UNIVERSITY OF TWENTE.

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SLIMMER VERBINDEN, BETER BOUWEN

Learning Trajectories within Mobilis

Master Thesis
Construction Management & Engineering

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Version: 1.3

Date: 18/05/2021

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Version control

Version	Date	Description
0.1	2-11-2020	Content of the final research proposal (version 0.5) added and the final comments (Assessment proposal Steven Schwarte) implemented. Elaboration of the theoretical background and conceptual framework.
0.2	10-11-2020	Regarding the discussion of the conceptual framework.
0.3	17-11-2020	Regarding the discussion of the conceptual framework.
0.4	29-11-2020	Regarding the discussion of the final framework and case study protocol.
0.5	16-1-2020	Description of the case studies and the analysis
0.6	6-2-2021	Analysis of the case studies
0.7	15-2-2021	Analysis of case 1
0.8	12-3-2021	Case analysis and cross-case conclusion
0.9	28-3-2021	Cross-case and recommendations
1.0	11-4-2021	Concept version
1.1	20-4-2021	Implementation of the feedback, given by M. van Buiten on concept version (1.0)
1.2	27-4-2021	Implementation of the feedback, given by A. Hartmann on concept version (1.1) Green-light version
1.3	18-5-2021	Implementation of the feedback on the green-light version. Final version.

Samenvatting

Projecten binnen de civiele techniek zijn opgemerkt als mechanismes voor het integreren van kennis, als een belangrijke leerplek en als een controle punt voor de ontwikkeling. Echter, het opnieuw uitvinden van het wiel wordt vaak opgemerkt binnen de project georiënteerde organisaties. Deze organisaties zijn aan het zoeken naar het efficiënt leren van projecten en van projecten naar de organisatie. De productie en inkomsten binnen deze organisaties zijn berust op de projecten. Hierbij zijn de projecten verbonden door de organisatorische omgeving en de ervaringen van de leden. Dit kan resulteren in de voortzetting van een techniek binnen een reeks van projecten. Mobilis is een Nederlandse civiele aannemer en is gekarakteriseerd als een project georiënteerde organisatie. Deze organisatie ziet mogelijkheden voor het verhogen van het leren door een betere sturing op de kennisontwikkeling te verkrijgen binnen de voortzetting van een techniek. In dit onderzoek is de voortzetting van de techniek binnen meerdere projecten, wat kan resulteren in kennisontwikkeling, gedefinieerd als een leertraject.

Dit onderzoek streeft ernaar om (1) een praktische kijk op het leren te vormen, (2) de leertrajecten binnen Mobilis te begrijpen, en (3) aanbevelingen te ontwikkelen voor het verbeteren van de leertrajecten en het projectmanagement. Deze drie doelstellingen hebben geresulteerd in de volgende onderzoeksvragen: (1) Hoe verlopen leertrajecten binnen Mobilis?, (2) Waarom verlopen de leertrajecten zo?, en (3) Hoe kunnen de project management processen verbeterd worden om de sturing op het leren tussen projecten en naar de organisatie te versterken?.

Voor het bereiken van de doelstellingen zijn de volgende onderzoeksactiviteiten uitgevoerd. Bij deze activiteiten zijn de relevante resultaten beschreven.

(1) Een conceptueel raamwerk is ontwikkeld om een praktische kijk op het leren te vormen. Binnen dit raamwerk wordt het leertraject gevormd door de interactie van de leden, tools en taken. Projectdocumenten met de technische kennis worden gezien als de tools. Deze interactie activeert de openbaring van de ervaringen. Deze ervaringen worden gebruikt om binnen de nieuwe context, de praktijk te creëren. De praktijk bestaat uit de technische kennis en de kennis over de vervolgstappen of welke leerprocessen benodigd zijn. Uiteindelijk wordt deze praktijk vastgehouden in de leden, tools en taken. Het leren vindt plaats binnen de organisatorische en project context door de processen activeren, creëren en vasthouden. Tot slot heeft deze fase geresulteerd in het raamwerk en een template voor het analyseren van de verschillende ontwikkelingen binnen verschillende contexten, welk beide gebruikt zijn voor de case analyses.

(2) Om de leertrajecten te onderzoeken zijn er twee casestudies opgezet: de zandpot en het storten van de wanden onder het spoordek. De case is omtrent een doorontwikkelde constructie of werk methode binnen meerdere projecten. Binnen dit onderzoek is het empirisch bewijs verkregen door het uitvoeren van zeven interviews en het analyseren van zes projecten. De casestudies hebben aangetoond dat het raamwerk te gebruiken is voor het in kaart brengen van de leerprocessen en mogelijke verbeteringen voor het leren.

    De casestudies hebben aangetoond dat het leertraject geïnitieerd kan worden vanuit verschillende projectfases. Initiatie vanuit de ontwerpfase resulteerde in de directe betrokkenheid van de opvolgende afdelingen. Daarentegen, de initiatie vanuit de uitvoeringsfase resulteerde niet direct in de betrokkenheid van de ontwerpafdeling. Binnen deze projecten wordt het leren gestimuleerd door de integrale samenwerking van de verschillende afdeling, doordat de ervaringen en voorwaarden vanuit de verschillende projectfases ingebracht worden. De opgemerkte ontwikkelingen hebben plaatsgevonden binnen opeenvolgende projecten. Deze projecten waren verbonden door de overeenkomende project missies en terugkomende taken. De voorgaande ervaringen zijn gebruikt door het terugkijken naar het voorgaande project of door de voortzetting

van de leden en tools. Deze tools worden ingebracht door de leden, waarin het netwerk van leden en tools is opgemerkt. Verscheidene actoren zijn opgemerkt binnen het leertraject. Namelijk de ontdekker, gebruiker, inbrenger en eigenaar. De eigenaar vervult een belangrijke rol binnen het traject, omdat deze persoon zorgt voor de voortzetting van de ontwikkeling en de integrale samenwerking. Het is te concluderen dat wanneer de ontwikkeling een bepaalde volwassenheid of succes heeft bereikt, de exploitatie van de kennis minder afhankelijk is van de eigenaar. Dit komt mede doordat de praktijk verspreid is over meerdere organisatorische leden door de toepassing binnen de verschillende projecten en doordat de tools een prominentere rol spelen in het overbrengen van de praktijk.

(3) Voor het versterken van de sturing op de leertrajecten binnen de organisatie is een flow diagram opgesteld. Dit diagram is gericht aan de afdeling, tender en ontwerp managers en de uitvoerder. Hierin is een verschil gemaakt in de momenten: voor het project, de projectfases en de evaluatie van de ontwikkeling. Dit diagram kan dienen als een startpunt voor de integratie van de leerprocessen in de organisatie en projectfasen. Het diagram start met de opzet van de strategische doelen waaraan de projecten gekoppeld worden. Deze strategische doelen bevatten project-overstijgende ambities: wat wil de organisatie bereiken? Door de interne project-overstijgende trajecten te achterhalen en bekend te maken, wordt het benutten van de voorgaande ervaringen gestimuleerd. De organisatie heeft een groot invloed in de vormgeving van de projectcontext door de bepaling van de leden, tools en taken en dient hier proactief mee bezig te zijn. Binnen de tender wordt geadviseerd om de incidenten en ontwikkelingen van de voorgaande projecten te achterhalen door middel van het raadplegen van de betrokken leden en tools. Binnen de ontwerpfase is het aanbevolen om het review moment en de integrale ontwerpoverleggen te laten plaats vinden. Zowel binnen ontwerp als in de uitvoeringsfase dienen de projectdocumenten voortgezet te worden. Deze document zijn ingebracht door het netwerk van leden en tools. Nadat de ontwikkeling heeft plaatsgevonden, dient de eigenaar van dit proces worden bepaald. Vervolgens moet het succes en de volwassenheid van de ontwikkeling worden beoordeeld en in hoeverre de eigenaar bij de opvolgende projecten moet worden betrokken en/of de tools verder uitgewerkt moeten worden. De organisatie moet deze tools reviewen en bepalen in hoeverre deze tools van toepassing zijn voor de volgende projecten. Tot slot, de managers dienen te achterhalen wat de projecten hebben bereikt om zo de doelen aan te passen of voort te zetten.

De geanalyseerde cases laten zien dat het leren binnen de projecten plaats vindt. Echter, het ontwikkelde raamwerk geeft aan dat het leren ook onafhankelijk van de projecten kan plaats vinden. Het ontbreken van deze processen in deze context zou verklaard kunnen worden door het ontbreken van een afdeling met de project-overkoepelende visie, de classificatie van de organisatie als een project georiënteerde organisatie, de afhankelijkheid van de cases aan de projecten en de continue stroom van projecten waarin een onderdoorgang is gerealiseerd.

Summary

Projects within the construction industry are considered as a mechanism to integrate knowledge, as an important context for learning and as a checkpoint for the development. However, the industry is still blamed for reinventing the wheel over and over. Project-based organisations (PBO's) are struggling with learning from projects and from projects into the organisation. The projects within these organisations are connected through the organisational setting and the experiences of the members. This interaction enables the continuous enactment of technology over a series of projects. Mobilis operates in the Dutch construction industry and is considered as a PBO. Opportunities are seen by Mobilis to increase learning by achieving better guidance and control on the knowledge creation by the continuous enactment across the projects and in the organisation. In this research, the continuous enactment of technology over the series of projects, which will result in the knowledge development, is defined as a learning trajectory.

This research aims to (1) provide a practical viewpoint on learning, (2) understand the learning trajectories within Mobilis, and (3) develop recommendations to improve the learning trajectories and their project management to enhance the guidance of learning across projects and into the organisation. These three objectives resulted in three research questions: (1) How do the learning trajectories unfold within Mobilis?, (2) Why do the learning trajectories unfold in this way?, and (3) How can the project management processes within Mobilis be improved to enhance learning across projects and within the organisation?

To achieve the objectives, the following research activities were conducted. The relevant results of each step are also described.

(1) To provide a practical viewpoint on learning within the organisation a conceptual framework of the learning trajectory was developed. Learning is constituted through the interplay of members, tools and tasks. The tools are project documents that contain the developed knowledge. This interplay triggers the revelation of the experiences. By the exploitation of these experiences within the new context, the practice will be created. The practice consists of technical knowledge and the knowledge of what to do next or which learning processes will stimulate the development. Eventually, the practice is retained in the members, tools and tasks. The processes of triggering, creating and retaining can take place within the organisational and project context. Finally, this phase resulted in a conceptual framework and a template. This template is used in the next phase to analyse the different developments within the contexts.

(2) To investigate the learning trajectories within its real-world context, two case studies have been executed: the zandpot and pouring the concrete walls underneath a railway deck. The empirical evidence is acquired by conducting seven interviews and analysing six projects. The cases showed that the framework was useful to identify the learning processes and opportunities for further learning. Within the next paragraph, the findings of the case studies are described.

    The trajectory can be initiated from different building phases. Initiation from the design phase resulted directly in the involvement of the subsequent departments. However, the initiation from the construction phase did not directly result in the involvement of the design department. This integral cooperation stimulates learning due to the contribution of the experiences and preconditions of the different teams. The developments have occurred within subsequent projects, which were connected by a similar project mission and recurring tasks. In each project, the members used the previous experiences by looking back or by the continuation of the members and tools. These tools are transferred by the members. Different members have played different roles within the trajectory related to learning. The following actors have been noticed:

explorer, exploiter, contributor and owner. The latter actor fulfils a major role in the trajectory because the owner ensured the continuation of the development and the integral cooperation. When the developments have reached a certain maturity, the exploitation of the knowledge is less dependent on the owner because the knowledge has been diffused over more members and the tools fulfilled a more prominent role.

(3) To enhance the guidance of the learning trajectories within the organisation, a flow diagram is developed. This diagram can perform as a starting point for the integration of the learning processes in the organisation and the different building phases to enhance the learning between projects and within the organisation. The diagram starts with defining the strategic goals to which the projects are linked. By identifying and communicating the internal project-crossing trajectories, the exploitation of the previous experiences may be stimulated. The organisation has a great influence on the design of the project context through the determination of the members, tools and tasks within the context and should be proactive in this. Within the tender, the members need to investigate the incidents or developments in similar projects by consulting the members and tools. Within the design, the execution of the project review and integral design meetings needs to be continued. In the design and construction phase, the documents of the previous project need to be continued. These tools are contributed due to the network of members and tools. After the development has occurred, the owner of this process needs to be determined. Subsequently, the success and maturity of the development needs to be reviewed and to what extent the owner should be involved in the future and whether the tools have to be elaborated further. The organisation needs to review these tools and determine to what extent these tools apply to the organisation. Finally, the consequences of the projects for the defined strategic goals need to be reviewed by the managers.

The studied cases showed that learning took place within the project. However, the developed framework indicates that learning may also take place within the organisational context (i.e., independently of the project). The absence of these processes in this context might be explained by the absence of a department with the project-overarching view, the classification of the organisation as a PBO, the dependency of the cases on the project context and the continuous flow of projects in which an underpass is constructed.

Preface

This report in front of you is the final product of the master 'Construction Management and Engineering' with the specialisation in 'Markets and Organisations' at the University of Twente. This product is the result of my thesis research project 'Learning trajectories within Mobilis'. As the title already stated, this research was carried out at Mobilis.

The extraordinary times, due to Covid-19, made the master thesis trajectory extra challenging. The social bubble was forced to be relatively small than normal, both at work as in personal life. Hereby missing out on the interesting conversations over a coffee at the coffee machine or the entertainment on the weekends. However, I experienced the full cooperation of the members at Mobilis and I still felt engaged during these detached times.

First, I would like to thank my graduation committee of the University for their excellent feedback and guidance during the past months. In addition, I want to thank my supervisor of Mobilis Remco Lensen for his feedback and the freedom in conducting this research within this interesting organisation.

Besides, I would like to thank the interview respondents for their time and the interesting dialogues during the (digital) meetings.

Finally, I want to use this spot to thank my girlfriend, family and friends. They supported me during this course by giving feedback or just with the essential motivation speeches.

I hope you enjoy your reading.

Steven Schwarte

Arnhem, May 2021

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Glossary and abbreviations

As	Assen (Project Onderdoorgang 'De Maten' Assen)
Bi	Bilthoven (Project Onderdoorgang Leijenseweg Bilthoven)
EN	Elst Noord (Project Elst Noord Spoorkruisingen)
ER	Engineering report
ES	Elst Station (Project Onderdoorgangen Spoorzone Elst)
He	Heiloo (Project Onderdoorgang Heiloo Vennewatersweg)
MQ	Main Question
OC	Organisational Context
PBO	Project-Based Organisation
Possession	*When a section of track is required for maintenance and trains cannot run, it is handed over by the operators to the engineers, who take "possession" (Network Rail, 2016).*
ProRail	The responsible company for the railways in The Netherlands.
SCC	Self-Compacting Concrete (*Dutch: Zelfverdichtend Beton)*
SPMT	Self-Propelled Modular Transporters
TA	TunnelAlliantie; The TunnelAlliantie is a chain programme between initiators (such as municipalities and provinces), ProRail and specifically recognised contractors for the realisation of rail underpasses (e.g., Mobilis).
TVP	Train free period (*Dutch: Trein Vrije Periode)*

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1. Introduction

Many companies within the construction industry can be classified as project-based organisations (PBO's), in which projects are considered as a significant part of the business (Wiewiora, Schmidt & Chang, 2018). Construction projects are considered as a checkpoint and a mechanism to integrate knowledge (Lindgren, Emmit & Widén, 2018), and as an important context in which learning takes place (Hartmann & Dorée, 2013; Ren et al., 2019; Scarbrough et al., 2004). However, the construction industry is still blamed for its poor performance (Hartmann & Dorée, 2013) and for reinventing the wheel over and over (Swan, Newell and Scarbrough, 2010). Within the Dutch construction industry, around 54 per cent of the failure costs occur within the realisation phase, due to an inappropriate preparation phase and time pressure (Van Heel et al., 2019). To improve the overall performance of the construction industry, thus reduce an organisation's failure costs, learning and knowledge sharing across the whole organisation are essential (Tortorella et al., 2020; Van Heel et al., 2019). In the last decade knowledge transfer and learning have received increased attention in the literature and within the management of organisations.

The organisation of Mobilis, which is considered as a PBO, is aware of these opportunities. Therefore, they implemented several facilities to endeavour an enhancement of learning and knowledge transfer within the organisation. Mobilis is one of the nineteen independent subsidiaries of TBI, see Appendix A for the organisation chart. This organisation is mainly operating in the Netherlands and offers solutions for issues in the field of infrastructure, water, energy, and industry (Mobilis, n.d.-a). Within this flexible organisation, three core values are being pursued: (1) build relationships within a team, within a business unit, with the client or chain partner, (2) continue learning as an individual and as an organisation, and (3) continue to achieve the objectives (Mobilis, n.d.-b). The organisation sees opportunities for improving the learning. Research demonstrates that PBO's experiences problems associated with learning within projects, from projects and to the wider organisation (Swan et al., 2010). The projects are connected through the organisational setting and the experiences of members (Hartmann & Dorée, 2015). The connectedness between those projects may result in a continuous enactment of technology, which results in continuous development over a series of projects. This is conceptualised as a learning trajectory.

The learning trajectories are the investigated phenomena in this research. The study of the two cases and their learning trajectories are found by conducting this research, of which its design is explained in chapter 2. Thereafter the theoretical background is explained to understand learning trajectories and to frame the analyses by the development of a conceptual framework, see chapter 3. The analyses and findings of the two cases are described in chapter 4. Eventually, in chapter 5 the findings are transformed into recommendations to enhance the guidance of learning between projects and within the organisation. The limitations of this research and directions for further research are described in chapter 6. Furthermore, learning in the organisational context is discussed in this chapter. Finally, the answers to the main research questions are provided and the research is concluded in chapter 7.

2. Research design

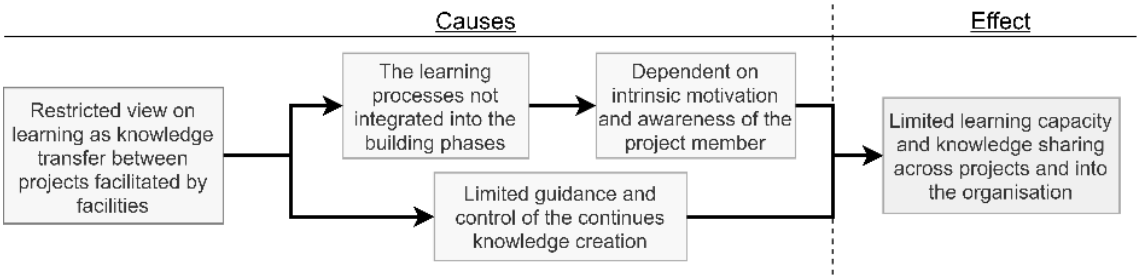
2.1 Problem statement

In this paragraph, the problem statement is described. A problem statement describes not necessarily something seriously wrong with a current situation, but a problem could also indicate a situation where research needs to be conducted to find the right answer for improvements (Hartmann, 2017). Through the execution of exploratory interviews with the organisational members, the current process regarding learning is uncovered.

In the current situation, Mobilis developed a system that should enable organisational learning and knowledge sharing. This approach is based on the implementation of several facilities to enhance learning and knowledge transfer. The existing facilities can be defined as (1) evaluation sessions and (2) intranet. *Evaluation sessions:* After the completion of the project, the process must be evaluated based on evaluation forms. *Intranet:* The intranet can be defined as a closed network for the company (Emazing, 2020). Within the organisation, this facility is known as 'de keet' (Dutch for portacabin) and contains elements such as 'durf-te-vragen' (Dutch for dare to ask) and 'Mobipedia' (a combination of Mobilis and Wikipedia). *Mobipedia* is a system that should facilitate knowledge transfer across the whole organisation. Knowledge sharing, by writing an article about relevant information and acquisition of the information, is being done on its own initiative and is not integrated within the project management. *Durf-te-vragen'* should facilitate the process of asking questions by one and answering that question by another one by using his/her knowledge and experiences. This facility is implemented by the organisation to enhance knowledge sharing and acquisition.

The exploratory interviews revealed that the knowledge of members or from previous projects are exploited in the projects, but that learning in this way is not integrated into the construction phases. Mobilis sees opportunities for increasing learning by achieving better guidance and control on the knowledge creation by the continuous enactment of the technology across the projects and in the organisation. Currently, the view on enhancing learning is mainly restricted to the knowledge transfer based on the facilities. This view is dependent on the members' intrinsic motivation and awareness of the available knowledge. Despite the initiated facilities, learning across projects and into the organisation is still considered limited. Figure 1 provides an overview of the causes and effects.

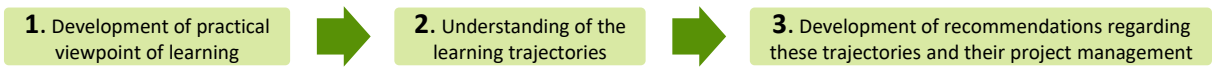
Figure 1: Cause and effect diagram



2.2 Research objectives

This research contains three consecutive objectives, which are visualised in figure 2. The first objective is to develop the practical viewpoint of learning as the continuous enactment of technology within projects, which lead to a learning trajectory. This viewpoint should frame the analysis of the learning trajectories. This is reflected in the second objective of this research. The second objective is to understand these learning trajectories. The third objective is the development of recommendations to improve the learning trajectories and their project management to enhance the guidance of learning across projects and into the organisation.

Figure 2: Research objectives



2.3 Research questions

To achieve the research objective, three main research questions (MQ's) are defined.

Main question 1:
How do the learning trajectories unfold within Mobilis?

Main question 2:
Why do the learning trajectories unfold in this way?

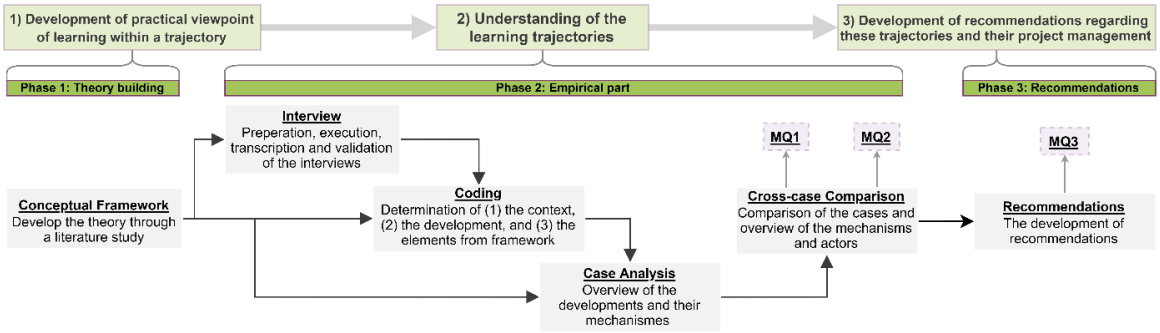
Main question 3:
How can the project management processes within Mobilis be improved to enhance learning across projects and within the organisation?

2.4 Research strategy

The studied phenomena in this research are the learning trajectories, which contain a continuous enactment of the technology over a series of projects. To analyse how and why phenomena emerge, develop, grow, or terminate over time a process study approach is executed (Langley, Smallman, Tsoukas & Van de Ven, 2013). The further specification of the research activities and their relations are visualised in figure 3.

The first research activity of the research is theory building, in which the practical viewpoint on learning is developed. This viewpoint will be used to frame the analysis. This phase is focused on acquiring and analysing empirical evidence. This empirical part contains an exploratory qualitative research methodology in which learning over a series of projects is investigated. Because the continuous enactment of technology over a series of projects is not well understood, qualitative research is a useful methodology (Edmondson, 2002). This methodology consists of two case studies to investigate the learning trajectories and conducting interviews within these cases. As is mentioned by Yin (2018), case studies allow the researcher to investigate organisational processes in-depth and within their real-world context. Eventually, this study produces insights into how the organisation is learning as well through the continuous enactment of technology. Within this last phase, recommendations are developed to achieve the third objective of this research.

Figure 3: Research strategy



2.4.1 Research phase

Phase 1: Theory-building

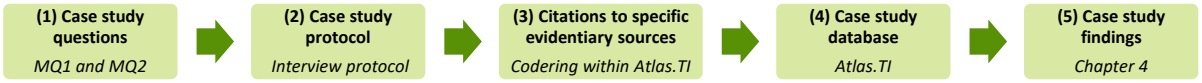
The first phase of this research is the theory-building phase. A theory simplifies and explains a complex real-world phenomenon (Van de Ven, 2007) and will help in generalising the lessons learnt from the case studies (Yin, 2018). The theory contains a description of the applied viewpoint of learning and the theoretical background, which underpins the chosen viewpoint. The theoretical background is acquired through a semi-systematic literature study. This approach aims to get an overview of the research area and to track the developments over time (Snyder, 2019). Eventually, the theory is conceptualised in a framework to visualise the relationships among concepts. The framework acts as the initial point for the following consecutive research activities: (1) development of the interview questions, (2) applied codes, and (3) the analysis on the developments and their underlying mechanisms within the learning trajectories.

Within this phase, the case studies for the empirical part of this research are selected. The case concerns the continuous enactment of a technology over a series of projects within an organisation, which resulted in the continuation of the knowledge development. The expectations about their information content are the basis for the selection of these cases, which will maximise the usefulness of the information (Flyvbjerg, 2011). A critical condition for this selection is the process of learning activities across a series of project and not just within one single project. Furthermore, the expectations for the presence of developments within these projects need to be there. The projects must have been carried out in the past five years to increase the chance of the project members and their experiences being present within the company. The cases are selected within the scope of projects with the mission of realising an underpass underneath a railway by pre-building a railway deck and transporting it to the location during the train free period. These projects are covered by Design & Construct contracts in which the organisation is responsible for the design and construction.

Phase 2: Empirical

The qualitative research method consists of two case studies and the data are acquired by interviews with the organisational members and analyses of the project documents. For conducting the case study, the multiple case study guidelines from Yin (2018) are followed. In the previous phase, the theory is developed and the case studies are selected. Before the interviews are prepared and conducted, project documents, such as evaluation reports, meeting records, the work plan, and the project mission are analysed to get familiar with the cases and to get insights into the social and technical content of these trajectories. The principle 'maintain a chain of evidence' is followed to increase the construct validity of the information, see figure 4 (Yin, 2018). This chain of evidence contains five steps. The italicised text underneath represents the specific steps related to this research.

Figure 4: Chain of evidence



Note. Adapted from *Case study research and applications (6th edition, p. 181)*, by R. K. Yin, *2018*, SAGE Publications.

(1) The case study questions aim to obtain the answers for main question one and two.
(2) To keep an overview of the process of analysing the case studies, a case study protocol is developed. This protocol is based on the conceptual framework. Multiple interviewees are engaged in both cases. Therefore, just one interview protocol is developed to structure the interview. Appendix B presents the interview protocol, which contains the aim of the question, questions, and applied codes.
(3) The interviews are transcribed and a summary with the essential results are sent to the respondents to validate the interpreted citations. Thereafter, the interview transcripts and projects documents are coded in three phases by processing in Atlas.Ti. Appendix C illustrates the code tree for the phasing and examples of the applied coding method. Phase one provides an answer to which context the citation belongs. Phase two consist of a search for the developments per context (this phase is not conducted through the application of specific codes in Atlas.Ti, but by making notes). These developments are further coded within phase three in which the elements from the framework are allocated to specific citations.
(4) Atlas.Ti is also used for the storage of the interview transcripts and project documents.
(5) The codes and their narrative materials are presented as the case study findings, which are extracted from the case study database. Through analysing the data, an overview of the developments over time is drawn up for each case based on the template developed in the theory-building phase.

The analysis provides a descriptive and interpretive result. A descriptive result describes what happened during these trajectories and an interpretive result adds an explanation of why these trajectories went like this (Hartmann, 2017). The descriptive result will provide an answer to MQ1. The

interpretive result is further described in the cross-case comparison. Within this research activity, the two cases are compared with each other to analyse the differences and similarities between the two learning trajectories. This comparison will result in answering MQ2.

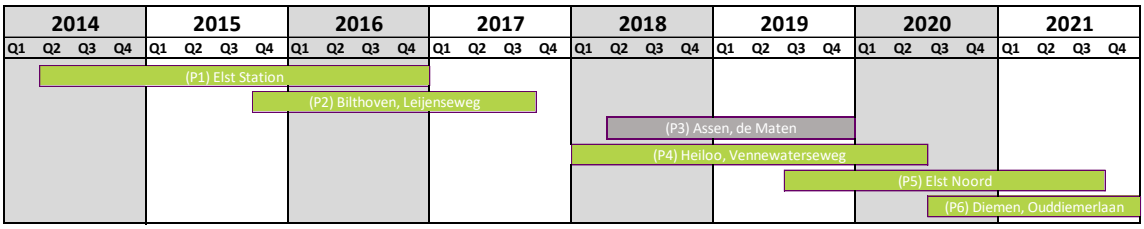
Phase 3: Recommendations

The last phase aims to deliver recommendations to the organisation. The cross-case conclusion is used for the development of the recommendations to enhance the guidance of learning across projects and into the organisation. The cases are compared with each other based on multiple themes. These themes are used in combination with the literature to develop the recommendations. A flow diagram for enhancing the guidance and control of the learning trajectories by the managers is developed. Eventually, this phase results in the answering of MQ3.

2.4.2 Case studies

To analyse the learning trajectory in depth and within its real-world context, the following two case studies are selected: (1) zandpot, and (2) concreting walls underneath the railway deck. In Appendix D the technical content of these case studies is described in more detail. The case concerns the continuous enactment of a technology over a series of projects within Mobilis. Figure 5 provides an overview of the projects in which the two technologies have been used or will be used.

Figure 5: Investigated projects over time



Case study 1: 'Zandpot'

The zandpot is used as temporary support for railway decks. This specialized work method has been executed in several projects. Project Assen (P3) was not part of this case, because in this project a different auxiliary construction was used. This case study is suitable for this research due to the execution across different projects over time in which the learning can be analysed.

Case study 2: 'Concreting underneath the railway deck'

It is noted, that Mobilis has experienced several problems with concreting walls underneath the railway deck within previous projects. However, in the last projects, a development is noticed to solve the experienced problems. Within the scope of this research six projects have been detected that are suitable for the analysis of the learning trajectory.

2.4.3 Interviews

The learning trajectories are considered as a social phenomenon, in which much of the information must come from the people. Interviews enable the collection of a wide variety of data from the stakeholders (Hartmann, 2017). The preference is given to conduct the interviews in the form of face-to-face interviews and to conduct the interviews on the location of the interviewee. However, due to the Covid-19 measures and the organisational policy most interviews are conducted digitally. The semi-structured interview approach is used because it is known what needs to be asked, but there is room for extra opinions and additional comments. The advantages of this form are that it is possible to adjust the questions on the spot and to clarify doubts and ambiguities (Hartmann, 2017). In total seven interviews are conducted. After the interview is conducted, the content is summarised and validated by the interviewee.

3. Theoretical background and conceptual framework

In this chapter, the body of knowledge, that is relevant to the research scope, is described. This body of knowledge is used for developing a conceptual framework. This framework represents the relations of certain concepts with each other and explains why these concepts are associated with each other (Hartmann, 2017). First, the different conceptions of learning are outlined. Second, the learning processes in the organisation and the multi-level view on learning are described. Furthermore, the management of projects and the different building phases are presented. Finally, the conceptualisation of a learning trajectory is described and presented.

3.1 Conceptions of learning

The traditional view on learning is primarily focused on the cognitive dimension of learning (Sense, 2008). The assumption within this theory is that a conflict is essential for learning and it stimulates the learning processes. These conflicts are caused by errors or different information and create different experiences, which are reflected by the individuals and changes their perceptions and actions (Sense, 2008). In other words, the input for conducting the cognitive processes is a stimulus (e.g., a conflict or an experience) and the output is a response by the individual. This conventional view on learning is seen as *mainly cerebral, unproblematic, and as a matter of transmission and assimilation (Sense, 2007, p. 406.).* This view is also the basis for the sender/receiver approach (Hartmann & Dorée, 2015). Within this approach, the flow of knowledge is produced and consumed between the individuals through the right transmission channels. The barriers (lack of time, usefulness, and purpose, focus on failures and commitment of staff and management) have a strong relationship with major limitations of the production structure, business paradigm and management style in PBO's (Hartmann & Dorée, 2015).

However, the cognitive view on learning neglects the nature of the learner, the environment of the learner, and their networks within that context (Sense, 2007). According to this researcher can learning be viewed as closely related to conditions in which it is generated and the people and their actions, because learning is achieved through the ongoing mutual interactions between people and the environmental influences of their context. This social perspective on learning emphasises the *social relations, sensemaking, informality, collective action and conversations within the workplace, and learning is also considered as an integral part of generative social practice within the context (Sense, 2007, p. 406).* This social and practical view on learning is defined as the situated learning theory (Sense, 2007) or the social learning theory (Hartmann & Dorée, 2013). Hartmann and Dorée (2015) investigated the context of projects to increase the effectiveness of learning on the inter-project level and concluded that inter-project learning appeared when employees were engaged in the current project work. Through the interaction of the individuals and project members in project meetings, discussions and workshops, their experience can be made explicit and be part of the project-related interactions. The main characteristic of this social view on learning is the discussion of the concept of context (Sense, 2008). These characteristics are reflected in the following four themes concerning the social learning theory (Sense, 2008):

- *Contextually situated:* Knowledge is attached to the practice and it is therefore positioned in the context and influenced by the social and cultural conditions of practice.
- *Social participation and interaction* within the actual processes are essential for learning and the development of knowledge.
- *Collective sensemaking* will help participants make sense of their world.
- *Identification of participants* with the right experiences and perceived social competencies is a negotiated process.

In the studies of Sense (2007; 2008) the two conceptions of learning are combined as the two elements of how learning unfolds in a natural working place. Cognitive learning theory is the cognitive aspect of a situated learning process, and thus, the context and its sociological aspects mediate the cognitive learning activities of an individual and are an integral part of the learning and knowledge creation

process. The social dimension of learning constitutes the cognitive dimension. Therefore, the focus needs to be placed on the social dimension of learning to better understand and improve the learning activities of project members within any context (Sense, 2008).

3.2 Organisational learning

Learning in an organisation is defined as organisational learning and concerns the process of improving organisational actions (Wiewiora et al., 2019). Organisational learning is considered as a dynamic process that unfolds on the following levels (Wiewiora et al., 2020):

1) *Individual:* For the individual level, the internal cognitive processes are essential elements regarding learning. The learning process of intuiting relates to this level and is the recognition of known patterns in the previous projects.
2) *Team/project level:* Within this level, the interpretation and integration of learning are essential. Interpreting is the process of making meaning and reforming new knowledge and integrating is the process of developing shared understanding at the team level, achieved through collective actions.
3) *Organisational:* The organisation can institutionalise learning into practices. Institutionalisation refers to individual and collective learning that is embedded in the systems, structures, strategies, routines, and practices of the organisation.

This multilevel learning occurs in two different learning directions: feed-forward and feedback (Crossan et al., 1999). Feedforward refers to the exploration of new knowledge by individuals and teams, which eventually becomes institutionalised at the organisational level. Feedback relates to the exploitation of existing and institutionalised knowledge and making this knowledge available to teams and individuals. Feedforward relates to learning within the project and feedback unfolds through the learning from projects towards other projects (Swan et al., 2010).

Argote and Miron-Spektor (2011) have developed a framework regarding the analysis of organisational learning. This framework is divided into the following contexts: environmental, latent and active organisational context. The difference between the latent and active context is that within the active context the members and tools perform the tasks and are capable of action. Organisational experiences interact with the context and results in the creation of knowledge. The learning processes in this framework occurs at different levels in the organisation and are formed by the subprocesses: creating, retaining, and transferring knowledge.

3.3 Learning within projects

Within project-based organisations (PBO's), the production and sources of profits are dependent on the projects (Ren et al., 2019). PBO's contain organisations that offer products or services that are customised (Van Waveren et al., 2014) and organisations that follow the 'management by project' basis to cope with new challenges and the dynamic business environment (Gareis, 1991). The importance of learning through and from a project within PBO's is increasing to achieve competitive success. Projects are considered as an important spot for learning (Hartmann & Dorée, 2013; Ren et al., 2019; Scarbrough et al., 2004). Projects are ideal contexts for organisational learning due to the bounded dynamic learning space, the selection of participants, multiple interactions and reflection opportunities, and the relative psychological safety to explore (Sense, 2011).

The knowledge can be integrated and be checked within a construction project (Lindgren et al., 2018). Therefore, project-based learning (i.e., learning within PBO's) is seen as the capitalisation of knowledge within the finalised projects, and the diffusion of the validated knowledge within new projects or elements of the organisation for future adoption or use (Wiewiora et al., 2018). Thus, project-based learning happens within projects (i.e., intra-project), between projects (i.e., inter-project) and from projects to the wider organisation (Wiewiora et al., 2018; Swan et al., 2010). A major part of project knowledge is tacit and are embedded in practice (Kitimbo & Dalkir, 2013). This tacit knowledge is

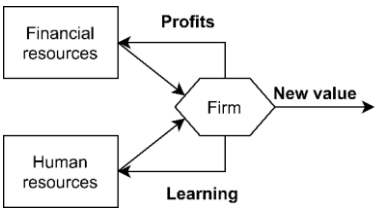
obtained through experiences, observation and reflection and is therefore highly personal (Khuzaimah & Hassan, 2012). Practical examples of explicit knowledge can be found in technical reports, manuals, standard operating procedures. Lindgren et al. (2018) described three types of knowledge to better understand the development of knowledge during the diffusion of innovation.

(1) *Domain-specific knowledge* concerns the knowledge in the form or function of an object and the knowledge gained from previous or current development processes, which have been developed by accident or strategically.
(2) *Procedural knowledge* is part of a systematic learning process, in which it is known what to do next. This knowledge is based on using insights from experience.
(3) *General knowledge* concerns the external influences on product development, such as legal or social issues, or customer and supplier issues.

3.3.1 Project management

Construction projects form a value system, see figure 6 (Winch, 2009). The inputs to this process are capital and human resources. The return on these two inputs is profits and learning. The learning takes place when problems are solved through the project life cycle and the profits are taken out of the process. Winch (2009) claims that the effective achievement of both these returns is problematic.

Figure 6: Construction projects as the creation of new value



Note. Adapted from *Managing Construction Projects (2nd edition, p. 5)*, by G. M. Winch, *2009*, Wiley.

The management of these projects is seen as organisational innovation, in which *the identification of a team responsible for ensuring the effective delivery of the project mission for the client (Winch, 2009, p. 8)* is established. Project management is mainly focused on the independence of projects with other projects. Chronéer and Backlund (2015) propose that project members should be appointed to two roles: (1) project team member, and (2) process team members. These roles are reflected by the two goals of a project, proposed by Bowen et al. (1994), namely: successful development of delivery and enhanced organisational learning. These two goals are also noticed within the construction projects as the creation of new value in figure 6.

3.3.2 Building phases

A project model contains numerous phases: initiating, planning, executing, monitoring, and closing process groups (Project Management Institute, 2013) and all the work within these models is performed as a series of planned and interconnected processes (Chronéer & Backlund, 2015). Figure 7 provides an overview of the building phases that fall under the responsibility of the contractor or client within design & construct contracts. The exploration, program of requirements and preliminary design are the responsibility of the client and the other phases are the responsibility of one contractor. The maintenance phase might be included however this can be awarded to another party. It is crucial to integrate the organisational learning practices into each project phase (AlMaian & Qammaz, 2019).

Figure 7: Responsibilities client and contractor per contract

Exploration	PVE	VO	DO	UO	Preperation	Construction	Maintenance
Client			**Contractor**				

Note. Adapted from De glijdende schaal: de aard van de opdrachten afgezet tegen de juridische kaders, by T. Aarsen, 2020, https://www.raw.nl/thema/gebruik-van-raw/blog/137-wat-is-het-verschil-in-de-taak-en-verantwoordelijkheidsverdeling-tussen-een-uav-en-een-uav-gc-contract

3.3.3 Project embeddedness

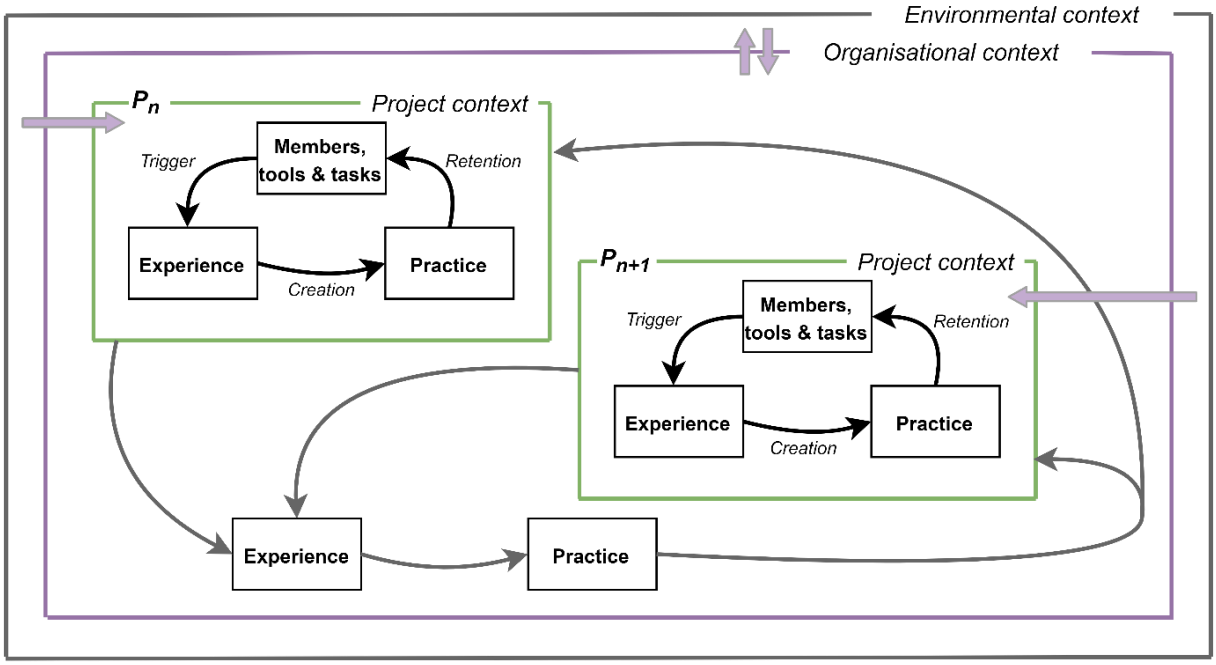
The connectedness of projects within the organisational context ensures the embeddedness of the project. Swan et al. (2010) define the embeddedness of projects as *the extent to which project activities*

are dependent on institutionalized knowledge, roles, routines, and practices (p. 8). In this study, three sources of variation in the embeddedness of projects have been described. (1) Structural embeddedness indicates the degree to which it is influenced by established roles, routines, and community of practice. (2) Cognitive embeddedness determines the extent to which project members can make use of already existing skills in carrying out the project tasks. (3) Mission embeddedness indicates the extent to which the project's mission is framed by established organisational repertoires and how far this view is shared by the project participants. Analysing the embeddedness of projects in the organisational context explains the different roles a project may play (Swan et al., 2010).

3.4 Conceptual framework

By analysing learning trajectories, addition of the time dimension is added to the view on learning. Hereby, a learning trajectory is defined as the continuous enactment of a technology over a series of projects, which results in the continuation of the development in which knowledge is created. The visualisation of the conceptual framework is presented in figure 8. Eventually, table 1 provides a template to analyse the developments within a learning trajectory based on this framework.

Figure 8: Conceptual framework of a learning trajectory



The conceptualisation of a learning trajectory is based on (1) the view on learning taking place within projects rooted in the historical, organisational, and cultural context of earlier and current projects (see 3.1), and (2) the explained framework of Argote and Miron-spektor (2011) in 3.2. The proposed framework of the researchers highlights the importance of the experiences, the different learning process and the different contexts. The active context in which the members and tools perform the tasks are visualised as the projects and this happens within the organisational context. Firstly, the different contexts in the developed framework are described. Secondly, the development processes within the different contexts are described. Thirdly, the processes that might be stimulated or hampered by certain mechanisms and the developed template are described.

This framework is divided into three different contexts: environmental, organisational and project context. The mutual influences between these contexts are visualised by the thick purple arrows between the different rectangles. The environmental context includes elements outside the boundaries of the organisation, such as clients, institutions, and regulators. This context influences the organisational and project contexts because they assess the organisational tasks and determine which projects are put into the market. The organisational context includes characteristics of the organisation, such as the structure, culture, technology, identity, memory, goals, incentives, and

strategy. Relationships with other organisations through alliances or joint ventures are also included within this context (Argote & Miron-Spektor, 2011). The organisation influences the project context through the determination of which members and tools interact with the organisation's tasks. Within PBO's, the organisation's tasks are focused on the realisation of projects. The project context includes the environment in which the tasks are performed through the interaction of the organisational elements. In this framework, two project contexts are visualised (i.e., P_n and P_{N+1}). These projects are connected through the development process within the organisation. Within $project_N$ the practice is created. The created practice undergoes a new development process through the gathering with $project_{N+1}$ within the organisation, which then will be retained into the members and tools of the next project.

The trajectory starts with the interaction of the organisational elements in the project context. These elements are considered as the members and tools that interact with the tasks. The tools contain specific knowledge regarding the development within that context. Learning starts with an experience. The revelation of these experiences is triggered in the context. The interaction of the organisational elements and the exploitation of the experiences will result in the creation of a practice. Eventually, this practice is retained in the organisational elements. A practice is seen as the 'know-how' and 'know-what' (Argote & Miron-Spektor, 2011) related to the technique, engineering, design, execution, tenders, and the related processes. These processes are regarding the project, technical, environmental, and contract management. The 'know-what' is related to the domain-specific knowledge and the 'know-how' is related to procedural knowledge (Argote & Miron-Spektor, 2011; Lindgren et al., 2018). Domain-specific knowledge means the knowledge of the object's function and procedural knowledge concerns the knowledge in what to do next or which learning processes are needed to stimulate the development process.

The processes of triggering, creating, and retaining are affected by mechanisms, which could stimulate or hamper the development process. *Triggering* causes the revelation of a certain experience, which is embedded in the members, tools, or tasks. *Creating* is the process of developing a new practice. *Retaining* is the act of holding a practice in the members, tools, or tasks. Besides the processes, certain members can perform as a specific actor. This *actor* may stimulate or hamper the development in the trajectory. Table 1 provides a template for analysing the developments within a trajectory to discover the mechanisms in this process. At the top of the table, a distinction is made between the project and the organisational context (OC) to specify in which context the development happens. The members are specified as key members because they have played a significant role in the specific development. The mechanism 'actors' is not part of this template since this mechanism is investigated for the whole trajectory and not just within one context.

Table 1: Template for analysing the different developments in a learning trajectory

Context	Project context 1	Organisational Context P1 – P2	Project context 2
Development			
Key members			
Tools			
Tasks			
Trigger			
Experiences			
Creation			
Practice			
Retention			
Retention in members, tools, or tasks			

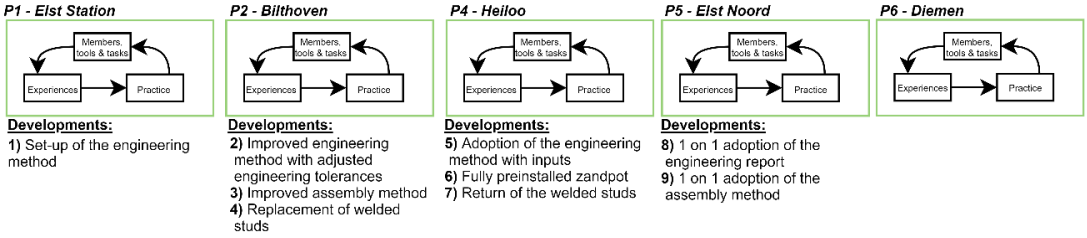
4. Case analyses

In this chapter, case one 'zandpot' and case two 'pouring the concrete walls underneath a railway deck' are analysed to understand the learning trajectories. The technical background of each case and the processes in each project are described in Appendix D. Furthermore, table 1 is used to provide an overview of the noticed developments within the interviews and these overviews are shown in Appendix E. Some members are mentioned multiple times within the trajectory. Therefore, the members are labelled with a letter to recognise the involved members (e.g., design engineer B). First, the cases are analysed individually with the following structure: (1) The developments within the project are described. (2) The overall trajectory is discussed regarding the mechanisms that affected the processes of triggering, creating and retaining. The actors within this trajectory are discussed as well. (3) Eventually, the key points, which affected the learning trajectory, are concluded. Secondly, the cases are compared in the cross-case conclusion. Furthermore, some additional findings regarding learning within the organisation indicated by the interviews are described. Finally, this chapter is summarised to highlight the key points of this empirical part of the research.

4.1 Case 1: Zandpot

The zandpot is an auxiliary construction with the function of supporting the railway deck during the construction phase. Figure 9 provides an overview of the noticed developments within the projects. Five of the six projects within the scope of this research are suitable for this case analysis.

Figure 9: Overview of the project contexts and their developments



4.1.1 Project context: Elst Station

Elst Station (2015) is the first project within the organisation in which the zandpot was elaborated and executed. In this project, the first set-up of the engineering method related to the zandpot and the implementation of the construction took place. Within the interviews, the construction phase was not directly discussed. Thus, the development within this phase is not described.

Development 1: Set-up of the engineering method

Due to the modification of the client's requirements, a new construction for the realisation of an underpass was required. This construction was engineered for the first time by a designer, who was not involved in this project anymore before the possession. The inexperienced design engineer A was engaged to elaborate on the engineering of the possession during this short time frame. Due to the absence of a previous execution of the zandpot, the design engineer could not build upon earlier experiences. This resulted in the exploration of the new engineering method based on his competencies as a design engineer. An engineering report was developed to present the calculations related to this auxiliary construction. This report is eventually assessed internally and by the client.

Eventually, the design engineer observed the zandpot in the construction phase during a project visit and concluded that the applied engineering tolerances were too narrow. These tolerances are essential for the performance of the zandpot because the railway deck must not be supported by the sheet pilings. This observation resulted in the need for adjusting the tolerances in the next project.

4.1.2 Project context: Bilthoven

Bilthoven is the second project in which the zandpot was executed. The zandpot was executed in 2016. Based on the previous execution in Elst Station, the engineering and assembly method was developed further. The work method for the realisation of an underpass was similar to the one in Elst Station.

Development 2: Improved engineering method with adjusted engineering tolerances

In this project, the engineering method of Elst Station was improved regarding the engineering tolerances and the elaboration of the calculation steps. The continuation of this construction was ensured by the coupling of design Manager A. He was aware of the previous execution and was certain about the construction, despite the performance in the previous project. To enhance the performance, he linked design engineer B and executor A with design engineer A, who was responsible for the engineering method within the previous project. The previous engineering report was contributed by design engineer A and revealed the brief engineering method, that was embedded in the report. The problems with the tolerances during the construction phase were transferred during a meeting between these members. They tried to improve the alignment of the tolerances with the construction phase.

The engineering method was explained by design engineer A and this enabled design engineer B to go further with the engineering. The new engineering method consists of an extended description with the adjustment of the tolerances and an organised excel sheet. Eventually, design engineer A conducted an internal control of the report before it was handed over to the client. This engineering method was also retained in the engineering report. Eventually, the usage of the engineered geometry in the construction phase showed that the alignment of the tolerances was improved and that the construction performed properly.

Development 3: Improved assembly method

In project Bilthoven, the assembly method has been further developed by exploiting the experiences of Elst Station. Executor A was responsible for the assembly of the construction during the possession. Through the coupling by design manager A, executor A contacted the previous executor. His predecessor indicated that the performed assembly method was a lot of work, due to the multiple small elements of the construction. Executor A prepared a method to simplify the assembly during the hectic period of possession. The construction was assembled with just one underlay plate (around 18 meters) instead of single elements of 3 meters. Eventually, the execution of this work method performed well.

Development 4: Replacement of welded studs

Executor A was also responsible for emptying the zandpot after the completion of the final foundation of the railway deck (i.e., the walls and floor). The zandpot is filled with sand and this material needs to be removed to take the zandpot out of operation. To catch the cover plate during the removal of the sand, studs were welded in the corner of the construction in Elst Station. Executor A tried to mitigate the costs for this construction and replaced the welded studs with wooden laths. Eventually, the wooden laths did not work properly. During the removal of the sand with water, the wooden laths started to float and obstructed the water flow.

4.1.3 Project context: Heiloo

Heiloo is the third project in which the zandpot was executed. This project contained the same work method for realising an underpass as in the previous projects. The zandpot was executed in 2019. The engineering method was adopted in this project and the assembly method was further developed. Furthermore, the execution of the wooden laths was substituted by the welded studs.

Development 5: Adoption of the engineering method

In this project, design Manager A continued the engineering method. Design engineer C was responsible for the elaboration of the engineering method and the predecessor of Bilthoven shared the engineering report. The developed engineering method, embedded in the previous engineering report, was followed and the project-specific inputs (e.g., the forces) were used. Design engineer A conducted an internal control on the report before it was handed over to the client. Eventually, this adoption in combination with the elaboration with the project-specific inputs was considered sufficient. The design engineer was able to work out the engineering report for this project based on the previous report and competencies as a design engineer.

Development 6: Fully preinstalled zandpot

Executor A was again responsible for the assembly of the zandpot and contributed his experiences of the previous work method into this project. Together with the inexperienced projectcoordinator B, they prepared and executed this assembly method. The method consisted of a fully preinstalled construction (i.e., installation of the underlay plate, filled with sand and cover plates) and the placement of the construction during the possession. The preinstallation of this construction required the integration of a crane company during the preparation and construction phase. Eventually, a work plan for the possession was developed that includes the 'lifting plan'.

Development 7: Return of the welded studs

Executor A was again responsible for emptying the construction in this project. The experiences regarding the replacement of the welded studs by wooden laths were contributed by executor A. The welded studs were used and considered effective during the task of emptying the zandpot.

4.1.4 Project context: Elst Noord

Elst Noord is the fourth project in which the zandpot was executed. The assembly of the construction was executed in 2020, but currently the construction is still in operation. In this project, the engineering and assembly method of Heiloo were adopted.

Development 8: 1 on 1 adoption of the engineering report

Design manager A continued the experiences from the previous project in this project again. The engineering reports of previous projects were transferred to the new design engineer. Eventually, the calculations related to the zandpot were adopted completely. As is stated in the engineering report: "*The following further calculations have been taken from the named previous projects [Bilthoven and Heiloo]"*. This complete adoption was ensured by the relatively smaller forces on the zandpot than in the previous projects. However, an adjustment to the geometry of the zandpot was implemented because the expectations of the soil influences were higher than in the previous projects.

Development 9: 1 on 1 adoption of the assembly method

The assembly method of the previous project was contributed by design manager A. The responsible key members for the assembly of the construction could not build upon earlier experiences. The experiences from Bilthoven and Heiloo were transferred by a presentation given by design manager A about the construction. Eventually, the assembly method was also created in collaboration with the crane company. This method was again retained in the integral work plan and the construction was executed within the possession.

4.1.5 Project context: Diemen

Diemen will be the fifth project in which the zandpot would be used. Currently, this project is in the design phase and the zandpot is not being prepared yet. However, it is already noticed that the same method will be implemented for realising an underpass as in the previous projects. In this project, the experiences from the previous project were already contributed early in the project by the involvement of the designer of Elst Noord and projectcoordinator B of Heiloo.

4.1.6 Discussion

The development process of the zandpot has occurred within these four projects. It can be concluded that the project context triggered the development and no independent development process outside the project are noticed. The five projects relate to each other through the fulfilment of the same task of realising an underpass underneath a railway by order of ProRail. In every project, the same requirement was in force and triggered the continuous enactment of the zandpot.

At the start of the trajectory, the members could not build upon experiences regarding the construction. However, in the subsequent projects in which a similar work method was chosen in the tender phase, the members were able to exploit the experiences. Table 2 describes the mechanisms that triggered the exploitation of the experiences and in which project these mechanisms were in force.

Table 2: Mechanisms that affected the process of triggering

Mechanism	Description	ES	Bi	He	EN	Di
Coupling by design manager A	In the second project, design manager A was aware of the execution in Elst Station. To overcome the problems and to continue the development, he linked the two projectteams with each other. Further in the trajectory, he linked the design engineers with each other to transfer the engineering report.		X	X	X	
Personal contact with predecessors	Through the coupling of design manager A, the members of the new project team were linked with their predecessors. This personal contact resulted in the transfer of the experiences and the tools.		X	X	X	
Involvement of members with the experiences	After the zandpot has been executed twice, the involvement of members who were already familiar with the construction stimulated the exploitation of their experiences. Inexperienced members could build upon the experiences of the involved members. An example is the elaboration of the assembly method by the inexperienced projectcoordinator B in Heiloo. Eventually, he contributed his experiences to the project Diemen.		X	X	X	X
Presentation	The presentation, given by design manager A, led to the transfer of the practice of Heiloo towards a new projectteam.				X	
Going through the engineering report	The engineering report was continued into each subsequent project. The new design engineer went through the engineering report and the previous engineering method was revealed. In the second project, the engineering method was revealed by the combination of report and explanation by the predecessor. However, later in the trajectory, no specific personal contact between the design engineers was noted.		X	X	X	

These experiences are eventually exploited to develop the engineering and assembly method further in the project context. Table 3 describes the mechanisms that stimulated the creation of the practice and in which project these mechanisms were in force.

Table 3: Mechanisms that affected the process of creating

Mechanism	Description	ES	Bi	He	EN	Di
Gathering of key members	The gathering of design engineer A with design engineer B and executor A in Bilthoven stimulated a better alignment of the tolerances with the construction phase. The preconditions of the construction phase were ensured by the involvement of the executor, who was responsible for the construction phase.		X			
Continuation of the engineering report	Through the continuous enactment of this report, the previous engineering method was further elaborated and used within a new project context. The major elaboration occurred in project Bilthoven in which the engineering steps were extensively described and an organised excel sheet was developed. This format was noticed in the next reports.		X	X	X	
Similarity and parameters were smaller	The parameters in Elst Noord were relatively smaller than the parameters in the previous projects. This resulted in that the engineering of the zandpot of the previous project was sufficient for this project.				X	
Execution of the zandpot	Through the assembly and use of the zandpot, the performance of the method was revealed. The zandpot is in operation during the construction phase when the walls and floor are constructed. Thus, the performance of the zandpot is monitored during this phase.	X	X	X	X	

The retention of the practice was noticed within the members and tools. The retention of this practice was stimulated by the involvement of the members during the execution and the elaboration of the engineering report and work plan. It can be noted that the know-how knowledge related to the performance of the zandpot and which process steps stimulate the development, were retained in the members. Besides that, the technical knowledge of the construction was retained in the members, but also in the tools: engineering report and work plan.

In the trajectory, some members stimulated the processes and performed as an actor. Table 4 provides an overview of the different actors that are noted in this trajectory.

Table 4: Actors

Actors	Description	ES	Bi	He	EN	Di
Explorer	Due to the lack of experiences regarding the zandpot, the design engineer within Elst Station was forced to explore the practice. The design engineer explored the knowledge regarding the engineering of the zandpot within the project. Besides that, executor A explored within Bilthoven a new assembly method.	X	X			
Owner	Design manager A took the responsibility for the continuous enactment of the practice from the previous project. The owner ensured the coupling between the two projectteams and presented the practice from Heiloo towards a new projectteam.		X	X	X	
Exploiter	An exploiter will use his or her knowledge or of other key members to fulfil the tasks. The design engineers from project two, three and four acted as an exploiter, due to the exploitation of the practice retained in the engineering reports. They used and adopted this practice within their project context.		X	X	X	
Contributor	Executor A contributed his experiences within Heiloo. Projectcoordinator B went further with the experiences from the contributor. Eventually, this projectcoordinator acted as a contributor, which transferred his experiences to Diemen. Design manager A is also allocated as a contributor. He contributed his experiences regarding the performance of the construction into the new project and presented the work methods in project Elst Noord.			X	X	X

4.1.7 Case conclusion

The following developments have occurred within the four projects: (1) The engineering of the zandpot has evolved from a first set-up with wrong tolerances to the adoption of the previous engineering in a new project. (2) The assembly method has evolved from an assembly method, which was considered a lot of work, to a fully preinstalled construction, which was placed completely during the possession. Within the project, during the tender, the choice is made for the work method and therefore the execution of the zandpot. Through this continuous enactment of the zandpot within similar and sequential projects, the construction has been developed and the organisation has learned. In this trajectory, the developments only occurred in the project context. It can be concluded that the following key points affected the learning trajectory of the zandpot:

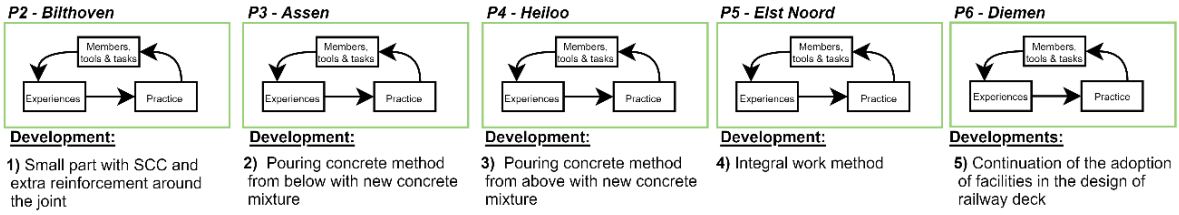
- *The role of the owner during the development:*
  - The first execution was not considered as a completely workable construction. However, the owner was certain about the construction and continued the construction in the second project.
  - In the second project, the owner arranged a gathering of the design and execution, which led to a better alignment of the tolerances. Eventually, the projectteam learned that these tolerances were better aligned than in the previous projects.
  - In the fifth project, the members who were responsible for the construction of the zandpot could not build upon previous experiences. The owner presented the experiences and work methods of the previous project. Eventually, this projectteam went further with this knowledge and the shared tools.
- *The achievement of a certain maturity level:* Both developments reached already soon a certain maturity level in which the construction was a success and was further optimised.
  - The engineering method, retained in the report, had reached a certain maturity after the elaboration in Bilthoven. After this project, no certain personal contact between the design engineers was noticed. The new design engineer was able to work out the engineering of the zandpot in the new project.
  - Eventually, the engineering calculations were adopted in the next project because the forces in this project were smaller and the previous executions were considered positive. These experiences were contributed by the owner.
  - The assembly method also reached a certain maturity level in the third project. This method and the tools were shared by the owner in the fourth project by a presentation.

- Eventually, project Diemen, which is currently in the design phase, is the first project without the involvement of the owner. However, it is already noticed that the tools of previous projects have been contributed into project by the involved members, who could build upon earlier experiences. Furthermore, the projectcoordinator also intends to get in contact with the owner at the time that the zandpot needs to be elaborated.

4.2 Case 2: Pouring the concrete walls underneath a railway deck

Underneath the railway deck, the concrete walls need to be constructed to support the railway deck in the utilisation phase. Figure 10 provides an overview of the noticed developments within projects. The first project within the scope of this research, Elst Station, is not part of the case analysis because no interviewees were involved in this project.

Figure 10: Overview of the project contexts and their developments



4.2.1 Project context: Bilthoven

The walls under the railway deck in Bilthoven were executed in 2016. Bilthoven is the second project within the scope of this research in which the walls underneath the railway deck have been executed. In this project, the experiences from Elst Station were used to develop a new work method.

Development 1: Small part with SCC and extra reinforcement

Executor A was responsible for pouring the concrete walls underneath the railway deck. During the preparation of the work method for this project, the executor looked back to the work method of Elst Station. He was aware of the problems after the construction of the walls and through personal contact with the previous executor, the work method and the experiences were transferred. In Elst Station, the wall was completely poured with Self-Compacting Concrete (SSC). However, this work method resulted in multiple cracks and leaks in the walls. In this project, SCC was still seen as the best mixture to fill and compact the walls. However, they created a work method in which just a small part around the joint was filled with SCC and extra reinforcement was implemented to mitigate the chances of cracks around this critical part. The extra reinforcement was used because around the joint of the old concrete (i.e., railway deck) and the new concrete (i.e., the wall) it was very likely that the cracks and leaks would occur. Because the engineering method needs to be assessed by the client, an engineering report has been elaborated on by the design engineer. Eventually, this work method resulted again in the cracks and leaks in the wall. The contractor is obliged to report the deviations to the client. The cracks and leaks in the wall were reported to the client by deviations reports, which contained a description of the deviation, consequences and measures.

4.2.2 Project context: Assen

The walls under the railway deck in Assen have been executed in 2019. Despite a different auxiliary construction, the task for pouring the concrete walls underneath the railway deck was still fulfilled. In this project, a work method was developed which resulted in no leaks or cracks.

Development 2: Pouring concrete method from below with a new concrete mixture

Projectcoordinator A was responsible for the preparation of the work method for the construction of the walls underneath the railway deck. He was aware of the previous problems with fulfilling the task of the realisation of a watertight wall in Elst Station and Bilthoven. As he stated: "*If we start doing it in the same way, then you have the chance to have to inject for 30,000 euros. Thus, you can invest quite a bit in a more expensive mixture, expensive facilities*." The previous experiences were transferred through personal contact with his predecessors. Together with the preparation team, he looked at the development of a work method to eliminate the cracks and leaks in the walls. This task is also partly

performed by subcontractors. The concrete technologist and concrete plant determine and supply the concrete mixture and the formwork in which the concrete is poured is supplied by the formwork supplier. In consultation with the concrete technologist of the concrete plant, a low-vibration mixture has been developed. This mixture has practically the same flow features as SCC, but in which fewer fine additives and plasticisers have been used. These adjustments mitigate the heat development, which is beneficial for mitigating the chance of cracks and leaks. Besides that, the concrete mixture was poured from underneath and for this reason, the formwork supplier had an essential role in the development of this work method. See Appendix D (*figuur 5*) for a visualisation of the work method, which was part of the concreting plan. In this project, a concreting plan was developed again. The development was only integrated within the construction phase because the design of the railway deck was already in a detailed stadium. Eventually, an evaluation was conducted with the key members to reveal the lessons learnt from this new work method.

4.2.3 Project context: Heiloo

The walls under the railway deck in Heiloo have been executed in 2019. The task for pouring the concrete walls in this project was executed approximately two months after the construction of the walls in Assen. Thus, the preparation and execution of these two projects took place almost simultaneously. In this project, a different work method for pouring the concrete walls underneath the railway deck was developed. However, some aspects were adopted from the work method of Assen.

Development 3: Work method from above with a new concrete mixture

In this project, the experiences from the previous project have been transferred in several ways. Executor A was able to build upon his experiences from Bilthoven and together with projectcoordinator B a different work method was developed. The inexperienced projectcoordinator B looked back to the previous projects due to the emphasise by the department manager. As he stated: "*I was warned by our department manager; In Bilthoven, it did no go well either. Many cracks in the walls. That must be eliminated now. So, we were very eager to do better here…*". Besides the involvement of these members, projectcoordinator A was shortly involved during the design phase of this project. He was aware of the similarities between the tasks in each project and shared the work method of Assen with this project team. Eventually, a work method with few adoptions from Assen was developed. Within this project, a pouring method from above was chosen, which was mainly determined by the precondition for seeing the concrete in the utilisation phase. This precondition differs from that in Assen in which the wall was not visible in the utilisation phase. Also, a concrete mixture like the one used in Assen was tried to develop with the involvement of another concrete plant. Similar to Assen, the design phase was not involved, because the design of the railway was already in a detailed stadium. Eventually, the developed mixture performed as a SCC and this work method resulted in cracks and leaks in the wall. Furthermore, during the filling of the walls, the hose got stuck and this resulted in a not filled wall. These deviations were reported to the client within the deviation reports.

Remarkable is that the assessing party was involved within this development because they compared the concreting plan of Assen with the concreting plan of this project. They were responsible for the assessment of the concreting plan. This party was part of the environmental context. The comparison was noticed within the questions that were asked to projectcoordinator B in which the reference was made with the work method of Assen. After the construction phase, an evaluation was conducted with concrete plant B because the expectations with the results did not match.

4.2.4 Project context: Elst Noord

For this project, the work method for pouring the concrete walls underneath the railway deck was developed during this research. However, the work method was not executed yet. In this project, the lessons from Assen were contributed and an integral work method was developed.

Development 4: Integral work method

Through the continuation of projectcoordinator A, the experiences of Assen were contributed to this

project. Due to the early involvement of projectcoordinator A in the project, design manager A was engaged to develop the work method of Assen further already in the design phase. The evaluation and the concreting plan of Assen were transferred and contained the practice of Assen. As the Design manager of this project pointed out, *"If I hadn't had projectcoordinator A, I wouldn't have thought of it [the facilities in the deck]".* The integral work method contains two adjustments to the design. (1) The wall attachment is inclined outwards by 2 degrees so that air can escape to the backside. (2) These wall attachments are equipped with ventilation facilities. These facilities enable pouring the concrete with a surplus height and allow the air to escape during concreting (see Appendix D for a visualisation of the work method, *figuur 9*). Together with a new concrete plant, a similar concrete mixture as used in Assen was developed.

4.2.5 Project context: Diemen

Diemen will be the sixth project in the scope of this research in which the walls underneath a railway deck are executed. This project is now in the design phase and the expectation is that the walls are completed in 2022. In the tender phase, the same method for the realisation of an underpass is chosen as in the previous project within this case.

Development 5: Continuation of the adoption of facilities in the design of railway deck

A development is already noticed due to the adoption of the facilities from Elst Noord in the design. The designer from Elst Noord is involved within this project and projectcoordinator B could build upon his experiences from Heiloo. Besides that, members from outside the project were engaged to review the process. In this project review, the urgency of the right work method for constructing these walls was emphasised by experienced members. In addition, projectcoordinator B was also involved in the design meeting and the work method of Elst Noord was discussed. Projectcoordinator B is also aware of the development in Elst Noord and will monitor the results of this work method.

4.2.6 Discussion

The development processes have occurred within the six projects. It can be concluded that the project context triggered the development and no independent development process outside of the project are noticed. The six projects relate to each other because in the tender phase it was decided to pre-build and place the railway deck with SPMT's. For this reason, the walls and floors are constructed underneath the railway deck. The task of realising a wall underneath the placed railway deck, which meet the requirements of the client, is noticed in every project. The organisation was looking for the right work method to eliminate the problems regarding the cracks and leaks in the walls. In the subsequent projects, the experiences from the previous work method were exploited. After four projects a work method with proper results was developed. Table 5 describes the mechanisms that triggered the exploitation of the experiences and in which project these mechanisms were in force.

Table 5: Mechanisms that affected the process of triggering

Mechanism	Description	Bi	As	He	EN	Di
Awareness of the previous problems	This awareness triggered the urgency to figure out the work method in the previous project to learn from these failures. In Elst and Bilthoven, 60.000 euros worth of injections had been carried out to solve the problems. The members of the subsequent project did not want to encounter these failure costs again.	X	X	X		
Personal contact	Through personal contact, the previous experiences of previous work methods were revealed and exploited to prepare the new work method. The tools were also transferred between these project teams by this personal contact.	X	X	X		
Emphasise by department manager	The emphasise by the department manager triggered the inexperienced projectcoordinator B to look back at the previous project and to exploit these experiences within the new project context.			X		
Early involvement	Projectcoordinator A was involved early in project Heiloo and Elst Noord. This early involvement stimulated the sharing between the projects and the contribution of the developed work method into the design phase of Elst Noord. Furthermore, the involvement of certain key members, the previous			X	X	X

	experiences of Heiloo, Assen and Elst Noord were contributed to Diemen.					
Project review / Design meeting	In the project review, members from outside the project were engaged to evaluate the process. This triggered the revaluation of a wider range of experiences. Besides that, projectcoordinator B is also involved in the design phase to ensure the conditions of the construction phase. In this meeting, the work method for pouring the concrete walls was already discussed between the design and construction team.					X
Awareness of work method	As projectcoordinator B indicated: "*I have now simply said of the work method of Elst Noord, I declare that it is also applicable to the Diemen project until proven otherwise when that method does not seem to work in the future.*" This awareness stimulates that the projectteam of Diemen is following the process of Elst Noord to make use of the results of this work method.					X

Within the project, the experiences are exploited to develop the work method for pouring the concrete walls further. Table 6 describes the mechanisms that stimulated or hampered (indicated with -) the creation of the practice and in which project these mechanisms were in force.

Table 6: Mechanisms that affected the process of creating

Mechanism	Description	Bi	As	He	EN
Gathering with subcontractors	In this trajectory, different gatherings are noticed. In the three projects, the gathering with the subcontractors is noted in which the work method is prepared.		X	X	X
Gathering design and construction	In Elst Noord, the gathering between the design and construction team is noticed. This gathering resulted in the integral work method for pouring the concrete walls.				X
Preparation and execution	The preparation and execution of this work method led to the creation of the knowledge related to the work method and performance. The results of this work method become visible quickly after pouring the concrete walls. The execution in different project conditions is also affected by different preconditions.	X	X	X	X
Evaluation	An evaluation with the subcontractors in Assen was conducted to figure out the attention points for the next project. This created the lessons learnt.		X	X	
Design was already in a detailed stadium (-)	No adjustments were executed to the design of the railway deck because it was already in a detailed stadium at the time that the new work method was developed. This mechanism hampered the development process because the developments were only integrated into the construction phase.		X	X	
Involvement of a different concrete plant (-)	It can be concluded that the involvement of a different concrete plant within Heiloo hampered the development. Concrete plant B was not able to supply the same product as was used in Assen and had a major influence on the results of the work method.			X	
Different preconditions	It is noticed, that different preconditions were in force in Assen and Heiloo. This resulted in the creation of a different work method.		X	X	
Results of Assen were not yet known (-)	The coupling between Assen and Heiloo was made. However, during the preparation phase of Heiloo, the results of the work method of Assen were not yet known. Thus, the project team of Heiloo prepared their work method with some adoptions from Assen.			X	

Eventually, the created practice was retained in the members or tools. Table 7 provides an overview of the mechanisms that affected the process of retaining.

Table 7: Mechanisms that affected the process of retaining

Mechanism	Description	Bi	As	He	EN
Involvement of key members during the work method	The involvement of the key members during the preparation and execution resulted in the retention of the technical knowledge and the know-how. Especially, the execution of the work method revealed the performance.	X	X	X	X
Elaboration of the concreting plan	The work method was elaborated in the concreting plan and contained the technical knowledge.	X	X	X	X
Obligation to report deviations	The problems that arose after the execution of the work method were retained in the deviation reports.	X		X	
Evaluation	The execution and elaboration of the evaluation stimulate the retention of the practice in the evaluation document or the involved members.		X	X	

Involvement of design team (-)	The design team is not involved during the construction phase. This hampered the retention of the performance of the work method because the performance is not directly retained in the members of the design team.	X	X	X	

In the trajectory, some members stimulated the processes and performed as an actor. Table 8 provides an overview of the different actors that are noted in this trajectory.

Table 8: Actors

Actor	Description	Bi	As	He	EN	Di
Explorer	Within the first four projects, the executor and projectcoordinator performed as an explorer. Despite, the use of previous experiences within the organisation, new work methods were developed to eliminate the cracks and leaks in the walls. Eventually, in Assen, a work method was developed without the appearance of these problems.	X	X	X		
Owner	Projectcoordinator A has taken responsibility within this trajectory to look at the previous project on his initiative and used these lessons by involving various parties in the project to develop a new work method. Projectcoordinator A also took the responsibility to contribute the practice in the new project.		X	X	X	
Exploiter	Several persons within this trajectory have used the experience of another. Remarkably is that design manager A used the experiences of another in his third. This engagement was ensured by the early contribution of the lessons learnt from Assen by projectcoordinator A.			X	X	
Contributor	Eventually, in project Diemen, two persons are already allocated as contributors. The designer and projectcoordinator B contributed their experiences from previous projects into the project. Besides that, executor A was also engaged in project Diemen during the project review.					X

4.2.7 Case conclusion

The organisation is learning by developing and executing the work methods to fulfil the task of realising a waterproof wall within the projects. Within the first four projects, different construction teams were looking for a suitable work method. In this trajectory, the developments only occurred in the project context. These projects were connected by a similar work method chosen in the tender phase. The organisation has learned to construct a wall underneath the railway deck, which met the requirements without the appearance of failure costs. It can be concluded that the time between Assen and Heiloo was too short to implement the practice of the project into the new project. Furthermore, the different preconditions and the subcontractor affected the work method and the performance. The following key points that affected the learning trajectory of pouring the concrete walls underneath the railway deck have been noticed:

- *Looking back to the previous project took place in different ways:*
    - The involved members used their network to get in contact with their predecessors because they were aware of their involvement in a similar previous project.
    - Some members were able to make use of their own experiences of previous similar projects and contributed these experiences to the new project.
    - A department manager emphasised to the inexperienced projectcoordinator to look back at the previous projects to mitigate the chance of reinventing the wheel.
    - During the project review in Diemen, the previous experiences have been discussed.
- *Role of the subcontractors:*
    - Multiple subcontractors were engaged to prepare and execute the work method. The two projects Assen and Heiloo indicate that the subcontractor had a major influence on the results of the development because a different concrete plant resulted in another concrete mixture and in which the problems still have occurred.
- *Involvement of design department:*
    - This learning trajectory is initiated by the construction department. It is noted that the design department was not directly engaged in the development. After a first successful execution of the task, the design department was engaged by the early involvement of the owner. During the development of the work method in Assen and Heiloo, the design of

the railway deck was already in a detailed stadium. This resulted in no implementation of the improvements into the railway deck.

4.3 Cross-case conclusion

The learning trajectories in the two cases are compared with each other to notice the similarities and differences between these learning trajectories. In this paragraph, the answer to the main questions one and two are provided. Table 9 provides an overview of the themes on which the two trajectories are analysed.

Table 9: Comparison of the cases

Theme	Case 1	Case 2
Initiation	• Modified requirement by the client • Complex and unfamiliar • Design phase	• Problems in previous project • Pouring concrete is not unknown for most of the members • Preparation and construction phase
Developments	• In consecutive project contexts • Higher maturity	• In consecutive project contexts • Lower maturity
Projects and their connections	Similar project mission; recurring tasks; TunnelAlliantie; members involved in earlier projects	Similar project mission; recurring tasks; TunnelAlliantie; members involved in earlier projects
Actors	• Explorer, exploiter and contributor • Owner: Design manager; not involved anymore	• Explorer, exploiter and contributor • Owner: Projectcoordinator; still involved
Looking back	Coupling by owner; personal network; own involvement; presentation	Personal network; own involvement; project review; department manager
Integral cooperation	• Gathering design engineers and executor after the first execution in which the construction did not perform well. • Subcontractor later involved to execute the placement of the fully preinstalled zandpot.	• After first successful execution • During the preparation of the work method, the design was already in a detailed stadium • Major involvement of subcontractor
Tools	Continuation of the engineering reports	Transfer of the work plans

Initiation of the trajectory

The learning trajectories are initiated by two different incentives and within different building phases. The trajectory of the zandpot was initiated by a modification of the client's requirements, which forced the organisation to develop a new work method. The design team was responsible for meeting this new requirement and explored the construction. Eventually, the construction team was responsible for the assembly method. On the other hand, the trajectory in case two was initiated to eliminate the failure costs, which arose after the execution in a previous project. The urgency for improving the work method is also enhanced by financial initiatives because the recovery measures involve high costs. Within this development, the preparation and construction team were engaged. Furthermore, a difference in complexity and familiarity of the technique is noticeable. The zandpot was a new construction and more complex. On the other hand, most of the members are familiar with pouring concrete because the realisation of concrete constructions is a core business of this organisation.

Developments

Both cases indicate that the development processes took place within the project context and not independently from these projects. Each development occurred through the interaction of the members and tools to fulfil the tasks. The difference between these two cases related to the development is that the zandpot reached a certain maturity. The involved members went further with the construction to further optimise the engineering and assembly method. Especially, the engineering method was fully adopted. Case two contained multiple projects in which the work method did not perform as expected. The project teams were looking for the right work method. After the execution of the successful work method, the owner went further with the development in the next project. Thus, the trajectory within case one is considered as more mature than the trajectory of pouring the concrete walls.

Project and their connections

The projects within these learning trajectories are interconnected. The cases are selected from the projects in one organisation with a similar project mission and work method. The projects are also part of the chain programme 'TunnelAlliantie' initiated by ProRail. Furthermore, a small stable group of members with experiences regarding the projects for Prorail is noticed within the organisation. In every project, there was always someone with previous experiences or with a personal network with the members of previous projects. As the executor stated: *"You have a small crew of people, who know each other. And when you make something suchlike [underpass], you know that you have to be with him/her when you make this. Because he/she did it before."*. In addition, the projects within the learning trajectories are interconnected because similar tasks related to that case had to be performed in each project. The projects are also connected by time. As is visualised in the overview of the projects in chapter two (see figure 5), the subsequent project is almost initiated after the finalisation of the previous project.

Actors

Within both learning trajectories, the same actors have been noticed. The owner fulfils a major role for the continuation of the development and the integration with all the related departments. In which phase the learning trajectory is initiated, determines who will perform as the owner. It can be concluded that the owner in case 1 is not directly involved anymore. Several members are familiar with the construction and the tools and contributed these to the new project. In case two, the owner is still engaged with the execution of the integral work method.

Looking back

The exploitation of the previous experiences has mainly occurred by looking back to that project triggered by their network or the emphasise by an experienced member. The experienced design manager ensured that the project members went further with the practice of the previous project. At a certain point, the owner presented the successful practice to the new project and the engineering report was shared without personal engagement. In case two, the department manager emphasised to the inexperienced projectcoordinator to look back at the previous work methods. Furthermore, a project review in the last project resulted in the awareness to monitor the work method that will be executed in Elst Noord. Besides that, during the trajectory, several members were involved, who could build upon their experiences regarding the different technologies.

Integral cooperation

Due to the integral cooperation, the different departments are learning from each other and the technology is further developed. In case one, the gathering between the design and construction department was noticed after the first execution of the zandpot. This resulted in a better alignment between the design of the construction and the execution. In case two, the gathering has been noticed after the first successful execution in the fourth project. The construction team was first looking within their team for a correct work method. After the development of the work method, the design was already in a detailed stadium. This resulted in no adaptations of the design related to this work method. In the next project, the owner was involved early in the project and was able to cooperate with the design team. In most projects, the design team is not involved anymore during the construction phase. However, it was noticed that the practice of the zandpot was still retained in the design team because these members were engaged actively to find out how the development has performed. Besides the cooperation between the design and construction departments, the cooperation of the subcontractors has been noticed. Especially, case two shows that the subcontractor had a major influence on the development. The assembly of the zandpot resulted in the engagement of a subcontractor but did not have any influence on the development.

Tools

The practice is eventually retained in the tools. These tools are eventually contributed to each project by a member. This revealed that the network of members and tools are essential for learning in the organisation. The extended description and the clear engineering sheets of the engineering method of

the zandpot are noticed within the consecutive projects. Due to this extended description, the new design engineer learned the engineering method and went further with this method in another project context. The work method within case two do not have reached the same level yet and this is noticeable in the elaboration of the concreting plans. However, these plans were contributed to each new project through the network of member and tools. Thus, the technical knowledge of that work method was revealed and used for developing a new concreting method. The documents do not describe how the process and execution have performed. This was again revealed by the network of members and tools.

4.4 Additional findings in general

The interviews highlighted certain aspects of learning within the organisation that are not directly attributed to the applied coding. These additional findings are divided into three groups related to case 1, case 2 and in general.

4.4.1 Additional findings case 1

The following additional findings are related to case 1:

(1) *Optimalisation:* In the beginning, no further optimisation of such a zandpot is being considered. Now that it has been further developed, the design of the zandpot could be further optimised. Thus, the zandpot may be optimised more, but this is not conducted yet.

(2) *Validated spreadsheet:* The engineering report with the addition of an Excel sheet has not been further developed into a validated spreadsheet. The design engineer in the second project indicated that developing a validated spreadsheet takes more time and that the zandpot is not used so often that it is profitable to make a validated spreadsheet. However, internal control is seen as sufficient within the situation of the zandpot.

4.4.2 Additional findings case 2

The following additional findings are related to case 2:

(1) *Sharing of the mistakes or problems*: It was indicated that the project members do not necessarily disclose their problems. The successes are strongly shared on the intranet, but the problems that should be learned from are not. When a problem occurs, a deviation should be written. Within this deviation, the preventive measures are described to think about the improvements in advance.

4.4.3 Additional findings in general

The following additional findings are related to learning in general:

(1) *Disclose the failure costs:* The feedback on failure costs of a projects needs to receive more attention as is indicated by the design manager and project coordinator. They see learning from mistakes made as the best learning moments for the organisation. However, it does not happen often that project members admit their own mistakes. The feedback still needs to occur with the consultation of the involved members.

(2) *Draft decision:* As is indicated by a project coordinator and executor, within the database 'Mobilizer' a module regarding draft decision is available. The draft decisions contain the underpinning for certain choices within the design phase. The retention of the practice within these documents might be of added value for the next project team. This project team can disclosure which choices are made within the design phase and why.

(3) *Organisational push:* Within the interviews, the question of how the project members will react when the organisation pushes some practices into the project to ensure continuous enactment, was asked. The respondents indicated the following possibilities for this organisational push.

- The organisation can be aware of the added value of a validated spreadsheet and might push members to set up such spreadsheets.
- The organisation can ensure the right coupling by bringing a couple of members together so that their experiences from other projects can be shared. Especially during

the tender phase. Within this phase, major decisions are made. Thus, bringing the members with the right experiences is essential within this phase.

- The organisation can push the project team in a certain direction, but each project context is different. Thus, this direction does not to be obliged. By establishing and maintaining a specific phasing and work method, a specific direction can be indicated. If you want to deviate from this, you must provide an underpinning, for example in the draft decisions.
- Besides that, a project always needs to fulfil the project mission for the right budget. If an innovation or new work method is pushed by the organisation, this indirectly provides the project team approval for applying this method.

4.5 Chapter summary

Within this chapter, the two cases have been analysed and the process of the learning trajectories have been described. The conceptual framework has been used to disclosure the processes within the trajectory and to find out which mechanisms influenced learning across projects and in the organisation. The following themes have been applied for comparing the two cases:

- *Initiation:* The initiation from the design phase resulted in the design manager as the owner and direct involvement of the preparation and construction team. On the other hand, the initiation from the construction phase resulted in the projectcoordinator as the owner and not directly in the engagement of the design team.
- *Developments:* The developments occurred within subsequent projects in which the zandpot has reached a higher maturity than the development of the work method for pouring the concrete walls. This higher maturity is noticeable in the involvement of the owner and the transfer and elaboration of the tools.
- *Interconnectedness:* The projects in the trajectories are interconnected by a similar project mission, recurring tasks, and the involvement of members with the experiences of previous projects.
- *Actors:* Different actors have been noticed in the learning trajectory. The explorer starts the development and is searching for the right process. The contributor brings their acquired knowledge into the new project. The knowledge is used by the exploiter to fulfil the tasks. Furthermore, the owner takes the responsibility for the continuation of the development and ensures integral cooperation with the different departments.
- *Looking back:* The members are always looking back to the previous project and this is triggered by the coupling ensured by the owner, personal network, own involvement, a given presentation about the technology, project review during the design phase and emphasise from the department manager.
- *Integral cooperation:* The organisation is learning by the integral cooperation with the different departments and subcontractors within the project. The construction department ensures that the preconditions and experiences from this building phase are integrated into the design and vice versa.
- *Tools:* The practice of the previous project is shared by the network member and tools. The tools contained mainly the technical knowledge of the technology and were continued within each project. The new members are learning by the network of members and tools.

The interviews also indicated some additional points: the development of validated spreadsheets, limited sharing of the mistakes and problems, failure costs as the learning points, draft decision for following the choices made, and organisational push.

5. Recommendations

To enhance the guidance and control of the learning trajectories by the project managers throughout the project, a flow diagram is developed (see figure 11). This flow diagram can perform as a starting point for the organisation to integrate the learning activities in the building processes. The diagram is divided into different segments and shapes. Recommended actions addressed to the different managers are represented by the rectangles and questions by diamond shapes. The department 'preparation' is not explicitly defined in this flow diagram since these members participate in both the design and construction phase.

Organisation

The department managers, who need to control the project-overarching view, are part of the organisation. They determine whether the organisation is making an offer for that project. Therefore, the recommendations are addressed to these managers. By uncovering the internal project-crossing trajectories (Dorée & Holmen, 2004) and reveal these trajectories within each building phase, the coupling between the new project team and the previous teams will be stimulated (see 1.1). The department managers need to define strategic goals and link these to specific projects (Hartmann & Dorée, 2015). These strategic goals contain the project-overarching ambitions (i.e., what does the organisation want to achieve?). As these researchers indicate, these goals act as binders between these projects. In addition, the organisation should consciously try to place the members in the projects or at the time of the project review (see 1.2). By placing the inexperienced members with experienced members, the interaction between the exploiter and contributor of the knowledge is facilitated. Ultimately in the further process, the exploiter can function as the contributor due to the acquired knowledge in the previous project. This will mitigate the dependency on one member.

Tender

Within this project phase, the broad strokes of the project are elaborated and an offer is submitted by the organisation for the realisation of the project. The tender manager is the responsible member during this project phase and therefore, these recommendations are addressed to this member. The members have to ascertain whether incidents or developments have occurred within the previous projects (see 2.1). These projects are also emphasised by uncovering the internal project-crossing trajectories by the organisation. The deviation reports of these projects can perform as a tool for identifying the incidents and Mobipedia can be applied for tracing certain developments. However, these tools do not provide the full range of knowledge of the development. For this reason, the members concerned have also to be engaged. These members will bring the procedural knowledge and the project documents with the technical knowledge with them. 'Durf-te-Vragen' may stimulate the disclosure of the members with the essential knowledge. Furthermore, the owner of the development should be engaged. This actor can perform as a knowledge broker. In the literature, Styhre, Josephson and Knauseder (2004) proposed that there is a need for the knowledge broker to enhance the learning capabilities in the construction industry. The knowledge broker serves as a transferring mechanism between the design and construction phase. This owner stimulates the triggering of the experiences, ensures the integral cooperation and the practice is embedded in this member. The role of the owner is especially important when the trajectory is initiated from the construction phase because this person needs to feel the responsibility to cooperate early with the design team.

Design

The design manager is the responsible person during this project phase and therefore, the recommendations are addressed to this member. Learning mainly takes place through personal contact with their predecessors and within the project. However, this low degree of formalisation results in learning as a self-organising process, which is difficult to manage (Styhre, Josephson & Knauseder, 2004). The project meetings and project reviews are an added value to assure that experiences are triggered. As Ren et al. (2019) indicate, these meetings are valuable institution arrangements to build their social relations and facilitate knowledge transfer. Therefore, a project

review needs to be organised to present and review the process (see 3.1). Furthermore, integral design meetings need to be conducted to ensure the contribution of the experiences and preconditions of the construction phase.

In addition, the awareness of the added value of the project documents as tools within the learning trajectory needs to be increased (see 3.2). This will be a task for the managers to emphasise this added value. Due to the engagement of the members and the execution of the project review, documents from the previous project might have been transferred. It is recommended to continue with these project documents to go further with the development of the technology. This recommendation is also in force within the construction phase. Therefore, the actions are placed in between the design and construction phase.

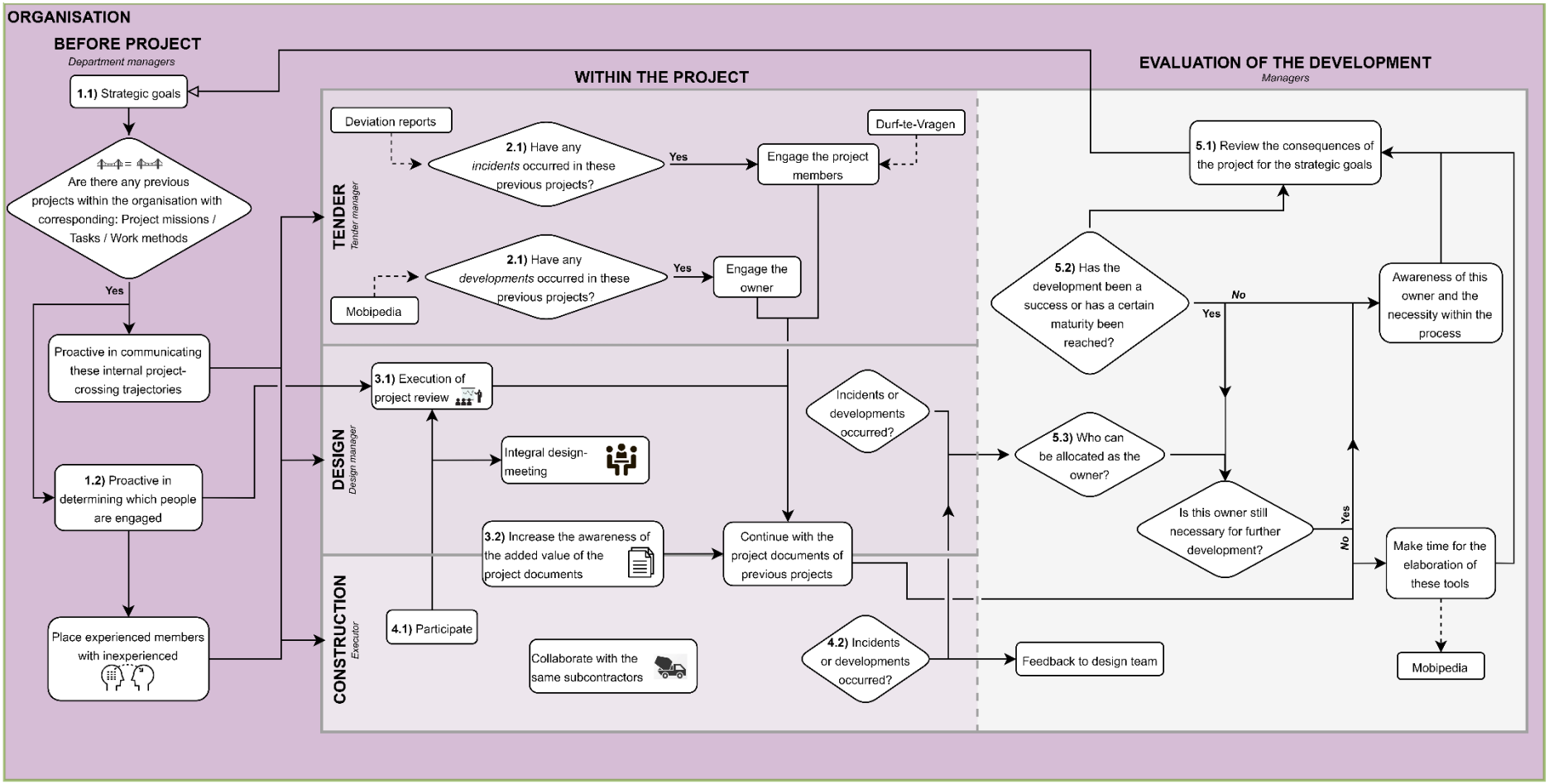
Construction

The recommendations are addressed to the executor. Within the construction phase, the members have to be engaged with the integral design meetings and the project reviews (see 4.1). This will enhance the learning between these different departments and the contribution of the preconditions and experiences from this phase into the design phase. When the development is mainly dependent on subcontractors, the recommendation is to collaborate again with these parties in the next projects When an incident or development has occurred within this building phase, feedback to the design team needs to be performed (see 4.2). This is important since, in most projects, the design team is not involved during the construction phase anymore.

Evaluation of the development

After the development has been executed, the performance of the process needs to be reviewed. The managers need to review the consequences of this project for the strategic goals (see 5.1). Have the goals been achieved or do the goals need to be adjusted? Furthermore, when the development has resulted in a success or reached a certain maturity, the involvement of the owner needs to be reviewed (see 5.2). The owner of the developments needs to be ascertained. From which phase the development is initiated will be an indicator for who the owner may be. This maturity relates to the engagement of the different departments, elaboration of the tools and the performance. Reaching this maturity needs to result in the elaboration of the tools to enhance the applicability in the organisation. The organisation needs to make time for this elaboration and should stimulate the sharing on Mobipedia, which may result in the contribution in the next project.

Figure 11: Flow diagram



6. Discussion

In this chapter, the absence of learning processes within the organisational context is discussed. Furthermore, an overview of the limitations that might affect the findings or caused incomplete research is provided and described. Finally, some directions for further research are proposed.

6.1 Learning in the organisational context

As already is concluded from the cases studies, no independent development processes from the project context in the organisation have been detected. However, the developed framework indicates that learning can take place within the organisational context. The learning trajectories are investigated within one organisation and this organisation is structured as visualised in Appendix A. Within this organisation, different departments and business models are defined. These departments are similar to the different construction phases (e.g., design and construction). A department with the project-overarching view or the objective to develop the practice independently from the projects is not directly noticed. Furthermore, the focus within this research is on the business model 'projects'. Within these projects, the human and financial resources are gathered and results in profits as money and knowledge. Due to the focus on the allocation of these resources to the projects, the execution of the development processes outside the projects is hampered. On the other hand, the findings of this research are based on the analysis of two case studies in which technology is continuously developed over a series of projects. Due to this research boundary, other cases of learning (e.g., IT facilities) are not investigated. The analysed work methods are dependent on the project context. The engineering and execution of these methods are based on the project-specific principles, requirements and factors. Additionally, both work methods are investigated within the same series of projects. This series of projects are characterised by the continuous flow of projects, which was enhanced by the chain programme 'TunnelAlliantie'. As a result, each project offered a new opportunity for further development and further elaboration within a different context. The time between the projects may be too short to gather the members and to develop the work method.

Mainly, this research showed that learning from projects takes place within the projects. The recommendations (see chapter 5) provide some implications for the department, tender, design manager and executor or projectcoordinator to enhance the guidance on the learning trajectories. The projects need to be linked through strategic goals within similar projects. These project-crossing trajectories stimulate the connections between the projects. Eventually, the project needs to be evaluated whether the consequence is related to these strategic goals. Furthermore, the department managers need to be proactive in the determination of which members are engaged. This supports the learning across projects by the network of members and tools. In addition, after the development has reached a certain maturity or success, the continuation of the practice is less dependent on the members and the importance of the tools has increased. The members need to evaluate whether an elaboration of the tools may stimulate the continuation of the practice.

6.2 Limitations

In this research, some choices have been made that can influence the results. These are based on the frameworks set in the research design (see chapter 2) and the theoretical framework (see chapter 3). Because of these choices, certain aspects have limited the research, see table 10.

Table 10: Limitations of this research

Limitations of research
The generalisation from two case studies: Assessing the two case studies was helpful to answer the research questions. However, it is unlikely that the two case studies provide all the possible information on the learning processes within this organisation. Furthermore, these cases concern practical work methods and other aspects from the construction projects (e.g., IT developments) are not investigated.

The continuous flow of projects and relatively short lead time:
The cases have been selected from the same series of projects and there is a continuous flow of project noticed. This continuous flow was also expected by the organisation due to the initiation of the chain programme 'TunnelAlliantie'. Furthermore, the lead time of the project was around two years. These aspects might stimulate the learning processes within the organisation due to the continuous flow of these similar projects.

Analysed projects:
The analysed projects have been chosen based on the presence of the technology. Thus, in which the continuous enactment has been successfully applied. However, there may also have been projects within the organisation in which this technology could have been or has been applied but which are not noticed. The focus on only the 'success stories' could have affected the observation of the hampering mechanisms related to learning in this organisation. Besides that, similar project complexities and contract forms might reduce the extent to which the recommendations are applicable within other contexts.

Data collection method:
The method for the data collection through semi-structured interviews limits the findings of this research. A limited number of interviews have been conducted due to the amount of time it takes to schedule, conduct, transcribe and code the interviews. The optimisation was seen to deal with both cases in one interview. However, each interview had a limited schedule to discuss both cases and the developments within the projects. In addition, the data can be categorised as self-reported data and is prone to selective memory, telescoping or attribution. These limitations were attempted to overcome by a validation after the interviews.

Time constraints:
The time constraints might affect the findings because no longitudinal data was acquired and certain developments in the project were not finished yet. In addition, the implemented facilities (e.g., intranet) were only available during the last two projects. Thus, the effect of these facilities is not discussed during this research.

Recall bias and discussing their positive input:
The data is obtained through interviews with the specific project members and this may be affected by the recall bias. This bias is related to that the interviewees might remember certain things differently from the way they happened. Besides that, the members can feel the urge to talk only about the positive results of the processes and neglect the negative.

6.3 Directions for further research

This research might be interesting for other PBO's in the construction industry. The developed framework can be applied by other organisations to understand the learning processes and opportunities for learning. Furthermore, the recommendations may apply to other organisations because the organisational structure within other construction firms is comparable. The scope of this research is focused on projects with a processing time of around two years and within one case. It might be interesting to investigate how these learning trajectories occur within projects with a longer processing time or within different cases. In addition, both cases were embedded within the same projects. It should be investigated whether similar findings occur in cases spread over different series of projects.

7. Conclusion

This research aimed to understand and enhance learning across projects and into the organisation. Therefore, the learning trajectories are analysed by the study of the two cases. To conclude, the answers to each main question are given.

- MQ1: *How do the learning trajectories unfold within Mobilis?*

The learning trajectory occurs within the project through the interaction of the members, tools and tasks. Within these projects, the developments are formed by the processes of triggering, creating and retaining. The experiences from this interaction are exploited to create the practice in the project. This practice is eventually retained in the members, tools and tasks. These organisational elements are continued within the next project or are engaged by the new project members. These projects are interconnected due to a similar project mission, chosen work method in the tender and recurring tasks.

The two cases show that these trajectories can be initiated from different project phases and departments. Case one 'zandpot' was initiated within the design phase and the construction was responsible for the assembly and emptying the construction. Eventually, the development of the zandpot resulted in the adoption of the engineering and assembly method within a new project team. Case two 'pouring the concrete walls underneath the railway deck' was initiated within the preparation and construction phase in which the construction team was responsible for the execution. The first four projectteams were looking for the right work method to fulfil the tasks. After the execution of a work method without failure costs, the work method was elaborated integrally with the design team. The performance of this work method is not revealed yet.

- MQ2: *Why do the learning trajectory unfold in this way?*

Within both cases, the mechanisms that stimulated or hampered the processes of triggering, creating and retained are revealed. Furthermore, the following actors have been noticed within the trajectory: explorer, exploiter, contributor and owner. It can be concluded that the continuous enactment of the technology and the knowledge is stimulated by the similarities between the projects. Every project team looked back to the previous similar projects, which led to the continuation of their practice. The network of members and tools resulted in the transfer of these tools in which the technical knowledge was retained. In case one, the transfer of the engineering report performed well after the elaboration in the second project. The role of the owner is more prominent at the beginning of the process than when the development has reached a certain level. Eventually, the owner is not involved anymore, and other members of the organisation contributed their knowledge to the project. This phase is not yet reached for the work method of pouring the concrete walls.

- MQ3: *How can the project management processes within Mobilis be improved to enhance learning across projects and within the organisation?*

A flow diagram is developed and can perform as a starting point for the integration of the learning processes in the organisation and the different building phases to enhance the learning between projects and within the organisation. The organisation needs to find out the internal project-crossing trajectory and determine which members are engaged in the project. After the development has occurred, the organisation needs to review whether these tools have to be elaborated to enhance the applicability in the organisation. Within the tender phase, the members have to find out which developments or incidents have occurred in similar previous projects. The experienced members regarding these developments or incidents have to be engaged. Within the design and construction phase, the transferred project documents need to be continued within this new project. Furthermore, in the design phase, the project review and integral design meeting have to be conducted to increase the range of experiences and to integrate the experiences and preconditions of the construction phase. After the development has occurred, the owner of this process needs to be determined. Subsequently, the success and maturity of the development needs to be reviewed and to what extent the owner

should be involved in the future and whether the tools have to be elaborated further. Finally, it is recommended to review the consequences of these projects for the defined strategic goals.

The case studies did not reveal development processes in the organisational context, but that the learning took place within the project. Lack of these processes outside the projects might be explained by the absence of a department with the project-overarching view, the classification of the organisation as a PBO, the dependency of the cases on the project context and the continuous flow of projects in which an underpass is constructed.

The results of this research are constrained by some limitations. These limitations are related to the generalisation from two cases within the same series of project, the continuous flow of projects, the data collection method, time constraints, and recall bias.

To conclude, other organisations can apply the conceptual framework to identify the learning processes and opportunities for further learning, and organisations can apply the flow diagram as a starting point to enhance learning from the project to project and from projects into the organisation.

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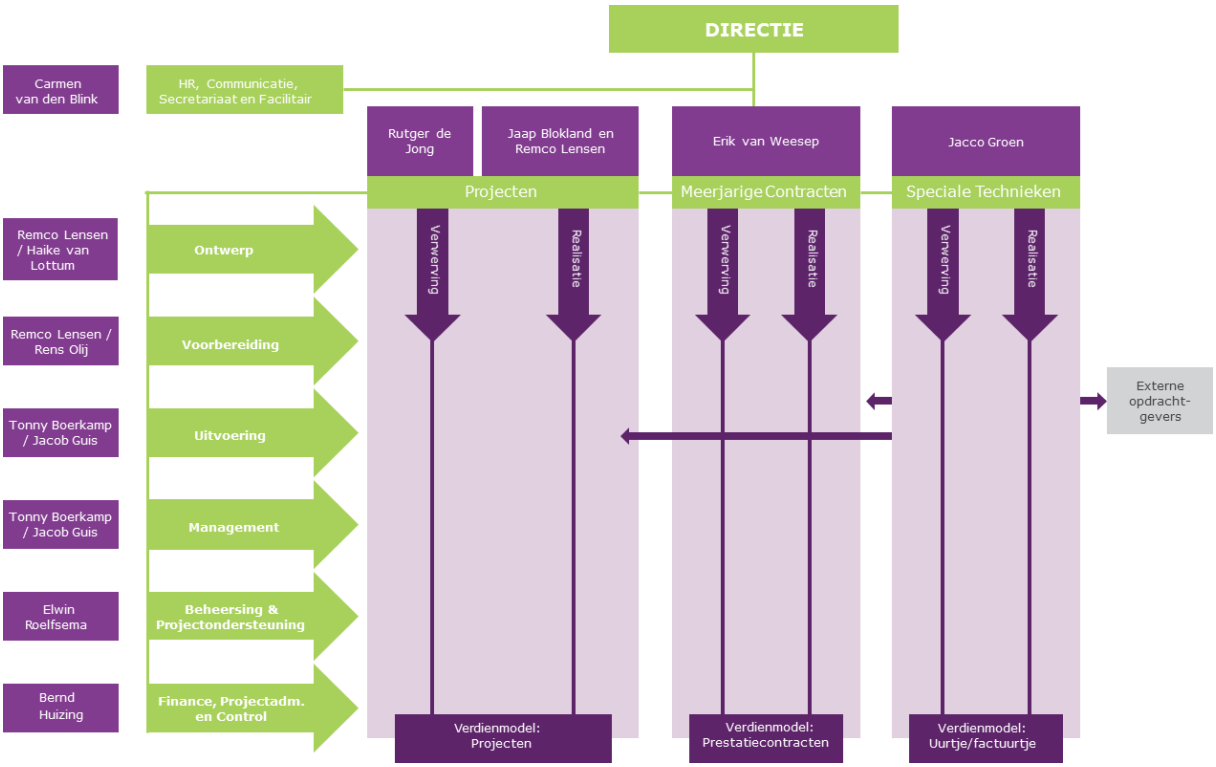
Appendices

- Appendix A - Organisation Chart
- Appendix B - Interview Protocol
- Appendix C - Code Tree
- Appendix D - Case study descriptions
- Appendix E - Analysis of developments within case 1 and case 2

Appendix A - Organisation Chart

Figure 12: Organisation chart derived from TBI Holding B.V. (2020)



Appendix B - Interview Protocol

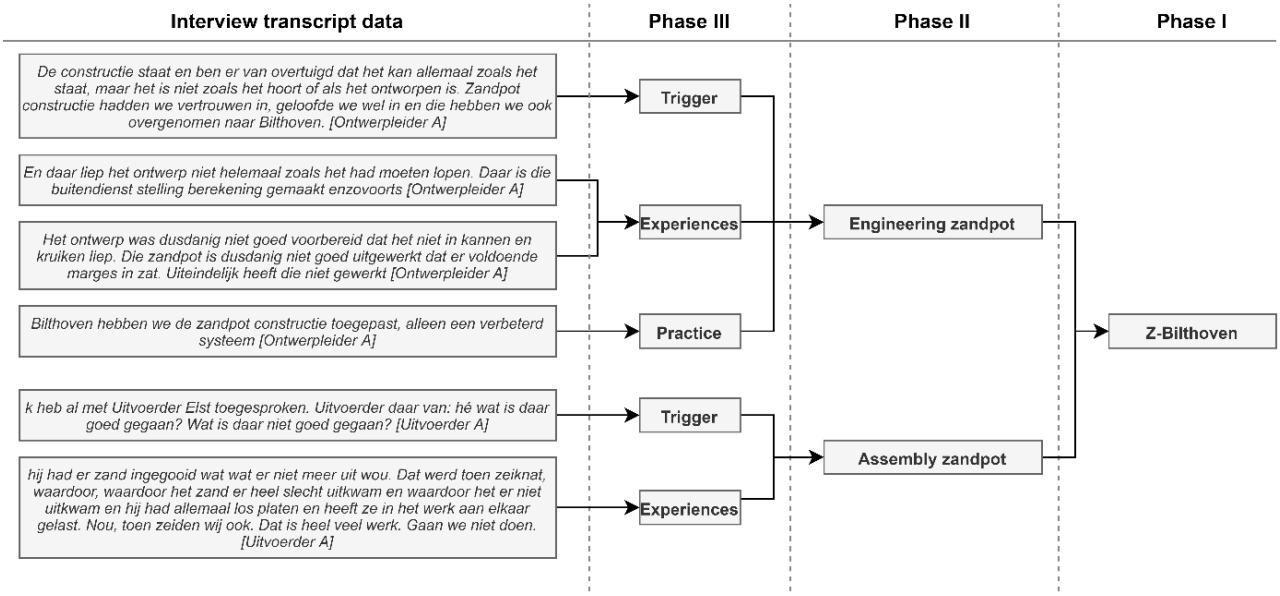
Protocol	Interview vragen	Codes Fase 1	Codes Fase 3
Introductie: *Leggen van de relaties tussen de data uit de bronnen met de verschillende cases en projecten. Achterhalen van de achtergrondinformatie van de databronnen.*	• Heeft u er problemen mee dat dit gesprek opgenomen wordt, zodat ik tijdens het verwerken van de data nog altijd een back-up heb van de interviews? • Voorstellen van beide partijen en uitleg/motivatie voor het uitvoeren van dit onderzoek. • Bij welke projecten waarin onderdoorgangen gerealiseerd zijn of worden door middel van het inschuiven van een voorgebouwde spoordek constructie bent u betrokken geweest? ○ Elst Station |Bilthoven | Assen | Heiloo | Elst Noord | Diemen | Geldermalsen • Welke functies heeft u vervuld binnen deze projecten? • Het doel is het begrijpen van het proces met betrekking tot de twee cases. Heeft u ervaringen met deze ontwikkelingen?	Z/W - Project	
	Indien de geïnterviewde betrokken is bij beide leertrajecten, dan starten met de zandpot.	**Z**andpot | **W**anden	

Processen binnen projectcontext
Achterhalen wat er zich af heeft gespeeld binnen de projectcontexten en hoe deze contexten gevormd zijn.
	Ik zou graag willen beginnen met wat er binnen de projecten heeft plaatsgevonden en dan het liefst in chronologische volgorde in hoeverre dat lukt.
	• Zijn er specifieke problemen, incidenten of uitdagingen die u bij gebleven zijn omtrent 1 van deze twee cases?
	• Hoe zijn deze opgelost en wie waren hierbij betrokken?
	• Is er gebruik gemaakt van voorgaande ervaringen/kennis?
	  ○ Ja: Wat waren hier de triggers van? Welke kennis is gebruikt? En hoe zijn deze relaties gelegd?
	  ○ Nee: Als er terug wordt gekeken, had je dan kennis van voorgaande projecten kunnen gebruiken?
	• Op welke gebied heeft er een ontwikkeling plaatsgevonden binnen het project?
	• Deze bepaalde kennis kan ingebed worden in bepaalde onderdelen. Hoe was de ontwikkeling ingebed?
		Algemeen
		Elst Station
		Bilthoven
		Assen
		Heiloo
		Elst Noord
		Diemen
		OC-project/project
			Members
			Tools
			Tasks
			Trigger
			Experiences
			Creation
			Practice
			Retention
			Actors
			Mechanisms

Processen binnen organisatorische context *Achterhalen wat er binnen de organisatie gezorgd heeft voor de voortzetting van de praktijk.*	• De kennis omtrent dit principe is voortgezet binnen andere projecten. Wat zorgde er volgens jou voor de voortzetting van deze kennis? • Heeft er een ontwikkeling plaats gevonden buiten de project context? • In welke vorm heeft deze ontwikkeling plaats gevonden?		
Factoren *Achterhalen van specifieke factoren binnen de leertrajecten omtrent de volgende categorieën: actors; mechanismes; verankering van de projecten binnen de organisatie*	• In welke mate waren de projecten verankerd binnen de organisatorische context? ○ Gevestigde rollen/routines, reeds bestaande vaardigheden, missie van project omkaderd wordt door gevestigde organisatorische repertoires. • Wat voor rol heb jij gespeeld binnen het leertraject? • Zijn er bepaalde mechanismes die een stimulerend of belemmerend effect hebben op het ontwikkelproces binnen en over de projecten?		
	Terug naar processen binnen projectcontext, indien de geïnterviewde betrokken is bij beide cases.		

Protocol	Interview vragen	Codes Fase 1	Code Fase 3
Omgevingscontext *Achterhalen wat de invloeden van de omgevingscontext zijn.*	• Wat voor invloeden heeft de opdrachtgever, contractvormen of externe partijen op het leerproces en voortzetting van kennis?	Omgevingscontext	
Organisatorisch vraagstuk	*Op bepaalde momenten zou de organisatie bepaalde processen in het project kunnen pushen om het leertraject verder te stimuleren.* • Heeft u behoefte aan dat bepaalde processen gepusht worden vanuit de organisatie? • Zou dit als positief of negatief ervaren worden? • Hoe zou jij je dit voor je kunnen zien?	Organisatorische push	
Onduidelijkheden/ tegenstrijdigheden	*Ruimte om nog onduidelijkheden of tegenstrijdigheden na te vragen bij de geïnterviewde.*		
Afsluiting	• Merkt u andere ontwikkelingen op binnen deze projecten? • Is er iemand die in u op komt, die mij nog meer informatie of inzichten kan aanleveren omtrent dit proces? • Zijn er nog aspecten die u mij mee wilt geven omtrent dit onderwerp? • Kan ik u een korte samenvatting opsturen van dit interview, zodat de gegevens gevalideerd zijn?	Meegegeven aspecten Overige ontwikkeling Algemeen A-Organisational context	

Appendix C - Code Tree



Appendix D - Case study descriptions

Deze bijlage geeft een beschrijving van de twee cases. Eerst wordt de afbakening van projecten waarin onderdoorgangen door middel van het inrijden van een voorgebouwd spoordek beschreven. Vervolgens worden per case de techniek en de processen binnen de projecten beschreven.

Algemeen

Voor een veiligere en betere doorstromingen worden veel bewaakte overgangen in Nederland vervangen door onderdoorgangen. Mobilis heeft in opdracht van ProRail verscheidene onderdoorgangen gerealiseerd. Hierbij is Mobilis verantwoordelijk geweest voor het ontwerp en de uitvoering. Om de projecten aan te nemen dient eerst een tender uitgevoerd te worden. Binnen een tender wordt een inschrijving gerealiseerd voor het project door verscheidende aannemers en wordt door de opdrachtgever de opdracht gegund aan de aannemer met de beste inschrijving. Ten tijde van de tender worden verschillende varianten voor het realiseren van een onderdoorgang uitgewerkt en wordt er een keuze gemaakt. Eén van de varianten is het realiseren van een onderdoorgang door middel van het inschuiven van een voorgebouwde spoordek constructie. Zie figuur 1 voor een weergave van het inrijden van het voorgebouwde spoordek en de uiteindelijke situatie.

Figuur 1: Inrijden van een voorgebouwd spoordek (links) en de onderdoorgang (rechts) (Intranet)

Tunnelalliantie

ProRail heeft diverse onderdoorgangen aangeboden binnen een ketenprogramma 'Tunnelalliantie' om de aanpak van deze projecten te optimaliseren. Tunnelalliantie (TA) is een nieuwe manier van werken specifiek voor het realiseren van onderdoorgangen en (indien nodig) het opheffen of aanpassen van overwegen met als doel het opleveren van een beter project door een toename in kwaliteit en een afname in kosten (Meijneken, 2019). De volgende partijen zijn betrokken binnen deze werkmethodiek:

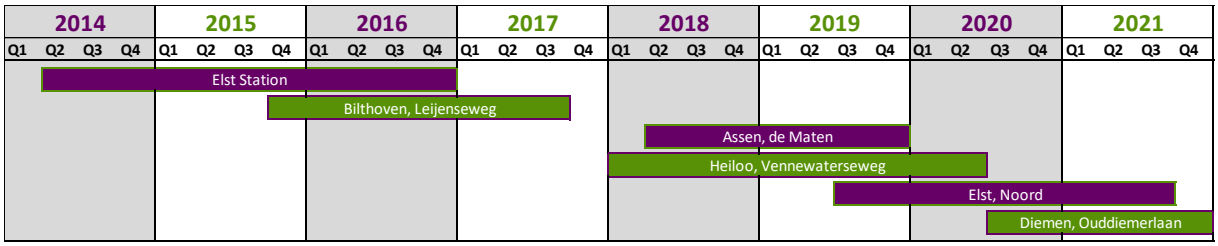
- De *initiatiefnemer* is een gemeenten, waterschap of provincie, die besloten heeft dat een onderdoorgang de juiste oplossing is voor zijn vraagstuk.
- *ProRail* is de verantwoordelijke organisatie voor het spoorwegennet van Nederland. Binnen de Tunnelalliantie verzorgt ProRail een projectteam die per fase en op basis van met de initiatiefnemer overeengekomen plannen van aanpak haar werk doet. Uiteindelijk draagt ProRail als uitvoerend opdrachtgever zorg voor aanbesteding, uitvoering en oplevering van het project.
- *Tunnelalliantie aannemers* zijn geselecteerd om mee mogen te doen aan de projecten.

Mobilis voert de projecten binnen de Tunnelalliantie in een combinatie met Hegeman uit. In totaal zijn er 23 projecten binnen de Tunnelalliantie op de markt gezet. De combinatie Mobilis en Hegeman hebben voor 21 projecten een aanbieding gedaan en daarvan zijn er acht projecten aan de combinatie gegund. Van deze acht gegungde projecten zijn zes projecten al opgeleverd.

Projecten

Figuur 2 geeft een overzicht van de projecten binnen de scope van het onderzoek. Alle projecten zijn of worden uitgevoerd in opdracht van Prorail. Vier projecten (Assen, Heiloo, Elst Noord en Diemen) vallen binnen de Tunnelalliantie en hiervan zijn de onderdoorgangen (Assen en Heiloo) reeds opgeleverd.

Figuur 2: Overzicht van de projecten in de loop van de tijd



Geïnterviewde

Tabel 1 geeft een overzicht van de betrokkenheid van de geïnterviewde leden per project.

Tabel 1: Overzicht van de geïnterviewde leden

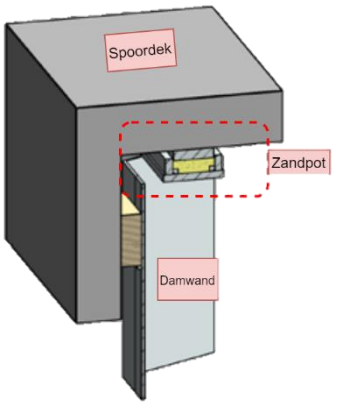
Geïnterviewde	Elst Station	Bilthoven	Heiloo	Assen	Elst Noord	Diemen
Ontwerpleider A *Design manager A*		Ontwerp	Ontwerp		Ontwerp	
Ontwerpleider B *Design manager B*	Ontwerp	Tender	Tender	Tender + Ontwerp	Tender	Tender + Ontwerp
Constructeur A *Design engineer A*	Ontwerp Zandpot	Interne controle	Interne controle			
Constructeur B *Design engineer B*		Ontwerp Zandpot				
Projectcoördinator A			Ontwerp + Voorbereiding	Voorbereiding +Uitvoering	Ontwerp + Voorbereiding + Uitvoering	
Projectcoördinator B			Voorbereiding + Uitvoering			Ontwerp
Uitvoerder A *Executor A*		Uitvoering	Ontwerp + Voorbereiding + Uitvoering			Review

Case 1: Zandpot

Algemene beschrijving

De zandpot draagt het betonnen dek ten tijde van de tijdelijke gebruiksfase, zodat de damwanden in de uiteindelijke situatie geen dragende functie meer vervullen. Zie figuur 3 voor een 3D visualisatie en figuur 4 voor de fasering van de zandpot. De zandpot bestaat uit twee staalplaten, twee staalstrips, twee staalnokken en is gevuld met zand. De zandpot is ongeveer 30cm breed en de lengte is afhankelijk van de breedte van het spoordek, wat steunt op de zandpot. Nadat de wanden en de vloer van de onderdoorgang zijn gecreëerd, kan de zandpot uit werking gehaald worden. Dit wordt bereikt door het wegspuiten van het zand onder hoge druk. Door het toevoegen van de twee staalnokken is het mogelijk om het zand volledig te verwijderen, doordat de stalen oplegplaat op de stalen nokken valt. De engineering van deze constructie valt onder hulpwerk.

Figuur 3: 3D visualisatie van zandpot



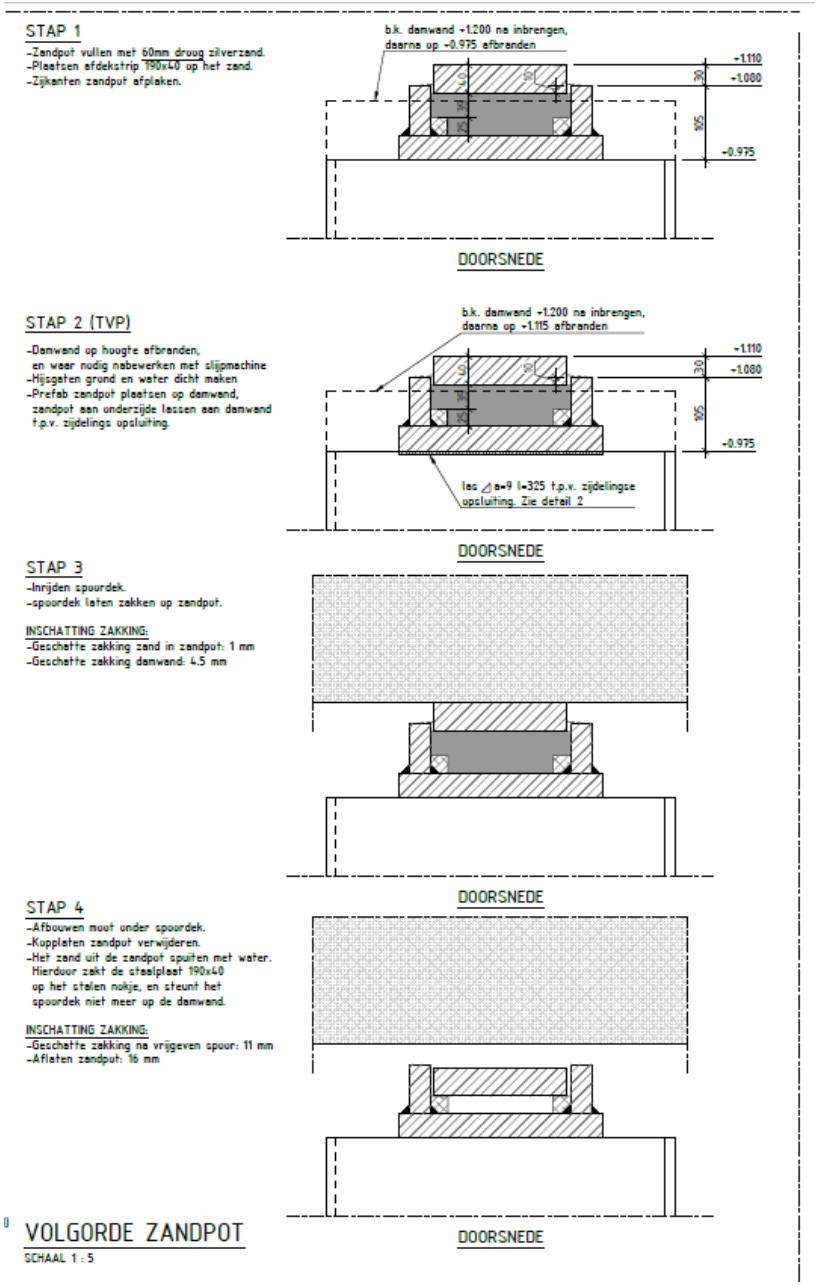
De toepassing van de zandpot is afhankelijk van enkele randvoorwaarden, die bepaald worden in de tenderfase. Zo moet er gekozen worden voor het inrijden van een voorgebouwd spoordek en het funderen van de onderdoorgang op staal.

Binnen het ontwerp van de zandpot dienen de volgende toleranties in acht genomen te worden:

- Zakking van de moot door mobilisatie fundatie op staal;
- Hoogtetolerantie op bovenzijde damwand;
- Plaatsingstoleranties bij installeren zandpot;
- Marge tijdens definitieve situatie.

De zandpot kent zijn toepassingen binnen vier projecten en bij vijf gerealiseerde onderdoorgangen. De eerste toepassing was binnen het project Elst Station, waar in opdracht voor ProRail twee onderdoorgangen zijn gerealiseerd. De volgende projecten zijn: Bilthoven, Heiloo en Elst Rijksweg Noord.

Figuur 4: Fasering Zandpot



Elst Station

Ontwerp

Binnen dit project zijn twee onderdoorgangen gerealiseerd: Langzaam Verkeer Tunnel (LVT) en Snel Verkeer Tunnel (SVT). Hiervoor is voor elke onderdoorgang een rapport opgesteld voor het inrijden van het spoordek. Het rapport voor de LVT was hier leidend, doordat het dek van de LVT zwaarder was dan die van de SVT. Hiermee kan geconcludeerd worden, als de berekening voor de LVT voldoet, voldoet die ook voor de SVT.

Binnen het ontwerp zijn meerdere toetsingsmomenten aanwezig, zowel intern als extern. Interne toetsing vindt plaats voordat het rapport verzonden wordt naar een externe partij. De externe toetsing wordt uitgevoerd door twee toetsende partijen: Arcadis en Movares.

Het proces verliep niet helemaal zoals het hoort. Drie weken voor de eerste buitendienststelling werd Constructeur A, die net een jaar werkzaam was als constructeur, erbij betrokken om een paar opmerkingen van Movares te behandelen. Voorafgaand aan zijn betrokkenheid was Persoon A, een ervaren constructeur, de verantwoordelijke voor het rapport van het inrijden van het spoordek. Persoon B was de verantwoordelijke voor de interne controle en had op het eerste rapport een aantal opmerkingen gegeven. Deze waren aangepast en Persoon B vertrouwde er wel op. Hierop heeft Arcadis een externe controle uitgevoerd en kwam ook weer met een aantal opmerkingen. Daarnaast was de uitwerking van de zandpot nog niet aanwezig in het gecontroleerde rapport (Versie A). Het verbeterde rapport is gecontroleerd door Movares. Hierop kwam Movares met een vraag. Ten tijde van dit proces was persoon A niet meer betrokken bij dit project en hierdoor werd Constructeur A aangewezen om de vragen van Movares te beantwoorden. Na de eerste aanpassingen door Constructeur A zijn de twee opgestelde rapporten door Persoon A aan de kant gelegd en zijn twee volledige nieuwe rapporten opgesteld in de laatste twee weken. Te concluderen is dat het proces voor het rapport veel haken en ogen heeft gekend. Om dit beter te begrijpen geeft tabel 2 een beschrijving van de verschillende versies in chronologische volgorde.

Tabel 2: Overzicht van de opgestelde berekeningsrapporten binnen Elst Station

Versie	Datum	Opsteller	Inhoud	Controle
A	25-6-15	Persoon A	20 pagina's	Door Persoon B op 17-7-15
A1	22-7-15	Persoon A	Geen verschil met A op te merken.	
B	9-9-15	Persoon A	33 pagina's met uitleg van de oplegging op de damwand (incl. tekening)	Arcadis op versie A, waar de zandpot dus nog niet in aanwezig is. 22-7-15. *Vraag* m.b.t. het principe van de zandpot: Hoe wordt loodrecht op de damwand de horizontale belastingen overgedragen? *Reactie*: Dit is weergegeven op tekening T_S-002_UO_DW_0266 (Doorsnede B en D)P-B 28-8-15
C1	17-9-15	Persoon A	32 pagina's, in geel de veranderingen aangegeven.	
C	22-9-15	Persoon A	33 pagina's	Persoon B 22-9-15 In versie C1 is de stalen opsluitconstructie gewijzigd.
D	2-10-15	Persoon A	39 pagina's	

E	9-10-15	Constructeur A	157 pagina's met uitleg en toetsing van de zandpot.	Movares: bevindingen op rapport versie C. Een aantal vragen.
F	19-10-15	Constructeur A	162 pagina's, uitbreiding bijlages zandpot	
G	21-10-15	Constructeur A	159 pagina's, handberekening en excel.	

De ontwikkeling van de zandpot in het ontwerp is ingebed in het berekeningsrapport, de handschetsen en de handberekeningen (bijlage F t/m J van berekeningsrapport).

Uitvoering
In het gesprek met de uitvoerder van project Bilthoven is de uitvoering van de zandpot binnen dit project beschreven. Het zand binnen de zandpot was nat geworden en hierdoor was het moeilijk om het zand uit de zandpot te krijgen. Daarnaast diende de secties van de zandpot aan elkaar gelast te worden in het werk. Dit staat vermeld in een afwijking (AFW-0004). De zandpot is op locatie in secties van 3 meter aangebracht, waardoor in het werk nog lassen aangebracht diende te worden. In het ontwerp van de zandpot waren oplegschotten aanwezig van 20x5mm, zodat de oplegplaat gecontroleerd op de zandpot zou vallen.

Terugblik
Terugkijkend op de werking van de zandpot binnen dit project is gebleken dat de zandpot niet gewerkt heeft zoals het had gemoeten. Dit wordt bevestigd door de Ontwerpleider A, Uitvoerder en Constructeur B van project Bilthoven en door de Constructeur A van dit project. Constructeur A benoemde dat ten tijde van een projectbezoek de ruimte tussen het dek en de wanden van de zandpot ongeveer één à twee mm was en dit hoort tien mm te zijn. Hierbij heeft Constructeur A, die pas een jaar werkzaam was als constructeur, in een zeer kort tijdbestek twee rapporten voor het inrijden van het spoordek op moeten stellen, zodat de ingeplande buitendienststelling uitgevoerd mocht worden.

Bilthoven

Ontwerp
Binnen dit project is de berekeningsmethode en uitvoeringswijze verder ontwikkeld op basis van het voorgaande project Elst Station. Constructeur B en Uitvoerder van dit project hebben samen met Constructeur A de verbeterpunten besproken. Deze koppeling is gelegd door Ontwerpleider A, die vertrouwen had in het principe van de zandpot.

De ontwikkeling heeft zich gefocust op de zettingen, toleranties en het ontwerp van de constructie en hiervoor zijn de voorgaande ervaringen van project Elst Station gebruikt. Hierbij is Constructeur B verdergegaan met de berekeningen van Constructeur A en is vooral de berekening overzichtelijker gemaakt. Deze ontwikkeling is te zien in de uitgebreidere beschrijving voor de bepaling van de geometrie en in de overzichtelijkheid van de Excel sheet. Dit berekeningsrapport is intern gecontroleerd door Constructeur A, zie bijlage 3 van het berekeningsrapport.

Uitvoering
De Uitvoerder van dit project heeft aangegeven dat Ontwerpleider A gezorgd heeft voor de link tussen Elst Station en Bilthoven. En doordat de uitvoerders elkaar kennen, is de benadering naar elkaar gemakkelijk verlopen. De uitvoerder van Elst Station heeft filmpjes en foto's doorgestuurd om de leerpunten aan te geven bij Uitvoerder. De zandpot bestaat uit een u-profiel, zand en een oplegplaat. Op dit project is het u-profiel voorgebouwd en ingehesen op locatie, waarna aangevuld met zand en afgesloten met een oplegplaat van twee à drie stukken. De uitvoering heeft op dit project een besparing doorgevoerd, door houten latten toe te passen in plaats van de stalen oplegschotten, die toegepast waren op project Elst Station.

Terugblik
De zandpot heeft binnen dit project gewerkt naar verwachting. Echter, het leegspuiten van de zandpot is niet helemaal zoals naar verwachting gegaan. De houten latten zijn gaan drijven door het inspuiten van het water, waardoor een blokkade ontstond voor de waterafvoer. Achteraf blijkt dus dat het gebruik van houten latten een verkeerde besparing is geweest.

Heiloo

Ontwerp
Constructeur B heeft de berekeningen, tekeningen en Excel sheets doorgestuurd naar de constructeur van dit project. Hierbij heeft Ontwerpleider A weer het ontwerp getrokken. De ervaringen die overgedragen waren door de documenten en personen waren al op een hoog niveau, zoals Projectcoördinator B benoemd heeft. Voor de Uitvoerder en Ontwerpleider A was de zandpot al een bekend principe door de ervaringen uit Bilthoven. Projectcoördinator A heeft hierbij de voorbereiding gedaan ten tijde van het ontwerpproces. Hierbij gaf hij aan dat het voornamelijk ontwerp specifieke aanpassingen waren voor dit project. Ook dit berekeningsrapport is intern gecontroleerd door Constructeur A. Daarnaast komen de Excel sheets van het voorgaande project Bilthoven in dit rapport terug. Een extra opmerkelijke toevoeging binnen dit rapport zijn de aandachtspunten voor de uitvoering.

Uitvoering
Projectcoördinator B heeft hierbij volledig moeten vertrouwen op de expertise en ervaringen van de uitvoerder, doordat dit voor hem de eerste kennismaking was met dit soort projecten en dus ook de zandpot. Hierbij heeft hij op detail niveau het werkplan voor de treinvrije periode (TVP) geschreven, waarin een hijsplan is opgesteld met de kranenleverancier. Dit hijsplan is opgesteld, doordat de algehele zandpot voorgebouwd is en in één geheel op locatie is geplaatst. De Uitvoerder heeft zijn eigen ervaringen meegenomen en ingebracht ten tijde van de opstart van dit project. Hierbij zijn de houten latten vervangen door de vast gelaste stalen nokken.

Elst Noord

Op basis van Heiloo is de berekening uitgevoerd door Constructeur D. Binnen dit rapport zijn veel overeenkomsten met het berekeningsrapport van het voorgaande project. De berekening van de zandpot constructie is 1 op 1 overgenomen vanuit Elst en Heiloo, doordat de belastingen op deze reeds uitgevoerde projecten groter waren dan binnen dit project. Het volgende staat vermeld in het rapport: "*Geconcludeerd kan dus worden dat de destijds berekende zandpot ook in dit project zal voldoen… Hiernavolgende verdere berekeningen zijn overgenomen uit de benoemde vorige projecten. (Eventuele aanvullingen als volgt gemarkeerd)'.* Een project specifieke aanpassingen is uitgevoerd in het ontwerp van de zandpot, doordat er een grotere zetting werd verwacht.

Ontwerpleider A heeft op dit project een presentatie gegeven met betrekking tot het principe van de zandpot. Deze presentatie is gegeven voor het projectteam en is uiteindelijk ook gedeeld op Mobipedia.

Diemen

Het berekeningsrapport is nog niet opgesteld voor dit project, doordat het project nog niet zover is. Projectcoördinator B van dit project heeft binnen project Heiloo kennis gemaakt met de zandpot en neemt hier de ervaringen van mee. De link met Elst Noord wordt gemaakt door een ontwerper die betrokken was bij Elst Noord. Een review moment heeft plaatsgevonden om de voorgaande ervaringen van buiten het projectteam erbij te betrekken.

Tabel 3: Overzicht van de documenten binnen case 1

C1 Zandpot

Interviews	Ontwerpleider-A | Ontwerpleider-B | Constructeur-A | Constructeur-B | Projectcoördinator-A | Projectcoördinator-B | Uitvoerder

1) Elst Station	2) Bilthoven	3) Heiloo	4) Elst Noord
Afwijkingsformulier [AFW-0044] BR1-ES [B_S-002_UO_BE_0457 Versie G - Rapport inrijden LVT] BE_0457 Rapport inrijden LVT BE_0456 Rapport inrijden SVT	BR2-Bi [Ontwerp oplegging spoordek op damwand B_S-003_UO_BE_0397 Versie A 18-01-2016]	BR3-He [UO berekening Hulpwerk spoordek Zandpotten en zijdelingse opsluiting] Werkplan TVP [Heiloo_1904-1583v1.0 Werkplan TVP werklocatie 1A Mobilis-Hegeman (incl bijlagen)]	BR4-EN [2002-1832-v1.0-g1 - UO Berekening ODG Elst tijdelijke constructies tbv spoordek] Controle BR4-EN [2002-1832 concept_opm.NSC] Integraal werkplan [Elst Noord 2002-5614 v2.0 Intergraal werkplan CMHE ODG Elst] Tekening van zandpot [2002-4774 v2.0 - zandpot, fixatie van het spoordek en aansluiting tijdelijke buispalen] Powerpoint cursus zandpotten [2019-10-11 Cursus zandpotten en zijdelingse opsluiting v1.0]

Analyse	C1_Analyse_Berekeningsrapporten
Bijkomende documenten	Foto's_Projectbezoek_Elst Noord

Case 2: Storten van de wanden onder spoordek

Algemene beschrijving

Na het inrijden van het spoordek dient de vloer en wanden onder het spoordek gestort te worden. De wanden worden gestort tussen de vloeren en het ingereden dek. Daarnaast ligt het dek op een hulpconstructie, waardoor de bereikbaarheid van de bekisting beperkt is. Dit brengt beperkingen met zich mee ten tijde van de stort. Deze case doet zich voor binnen alle zes projecten, waarvan de stort voor twee projecten nog uitgevoerd dient te worden.

Elst Station

Binnen Elst Station was de gehele wand gestort met zelfverdichtend beton (ZVB), omdat ZVB gezien wordt gezien als het beste mengsel om de wand vol te krijgen. Uiteindelijk waren er veel scheuren ontstaan en was de wand niet waterdicht. De wand werd bekleed met tegeltjes en hiervoor moet de wand wel waterdicht zijn. Om de wand waterdicht te krijgen, is de wand geïnjecteerd.

Bilthoven

Op dit project was gekozen voor een strook met de toepassing van ZVB en dus niet de algehele wand. Ter plaatse van het oude beton en de strook ZVB was extra wapening aangebracht, zodat de kans minder groot was dat het ging scheuren. Uiteindelijk was ook deze wand gaan scheuren. Deze bevinding was ook verwerkt in twee afwijkingen: afwijking-0120 en afwijking-0136. Zoals vermeld is in afwijking-0120 ‘Krimpscheuring in 2^{e} stort wand van moot 5A oostzijde (ZVB): in de stort met ZVB waren scheuren geconstateerd en deze zijn geïnjecteerd. Voor het injecteren van de wand was een werkplan opgesteld. Als beheersmaatregel was aanbevolen om het beton minimaal een week langer in de kist te laten staan. Ondanks het hanteren van deze beheersmaatregel waren er alsnog scheuren opgetreden, zoals vermeld in afwijking-0136 ‘In wanden moot 5b, stort zelfverdichtende beton (ZVB) zijn scheuren opgetreden’. Hierbij zijn de wanden eerst gedicht met een poly-urethaan Grouttech 4130 en waren nagenoeg dicht, enkel op sommige plekken trad nog vocht uit. Ook deze optredende vochtplekken waren geïnjecteerd volgens het opgestelde werkplan.

Assen

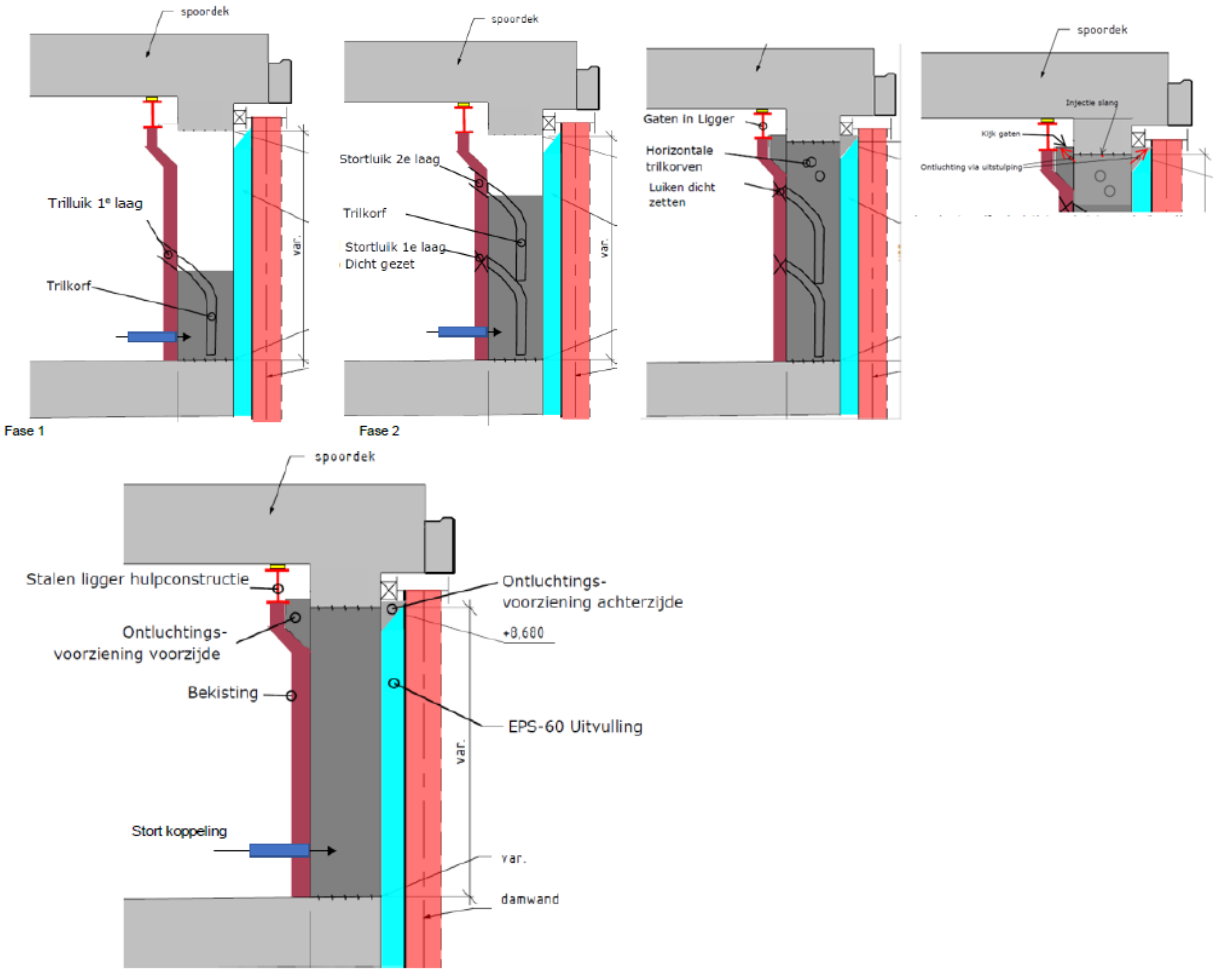
Projectcoördinator A heeft op eigen initiatief gekeken naar de voorgaande projecten en uitgezocht waarom het daar mis is gegaan. Hierbij heeft de werkvoorbereiding, de betoncentrale en de leverancier van de bekisting samen gekeken naar hoe de stort van de wanden een beter resultaat zou krijgen. De centrale en bekistingsleverancier waren beide al ingekocht, dus hiervoor waren de contacten al gelegd.

In overleg met de betontechnoloog van de betoncentrale (Mebin) is een trillingsarm mengsel uitgewerkt, wat nagenoeg dezelfde vloei-eigenschappen van ZVB heeft, maar waarin minder fijne hulpstoffen en plasticificeerders zijn toegepast. Deze aanpassingen beperken de warmteontwikkeling, wat gunstig is voor het beperken van de krimp.

Figuur 5 geeft een schematisering van de wijze van storten onder de wand. Het beton wordt door middel van een nozzle aan de onderkant van de bekisting de wand ingepompt. Aan beide zijden van de wand is een ontluchtingsvoorziening getroffen, zodat het lucht kan ontsnappen en het beton met een overhoogte aangebracht kan worden. Aan de voorzijde ontstaan hier dan een uitstulping van het beton en dient later verwijderd en afgewerkt te worden. Dit was toepasbaar, doordat er binnen dit project geen sprake was van zichtwerk. De wand is weggewerkt door een groen talud. Doordat het beton verdicht moest worden, zijn er luiken in de kisten aangebracht om met behulp van trilkorven de verdichting mogelijk te maken. Daarnaast zijn er horizontale trilkorven aangebracht om met behulp van het doorheen trekken van een trilnaad het beton aan de bovenzijde ook te kunnen verdichten. Doordat de verwachting was dat het beton, ondanks de overhoogte, nog steeds zou kunnen nazakken. Om dit te probleemloos te kunnen herstellen zijn injectieslangen aangebracht in de stortnaad.

Doordat het ontwerp van het dek al in ver stadium was uitgewerkt, konden er geen hulpmiddelen in het dek toegepast worden.

Figuur 5: Fasering stort onder spoordek



Terugblik

In het uiteindelijke resultaat waren de voorgaande problemen niet opgetreden. De wand was volledig tot aan het dek gestort en de wand was niet lek. Echter, er waren nog wel kleine krimpscheuren in de wand opgemerkt en hiervoor is een afwijking (AFW-0058 – Krimpscheuren in wanden onder spoordek) opgesteld.

Projectcoördinator A heeft ook aangegeven dat een evaluatie van de betonstort is uitgevoerd met het uitvoeringsteam, toetsende partij en de betonleverancier. De aandachtspunten waren voornamelijk gericht op de uitvoerbaarheid

Heiloo

Binnen dit project was het probleem met het storten van de wanden onder het spoordek benadrukt door het afdelingshoofd. Projectcoördinator gaf aan dat het projectteam gebrand was om met deze stort wel een positief resultaat te leveren, zonder die optredende problemen. Er is een uitgebreid plan geschreven voor deze stort en besproken met de desbetreffende partijen. Daarnaast heeft het projectteam van Assen hun evaluatie van de stort gedeeld met dit projectteam.

Binnen dit project was een andere betonleverancier (Cementbouw) betrokken. In overleg met deze betonleverancier is er gekozen voor hoog vloeibare beton. Ook dit mengsel hoef je amper te trillen. Daarnaast is er bewust gekozen voor het storten vanaf bovenaf, doordat hier de ruimte voor was.

De toetsende partij (IRI-ARUP) vanuit ProRail legt binnen de toets van het stortplan meerdere keren de relatie met het project Assen, waarvoor zij ook de toetsende partij zijn. Figuur 6 geeft een vraag, waarin het leggen van de relatie terugkomt, weer.

Figuur 6: Vraag en antwoord vanuit toets

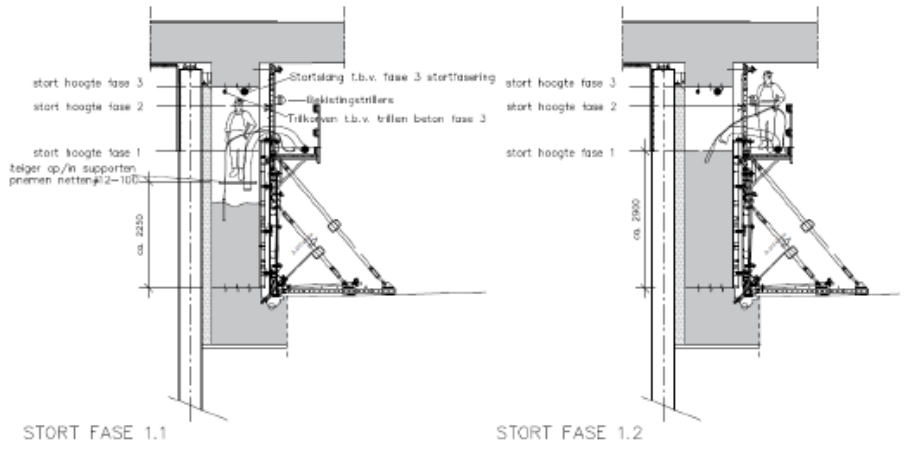
Welke lessen zijn getrokken van de stort bij Assen en hoe zijn deze lessen geland in dit stortplan?
Het werkplan is in samenspraak met de collega's in Assen opgesteld, de situatie in Heiloo is echter niet identiek. De aanpak in Heiloo is gebaseerd op ervaring in Assen en andere projecten. De evaluatie van de stort in Assen is met het team in Heiloo gedeeld. De volgende leerpunten uit Assen zijn meegenomen in de uitwerking van de werkmethode in Heiloo: Het toepassen van trilkorven om het beton over de laatste 0,5m1 goed te kunnen verspreiden en verdichten, het aanbrengen van verlichting in de bekisting, het toepassen van plexiglas kijkstroken, het toepassen van brievenbussen om de stijghoogte van het beton te controleren, het toepassen van drukmeters op de centerpennen van de bekisting.

Zo is op te merken dat er bewust afgeweken is van de werkwijze van Assen, maar dat er ook punten van meegenomen zijn. De afwijking in stort heeft voornamelijk te maken met het te verkrijgen betonmengsel bij de andere betonleverancier. Ook hier was het ontwerp van het dek al in een ver stadium en konden er geen hulpmiddelen in het dek toegepast worden. Daarnaast is het lastig om een ontwerp en voorbereiding, waarin allerlei werk aan de tekeningen en berekeningen zit, om te kunnen gooien.

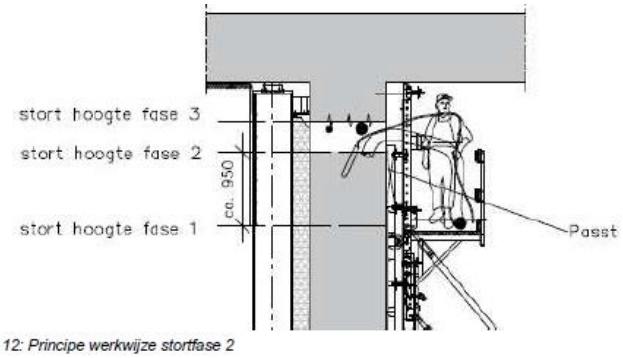
Terugblik

Uiteindelijk waren hier ook scheuren ontstaan en was de wand niet volledig aangesloten met het spoordek. Deze twee optredende problemen zijn verwerkt als een afwijking: 'AFW-0030 – Buitenwanden moot 5 niet volledig aangesloten tot het dek' en 'AFW-0035 – Scheurvorming wanden moot 5'. De betrokken projectcoördinator B gaf aan dat er naderhand wel een evaluatie heeft plaatsgevonden met de betonleverancier, omdat het mengsel niet overeenkwam met de verwachtingen. Maar intern heeft er geen evaluatiemoment plaatsgevonden.

Figuur 7: Fasering stort onder spoordek Heiloo



9: Principe werkwijze stortfase 1



12: Principe werkwijze stortfase 2

Assen – Heiloo

Figuur 8 geeft een overzicht van de werkzaamheden omtrent de betonstort van beide projecten in de tijd weergegeven.

Figuur 8: Planning Assen en Heiloo

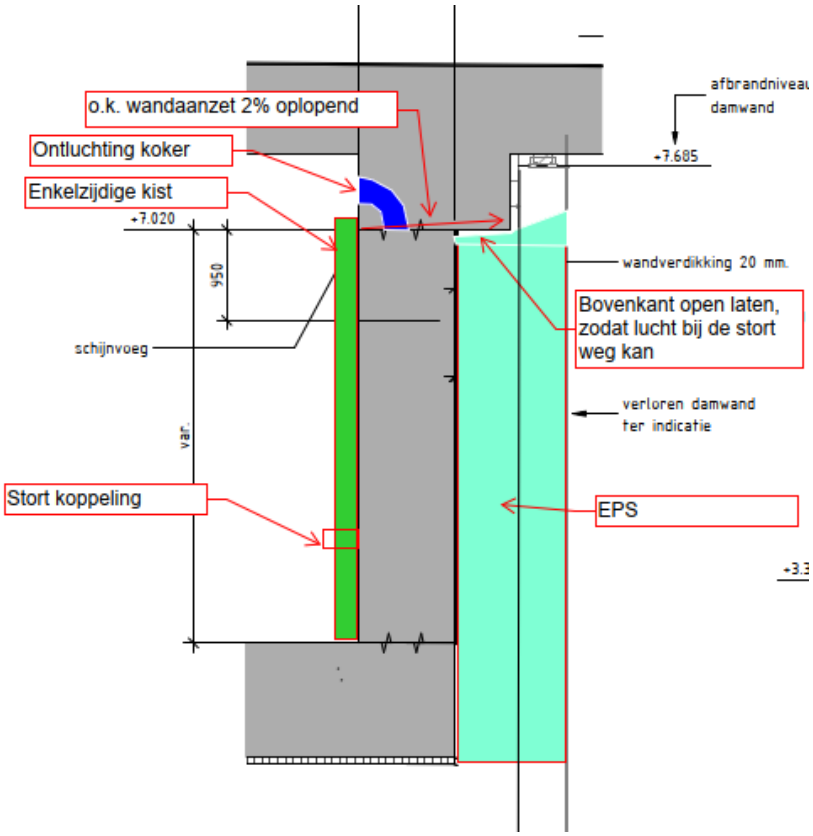
	2018					2019											
	Aug	Sep	Okt	Nov	Dec	Jan	Feb	Mrt	Apr	Mei	Jun	Jul	Aug	Sep	Okt	Nov	Dec
Assen																	
UO spoormoot onderbouw																	
Realisatie Betonwerk wanden onder dek																	
Stortplan wanden onderbouw																	
Heiloo																	
UO afbouw																	
Realiseren betonwerk onderbouw wanden spoormoot																	
Stortplan wanden spoormoot																	

Elst Noord

Binnen dit project heeft projectcoördinator A zijn opgedane ervaringen met de toegepaste werkmethode vroegtijdig kunnen implementeren in de ontwerpfase. Hierdoor heeft de constructeur ook de kans om het te verwerken in het ontwerp. Zie figuur 9 voor een visualisatie van de aanpassingen. Om de uitstulping aan de binnenkant van de wand weg te halen, zijn er stortkokers om de 1,5 m^1 aangebracht in het spoordek. Zo kan het beton met een overhoogte aangebracht worden en de lucht tijdens het storten ontsnappen. Daarnaast is de onderkant van het spoordek schuin afgewerkt, zodat de lucht aan de achterzijde ook kan ontsnappen. Binnen dit project is het betonwerk ook de definitieve afwerking. Ook binnen dit project wordt de wand vanuit de onderkant gestort. Het trillen vindt plaats door het aanbrengen van een trillingsnaald in de stortkokers.

Binnen het stortplan wordt er specifiek teruggekeken naar de voorgaande projecten en waarom er afgeweken wordt van ZVB. Voor deze stort wordt gebruik gemaakt van een trillingsarm vrij mengsel, wat vergelijkbaar is met het mengsel binnen project Assen.

Figuur 9: Betonstort Elst Noord



Diemen

Binnen dit project wordt nu gewerkt aan het ontwerp en is al gekeken naar hoe de wandaansluiting eruit komt te zien en welke voorzieningen meegenomen dienen te worden. De verdere detaillering komt ten tijde van de voorbereiding en uitvoering. De ervaringen vanuit Elst Station zijn meegenomen door de ontwerper van het voorgaande project. Daarnaast heeft er binnen dit project een review plaatsgevonden, waardoor de ervaringen van een breder team geactiveerd is. Binnen deze projectreview zijn er mensen buiten de projectcontext benaderd om naar het ontwerp en fasering te kijken.

Tabel 4: Overzicht van de documenten binnen case 2

C2 Storten van de wanden

Interviews	Ontwerpleider-A | Ontwerpleider-B | Projectcoördinator-A | Projectcoördinator-B | Uitvoerder			
1) Elst Station	**2) Bilthoven**	**3) Assen**	**4) Heiloo**	**5) Elst Noord**
	Afwijking-0120_Krimscheuring in wand oost van moot 5a (ZVB) Afwijking-0136 Scheuren ZVB (moot 5b) onder het verkeersdek K_S-001_UO_WP_0036 - werkplan betonwerk vB incl. bijlagen K_S-001_UO_WP_0763, Werkplan injecteren betonwerk, versie A	1811-5811 v1.0 Integraal werkplan TVP 2 - TVP 2 wk7-2019 1903-6463-v1.0-g1 - Stortplan wanden onderbouw 1805-3425 v 4.0_ATS-Overall Planning ODG De maten Assen 1909-3912 v1.0 - Evaluatie Betonstort wand Noord (as4) Mobipedia_Realisatie van wanden bij ingeschoven dekconstructie Afwijking-0058-Krimspscheuren in wanden onder spoordek	1906-4824v1.0 Stortplan wanden spoormoot Toets 00873 C Stortplan wanden spoormoot_reactie CMHH 1804-4228 Overallplanning ODG Vennewatersweg - Heiloo_v.3.0 Afwijking 030 - Wandaansluiting spoordek Afwijking 035 - Scheurvorming wanden moot 5	Stortplan wanden - aanvullingen Paul
Analyse				
Bijkomende documenten				

Appendix E - Analysis of developments within case 1 and case 2

Case 1: Zandpot

Context	**P1 - Elst Station [2015]**		**P2 – Bilthoven [2016]**				**P4– Heiloo [2019]**			**P5 - Elst Noord [2020]**		**P6 – Diemen [2021]**	
Develop-ment	***1)*** *The first set-up of the engineering method with knowledge of the narrow tolerances during construction*		***2)*** *Improved engineering method with adjusted tolerances*		***3)*** *Assembly with one underlay plate and multiple cover plates*	***4)*** *Replacement of welded studs by wooden laths*	***5)*** *Adoption of the engineering method*	***6)*** *Fully preinstalled zandpot (underlay plate, sand, and cover plates)*	***7)*** *Return of the welded studs*	***8)*** *1 on 1 adoption of the engineering reports with adjustment of the geometry*	***9)*** *1 on 1 adoption of the assembly*	*Continuation*	
Key members	• Design Engineer A • Previous Design Engineer within this project	Design Engineer A	• Design Engineer A • Design Engineer B • Design Manager A • Executor A	• Design Engineer B • Design Engineer A • Design Manager A	• Executor A • Previous Executor	Executor A	• Design Engineer C • Design Manager A • Design Engineer B	• Executor A • Projectcoordinator B • Crane company	Executor A	• Design Engineer D • Design Manager A	• Design Manager A • New Executor and Projectcoordinator • Crane Company	Designer	Project-coordinator B
Tools			Engineering report (ER01-ES)	Engineering report (ER01-ES)	Visual material		ER02-Bi			• ER02-Bi • ER03-He		Drawings	Drawings
Tasks	Elaboration of the possession		Elaboration of the possession	Elaboration of the possession	Assembly of the zandpot	Emptying the zandpot	Elaboration of the possession	Assembly of the zandpot	Emptying the zandpot	Elaboration of the possession	Preparation of the execution		
Trigger	New construction implemented by the previous design engineer, which was not involved anymore[1]	Project visit	Design Manager A ensured the coupling due to his awareness of Elst Station and the gained confidence in the construction	• Personal contact between Design engineer A and Design engineer B • Going through the engineering report	Personal contact in combination with the sharing of visual material between the executors, ensured by the coupling of Design Manager A	Involvement of Executor	• Coupling by Design Manager A • Going through the engineering report by the new design engineer	Involvement of Executor early in the project	Involvement of Executor	• Going through the engineering report • Coupling by design manager A	• Involvement of Design Manager A • A presentation about the previous projects with visual materials and drawings	Involvement	Involvement
Experien-ces	Basic competencies of (inexperienced) Design engineer A	Observation of the zandpot in operation	The problems that were seen in the narrow engineering tolerances and positive experiences from past project (Elst Station)	• Brief engineering method • The urgency of the alignment with the construction phase	Experiences with the assembly method of Elst Station, which was considered as a lot of work, due to the multiple small elements	Own basic competencies + Experiences of welded studs in Elst Station	Engineering method with the positive functioning in the construction phase	Previous experiences regarding the assembly method in Bilthoven	Own negative experiences from Bilthoven and experiences from Elst Station	Positive experiences from the past two projects	Experiences of Design Manager A from previous projects	Previous experiences from Elst Noord	Previous experiences from Heiloo
Creation	Exploration of new knowledge within a short time frame[1]	Knowledge of engineering	• Gathering of Design engineer A, Design engineer B and Executor A • Preparation and execution of the zandpot in the construction phase	• Time • Continuation of the previous report • Own basic competencies as a design engineer • Internal control by Design engineer A	Preparation and execution of the assembly method	Preparation and execution of this adjustment	• Own basic competencies as a design engineer • Continuation of the engineering report • Internal control by Design engineer A	• Translation of the experiences and knowledge of the Executor by the Projectcoordinator B • Execution of this work method	Preparation and execution of the assembly method	Similarity and the parameters (forces) were smaller than within the previous projects.	Preparation and execution of this assembly method	*Project is in the preparation phase*	*Project is in the preparation phase*
Practice	Engineering method	Better alignment with construction is required	Improved engineering by better alignment with the construction which eventually performed well	Elaborated engineering method and organised excel sheet	Assembly method with positive results	'Saving' did not work out well, because the wooden laths floated during the emptying	Adoption of the previous engineering method with the project-specific inputs	Fully preinstalled zandpot with positive results	Welded studs instead of wooden laths did work out well	1 on 1 adoption of the engineering report with adjustment to the geometry	Execution of a similar assembly method by a new construction team	*Project is in the preparation phase*	*Project is in the preparation phase*
Retention	• Elaboration of the engineering method • Involvement	Project visit	Involvement	• Elaboration of the engineering method • Involvement	Involvement	Involvement	• Elaboration of the engineering method • Involvement	• Elaboration of the integral workplan • Involvement	• Elaboration of the design • Involvement	• Elaboration of the engineering method • Involvement	• Elaboration of the integral workplan • Involvement	*Project is in the preparation phase*	*Project is in the preparation phase*
Retention in members, tools or tasks	• Design Engineer A • Engineering report (ER01-ES)	• Design engineer A	• Design Engineer A • Design Engineer B • Executor A • Design Manager A	• Design Engineer A • Design Engineer B • Design Manager A • ER02-Bi	Executor A	Executor A	• Design Engineer C • Design Manager A • ER03-He	• Executor A • Project coordinator B • Workplan • Design	• Executor A • Design	• Design Engineer D • Design Manager A • ER04-EN	• New Executor and Projectcoordinator • Workplan	*Project is in the preparation phase*	*Project is in the preparation phase*

[1] A hampering mechanism

Case 2: Pouring the concrete walls underneath the railway deck

Context	P2 – Bilthoven [2016]	P3 – Assen [2019]	P4 – Heiloo [2019]			P5 – Elst Noord [2020/2021]	P6 – Diemen [2021/2022]
Development	***1)*** *Small part with SCC and extra reinforcement around the joint of the old concrete and new SCC.*	***2)*** *Different work method and a concrete mixture with the positive features of SCC, but with absence of the negative features.*	***3)*** *Different work method with adoption of certain elements from Assen, but another concrete mixture, which did not work out well.*			***4)*** *Integral work method with the adoption from Assen*	***5)*** *Adoption of the facilities*
Key members	• Executor A • Previous Executor	• Projectcoordinator A • Concrete technologist • Formwork supplier • Concrete plant A	• Executor A • Projectcoordinator B • Projectcoordinator A • Department manager • Concrete technologist • Formwork supplier • Concrete plant B	• Projectcoordinator B • Assessing party	• Projectcoordinator B • Concrete plant B	• Projectcoordinator A • Design Manager A • Concrete plant C	• Projectcoordinator A • Designer
Tools	Concreting plan Elst Station	Concreting plan Elst Station and Bilthoven	Concreting plan of Assen		Evaluation	• Evaluation of Assen • Concreting plan of Assen	
Tasks	Pouring the concrete walls	Pouring the concrete walls	Pouring the concrete walls	Assessment of concreting plan		• Designing the walls and railway deck • Pouring the concrete walls	• Designing the walls and railway deck • Pouring the concrete walls
Trigger	• Awareness of the previous problems • Personal contact with the previous Executor	• Awareness of the previous problems • Urgency for solving the problem due to their 60.000 euros of reparation costs in previous projects. • Personal contact	• Emphasise by department manager. • Short involvement by Projectcoordinator A • Personal contact • Similarity with Assen	• Involvement of assessing party in both projects. • Similarity	Different expectations of the mixture and still appearance problems	Early involvement of Projectcoordinator A during design phase	• Project review • Design meeting • Involvement • Awareness of Elst Noord
Experiences	The previous work method with the complete wall filled with SCC and the problems regarding cracks	The previous work method with the problems regarding cracks	• Previous problems of Elst Station and Bilthoven • Work method of Assen	Experiences from work method of Assen	Experiences of both parties	The work method and the lessons learnt from Assen	Experiences from previous projects (Heiloo, Assen, Elst Noord)
Creation	Preparation and execution of the adjusted work method	• Gathering of the key members to prepare and construct the concreting of the walls. • Design of the railway deck was already in a detailed stadium.[2] • Conducting an evaluation	• Gathering of the key members • Preconditions: Visibility of the concrete • Trust in own method • Design of the railway deck was already in a detailed stadium [2] • Another concrete plant involved, which could not supply a similar concrete mixture.[2] • Still not the experiences from the concreting method[2]	Coupling of the two work methods	Conducting an evaluation	• Gathering of Design and Construction phase, in which the Design Manager A supported the development process. • Gathering of the concrete plant • Preparation of the work method	*Project is in the preparation phase*
Practice	Even with the small part with ZVB and extra reinforcement around the joint of the old concrete and new SCC the problems have occurred	New concrete mixture with pouring the concrete from underneath, which resulted in a wall without cracks	Concrete method from above and adoption of certain elements from Assen, but another concrete mixture, which did not work out well	Elaboration of which elements are adopted from Assen	Evaluation of the mixture, which resulted in that the mixture was almost the same as SCC	• Adoption of the work method of Assen with facilities within the railway deck. • *The execution is not performed yet.*	*Project is in the preparation phase*
Retention	• Development of concreting plan • Obligation to report deviations. • Involvement of key members	• Development of concreting plan • Involvement of key members • Execution and elaboration of the evaluation	• Development of concreting plan • Obligation to report deviations. • Involvement of key members	• Elaboration of the assessment	• Involvement during the evaluation	• Elaboration of the concreting plan • Involvement during the preparation[3]	*Project is in the preparation phase*
Retention in members, tools, or tasks	• Executor A • Concreting plan • Deviations reports	• Projectcoordinator A • Concrete technologist • Formwork supplier • Concrete plant • Concreting plan • Evaluation	• Projectcoordinator A • Executor A • Concreting plan • Deviation report	Assessment (toets 00873 C Stortplan wanden spoormoot_reactie CMHH)	• Projectcoordinator B • Concrete plant B	• Concreting plan • Projectcoordinator A • Design Manager A	*Project is in the preparation phase*

[2] A hampering mechanism
[3] Work method is not yet executed.