

- Wat ziet u als de hoofdtaken van Goetechniek in het geval van zo'n basis tunnel?

Identificeren van grondlagen, hier parameters aan hangen grondonderzoek, hier dan sterktes aan hangen, dan interacties met constructieve elementen bepalen.

TAAK

- Uit welke stappen bestaat deze taak: gedetailleerd, wat zijn de sub-taken?

Verkenning, literatuurstudie wat voor grond je kan verwachten
Grondonderzoek uitzetten & uitvoeren → kan nog een keer voorkomen bij aanpassingen
Labonderzoek op bodem monsters
Deze onderzoeken bundelen tot uitgangsrapport geotechniek
Ontwerpcyclus voor damwanden, palen etc. (modellen, hangen rapporten aan vast)
Interne toets, dan outputs (tekeningen) produceren

- Per sub taak: Wat voor inputs heeft u nodig om te beginnen?

Verkenning: Literatuur
Grondonderzoek: vergunningen, van wie is het land, etc. Hoofdlijnen ~~[illegible]~~ van soort constructie en alignement.
Lab: Beetje idee van de ontwerpoplossing: moet beetje weten wat de bouwstenen van het ontwerp zijn.
Rapport: Eigen expertise
Input loop begint bij ontwerp. Meesten wachten op geo, grondonderzoek duurt lang

- Per input: Van welke discipline/team komt deze input?

Meeste raakvlakken met constructie.
Weinig direct contact met wegontwerp, loopt vooral via constructie
Ook veel contact met geohydrologie: bepaalt belastingen van grondwater op constructie. Bij tunnel is grondwaterstand erg relevant.
Niet heel veel contact met ontwerp. Leveren aan wat er in moet komen, krijgen dan tekening terug en toetsen die: ook een loop.

- Welk specifiek deel van deze input heeft u ook echt daadwerkelijk nodig om te beginnen aan de taak?

Ideaal om bij elkaar te zitten. Kan ook per mail of telefoon, maar dan vaker zinloze loop.

Wordt wel eens vaak geladen door rapporten: hangt er af van met wie je contact hebt. Makkelijker om dan te mailen met wat je nodig hebt

1

- Komt het voor dat deze input een aantal keer heen en weer gaat, omdat er aanpassingen worden gedaan en deze moeten worden doorgevoerd in andere specialisaties?

- Zou u de aangeleverde input graag anders zien: sluit de input en de vorm waarin hij aankomt aan op hoe uw specialisatie hem nodig heeft?

In hoofdlijnen wel door waar alles voor gebruikt gaat worden. Ook gebaseerd op expertise.

- Per sub-taak, wat voor output wordt er geproduceerd, waar gaat deze output heen, en met welke disciplines wordt er informatie uitgewisseld?

Grondonderzoek → Veld: lagen (wordt gecommuniceerd omdat mensen wel ongeveer weten wat het inhoudt).
↘ lab: sterktes etc (parameters)

2

- Worden de outputs van geotechniek individueel weggestuurd, of als bulk?

Verschilt heel erg: constructeur stelt vaak hele concrete vragen, dan stuur je 1 waarde.

Het gehele rapport is vaak te laat klaar.

- Zit er tijd tussen het af hebben van de output en het wegsturen van de output?

- Weet je welke delen van uw output worden gebruikt door andere specialisaties?

- Weet u of de manier waarop u uw output publiceert aansluit op de manier waarop de andere specialisaties hun input graag zien, heeft u hier inzicht in?

3

- Hoe lang duurt de globale/gehele taak normaal?

Verkenning
Grondonderzoek } 30%
Labonderzoek
Rapporten
Ontwerpcyclus 50% in modellen en sommen
Toetsen, updaten, foutjes verbeteren, etc. 20%

- Best case: Al je inputs staan goed en op tijd klaar, hoe snel kan je het dan af hebben?

- Worst case: Als het een keer flink tegen zit, hoe lang kan het dan duren?

- Wat zijn de "ratio's" van de sub-taken qua tijdsbesteding, dus hoe lang ben je relatief bezig met elke sub-taak?

4

- Bent u tevreden met de snelheid waarop informatie wordt uitgewisseld met andere teams, met name de snelheid waarop u dingen binnen krijgt. (Zit u vaak te wachten op bepaalde informatie die u nodig heeft om ergens aan te werken)?

Binnen WB tevreden. Met externen wat lastiger

- Bent u tevreden met de kwaliteit van de inputs die u krijgt: Is de informatie die u nodig heeft makkelijk te vinden in rapporten, en is deze informatie concreet, of zorgt het rapport voor "ruis"?

Wel eens onduidelijk, dat mensen net langs elkaar communiceren.

- Hoe vaak kunt u informatie verkrijgen via het Ontwerpteam? Heb nu het idee dat zij een centraal punt zijn waar alles informatie samen komt.

- Welke vorm van communicatie vindt u het fijnst?

Samen in 1 kamer

Ook 1 project per dag werkt goed, zonder switchen.

Gebruikt veel email. Telefoon heel irritant. Telefoongesprek haalt vaak uit de flow. Skype lost deels op, omdat je "aan kan wijzen"

- Welke vorm van communicatie komt het meest voor?

Veel emails, ook veel bellen.

- Vindt u dat er te veel, genoeg of te weinig wordt gecommuniceerd? (focus op meetings)

Hangt af van de persoon met wie je werkt.

Constructeurs nemen vaak dingen aan omdat ze niet erg veel communiceren.

Gaat meestal goed

Ontwikkeling is om wat meer meetings te hebben

Appendix E: Questions & Answers notes design interview 2

Bij final outputs wil je dat alles al klopt volgens de klant, dat er geen aanpassingen meer hoeven worden gedaan, maar komt wel eens voor.

Bij DO is de input van de klant al een referentie-ontwerp / VO

Bij "design-rough sketch" is eigenlijk al beetje design-loop, maar hoe het nu in de flowchart staat is wel duidelijk.

Bij final output eenzijdige communicatie met de klant: communicatie is al gebeurt in de design-loop.

Feedback op verificatierapport kan leiden tot stap terug naar model aanpassen.

"All teams satisfied" is al soort interne toets.

Voor ontwerp geen toets van 3e partij.

Tijdsbestek:

- Input vergaren: Weinig tijd, ong. minder dan 10%
- Rough model: Ong. 20%
- Model loop: Ong. 40%
- Drawing loop: Minder dan model loop, 20% tot 30% (*25% doen?*)
- Rapport schrijven & outputs leveren: 20%

Generate final model & drawings en aanleveren aan klant gebeurt al eerder dan opleveren: model en tekeningen worden veel gebruikt voor bijvoorbeeld kostenberekening.

Communicatie in loop:

- Bellen (zo min mogelijk, meestal daarna ook email zodat het zwart op wit staat)
- Email
- Overleg

Failure demand komt het meest voor. Hangt ook af van contract: sommige contracten zijn heel streng met deadlines, dan kan je niet zomaar deadlines missen en moet je dus op tijd klaar zijn. Andere contracten zijn minder streng, dus dan gebeurt het wel eens dat mensen te laat klaar zijn, en informatie dus nog niet beschikbaar is.

Intern loopt het proces best goed: Inefficiënties liggen vooral in communicatie met externen.

Komt wel eens voor dat informatie niet aankomt, komt in de ontwerp-loop wel eens voor.

Eventuele KPI: Tijd tussen begin model en wanneer het model klaar is.

E-mails tellen is niet heel handig: heel persoonlijk of diegene e-mails gebruikt of liever een andere vorm van communicatie gebruikt.

Beste manier van meten is tijd.

Meten kan het beste met een case: 2 teams, 1 met traditionele proces, 1 met ANT. Dit is echter enorm lastig om te doen: kost tijd en geld.

Bij ontwerp wordt op het moment met ANT gewerkt, binnen het team. Database wordt gebruikt om input te archiveren, en informatie up-to-date te houden. Is er positief over.

In ideale wereld zou ANT heel goed wijzingen kunnen aantonen. Niet alleen sneller informatie vinden, maar ook wijzigingen anticiperen doordat er links zijn tussen waardes.

Database zorgt ervoor dat mensen meer verantwoordelijkheden krijgen richting elkaar: hier kan niet iedereen zo goed mee omgaan. Hoeven maar een paar mensen te zijn die deze verantwoordelijkheid niet nemen, en de database werkt al niet efficiënt meer.

De baten van een database moeten echt duidelijk zijn richting mensen: wat levert dit extra werk voor hen op?

Input Lijstje Database:

Sketch: De inputs uit de flowchart

Design rough model: Extra eisen vanuit klant

Na model-loop: Alter & Improve: Alle opmerkingen andere teams

Drawings: Akkoord & gezien van andere teams

Na drawing-loop: Ook weer feedback & opmerkingen andere teams

Voor het opstellen rapport: Akkoord & gezien van andere teams.

Opstellen rapport: Models & drawings gebruiken om requirements te checken.

Output Lijstje Database:

Model loop: Model als output & feedback naar andere teams.

Drawing loop: Drawings als output & feedback naar andere teams.

Bij beide “satisfied” blokjes: interne toetsing, dan feedback.

Writing verification report: (concept) report. Voor het ontwerpteam is het al een definitief ontwerp, maar als de klant aanpassingen wil, moet dit gebeuren.

Opmerking van klant op rapport kan leiden tot aanpassing, maar kan een hele kleine aanpassing zijn, zoals een opmerking bij een tekening. Dan hoeft niet de hele loop weer doorlopen te worden.

Generate final outputs kan weg: als klant eens is is het klaar.

Models & Drawings als input voor het schrijven van het rapport.

Appendix F: Questions & Answers construction interview 2

Nog aan flowchart toevoegen: Input environmental conditions van klant.

Bij ingewikkelde projecten laat je de “toetser” al meekijken in de ontwerploop, zo voorkom je dat er constant enorme aanpassingen moeten gedaan tussen alle teams.

Per tunnel maakt constructie meerdere rapporten, stuk of 5.

Voor tunnel wordt er vaak wel een centrale toets gedaan, maar door een externe partij, steekproefsgewijs.

Soms intern review-team opstellen van experts per discipline. Experts van Witteveen+Bos die niet aan het project hebben gewerkt.

Schets en model gaan eigenlijk een beetje tegelijkertijd.

ANT maakt het model opstellen langer, omdat alle onderlinge relaties met andere teams moeten worden opgesteld, maar de ontwerploop wordt korter omdat er minder geïtereerd hoeft te worden.

In het huidige model zit er meer tijd in het opstellen van het eigen model dan in het itereren in de design-loop.

Tijd: 50% zelf opstellen model, 25% tot 50% tijd aan itereren.

Failure demand heeft meeste impact, kost erg veel tijd. Komt ook veel voor, vooral met projecten in het buitenland. In NL is dit vaak wel op orde: als het dan voorkomt weet je bij wie je moet zijn om het op te lossen.

ANT gaat het complex maken door informatie overload en doordat mensen data verschillend nodig hebben.

Email wordt minder; whatsapp & Skype.

Meerdere mensen de duur van de taken in de flowchart vragen.

Praten met mensen die ANT gebruikt hebben.

Moet makkelijker worden om even snel iets te vragen, bij mail wordt er vaak gedacht “oh dit al wel zo zijn, mail ik niet over”. Skype helpt hier al mee. Ontwerp overleggen zijn moeilijk te plannen, Skype helpt hier ook bij. Kan wel even in database kijken om bijvoorbeeld up-to-date informatie te vinden.

ANT maakt werk leuker, want focus komt meer op je eigen werk te liggen, i.p.v. het onderling afstemmen.

Vraag aan ANT of ze screenshot of inzicht in database kunnen laten zien.

Nodig uit database voor "Model made":

- Waterstand (geotechniek/geohydrologie)
    - Minimale waterstand
    - Gemiddelde waterstand
    - Maximale waterstand
- Hoogte wegas/ alignement (wegontwerp)
    - Hier onder valt verkanting (scheefte weg)
- Aantal rijstroken (klant)
- Levensduur object (klant)
- Welke scheepvaart van rivier (klant)
- Grondeigenschappen, bijv. gewicht van grondlagen en 10-tallen andere parameters van de grond (geotechniek).

Constructief zet in database:

- Dikte wand
- Dikte vloer
- Beton sterke klasse (type beton)

ANT verhaal is ook verkooppraatje richting klant & aannemer, om zo opdrachten binnen te slepen.

Eventueel kijken wat ANT verwacht voor de offerte: wordt deze goedkoper als het proces efficiënter is, i.v.m. uurloon?

Appendix G: Questions & Answers road-design interview 2

Worden rapporten geschreven ter ondersteuning van het alignement en de modellen.

Interne testen worden in de design-loop al meegenomen.

Alignement staat na de loop pas vast: voor de loop is er een "concept" versie, die dan eventueel wordt aangepast gebaseerd op feedback van een andere partij.

Ongeveer tijdsduur:

- Schets & model loop: 30%
- Design-loop: 45%
- Puntjes op de i: 25%

Flawed flow & zelf achter info aangaan zorgt voor grote verspilling in het proces.

Flawed flow komt het meeste voor.

Belangrijk om in een project 1 aanspreekpunt te hebben die overzicht heeft over de communicatie. Projectleider voor communicatie.

Voor klant, aannemer of andere externe partijen is dit ook handig, zo weten ze bij wie ze vragen kunnen stellen.

Constructie levert wel eens updates zonder duidelijk te communiceren: dan is het onduidelijk wat er precies is veranderd in een nieuwe versie, en wat de reden van deze aanpassing is.

Info wordt wel eens geüpdatet zonder uitleg waarom.

ANT zou wel werken: kan lijnen trekken om duidelijk aan te geven wat er wordt verwacht van de communicatie.

Aanpassen blijft altijd belangrijk: die design-loop blijft, zelfs met een database, maar zou wel ingekort kunnen worden.

Klant eventueel toegang geven tot de database voor "mijlpalen", zodat hij wel op de hoogte blijft van voortgang, maar niet constant over je schouder mee kan kijken.

<u>Benodigdheden database:</u>
Schetsen + modellen: Info van klant + Info van omgeving (omwonenden, waterschappen, etc.)
Bespreken met klant: Feedback van klant
Klant gaat akkoord: Akkoord klant, voldoet het aan de verwachtingen?
Optimize & alter model: Bijvoorbeeld input van landschapper, zegt dat je rekening moet houden met een rijtje bomen. Verschilt heel erg van de ontwerpfase (VO, DO, UO).
Design-loop: Zet 3D-modellen in database, deze modellen worden dan bijvoorbeeld door constructie gebruikt. Wil feedback van andere disciplines of het aansluit op hun werk.
Satisfied: Akkoord & gezien andere teams. Ook dat het op slot gaat zodat de correcte versie vast staat.
Toetsen: Model, uitgangspunten, eisen/richtlijnen klant en handboek wegontwerp / expertise zijn nodig om te toetsen. Denk alleen model en uitgangspunten (rapport) in de database.
Test satisfied: Akkoord & gezien, ook weer op slot.
Final output: Model, rapport & alignement in de database. Klant kan dan vragen stellen of feedback geven.

Lijstje database:
Schetsen + modellen:
- Info van klant
- Info van omgeving (omwonenden, waterschappen)

Bespreken klant:
- Feedback van klant

Client agrees:
- Akkoord klant, voldoet het aan de verwachtingen?

Optimize & alter model:
- Bijvoorbeeld input van landschapsarchitect, zegt dat je rekening moet houden met rijtje bomen.

Design-loop:
- Zet 3-Modellen in database, deze gebruikt constructie team dan bijvoorbeeld
- Wil feedback van andere disciplines of het aansluit op hun werk.

Satisfied
- Akkoord en gezien van andere teams.
- Versie gaat dan op slot, zodat de versie vast staat.

Toetsen:
- Model
- Uitgangspunten
- Eisen/richtlijnen klant
- Handboek wegontwerp/ expertise

Test satisfied:
- Akkoord en gezien
- Versie op slot

Final output:
- Model, rapport & alignement in de database zetten
- Klant kan dan vragen stellen of feedback geven

Appendix H: Questions & Answers geotechnics interview 2

Uit het labonderzoek komt een rapport: de interpretatie van het onderzoek met parameters.

Labonderzoek bestaat eigenlijk uit 2 stappen:

1. Labonderzoek zelf
2. Interpretatie & rapporteren bevindingen

Dat rapport is vanaf dan het uitgangsrapport voor geotechniek.

Het model is een grondmodel met krachten die de grond op de constructie uitoefenen, en andersom.

Tekeningen bij geotechniek zijn vaak heel beperkt.

Geotechniek is vaak aan de toetsende kant: wordt veel werk getoetst en gecheckt.

Model is soms output, afhankelijk van de klant.

Design-loop: weinig contact met wegontwerp. Vooral toetsen van werk wegontwerp, weinig afstemming.

In change & improve zit al afstemming.

<u>Tijdsduur:</u>

- "Desk-studies" zijn vrij beperkt.
- Veld- en labonderzoek niet bijzonder veel werk, hangt wel af van de complexiteit van het product.
- Veld- en labonderzoek zijn niet veel inspanning, wel erg veel doorlooptijd. Bedrijven die grondonderzoek uitvoeren hebben wachtlijsten, etc.
- Winst valt te pakken op de doorlooptijd van de onderzoeken. Als er eerder in het proces een geotechnicus wordt betrokken, kan deze eerder inspelen op de verwachte benodigde onderzoeken.

<u>Tijdsduur:</u>

- Vooronderzoek: exploration, veldwerk, labwerk: 10%
- Interpretatie van de parameters: 10%
- Gehele loop inclusief toetsing: 60%
- Rapporteren & toetsen producten: 20%

Rapporteren & toetsen kost altijd best veel tijd, meestal meer dan gehoopt.

Rapporten staan vaak best veel irrelevante dingen in, zorgt voor veel te dikke rapporten, kost veel te veel tijd.

Vormen communicatie:

- Projectmeeting
- Email
- Bellen
- Skypen (meestal vergadering, niet 1 op 1)
- Langs bureau lopen

Hangt erg af van de projectleider welke communicatie vormen worden gebruikt, en hoe gestructureerd dit gebeurt.

Voortgangsoverleg is vaak wel nuttig, maar kost veel tijd. Komt waarschijnlijk doordat disciplines enthousiast zijn over hun eigen werk, en dus lang praten over irrelevante dingen.

Denkt wel dat baten vergaderen opwegen tegen de kosten van tijdsduur, als er maar wat efficiënter vergadert wordt.

Verspilling in informatie-uitwisseling is heel afhankelijk van de klant. Als er bijvoorbeeld met een projectontwikkelaar wordt gewerkt is er vaak te weinig informatie.

Overheid vaak excess: Leveren vaak enorm vele informatie, zodat ze later kunnen zeggen “nee maar dat hadden we in dat rapport staan op pagina 2031”.

Binnen Witteveen+Bos vloeit informatie relatief geod, wel vrij duidelijk wie wat moet hebben

Flawed flow komt wel voor: dat je bijvoorbeeld niet weet dat er er een nieuwe keuze gemaakt is.

Misschien als je het wil meten: typische projectweek uitkaarten met de 4 acteurs, en dan kijken hoe ANT dit zou kunnen verbeteren. Bijvoorbeeld aantonen dat beepalde vergaderingen korter kunnen, of niet meer nodig zijn.

Door ANT komt er meer focus op de juiste methode kiezen, en deze methode dan laten runnen door computer.

Heel positief over ANT: als dit niet gebeurt dan kan Witteveen+Bos de deuren wel sluiten. Hoeft niet eens persé ANT te zijn, maar moet een goede database met goede invulling komen.

Moeten heel strikte afspraken komen over de structuur van de database.

Database heeft nog steeds kans op miscommunicatie. Deze gevolgen zouden veel groter zijn, omdat het dan gelijk overal fout is.

Lijstje database:

Parameters die uit de lab-interpretatie komen worden intern gebruikt:
- Wrijvingshoek (per grondlaag)
- Cohesie (per grondlaag)
- Tabel met grondopbouw voor verschillende locaties

Field research:
- Alignement nodig (op een kaart) dan kan je op die kaart je grondonderzoekspunten zetten, komt dan weer als output op de kaart.
- Basics constructie: geometrie, belasting constructie & type constructie.

Discuss model:
- Output: Verplaatsingen grond, vervormingen, vooral uitkomsten van een model. Weet wat anderen nodig hebben.
- Input: Feedback andere partijen.

Satisfied:
- Gelezen & akkoord andere partijen, of de resultaten acceptabel zijn voor andere disciplines.

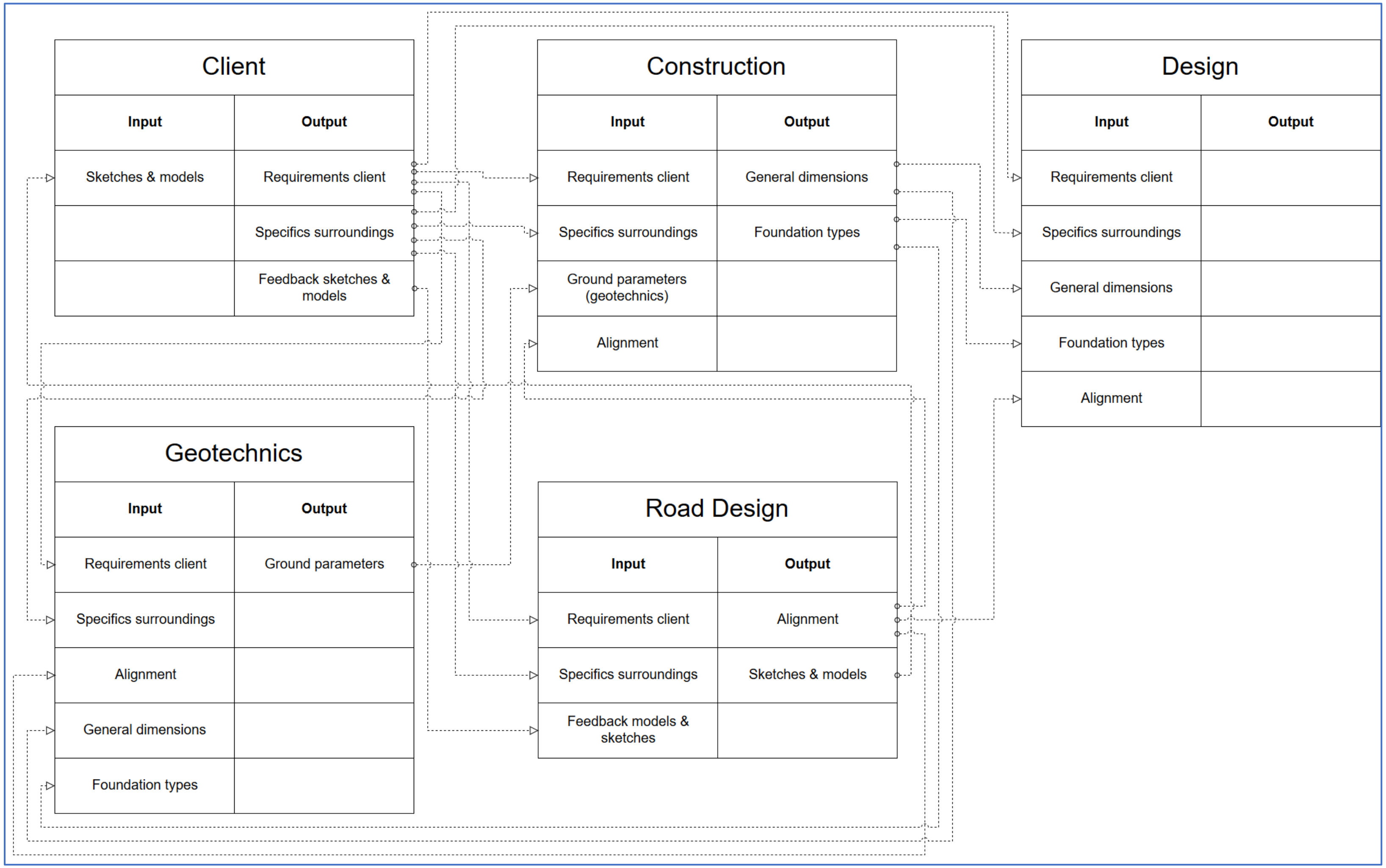
Toetsing:
- Feedback
- Gelezen & akkoord

Final output:

- Model
- Tekeningen
- Rapport

Externe toets gebeurt niet altijd

Appendix I: Prebuilt rules database



Appendix J: Flowchart current process

See page 71

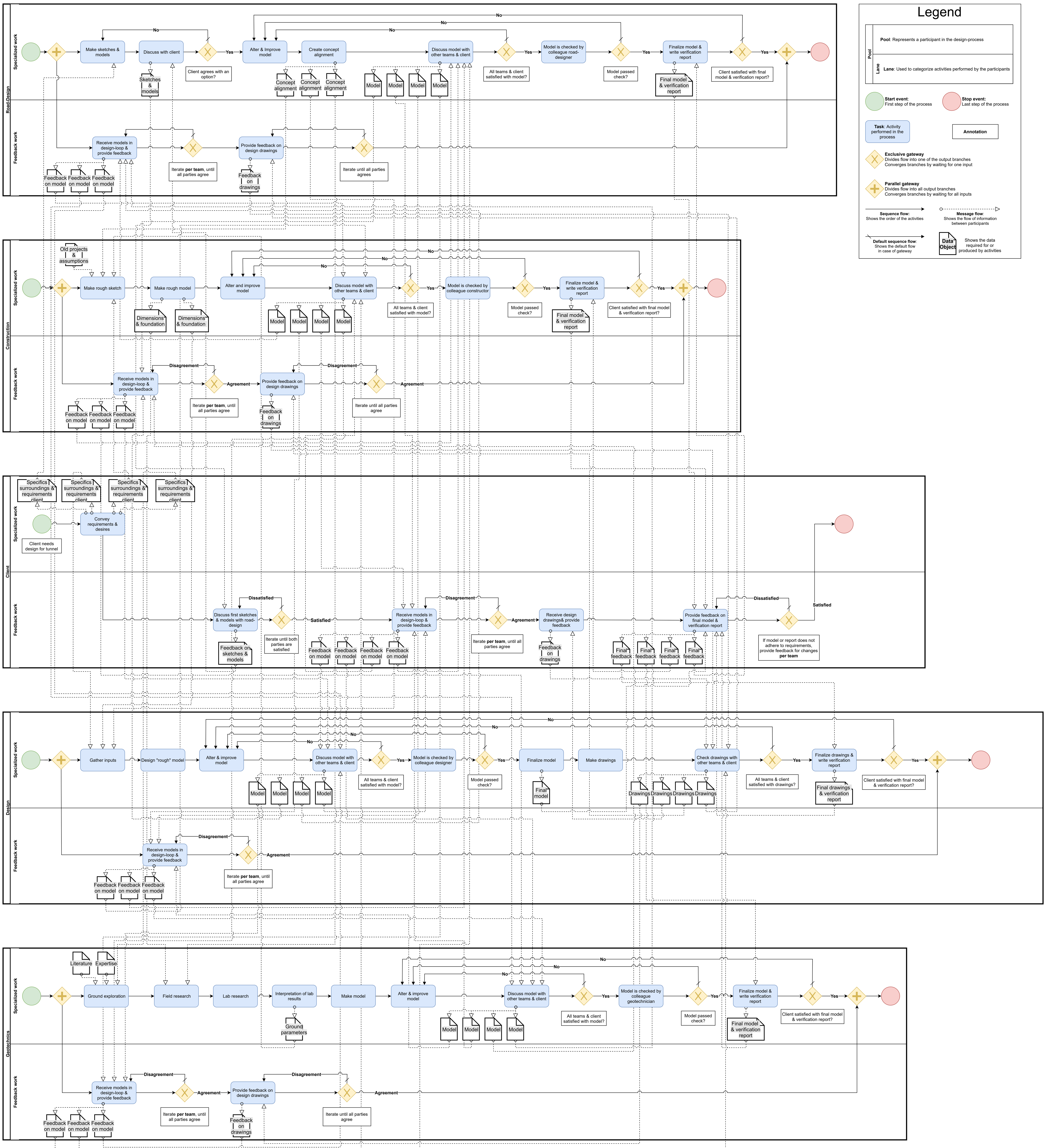
Appendix K: Flowchart current process simplified

See page 72

Appendix L: Flowchart improved process

See page 73

Flowchart current process



Flowchart current process simplified

Flowchart improved process