

DESIGNING CONSTRUCTION MANAGEMENT

Master thesis

The application of design thinking by construction managers in a construction-driven FEED phase of oil and gas projects

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 **TU Delft**

FLUOR.

COLOPHON

This thesis is for the completion of the Master Construction Management and Engineering at the Delft University of Technology, the Netherlands.

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PREFACE

The topic of this research is in close relation to my interests as it connects two worlds I was involved with during my student-career the past nine years. In 2009, I started with HBO Architecture & the Built Environment in Groningen. This bachelor taught me the basics of how to think like a designer, but also how to reason like a construction manager. My interests to the field of construction management increased over time. For this reason, I decided to subscribe myself to the pre-Master and Master of Construction Management & Engineering in Delft in 2015. This thesis combines the worlds of design thinking and construction management.

I was lucky to be directed by Hans Bakker to the company that would eventually guide me towards fulfilling the task that was ahead of me. The decision to perform my thesis in cooperation with Fluor was a decision I valued until now. Conducting my thesis at Fluor also provided me the opportunity to discover a new construction industry, namely oil & gas projects. Since I was already familiar with buildings (HBO) and Infrastructure (MSc), this thesis made it possible to widen my horizon even further.

Besides the industry, I've learned a lot about how construction managers perceive complexities and approach complex situations, what the influences of early involvement of construction management are, and how design thinking principles can be applied to approach complex issues in a considerate manner. All these subjects will be of much value in my future career. Additionally, I've gained scientific knowledge and insights into how theories are transferred to practice and how a qualitative case-study research is performed. Furthermore, it was very interesting to interview people with a wide variety of backgrounds. Even though it was quite hard to make sense out of a variety of different views, it was also one of the most interesting and educational parts of the research.

After six months of hard work with many ups and downs, this research thesis has come to an end. I could not have accomplished it without the help of many people who were involved during this period. First of all, I would like to thank my graduation committee Hans Bakker, Louis Lousberg and Martijn Leijten for their guidance and advice. Especially, Louis Lousberg for connecting me to this research subject and for providing direction when my head was full of thoughts. A special thanks goes out to my company supervisors Amanda McCarthy for always being available to provide me with advice, and Duncan Goodall who was always ready to provide me with new insights and energy. Lastly, I would like to thank my girlfriend Elodie, family members, close friends, fellow graduate students and Fluor colleagues for their support, advice, distractions and patience during the last six months.

*Eric Engelhart
Amsterdam, November 2018*

SUMMARY

“Who of us would not be happy to lift the veil behind which the future is hidden and to focus our thoughts on the unknown future” (Shepherd & Williams, 2015). What if we already know our unknowns, would it not be a piece of cake to deliver construction projects of high quality within time and budget? In order to predict the unknown future, Fluor introduced Construction-Driven Execution philosophy. In a construction-driven project, construction managers are involved early in the process during front-end engineering and design (FEED) to provide input to office departments in order to prevent mistakes from happening in later stages of the project. By this it is aimed to ‘lift the veil’ and focus on the unknown knowns (i.e. complex issues) in an integrated effort.

Construction managers typically focus on operational decisions during construction on-site and focus on tactical and strategical decision-making during FEED. This transition has a major impact on the way construction managers should approach issues in their daily functioning: they shift from a firefighting to a fire preventing approach. In this perspective, the role of construction managers in FEED is compared to that of project managers, in which the construction manager is responsible for the management of the execution portion of the project.

The Project Design School assumes that some kind of design thinking is involved by project managers, in which they use a certain frame and go through certain steps when approaching complex issues. To apply this frame for educational purposes, the Project Design School has created the Project Design Cycle. This cycle consists of four elements: Awareness, Design, Performance and Reflection. The Project Design School aims to fill a literature gap in project management research, which concerns the approach project managers use when choosing and adapting project management tools and systems to be applied in specific situations. These two problem fields of Construction-Driven Execution and the Project Design School are combined into the following research objective:

1. Gather and provide empirical data to firmly establish the ubiquity of the Project Design Cycle elements, their cyclic relationship, and the degree to which managers use these elements as an explicit method,
2. Provide Fluor with advice on how to apply design thinking principles (as incorporated in the Project Design Cycle) within the construction management department in order to enhance the Construction-Driven Execution philosophy.

In order to achieve this objective, the following research question is answered in this report:

- *How can the Project Design Cycle enable construction managers to identify and approach complex situations in a construction-driven FEED phase?*

A theoretical framework and empirical research are conducted to answer this question. First, a theoretical framework is determined, which includes the influence of Construction-Driven Execution on construction management practices in FEED and the incorporation of design thinking principles in the Project Design Cycle. Subsequently, the current application of the Project Design Cycle by construction managers is researched in a qualitative case-study analysis. In total five construction managers (respondents) are selected of three oil & gas projects (case-studies). Each respondent is interviewed twice by use of semi-structured interviews. The main goal of the first interview is to get background information of the respondent and to identify complex issues they were confronted with in their current project. The complex issues are discussed in-depth in the second interview, in order to analyze the Project Design Cycle elements in the applied approach of the respondents in their daily practice.

The main findings obtained in the cross-case analysis are:

- The respondents often did not recognize or perceive the complexity of the issues. It is observed that the recognition of the complexity has a large influence on the way the respondents approach issues. Issue-categories that were perceived as complex concern: modularization, pre-assembly, sequencing of work and revising the plot plan. Alignment of disciplines is not recognized as complex by the respondents. From the twenty issues identified in the first interview, ten were defined as complex in the cross-case analysis.
- When an issue is recognized as complex, nearly all Project Design Cycle elements were applied most of the times by the respondent. However, the sequence of the elements was often not correct. The design element was conducted separately (generate and test) sometimes.
- When an issue is not recognized as complex, it is observed that practically always one or two Project Design Cycle elements were not applied by the respondents. It is found that the design element is recognized the least, followed by performance. Moreover, it is observed that the sequence is most likely not to be performed in the correct order.

It can be concluded that construction managers do apply the elements of the Project Design Cycle in their daily function in FEED. However, only when the issue is recognized as complex. Thus, the approach of the construction manager strongly depends on their ability to identify and recognize complexity elements within issues. Furthermore, it is found that the design element is most likely not to be applied when the issue is not recognized as complex. This indicates that the searching and experimenting nature of design thinking is often not applied by the respondents in this situation. It is observed that the construction managers fall back in their on-site problem-solving mode when they do not recognize the complexity of the issue. In this simplified problem-solving approach, the respondents go straight from awareness of the problem to the performance of a solution. The design and reflection elements are often skipped in such approaches.

It is determined that the Project Design Cycle provides a suitable framework to educate and support construction managers in approaching complex issues in FEED. However, the Project Design Cycle needs to be adjusted in order to create acceptance and support within the construction management community. Based on the empirical research, the Project Design Cycle has been transformed to the ADAPT – decision-making cycle (figure 1). ADAPT is an abbreviation of the elements Awareness, Development, Assessment, Performance, and Throw-back. In this research context, the essence of ADAPT is precisely that: construction managers have to adapt in order to change something (their approach) to suit different conditions (construction-driven FEED). By doing so, they *“have to become familiar with a new situation”*, which represents the new role and responsibilities they have to fulfill in order to solve complex issues in the early stages of the project.

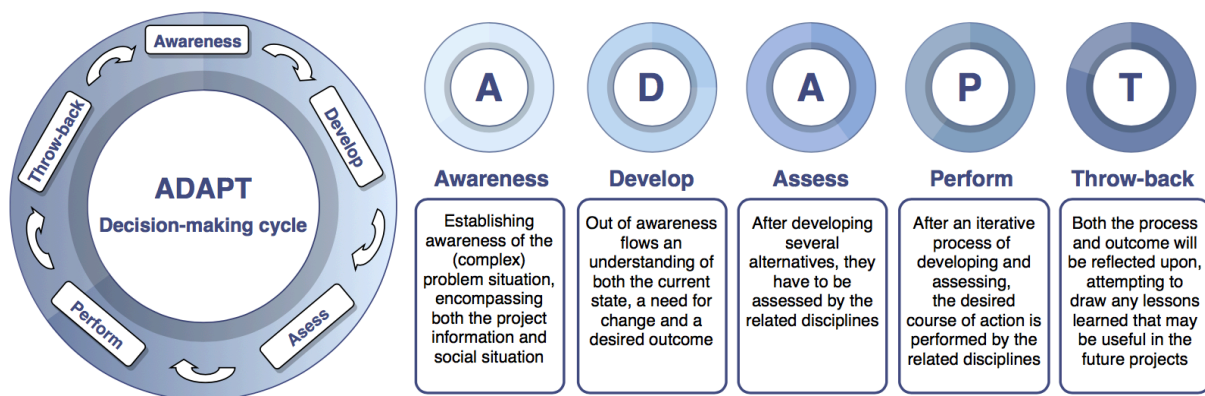


Figure 1: ADAPT – Decision-making cycle (own figure)

ADAPT incorporates the identification of complexities, development and assessment of alternatives, creation of a solution with the highest value, and a reflection upon the outcome. This framework can be used to educate and support construction managers by improving their capabilities and skills that are required to approach complex issues during FEED. ADAPT serves a double purpose in construction management practices and could be applied in the form of a cognitive processing model and in the form of a decision support system:

- Cognitive processing model: remind and support construction managers not to make decision merely based on old experiences, but to take their time to properly reflect on situations and share their knowledge in order to identify, recognize and acknowledge complex situations.
- Decision support system: structure constructability meetings to approach complex issues in a multi-disciplinary way and to provide construction managers the ability to get an understanding of the problem situation, in order to determine an effective course of action by drawing upon the entire repository of construction management research, knowledge and tools.

It is recommended to implement ADAPT both top-down and bottom-up. Top-down support is required to estimate enough man-hours for construction managers in FEED and by selecting the right people that are able to approach complex issues. Additionally, ADAPT should be implemented bottom-up as an integrated approach in which the construction manager is pro-active and takes it upon themselves to drive, adopt, and move it forward. This can be done by making individual construction managers aware of the cycle and its added value.

Moreover, the constructability program serves as a perfect platform to implement and test the application of ADAPT. In constructability, multiple disciplines work together to create integrated solutions in order to prevent 'fires' from happening on-site. ADAPT can be used as a structure to identify complex situations in the constructability program. These identified complex issues can then be discussed in so called 'constructability focus' sessions. In these sessions the focus is put on a specific component or sub-area of the design that contains high complexity, by a multidisciplinary team. As construction management lead these sessions, it is a perfect opportunity to implement the ADAPT decision-making cycle and use its elements to shape and formalize these sessions in a structured way. Additionally, by being aware of the elements, and in special 'throw-back', construction managers learn to share their knowledge with other colleagues, disciplines, and projects. In this way, awareness is created for future situations and enables others to identify and solve complex situations in an early stage.

Further research should be performed to investigate the underlying reasons of *why* and *when* construction managers perceive issues as complex (or not), *how* construction managers could identify complex situations in the FEED phase, and *which* qualifications are required of construction managers to properly function in a construction-driven FEED phase. Also, the relation between the recognition of complexity and the occurrence of the design element need to be further examined. Finally, further research should be conducted to determine the effectiveness of the application of the Project Design Cycle (in the form of ADAPT) in construction management.

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TERMINOLOGY AND ABBREVIATIONS

Construction-Driven Execution

The purpose of Construction-Driven Execution is to take construction from a reactive process in the end to a more pro-active process in the beginning in order to reduce potential probabilities of issues occurring in the end.

Construction management

Early in the process during the pre-FEED and FEED phase, the (home office) construction management team is relatively small and consists of a site manager, construction manager, an AWP manager, construction engineer, and a heavy lift manager. Together they will determine the initial and detailed construction execution plan and lead the constructability program. The site- and construction managers both perform a key position in Construction-Driven Execution. Since a site manager is in fact a more experienced construction manager, and the difference in function only lies in hierarchy and not in functional content, both are referred to as construction managers in this research to prevent any confusion throughout the report.

Design thinking

The basic reasoning pattern of design thinking can be compromised to: *“thing (what) + working principle (how) leads to observed result”*. In design practices the result cannot be defined upfront and is therefore presented by an aspired value. The core challenge of design thinking concerns the performance of a complex creative feat in which a thing (object, service, system) and a working principle are created simultaneously. By doing so, the problem and solution are developed at the same time (Dorst, 2011).

Project Design School

TU Delft professors Heintz, Lousberg & van de Putte (2017) have created the Project Design School. The Project Design School has identified a significant gap in existent project management literature. It is not the intention of the Project Design School to reinvent project management from scratch, but rather to provide a lens through which project management action can be viewed, and also to confirm the use of design thinking by project management when approaching complex issues.

Project Design Cycle

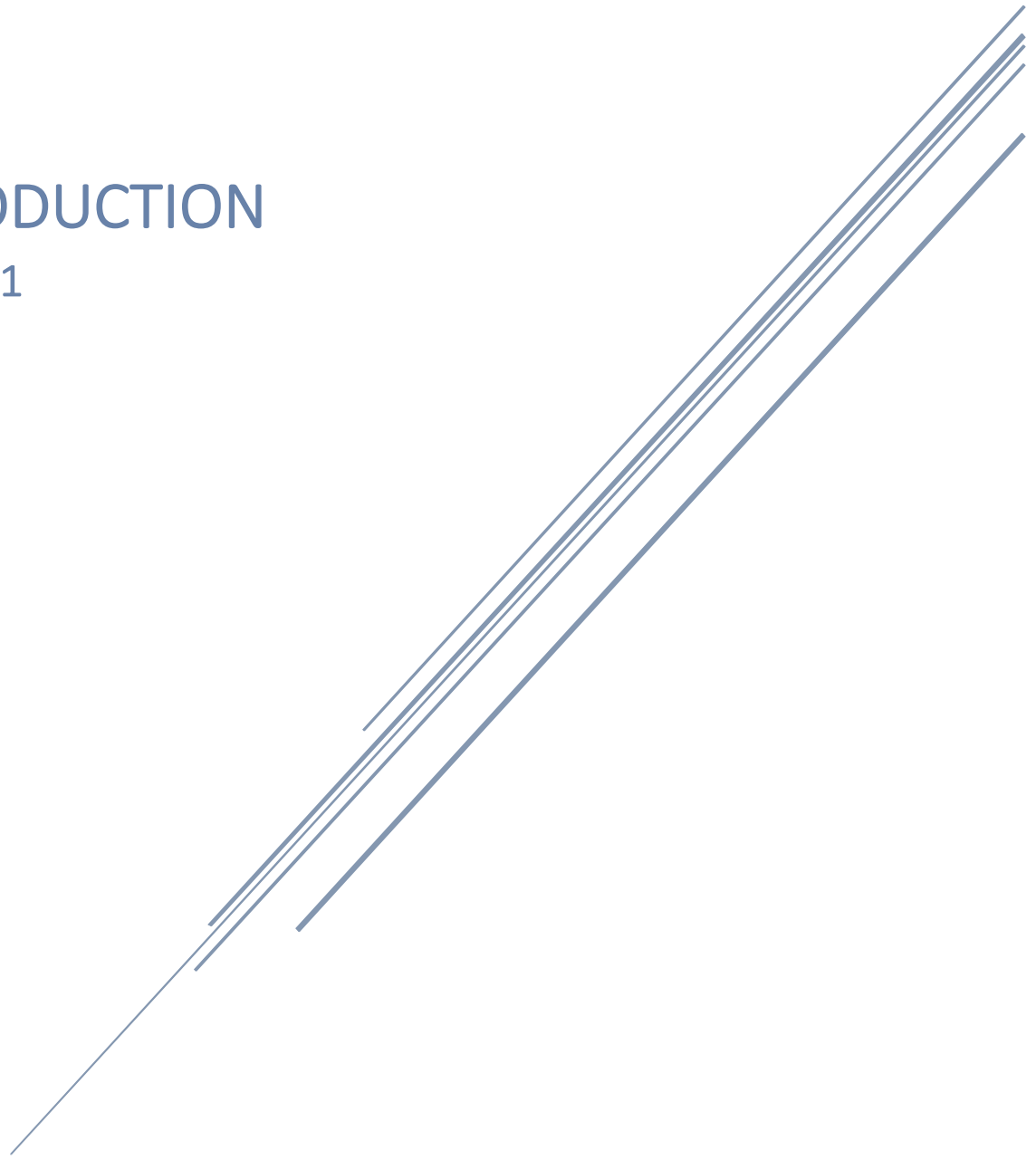
The Project Design School proposed a framework for project management practice. They have named this framework the Project Design Cycle, which consists of the elements: Awareness, Design, Performance and Reflection. This cyclic model incorporates design thinking principles and aims to educate and guide project managers and students in project management how to identify, approach and solve complex situations.

ADAPT	Awareness, development, assessment, performance, throw-back
AWP	Advanced work packaging
CB	Constructability
CDE	Construction-Driven Execution
CE	Construction engineer
CEP	Construction execution plan
CI	Construction execution plan
CII	Construction Industry Institute

CM	Construction management
(C)PS	(Complex) problem-solving
CSA	Civil, structural and architectural
CWP	Construction work package
DT	Design thinking
EAME	Europe, Africa and Middle-East
ECI	European Construction Institute
EPC	Engineering, procurement and construction
EPCM	Engineering, procurement and contract management
EPFC	Engineering, procurement, fabrication and construction
FE	Field engineer
FEED	Front-end engineering and design
FID	Final investment decision
FM	Fabrication manager
HSE	Health, safety and environment
ISBL	Inside battery limit
IFC	Issued for construction
IFWP	Instrumentation field work package
ISO	International Standards Organization
IT	Information technology
LL	Learned lesson
LS	Lump sum
O&G	Oil and gas
OSBL	Outside battery limit
PDC	Project Design Cycle (Elements: awareness, design, performance, reflection)
PDDM	Project document and data manager
PDS	Project Design School
PEP	Project execution plan
PM	Project management
PMC	Project management and construction
QA/QC	Quality assurance/ quality control
RFI	Request for information
RQ	Research question
SQ	Sub-questions
SM	Site manager
TIC	Total installed costs
WFP	Work Face Planning

INTRODUCTION

Chapter 1



Chapter 1 concerns the introduction of this research thesis. The main topics of this research are Construction-Driven Execution and the Project Design School. Respectively, these topics are discussed in sub-chapters 1.1 and 1.2, which also describes the relevance of the research theme. Furthermore, the problem statement, research objective and scope are determined in sub-chapter 1.3. This chapter describes the relevance of this research and provides a base for the research methodology in chapter 2.

1.1 CONSTRUCTION-DRIVEN EXECUTION

Recent revenue reductions in the oil and gas industry caused a difficult situation for contractors (Marten, Whittaker, & Martinez, 2015). Under tight conditions like these, it is more challenging for contractors to execute projects successfully, especially due to the highly complex nature and wide scope of oil and gas projects. Additionally, oil and gas projects are often executed under fixed price terms (lump-sum), which requires contractors to change strategies (Changali, Mohammad, & Nieuwland, 2015).

Fluor, the host company of this research, is currently in a transition from EPCm projects on reimbursable terms to EPC lumpsum projects, as the vast majority of their project(s) portfolio is executed fast-track, design-built. From the client’s point of view, this allows for a shorter overall schedule and earlier return on invested capital (Fluor, 2018a). At the same time, this strategy presents a challenge to project and construction management, who must continually balance the technical and execution risks inherent in this approach.

Fluor presents itself as “one of the world’s largest publicly-traded engineering, procurement, fabrication, construction (EPFC) and maintenance companies, offering integrated solutions for Clients’ complex and challenging capital projects” (Fluor, 2018c). Fluor executes projects on six continents and has over 56,000 employees worldwide. The company ranks 149 on the Fortune 500® list with a revenue of \$19.5 billion. These figures represent Fluor’s position as an industry leader (Fluor, 2018d).

Fluor facilitates this research by providing their internal documentation, working procedures, strategies, and three case-study projects. Besides documentation of these case-study projects, the construction managers working at these projects will also be set available for interviews.

As projects proceed, the ability to influence costs decreases while the consequence increases (figure 2). In a lumpsum environment, any mistakes made during the engineering, procurement or construction phase that result in higher costs, are for Fluor’s own account. Therefore, it is important to prevent mistakes from happening in the later phases of the Project Design Cycle, and in special during construction.

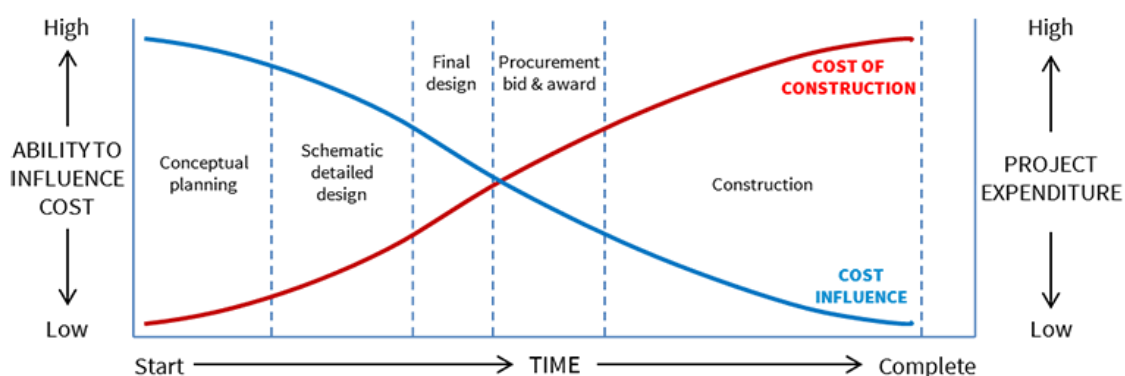


Figure 2: Cost influence curve (2H offshore, n.d.)

In order to do so, Fluor implemented a new philosophy in 2016 named ‘Construction-Driven Execution’ (CDE). Fluor defines CDE as follows (Fluor, 2018a): “The strategies, work practices and accountabilities that drive the delivery of construction and fabrication services in the most cost-efficient, predictable manner possible”. This philosophy is about the early involvement of construction management in the project, in order to seize opportunities during FEED and create integrated solutions in cooperation with engineering and procurement disciplines.

Construction-Driven Execution requires a mind shift in the entire organization, especially in construction management. In theory, construction managers are leading a 100million 'business store' during construction by just using a phone and personal acquaintances. There have to be more effective ways to lead these kinds of businesses to success. By involving the construction managers early in the process, Fluor aims to solve problems in advance by delivering integrated solutions.

In a construction-driven project the role of construction management changes drastically. Instead of waiting in the back-end of the project, construction managers are involved in the front-end to share knowledge in order to prevent mistakes from happening later on in the process. It could be stated that the new role of the construction management in a construction-driven FEED phase can be compared to the role of the project manager. In which the main responsibility of the construction manager is to create a construction execution strategy, leading the constructability program to create integrated solutions, and thereby aligning several disciplines.

Fluor has implemented the Construction-Driven Execution philosophy top down and created the CDE-playbook was created to provide the entire project team with an overview of key concepts, activities and deliverables that should be applied and completed during all project phases (Fluor, 2016). Even though CDE was implemented in the Americas back in 2016, it was implemented in the Hoofddorp office in the Netherlands from late 2017. Currently, the first couple of projects are executed in a 'construction-driven' way. The CDE-playbook offers a good framework from a higher strategic level. However, at the lower levels of the organization, issues are noticed in its implementation. Several assumptions are found in the preliminary research that could clarify the current problem with the implementation of CDE:

1. Construction managers are focused on fighting fires on-site for many years;
2. Construction managers base their approach and solutions predominantly on previous experiences;
3. Issues in FEED are more complex since they are multi-disciplinary, address multiple phases and are executed on different locations;
4. The name 'Construction-Driven Execution' creates resistance with other departments;
5. Reflection practices are often not applied as there is no time reserved.

Based on these assumptions, it can be stated that construction managers require a tool that provides a certain structure to educate and guide them in order to approach complex issues in FEED. It is found that the construction manager is the manager of the execution part of the project during FEED. Therefore, it has been decided to use project management research to find a framework that can be used as a tool to enhance Construction-Driven Execution within Fluor's construction management.

In special, it has been chosen to look into a framework created by the Project Design School. This framework is called the Project Design Cycle, which incorporates design thinking principles to educate (future) project managers in order to approach complex issues that occur in their daily functioning. The Project Design School, design thinking, and the Project Design Cycle will be further elaborated in the following paragraph.

1.2 THE PROJECT DESIGN SCHOOL

By comparing construction management practice in a construction-driven FEED phase to project management, another field of interest has been touched. This field concerns project management research regarding the ability of project managers to approach complex issues, as project management is seen as a form of complex problem solving (Ahern et al., 2014a). TU Delft professors Heintz, Lousberg & van de Putte (2017) have defined a significant gap in existent project management literature. Contrary to traditional project management literature, which mainly focusses on knowledge of the tools and systems, Lousberg, Heintz, & van de Putte (2017) focus on the way project managers choose and adapt management tools and systems in order to apply them in specific situations. Here the focus lays on “how to be a project manager”. They have named this research stream ‘Designing project management’.

In previous research, Heintz et al. (2015) have found that the process that an experienced project manager goes through when choosing and adapting management systems and tools, is highly intuitive and can be considered as an application of ‘design thinking’. Design thinking is solution-oriented and characterized by abduction (Dorst, 2011). In abduction people know what they want to have as an outcome (merely than a result), but they don't yet know exactly what the problem is from the given situation, and don't know how they may come from the given situation to the desired situation (Dorst, 2011). This also represents the essence of design thinking, namely: the simultaneous development of the problem and solution. In many businesses and management communities, design thinking is seen as a useful approach to address complex and open-ended challenges (Stacey, Griffin, & Shaw, 2000).

In order to fill the literature gap mentioned above, Heintz, Lousberg & van de Putte have joint forces and developed the Project Design School. The objective of the Project Design School is to assemble an alternative approach and framework for the education of future project managers. It is their intention to provide a foundation to develop a new approach to project management education (Heintz et al., 2015). It is not the intention of the Project Design School to reinvent project management from scratch, but rather to provide a lens through which to view project management action, and also to confirm the use of design thinking approaches to problem solving (Heintz et al., 2016).

A framework for project management practice is proposed by the Project Design School. They have named this framework the Project Design Cycle (figure 3), which consists of the elements: Awareness, Design, Performance and Reflection (Heintz et al., 2016). This cyclic model incorporates design thinking principles and can be applied by project managers or students in project management to learn how to approach complex (i.e. unstable, unexpected, insecure and unique) situations (Lousberg et al., 2015).

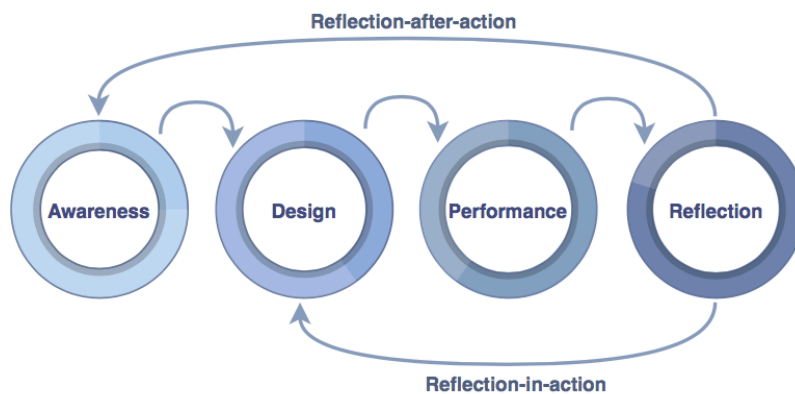


Figure 3: Project Design Cycle (own figure, based on Heintz et al. [2016])

1.3 PROBLEM STATEMENT, RESEARCH OBJECTIVE AND SCOPE

The main topics of this research (Construction-Driven Execution and the Project Design School) are introduced in the previous sub-chapters. This sub-chapter determines the problem statement that can be derived from these topics, a research objective to solve the problem statement, and demarcation to provide a clear scope throughout this research.

1.3.1 PROBLEM STATEMENT

Fluor recently implemented the Construction-Driven philosophy to successfully execute lumpsum EPC oil and gas projects. In a construction-driven project, construction managers are involved early in the process to prevent mistakes from happening in later stages of the project. It is assumed that construction managers require a practical tool since they are used to fighting fires, base their decisions predominantly on experience, are usually confronted with 'less' complex issues, and often neglect reflection practices. As the role of construction management in a Construction-Driven Execution can be compared to project management, and project management can be seen as a complex problem-solving practice (Ahern et al., 2013a), it is decided to base this tool on project management research.

The theoretical framework chosen for this tool is the Project Design School, which is developed by Heintz, Lousberg & van de Putte (2017). They assume that some kind of design thinking is involved by project managers when making a framework to solve complex issues. Furthermore, Heintz et al. (2016) state that experienced project managers use a certain frame and go through certain steps when solving complex issues. To apply this frame for educational purposes, they created the Project Design Cycle (PDC), which consists of four elements: Awareness, Design, Performance and Reflection.

The Project Design School concludes that further research (both theoretical and practical) is required to *"firmly establish the ubiquity of the Project Design Cycle elements, their cyclic relationship, and the degree to which project managers use these elements as an explicit method"* (Lousberg et al., 2015). Hereby, the Project Design School aims to fill a literature gap in project management research, which concerns the approach project managers use when choosing and adapting project management tools and systems to be applied in specific situations (Heintz et al., 2016).

1.3.2 RESEARCH OBJECTIVE

A research objective is formulated in order to solve a beforementioned problem statement. This research incorporates both a theoretical purpose (gather and present empirical data for the Project Design School) and a practical purpose (support Fluor's construction management). Therefore, this research aims to achieve following two objectives:

1. Gather and provide empirical data to firmly establish the ubiquity of the Project Design Cycle elements, their cyclic relationship, and the degree to which managers use these elements as an explicit method,
2. Provide Fluor with advice on how to apply design thinking principles (as incorporated in the Project Design Cycle) within the construction management department in order to enhance the Construction-Driven Execution philosophy.

This will be done by reviewing the theories of Construction-Driven Execution and design thinking, analyzing the current application of the Project Design Cycle in Fluor's construction management, and by incorporating the Project Design Cycle elements into a structure that can be used as a practical tool by construction managers. By enabling construction managers to identify and solve complex issues in the FEED phase it is aimed to enhance the construction-driven philosophy within Fluor.

1.3.3 RESEARCH SCOPE

Several demarcations are determined to provide the reader a clear scope for this research. The scope is divided into three areas: inside scope, touching the scope, and outside scope. The first area displays the main topics and focus points of this research. The second area contains topics that are connected to the main topics or are relevant as background information to this research. The third area contains topics which are deliberately put outside the scope to make sure the research can be completed in a given time frame. An overview of the various topics is given below in figure 4.

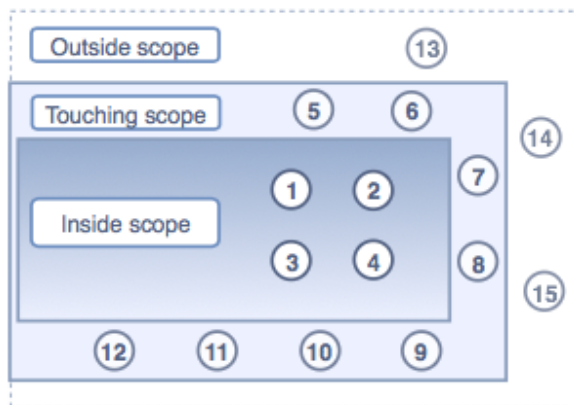


Figure 4: Research scope

Inside scope:

1. Construction-Driven Execution
2. Construction management
3. Design thinking
4. Project Design Cycle

Touching the scope:

5. Project management
6. Early contractor involvement
7. Organizational learning and knowledge sharing
8. Decision-making
9. Reflection practices and learned lessons
10. Modularization and constructability
11. Different forms of contracts
12. Implementation of design thinking in Fluor

Outside scope:

13. Alternative design thinking tools and models
14. Defining complexity in projects
15. AWP, WFP and Automation tools

This research is mainly focused on Construction-Driven Execution, and its influence on current construction management practices. Furthermore, the theories of design thinking and the Project Design Cycle are used to find possible solutions, tools and methods that can be used to support, educate and guide construction managers to solve complex issues in FEED. The beforementioned represents two clear demarcations:

- This research focusses on the role and responsibilities of site- and construction managers in a construction-driven environment. Other departments such as engineering, procurement, project control or project management are mentioned, but not discussed in further detail. Since a site manager is in fact a more experienced construction manager, and the difference in function only lays in hierarchy and not in functional content, both are referred to as construction managers. This done to prevent confusion throughout the research.
- The Project Design Cycle is used to research whether construction managers apply design thinking principles when solving problems. This cycle is developed by the Project Design School in order to fill a literature gap in project management research. They have called this stream 'Designing project management'. The design thinking theory incorporated in the Project Design Cycle is defined by Dorst (2011). Other project management or design thinking research about decision-making tools that can be applied to solve complex issues, is elaborately left out of the research scope.

RESEARCH METHODOLOGY

Chapter 2



In chapter 2, a research methodology is determined based on the problem statement and research objective described in chapter 1. First, the research question and related sub-questions are given. For each sub-question it is described what the objective is, how the data is collected, what the result looks like and how they are interrelated to each other. Furthermore, sub-chapter 2.2 displays and describes the research structure. Finally, in sub-chapter 2.3 the case-study approach and empirical research strategy are discussed. The methodology described in this chapter will be used for the theoretical framework (chapter 3 & 4) and the empirical research (chapter 5 & 6).

2.1 RESEARCH QUESTIONS

In the previous chapter the problem statement and the research objectives are determined. In order to achieve these objectives, the following research question is answered in this research:

- *How can the Project Design Cycle enable construction managers to identify and approach complex situations in a construction-driven FEED phase?*

The research question has been divided into several sub-questions in order to make it more manageable. These sub-questions will be answered throughout the report and provide a certain structure in the research. How these sub-questions relate to the main focus areas of this research (Construction-Driven Execution, construction management, design thinking, and the Project Design Cycle) is shown in figure 5. The numbers in this figure represents the following sub-questions:

1. *What is the influence of Construction-Driven Execution on construction management practices?*
2. *What is the essence of design thinking and the Project Design Cycle?*
3. *To what extent are the elements of the Project Design Cycle currently applied by construction managers when approaching complex issues in a construction-driven FEED phase?*
4. *How can the Project Design Cycle be transformed to serve as a practical tool for construction managers in a construction-driven FEED phase?*

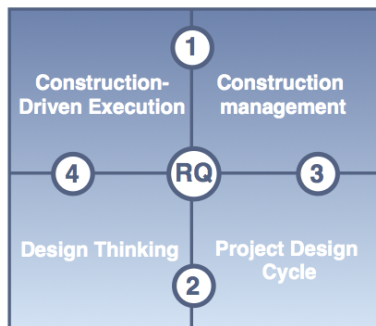


Figure 5: Relation sub-questions

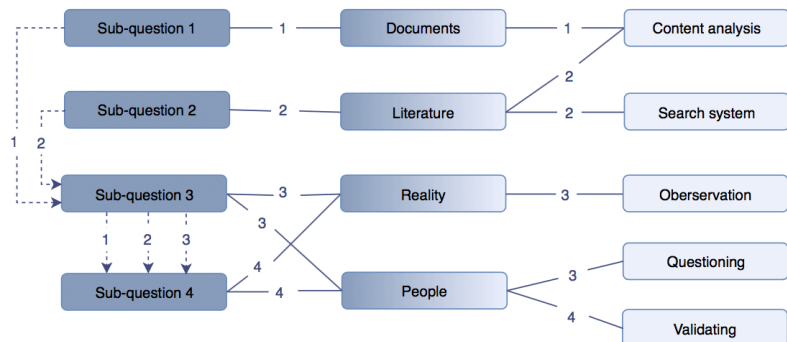


Figure 6: Data gathering

Several sources and extraction methods (as defined by Verschuren & Doorewaard (2015)) will be used throughout the research. Figure 6 shows how the sub-questions are interrelated, what data source is used, and how the required information is extracted from these sources. The research strategy is presented below by elaborating all four sub-questions. Of each sub-question the main objective, aimed result, data collection method, and interrelationship with other sub-questions is described.

1. *What is the influence of Construction-Driven Execution on construction management practices?*

The goal of this question is to describe; what Construction-Driven Execution is about, why Fluor implemented this new philosophy, and what its effect is on the project life cycle, construction management and the role of construction managers. Required data to answer this sub-question is gathered by (1) diving into Fluor’s database to create a search of relevant documentation and (2) analyzing the working documents and procedures within Fluor. Furthermore, multiple conversations with Fluor employees of the construction management department are performed to gain a better understanding of Fluor’s construction practice and Construction-Driven Execution.

2. What is the essence of design thinking and the Project Design Cycle?

The objective of this sub-question is to further elaborate design thinking and the Project Design Cycle. First, the literature gap in project management research is described, followed by the application of design thinking in project management, and finally the Project Design Cycle. To answer this sub-question, a search is developed by diving into relevant literature of Designing project management, design thinking and the Project Design School. Then, this search is used to find additional scientific sources, which is used to perform a literature study. Theoretical framework and its components provide the information required to describe the essence of Design thinking and the Project Design Cycle.

3. To what extent are the elements of the Project Design Cycle currently applied by construction managers when approaching complex issues in a construction-driven FEED phase?

The goal of this question is to analyze if, and to what extent, construction managers incorporate elements of the Project Design Cycle when approaching complex issues. Results of the empirical research provides practical insights in the current application of CDE in the case-study projects and contributes as empirical data to further embed the framework of the Project Design School. Information gained by answering the sub-question 1 and 2 is used as a starting point for this sub-question. Project specific documents like the construction execution plan, project execution strategy, plot plan, and progress of the respondents are analyzed to get a better understanding of the project drivers, strategies and construction-driven considerations.

Per case-study project, two respondents (construction managers) are interviewed by use of semi-structured interviews. The information extracted from the first interview is used to determine potential complex issues, which provides the structure of the second interview. Additionally, by attending several constructability meetings, a better understanding is gained of the way construction managers lead these meetings and approach complex issues. The objective of the second interview is to dive deeper into the complex issues that came to attention in the previous interviews. Then, the collected data is analyzed by performing a qualitative data analysis, which is done by use of Atlas.TI software. The elements of the Project Design Cycle serve as codes and are highlighted in the transcripts of the interviews. Finally, a cross-case analysis is performed to observe and analyze any occurring patterns in order to define conclusions.

4. How can the Project Design Cycle be transformed to serve as a practical tool for construction managers in a construction-driven FEED phase?

The objective of this sub-question is to incorporate design thinking principles and the Project Design Cycle in Fluor's construction management practices by creating a practical tool. This tool contains all elements of the Project Design Cycle in order to educate and guide construction managers to approach complex issues in FEED. All the data collected by answering the previous sub-questions is used to answer this sub-question. First, a good understanding of Construction-Driven Execution needs to be developed (SQ1), followed by a literature review of design thinking and the Project Design Cycle (SQ2), and insights of the application of the Project Design Cycle elements by construction managers in a construction-driven FEED-phase (SQ3). Combining this information provides the knowledge required to create a practical tool that can be applied by the construction managers in the related case-study projects.

2.2 STRUCTURE OF THE RESEARCH

The structure of this research is displayed in figure 7. As shown, the amount of information and data will first diverge, after which it will converge into clearly defined results. This research consists of four main components: research proposal, theoretical framework, empirical research and results.

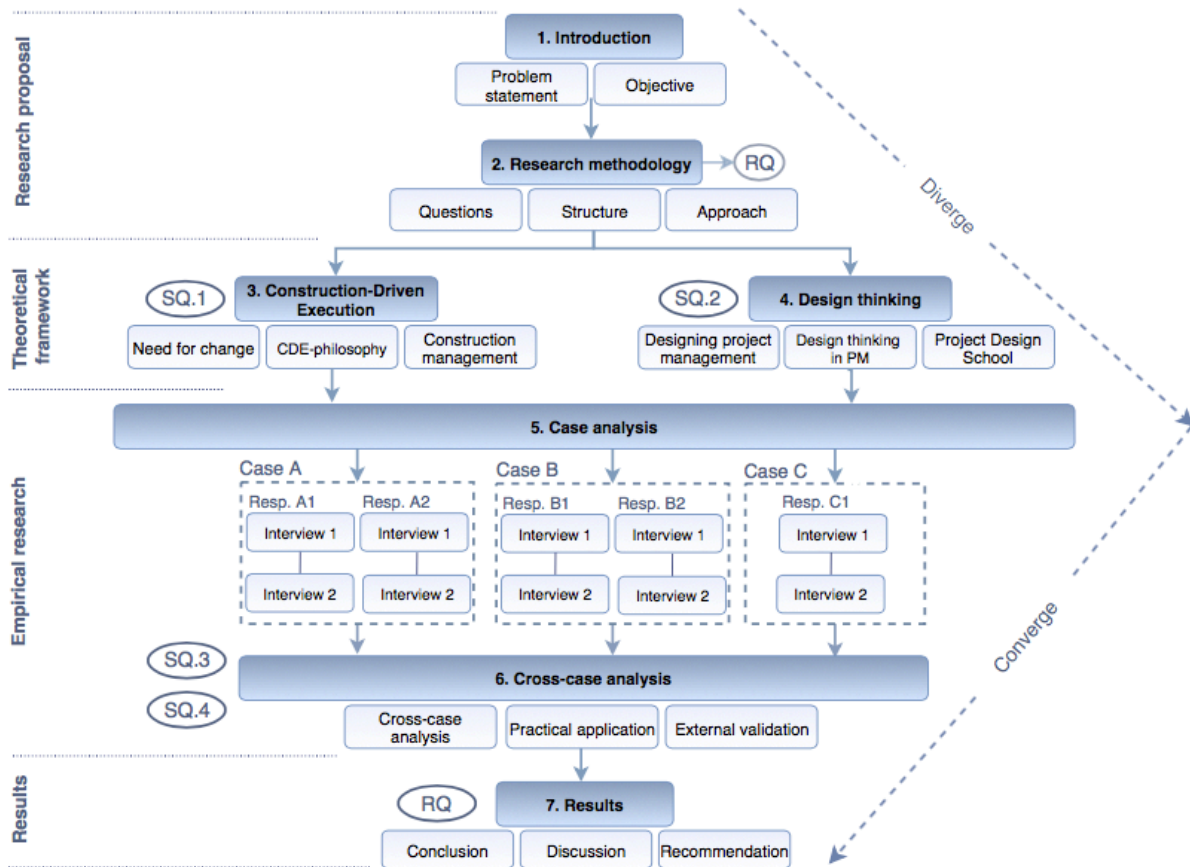


Figure 7: Structure of the report

The problem statement, objective and research questions have already been discussed in *Chapter 1: Introduction* and *Chapter 2: Research methodology*. These two chapters represent the research proposal.

The theoretical framework consists of Construction-Driven Execution and Design thinking, which are described in Chapter 3 and Chapter 4. By describing the theoretical framework, information is found to answer sub-question 1 and 2. The theoretical framework will also serve as input for the empirical research.

The empirical research is elaborated in *Chapter 5: Case analysis* and *Chapter 6: Cross-case analysis*. In total ten interviews are conducted with five construction managers of three different case-study projects; each respondent is interviewed twice. Respectively, the empirical research will provide the information to answer sub-question 3 and sub-question 4.

In *Chapter 7: Results* the findings of the previous chapters are collected and summarized to answer the main research question in the conclusions. Then, the implications and limitations of the research are determined and discussed. Finally, scientific and practical recommendations are presented for Fluor’s construction management department and future research opportunities.

2.3 RESEARCH APPROACH AND STRATEGY

The research approach and strategy applied to answer the research questions and to achieve the research objectives is explained in this sub-chapter. First, the chosen case-study approach is elaborated. After which the empirical data collection and qualitative data analysis are explained step-by-step.

2.3.1 CASE-STUDY APPROACH

This research is practice-oriented and of a diagnostic nature. The main goal of a diagnostic research is to contribute an intervention to change an existing practical situation, in which it is already clear what, why, and who's problem it is (Verschuren & Doorewaard, 2015). Insight is obtained of the backgrounds, causes, and cohesion of the problems in question. Therefore, it is important that the problem is well defined to prevent confusion and loss of time (Verschuren & Doorewaard, 2015).

Yin (2014) describes that case-studies benefit from the development of a theoretical framework, as this framework guides the data gathering and analysis in the empirical research. This research study consists of two components which are complementary to each other. First, a theoretical framework will be determined through a literature review. This framework will then be used to provide basis for the second component; a case-study research (Verschuren & Doorewaard, 2015).

A case-study approach is chosen over surveys because this approach is useful to obtain a large amount of data from multiple case-studies and because it is easier to derive complex relations from qualitative data (Sapsford, 2007). Since the elements of the Project Design Cycle can only be recognized in the problem-solving approach of construction managers, it is important to collect a large amount of data in order to derive complex relations between the elements. Contrary to surveys, the case-study approach is often used to analyze complex problems (Yin, 2014)

Case-study research can be divided either into holistic or embedded, and into single- or multiple (Verschuren & Doorewaard, 2015). This research is a holistic multiple-case study, which means the focus lays on several respondents, which will be used to collect the qualitative data (Yin, 2014). Even though it is a multiple-case study, all cases are Fluor projects. In the case-study approach, it is useful to apply several methods of data gathering in order to create depth in the qualitative research (Verschuren & Doorewaard, 2015). As shown in figure 6, the data is gathered by use of different methods, such as; analysis of company documentation on Construction-Driven Execution, observations during constructability meetings, and semi-structured interviews with the respondents.

The sample for the case-studies is strategically chosen and consist of a small number of research units with limited differences between them (Verschuren & Doorewaard, 2015). The sample consists of five construction managers, who are part of the construction management team of comparable middle to large EPC lumpsum construction projects in the oil and gas industry. An important feature of these projects is that they are all executed by the construction-driven philosophy. The choice of sample will be further elaborated in chapter 5.1. A quantitative analysis of the collected results will not be possible since the case study has a limited amount of research units (Yin, 2014). Also, the study will be more in-depth than broad. This is accomplished by several labor-intensive forms of data generating such as semi-structured interviews.

2.3.2 CASE-STUDY STRATEGY

Yin (2014) describes two main components of a qualitative case-study research: case-study preparation and case-study analysis. These components are further divided into seven steps: step 1 to 4 concerns the empirical data collection (Chapter 5) and step 5 to 7 covers the qualitative data analysis (Chapter 6). These steps are shown in figure 8 and figure 9.

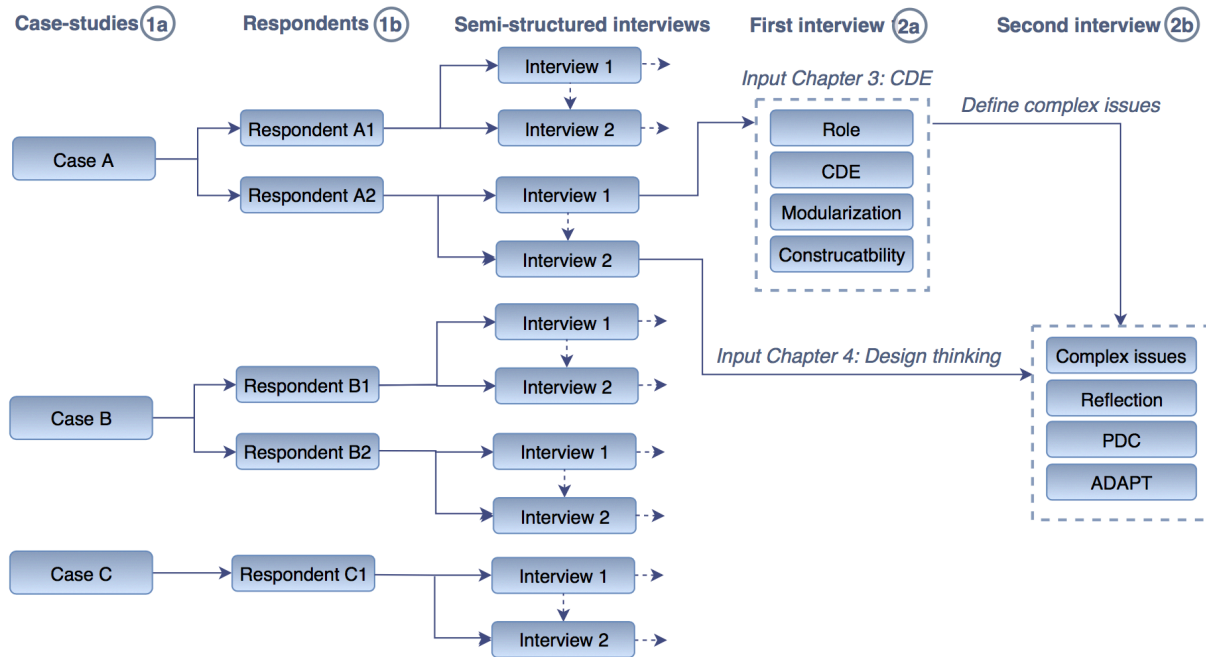


Figure 8: Empirical data collection

1. The first step is to identify and describe case-studies (projects) and its related respondents (construction managers). The case-study projects are comparable on various characteristics: region, business line, size (total installed cost), contract type, and project phase. Additionally, all case-study projects should be construction-driven, which indicates construction managers are involved early in the process. After selecting the projects, one or two construction managers are identified per project (depending on availability). Requirements for determining the respondents are; key position within construction management, stationed in the home office during FEED, and at least 15 years of experience in the field.
2. The second step concerns two semi-structured interviews with each respondent. The questionnaire of the initial interview is composed based on the findings of *Chapter 3: Construction-Driven Execution* and also on preliminary (unstructured) interviews with members of the construction department. The questionnaire of the second interview is based on the findings of *Chapter 4: Design thinking and an analysis of the initial interview*. Key components of design thinking are extracted from the literature, which gives direction to the interview. The complex issues are defined in the transcripts of the first interview. These issues are used to structure the 2nd interview. Both interviews are recorded and transcribed.

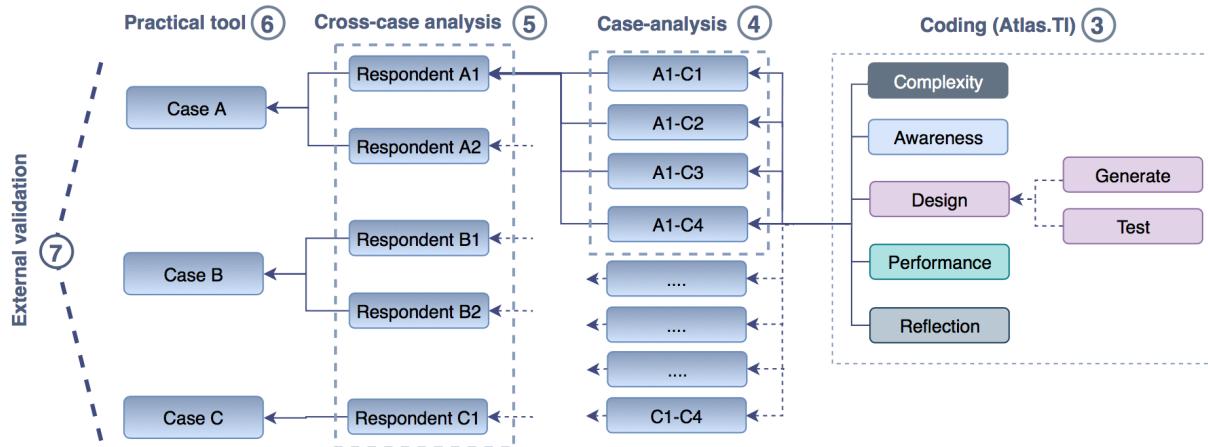
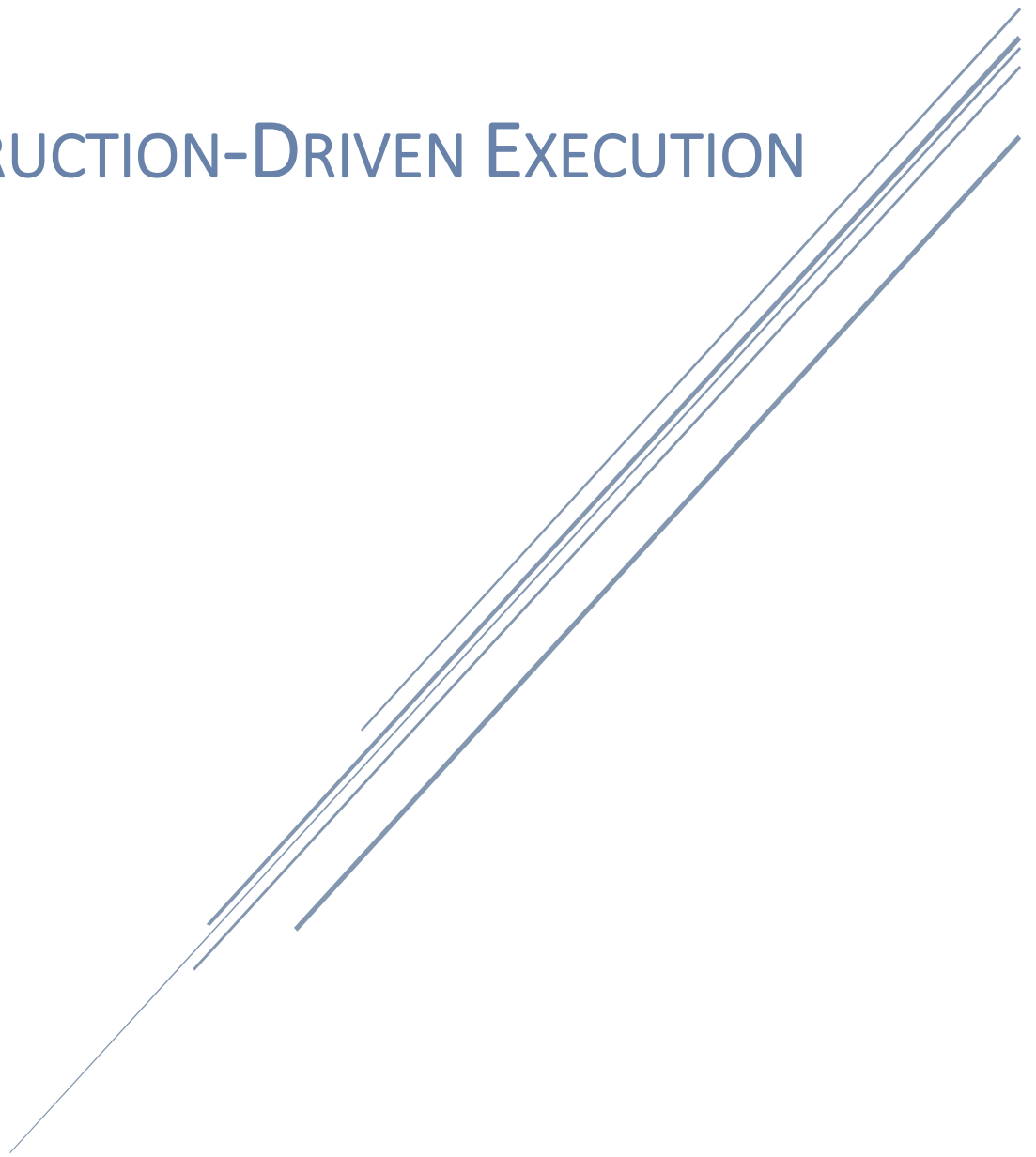


Figure 9: Qualitative data analysis

3. The third step is to retrieve qualitative data from the interview transcripts. First, the transcripts are printed and supplemented with initial thoughts of potential codes and patterns. Secondly, the coding is done in specific qualitative data analyzing software named Atlas.TI. In Atlas.TI the codes are quoted first, after which comments and memos are added to substantiate the assigned codes. Thirdly, the findings are put into an Atlas.TI report and added to the appendices.
4. The cases and respondents are analyzed in the fourth step. The potential complex issues identified in the transcripts of the first interview will be compared with the TOE complexity model of Bosch-Rekvelde et al. (2011) to determine the complexity of each issue. The transcripts of the second interview will be used to analyze the respondent’s approach to solve the beforementioned issues. The findings will be summarized and clustered per issue in a table, after which the findings will be discussed per respondent. Finally, the cases will be analyzed by comparing the findings and approaches of both respondent to comparable issues.
5. The fifth step concerns a cross-case analysis, in which the case-studies and respondents are compared to each other. First, the complexities are categorized in order to compare the approaches of the respondents. By doing so, it is enabled to separate complex issues from non-complex issues. Only at this stage, it can be determined whether construction managers apply the Project Design Cycle elements when approaching complex issues. Furthermore, any differences and similarities between the several respondents are discussed. Finally, the opinion of the respondents regarding the Project Design Cycle and reflection practices in current construction management are reviewed.
6. In the sixth step the Project Design Cycle is transformed into a practical tool that could be implemented in the case projects and can be applied by construction managers to approach complex issues during FEED. The tool is based on both the theoretical framework and the findings of the empirical research.
7. The final step is an external validation of the results, which is done by an independent expert panel within the host company. These experts are active in Fluor’s energy & chemicals business line and have not been involved in the case-studies. The findings of the cross-case analysis and the practical tool (step 5 and 6) are presented to the expert panel, after which an open discussion takes place. Any new findings, limitations or discussion points are summarized and incorporated in the discussion.

CONSTRUCTION-DRIVEN EXECUTION

Chapter 3



Chapter 3 provides the theoretical framework of Construction-Driven Execution, which is one of the main topics of this research. First, it is explained why there is a need for change within Fluor's Hoofddorp office in sub-chapter 3.1. Secondly, the Construction-Driven Execution philosophy is elaborated in sub-chapter 3.2. Thirdly, in sub-chapter 3.3 a construction-driven project organization is discussed, including the project team, construction management team, and the role and responsibilities of the construction manager. Finally, in sub-chapter 3.4 the transition of construction managers from 'firefighting' to 'fire preventing' is discussed. This chapter delivers data to answer sub-question 1 and serves as input to define the interview questions of the empirical research in chapter 5.

3.1 A NEED FOR CHANGE

Fluor’s services, approaches, and contracts with regard to oil & gas projects have changed drastically in the last decade, especially in Fluor’s Hoofddorp office. The Hoofddorp office used to be an engineering-driven organization that offered EPCm services to projects on a reimbursable contract basis. These projects were often designed and procured based on a traditional stick-build execution approach. Nowadays, the Hoofddorp office gradually transforms towards a construction-driven organization that offers EPC services to projects on lump-sum contact basis. Additionally, the execution approach shifts to modular, which has major impacts on the way projects should be designed and procured. To summarize, Fluor’s Hoofddorp office transformed from:

- EPCm towards EPC contracts (3.1.1)
- Reimbursable towards lump-sum contracts (3.1.2)
- Stick-build execution towards a modular execution approach: EPC to EPFC (3.1.3)

3.1.1 SERVICE: EPCM TO EPC

After the preliminary design phase (FEED), there are three main option’s the client can choose from (Fluor, 2010):

- Appoint a contractor to develop the FEED into a detailed design and then manage on its behalf the procurement and construction of the works (EPCm).
- The FEED contractor delivers the project in the form of a reimbursable or lump sum EPC contract (EPC);
- A FEED contractor is appointed to assist the client to manage and procure a third-party EPC contractor (PMC);

The first two (EPCm and EPC) are elaborated below and shown in figure 10. EPCm stands for engineering, procurement and contract management, which means the contractor (Fluor) doesn’t do construction. The contractor only develops the design and manages the construction process on behalf of the client. In an EPCm contract, the contractor is responsible for the basic engineering and FEED, the detailed design, procurement, and management of the construction contracts (Loots & Henchie, 2007).

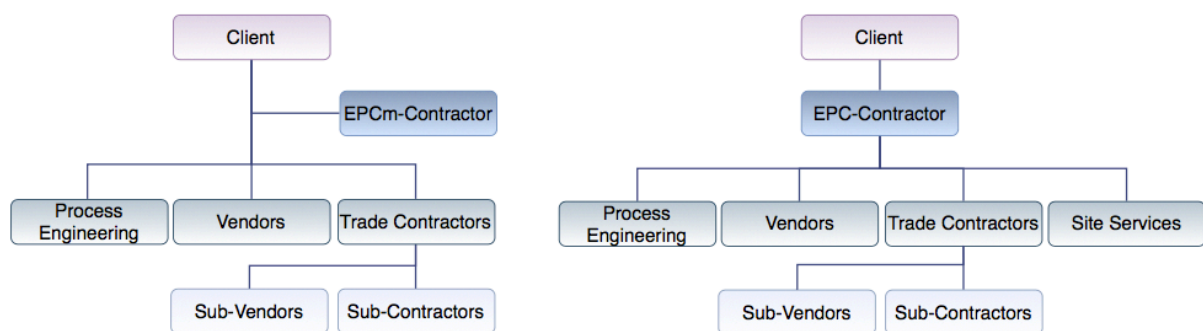


Figure 10: EPCm vs EPC organization chart (Loots & Henchie, 2007)

EPC stands for engineering, procurement and construction, and does include the construction part. Often, the preliminary design phase (FEED) is contracted separately from the detailed engineering, procurement and construction (EPC) contract. When the FEED is not included, the client works with a design firm to develop the preliminary design. An EPC contractor is then assigned to bid on the work based on the FEED (Fluor, 2010).

Compared to an EPCm contract, EPC has different risk allocation and legal consequences. The main difference is that under an EPC contract, the contractor takes all responsibilities as he also executes the entire project. In an EPCm contract, another contractor takes this responsibility and is therefore allocated the corresponding risks and legal consequences (Loots & Henchie, 2007).

3.1.2 CONTRACT: REIMBURSABLE TO LUMP-SUM

Another consequence related from going from EPCm to EPC contracts, is that most of the EPC contracts are awarded on lump-sum fixed price terms. The final costs for the client, and profit for the contractor, heavily rely on the type of contract (Fluor, 2010). In cost reimbursable contracts, the contractor builds projects for its client for the costs of goods and services provided, plus a negotiated fee that serves as the contractor’s profit (Clough et al. 2005). When the scope of work is highly uncertain, this contract type is favoured by the contractor. In these contracts, the contractor's profit is set at a fixed percentage (Fluor, 2010). There are several forms of cost reimbursable, of which some include incentives.

In lump-sum contracts, the contractor carefully estimates the project and agrees to execute the work for a given or fixed price. In some lump-sum contracts, the client may agree to pay incentives. Lump-sum contracts include planning and estimate errors, minor price fluctuations, design developments and changes within the scope, and changes in markets and environments. Because the contractor owns this additional contract risk and obligation, the costs for the client are driven up. This means that lump-sum contracts have higher gross margins than reimbursable contracts. However, the contractor bears the risk of cost overruns, rather than the owner (Fluor, 2010). This type of contract is suitable for a contractor in a project in which the scope of work and costs can be estimated with a high level of certainty at the time of contracting.

Changing from reimbursable contracts means the risks allocation is shifting. As shown in figure 11, the client assumes more risk on reimbursable-type contracts, while contractors assume more risk on fixed price-type contracts. However, it is essential to understand that even though the same risks exist on a lumpsum project, the party who assumes those risks changes depending on the type of contract utilized (Menches et al., 2012)

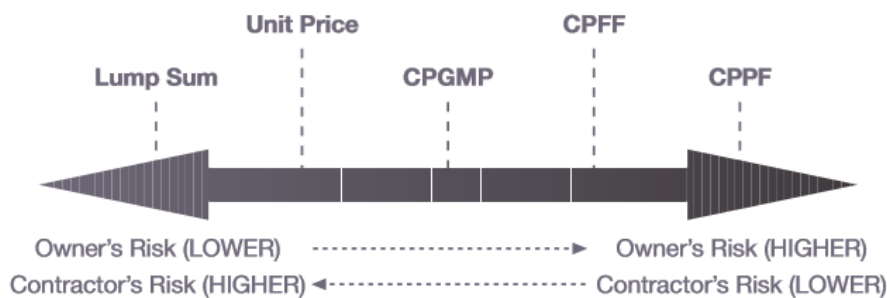


Figure 11: Reimbursable vs Lump-sum (Menches et al., 2012)

3.1.3 APPROACH: STICK-BUILT TO MODULARIZATION (EPC TO EPFC)

Furthermore, Fluor shifted from a stick-built to a modular execution approach. Modularization is seen as a method to reduce risks that are for Fluor’s own account in EPC lump-sum projects. Modularization adds the ‘F’ to EPFC and means Fluor is also fabricating the work (Fluor, 2017). Modularization can be seen as a form of project execution strategy. It entails the large-scale transfer of stick-built construction effort to one of the four fabrication yards owned by Fluor.

The decision to apply a modularization strategy should be made early in the process in Pre-FEED. Modularization has shown to provide schedule and cost benefits over a stick-built construction approach. Especially on projects that are located in regions with extreme weather or limited labor constraints, or projects that have permit or schedule constraints. As modularization is an integrated solution, it requires a different approach from all disciplines. Modularization might even affect plot plan development and site selection. Due to the scale of modularization solutions, it is important that the entire project team understands the impact of a modular execution strategy to the schedule and design (CII 310-6, 2015).

The difference between stick-built and modularization is shown in figure 12. In a stick-built approach, the equipment and materials are directly delivered to the construction site. At the construction site it gets fabricated and assembled. In a modular approach, the equipment and materials are first delivered and assembled on a fabrication yard, after which the modules are shipped to the construction site and put into place (Fluor, 2017).

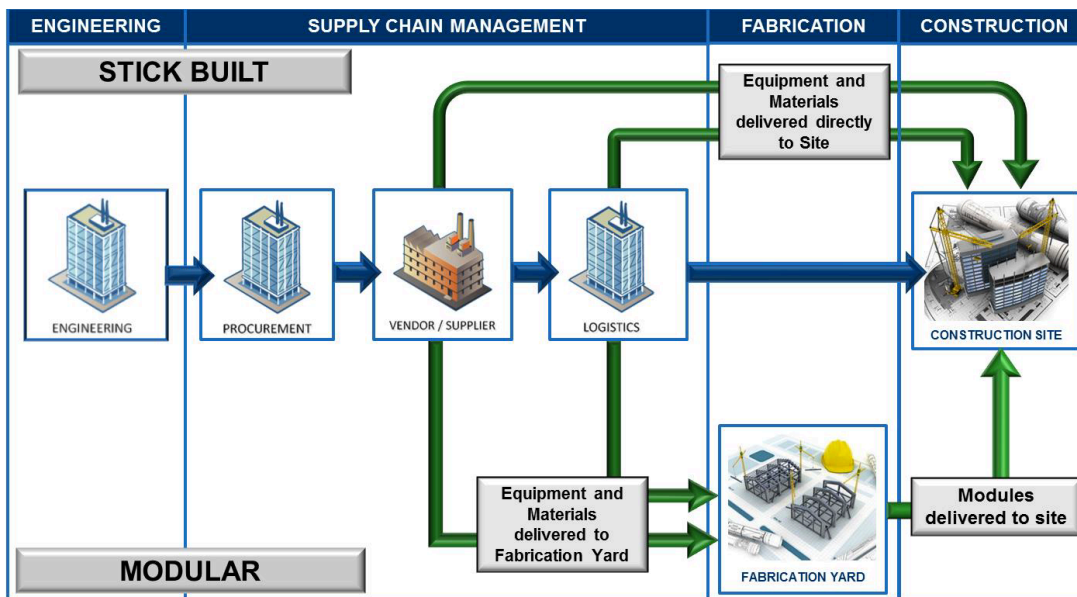


Figure 12: Stick-built vs modularization (Fluor, 2017)

A consequence of the modular approach is that engineering and procurement programs need to be accelerated in order to facilitate timely assembly at the fabrication yard. The modular component further increases logistics and supply chain complexity. Due to multiple remote work locations the transportation considerations (i.e. quality of roads, bridges, site access, weight management etc.) become of a significant importance in order to ensure successful delivery of modules (Fluor, 2017).

3.2 CONSTRUCTION-DRIVEN EXECUTION PHILOSOPHY

As discussed in the previous sub-chapter, Fluor shifted from traditional project execution to EPC lumpsum project execution. These changes in Fluor's services, contracts and approach bring along many consequences for Fluor's execution strategy of oil and gas projects. It can be concluded that a different mind-set is required to successfully execute EP(F)C lump-sum projects with a modular approach. Fluor has found that a construction-driven philosophy is needed to execute a project successfully.

Construction-Driven Execution is Fluor's key to integrate engineering, procurement and fabrication with the field of construction effort. Fluor's strategy to approach these projects in an integrated way, presents a challenge to project and construction management, who must continually balance the technical, execution, and business risks inherent in this approach (Fluor, 2016). The three key drivers of CDE are People, Planning and Delivery (Fluor, 2018a). These drivers stand for:

1. People

- Assigning construction regional managers and include them in estimate reviews,
- Budgeting for construction personnel in proposal, FEED and EPC,
- Planning and budget for home office personnel to move to site during construction.

2. Planning

- Identifying and planning for the use of construction automation tools,
- Implementing advanced work packaging (AWP) to improve field efficiency,
- Utilizing Better-Build techniques such as 3rd Gen modularization.

3. Delivery

- Achieving pre-defined targets for construction execution,
- Exceeding client expectation for delivery,
- Positioning Fluor for future work.

Construction management fulfills a crucial position in Construction-Driven Execution. The main focus of construction management is to define the execution of the project and to influence the engineering, procurement and fabrication departments in the home office. It is important that construction management is on equal footing with project management in decision making relating to execution decisions. Furthermore, the construction management representatives should ensure enough budget is estimated for construction disciplines during the early stages (Fluor, 2018a).

A project is typically divided into six phases. Each phase has a series of key activities and deliverables to be completed by the end of the given phase and prior to initiating the subsequent phase. The CDE-Playbook will help guide the project team in the development and completion of each of the key activities and deliverables by phase, as well as provide an overview of the key support functions (Fluor, 2016).

From the proposal phase onward, the project team must consider how the project will be built and solicit input from appropriate representatives from all departments. The project team must determine if modularization is applied, and how constructability and Advanced Work Packaging (AWP) will be implemented and who will provide construction input and establish appropriate plans and budgets (Fluor, 2016)

3.3 CONSTRUCTION-DRIVEN PROJECT ORGANIZATION

The application of Construction-Driven Execution clearly influences the deliverables in each project stage, the composition of the project team and construction management team, and in special, the role and responsibilities of the construction managers. These four subjects will be elaborated below.

3.3.1 PROJECT LIFE CYCLE

The project life cycle of a typical EPC oil and gas project contains six phases: initial proposal, conceptual design & front-end engineering design (FEED), detailed engineering & design, procurement & fabrication, construction, and commissioning. The six phases are shown in figure 13. This figure also displays the output of each phase.

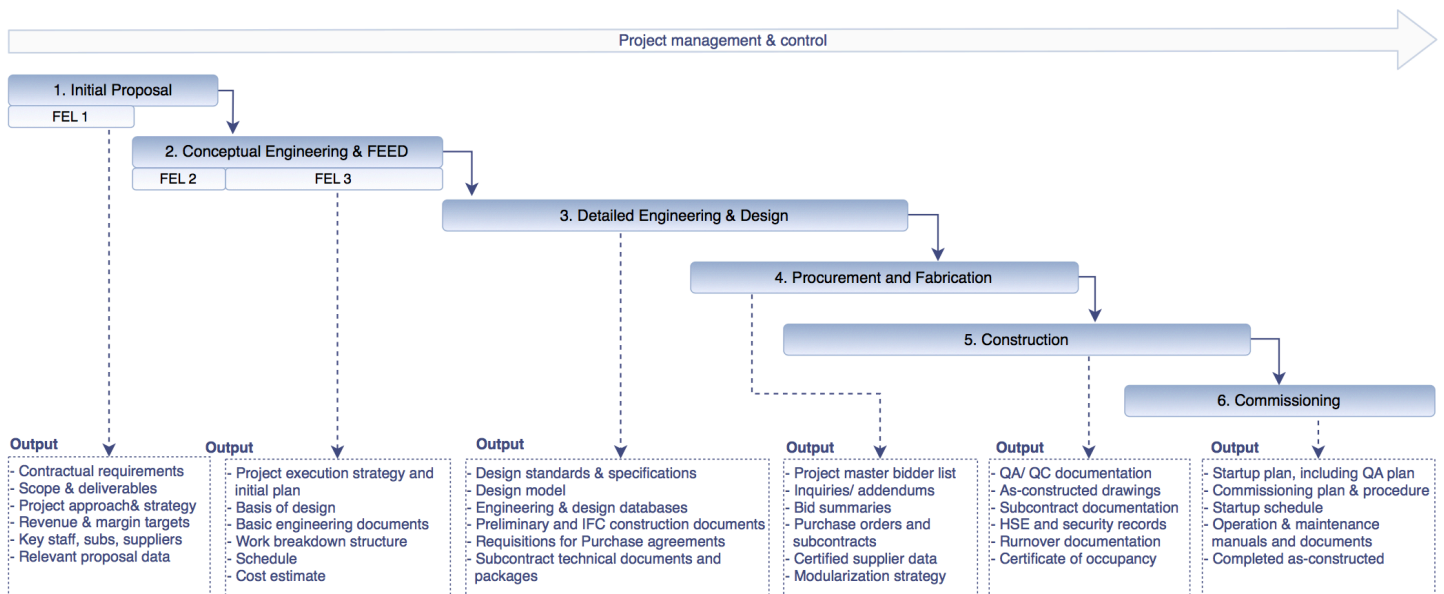


Figure 13: Project life cycle (own figure, based on CII 310-6 (2015))

PHASE 1 – INITIAL PROPOSAL

The proper start-up of a project is the most critical aspect of ensuring the future success of the project. It is imperative that the groundwork laid out in the proposal phase be reviewed and expanded upon to the next level of detail in an effort to define the baseline. This phase encompasses the interface with the proposal team and commercial alignment; project kickoff and alignment; project setup (e.g., integrated framework); early Project Controls activities (e.g., work breakdown structure and staffing plan); review of the standard Project Procedures Manual (PPM) to identify any deviations (Fluor, 2016).

PHASE 2 – CONCEPTUAL ENGINEERING & FEED

The preliminary engineering phases complete the functional requirements or schematic design. This phase is also called front-end engineering and design (FEED) or front-end loading (FEL) and defines the project as it involves the development of all the strategic information that enables a successful project (CII 310-6, 2015). The preliminary engineering schematic design usually includes general site layouts, overall process flow diagrams, mechanical flow diagrams, and process datasheets on all process and utility equipment. Considerable construction execution influence and thinking must go into the feasibility and broad-scale planning of the new facility. Engineering and supply chain efforts in Phases 1 and 2 lay the groundwork for a successful, productive construction site (Fluor, 2016).

PHASE 3 – DETAILED ENGINEERING & DESIGN

Detailed engineering & design involves taking the approved preliminary or schematic design and developing it into detailed construction drawings and specifications. Detailed engineering is the process of successfully analyzing and designing all the components of the facility so that they comply with recognized codes and standards of safety and performance. The resulting design is documented in a set of detailed drawings and specifications that will tell the constructors exactly what to purchase and how to build the structures and systems in the field (Fluor, 2016).

PHASE 4 – PROCUREMENT & FABRICATION

Procurement and fabrication are the essential ties between phase 2, 3 and 5. It is important to align procurement with the various disciplines throughout all phases of the project, in order to allow for proper delivery of materials, equipment, and sub-contractors. In order to be aligned with the other disciplines, this phase should include a clear understanding of cost and contractual requirements, schedule, commitment to quality, timely delivery of work products, transparency and organized processes (CII 310-6, 2015).

PHASE 5 – CONSTRUCTION

Although construction activities were initiated in previous phases, this is the phase where effective construction begins. The construction phase involves the most risk and concerns a large portion of the total installed costs. Construction represents the process whereby the detailed engineering drawings and specifications are converted into physical structures and systems that comprise the new facility. The challenge of the construction phase is to safely construct the new facility within the technical requirements and maintain or improve both the cost and schedule baseline objectives (Fluor, 2016).

PHASE 6 – TURNOVER & COMMISSIONING

At (approx.) 65 percent of construction progress, the focus of the project shall change from construction work within a defined geographical area to turnover systems. Project Controls, in conjunction with Turnover & Commissioning, will develop and manage a detailed plan for turnover of the plant/facility by system according to the turnover sequence (Fluor, 2016).

3.3.2 CONSTRUCTION MANAGEMENT TEAM

PROJECT TEAM ORGANIZATION

A traditional project organization structure at Fluor oil & gas projects is shown in figure 14. This figure contains the entire organization, including the client (purple), project management (green), construction managers (blue), other management functions (light blue), and Fluor staffing (grey).

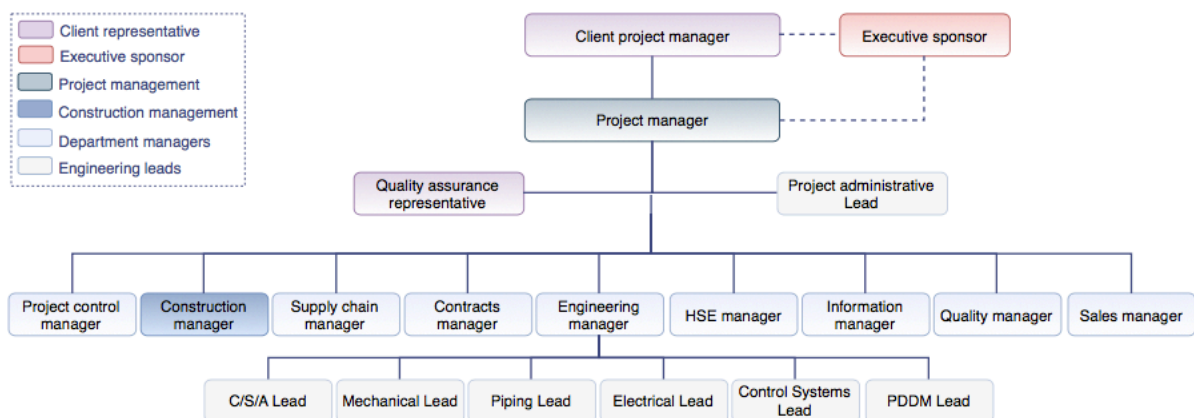


Figure 14: Traditional Fluor EPC Project Organization (Fluor, 2010)

In a construction-driven project organization, the construction manager is positioned on the same level as the project manager (figure 15). Both managers report back to the project director, who has the final say in project decisions. The construction manager is responsible for the construction leads, while the project manager responsible for the project and engineering leads. Both roles and responsibilities are summarized as follows (Fluor, 2014a; Fluor, 2014b):

- The construction manager purpose is to manage a medium- to large-sized EPFC project; to oversee and direct the performance of all construction and related activities in conformance with contract, plans, specifications, schedules, and cost estimates. The construction manager directs all staff in all functions necessary in their roles to meet or exceed all project objectives. This position will typically be the lead person directing all construction activity for a project including the office and project site; serving as the lead staff position responsible for and directing all activities at the site.
- The project managers purpose is to perform with the overall objective of establishing an execution framework on the project that complies with the contract and ensures the safety, quality, value, timeliness, and Fluor profitability of the completed project. The project manager is accountable for performing all project management responsibilities on a medium to large sized, moderate risk EPFC projects. When acting in the role of a proposal manager (pre-FEED), this position is responsible for managing completion of technical and commercial proposals, providing proposed Fluor project organization, project planning, means and methods of project execution, schedule preparation, cost estimating, and commercial strategy.

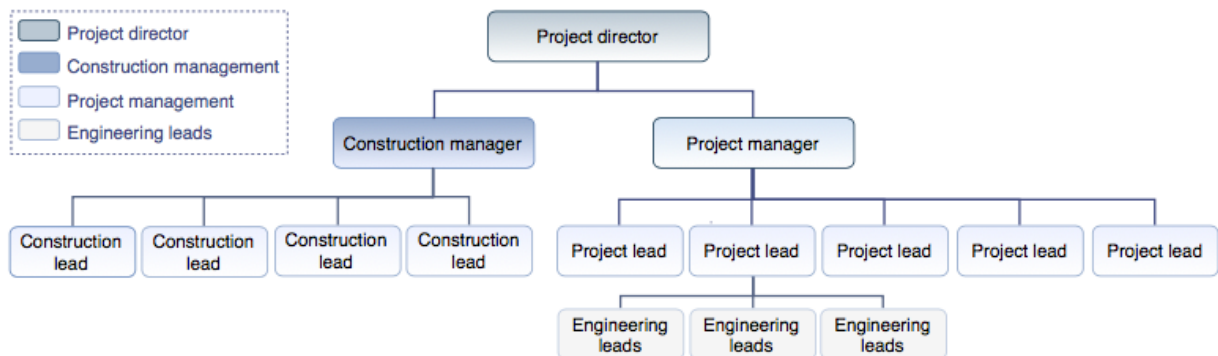


Figure 15: Construction-driven project team organization (own figure)

CONSTRUCTION MANAGEMENT TEAM ORGANIZATION

The case-study projects which are part of the case-study research are in the pre-FEED or FEED phase at the time of the research. Since the construction managers in these projects are used as respondents, the focus is put on the construction management team in the FEED.

In a construction-driven project, the construction manager is leading the construction management team from pre-FEED all the way upon completion. Together with the regional construction director, it will be the responsibility of the construction manager to drive the construction execution strategies in conceptual design, and subsequently, through engineering and procurement towards commissioning.

Early in the process during the pre-FEED and FEED phase, the (home office) construction management team is relatively small. This team will at least consist of an (area) construction manager, an AWP manager, construction engineer, and a heavy lift manager (figure 16). Together they will determine the initial and detailed construction execution plan.

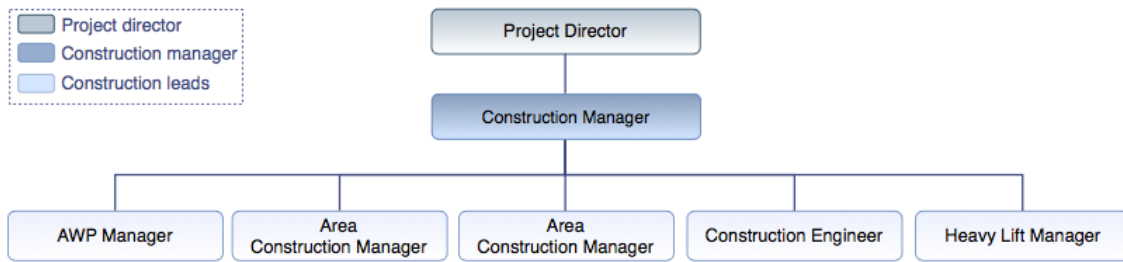


Figure 16: Pre-FEED/ FEED home office construction management team (Fluor, 2018b)

In the construction phase, the construction manager will move to site in order to lead the (site) construction management team (figure 17). Besides the construction managers, the team will now consist of an HSE manager, site contracts manager, site quality manager, field engineering manager, project controls manager, and field material manager. All managers will also have multiple Fluor staffing below them, just as is shown below the area construction managers.

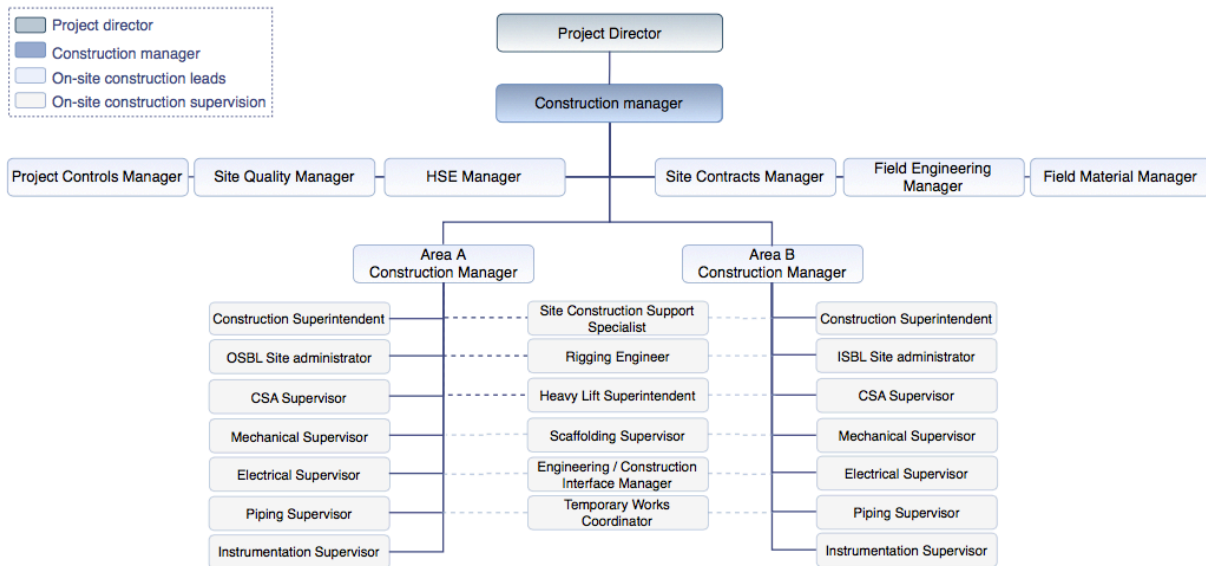


Figure 17: On-site construction management team (Fluor, 2018b)

3.3.3 CONSTRUCTION ROLE AND RESPONSIBILITIES DURING FEED

In a construction-driven project, the construction managers are responsible for management of all project construction activities on the site, as well as the construction support and planning activities in the home office prior to mobilization. Each project undergoes a series of development phases from initial conception through completion.

The construction effort on-site represents a large part of the project cost, and the way construction is executed has a significant influence over the ultimate cost and completion date of the project. Therefore, the key function of the construction management team is to effectively plan, schedule and sequence the work. Also, the use of methods, techniques, tools, equipment and qualified workforce to perform the work have to be described in the Construction Execution Plan (CEP) (Fluor, 2016).

In the initial CEP the scope of work is determined. The construction manager is responsible for developing and issuing the CEP and can draw on support from a number of resources, such as construction area managers, construction engineering, material management and superintendents, in

order to develop and submit a complete execution plan. The initial CEP contains the following elements (Fluor, 2016):

- Construction sequence and execution approach
- Home office construction support during FEED and detailed design
- Constructability program
- Use of modular construction and/or extent of on-site/offsite fabrication
- Implementation plan for advanced work packaging/workforce planning principles
- Development of site quality, HSE and other programs
- Labor strategy and sourcing
- Preliminary site team staffing plan, site logistics and temporary facilities

The detailed CEP is built upon strategies outlined in the initial CEP in the proposal. The detailed CEP will provide a summary of the scope of construction and the execution approach to completing the work. The construction execution section of the PEP will (Fluor, 2016):

- Provide an overview of how Fluor will execute the work
- Provide the specific strategy and framework for how the project will be constructed
- Integrate the construction effort into the engineering, procurement and contracting
- Use the construction team’s knowledge and experience to control costs and achieve the project’s schedule, quality and safety objectives during the construction of the facility

Besides the construction execution plan, the construction managers are also responsible for the constructability program. Constructability is defined as: *“the optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives”* (Fluor, 2016). The primary goal of the Constructability Program is to promote a focus on delivering integrated solutions, based on the requirements of the Project Execution Plan and Construction Execution Plan with regarding goals for quality, schedule savings, cost-reduction, and safety. The effective utilization of construction knowledge and experience is a key element in the process of planning how a project is to be assembled in the field.

Constructability is led by the construction managers, but it requires involvement and communication from all parties and all engineering disciplines. A typical constructability team during FEED and detailed engineering is shown in figure 18. During FEED, it is important that the key areas of focus for the early constructability and construction planning efforts are highlighted. This may include (Fluor, 2012): modularize, pre-assemble and pre-cast; standardize materials; sequencing of work; and maximize automated systems.

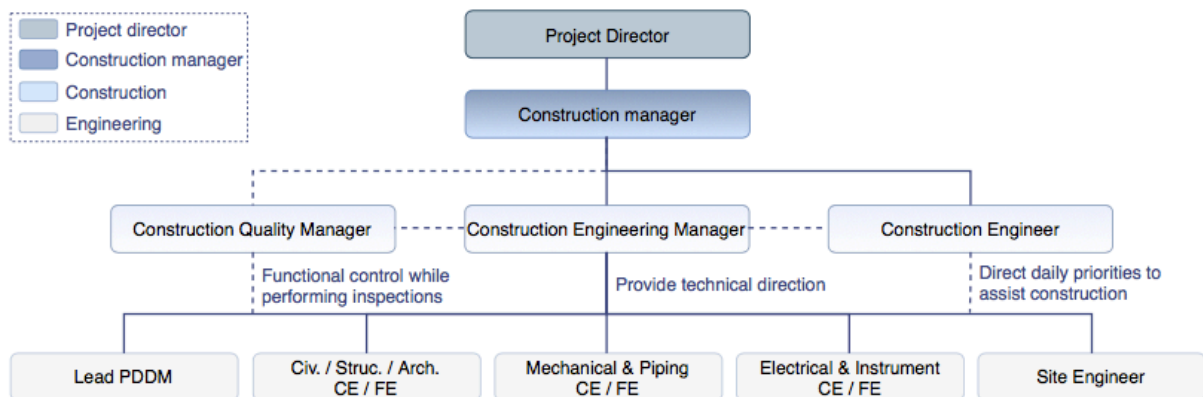


Figure 18: Constructability team during FEED and detailed engineering (based on CII 310-6 (2015))

3.4 CONSTRUCTION-DRIVEN: FROM FIREFIGHTING TO FIRE PREVENTING

As described in the previous sub-chapters, the role and responsibilities of construction management in a construction-driven project has changed in comparison to traditional execution philosophies. In Construction-Driven Execution, the role of the construction manager can be compared to that of project manager, especially on large and complex projects such as in the oil and gas industry. In fact, the construction manager is responsible for managing the execution part of the project.

Traditionally, construction managers are focused on making operational decisions during construction and conducting reviews over some tactical decisions made in the home office during detailed design. When a project becomes construction-driven, construction managers focuses more on tactical and strategic decision made in the FEED. After FEED is delivered and pre-works on-site starts, construction managers shift more to an operational decision-making focus. As shown by figure 19, there is a clear correlation between the scale and quantity of the levels of decision making, and how decisions evolve over time. Little strategic decisions are made, while the scope and impact of these decisions is very large. The contrary applies to operational decisions; these decisions are made late in the process, have little impact on other fields, and occur in large quantities.

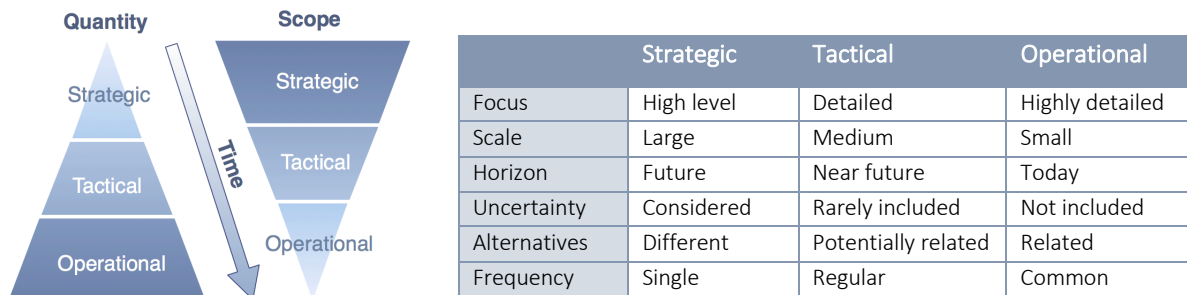


Figure 19: Levels of decision-making (Fluor, 2017)

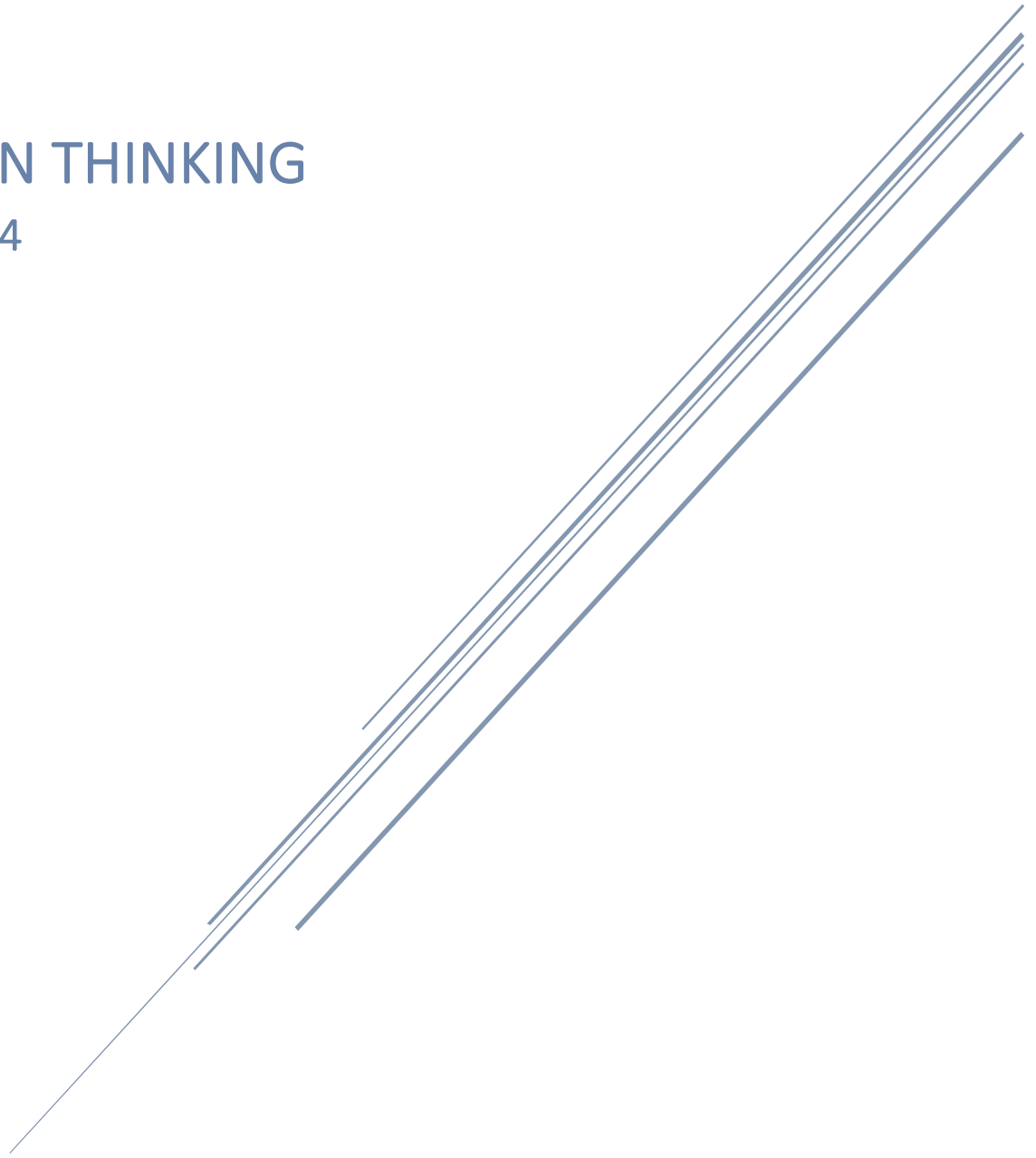
Strategic decisions are long-term in their impact and affect and shape the direction of the whole project (Fluor, 2017). These decisions are made by senior managers in the very start of the project and concern the project execution plan, or decisions to execute the project as modular instead of stick built, for instance. Tactical decisions help to implement the strategy. On a typical modular project this includes decisions such as; where to fabricate the modules, how to deliver them to site, and what is the contracting strategy going to be. Operational decisions relate to the day-to-day running of the project. These decisions are routine and include simple operational decisions such as; select how the module is to be secured during transportation, how are the modules tested, and how many lifting points are needed in the design (Fluor, 2017).

On-site, construction managers typically focus on operational decision-making. The problems on-site often occur under pressure and require a quick solution to solve the problem. In a construction-driven FEED, construction managers are more focused on tactical and strategic decision-making, in which the role of construction managers shift from firefighting to fire preventing. By doing so, the construction managers aim to prevent potential mistakes from happening during later stages in the project life cycle.

This transition has a major impact on the approach construction managers should apply to solve issues in their daily functioning. Strategic and tactical decisions are much more complex and create difficulties for the construction manager to frame the problem situation upfront. Since construction managers are not used to this kind of decision-making, it is assumed they require a practical tool enable them to identify, approach and solve these complex issues in FEED.

DESIGN THINKING

Chapter 4



Chapter 4 provides the theoretical framework of design thinking and the Project Design School. First, an alternative approach to project management research (Designing Project Management) is suggested by the Project Design School in sub-chapter 4.1. Then, the essence of design thinking and the application of design thinking in project management practice is described in sub-chapter 4.2. Finally, the Project Design Cycle framework, is elaborated in sub-chapter 4.3. This chapter delivers data to answer sub-question 2 and serves as input for the case analysis in chapter 5.

4.1 DESIGNING PROJECT MANAGEMENT

This sub-chapter describes the theoretical framework of Designing project management. First, the focus of recent project management research is determined. Secondly, the essence of complex problem-solving practices in project management is described. Finally, an alternative approach to project management (designing project management) is described based on the research of the Project Design School. This alternative approach focusses on the application of design thinking in project management to solve complex problems.

4.1.1 PROJECT MANAGEMENT RESEARCH

The focus of project management research has shifted a lot over the last 20 years. Traditional project management research (also known as type 1 project management) applies a knowledge approach which is based on rationality. This plan-then-act approach is reflected by the Project Management Bodies of Knowledge (PMBOK's), such as PMI (2013). Ahern (2014b) confirms this by stating that traditional project management research revolves around designs, plans and related activities performed by project team members to accomplish predetermined targets concerning time, cost and schedule.

However, the investigation of specific topic areas in project research is limited as a consequence of this traditional approach (Ahern et al., 2014b). Morris (2003) adds that project management is more than an execution profession for completing a pre-determined set of tasks to scope, time and budget. Project management also involves front end work in which the project manager is concerned with the strategic approach, compliance issues (quality, HSE, etc.), financing, and management of the development of the design before moving to construction. Subsequently, the project manager has to plan, monitor, optimize, and deal with risks and changes throughout the project life cycle.

Even though project managers apply standardized practices and techniques on their projects, many projects still underperform: objectives are failed to be delivered and the project is running over time and budget. Morris (2013) has found that many factors behind the underperformance of projects can be traced back to the front end of the project. Heintz et al. (2015) show that these findings reflect a shift in focus within project management research. Many researchers have tried to change the perspective of project management in the last 20 years. These authors can be summarized in the following research-streams (Heintz et al., 2015):

- Rethinking of project management (Winter et al., 2006; Cicmil et al., 2006; Svejvig, 2015),
- Reconstructing project management (Morris, 1994; Morris, 2013),
- Making projects critical (Cicmil et al., 2006),
- Making projects Scandinavian (Packendorff, 1995; Lundin, 1995; Sahlin-Andersson, 2002),
- Recasting projects as practices (Blomquist, 2010).

Interesting to observe is that all of these authors conclude that traditional project management is not addressing many of the complex and important issues which project managers are confronted with these days. Even though this limitation in traditional project management is identified, Morris (2013) and Svejvig (2015) has come to the conclusion that little of these researches has led to considerable advances or improvements in tools, practices or education for project management practices.

4.1.2 PROBLEM-SOLVING AND ORGANIZATIONAL LEARNING IN COMPLEX PROJECTS

Continuing on project management research, Ahern et al. (2014b) developed an integrated view of project management and practices in which he sees complex projects as learning organizations due to knowledge uncertainty. This view is grounded in problem-solving learning and organizing. When looking at a project’s complexity, Shenhar (2001) includes three dimensions in his UPC model: uncertainty, pace and complexity/scope. In the UPC model, pace reflects the “*speed and criticality of time goals*”.

An important characteristic of project management throughout the project life cycle is problem-solving, which is often seen as a heuristic practice in projects, rather than a central creative aspect of project management practices (Lenfle & Loch, 2010). Ahern et al. (2014a) has collected several researches about modes of problem-solving learning and combined them to identify four types of problems (table 1). This table shows that the dynamics of the problem domain, with respect to the knowledge change from a previous level and the pace of the change, are associated with different modes of problem solving (Ahern et al., 2014a).

Table 1: Modes of problem-solving learning (Ahern et al., 2014a)

Authors	Single-loop problems	Double-loop problems	Complex problems	Wicked problems
Cleden (2009)	Known knowns (knowledge)	Known unknowns (risks)	Unknown knowns (untapped knowledge)	Unknown unknowns (uncertainty)
Showden (2002)	Known	Knowable	Complex	Chaos
Weinberg (2001)	Simple systems	Machine systems	Organized complexity	-

Ahern et al. (2014a) state that complex projects cannot be fully specified at the start and require continuous learning during the project life cycle. This is in contrast with traditional projects, which are expected to be executed with little learning anticipated (Ahern et al., 2014a). Characteristics of a problem domain in complex problem-solving are defined by Argyris & Schön (1996) and Newell & Simon (1970) as unstructured, non-linear, little pre-given inputs or outputs, and little feedback. In complex problem-solving the key role of the project manager is to frame the problem to be resolved (Daft and Weick, 1984; Teece et al., 1997).

A second important characteristic of project management is learning (Bredillet, 2004). Methods and procedures to stimulate and improve learning within a project can be found in several areas of project management, including building and construction project management (Storm & Savelsbergh, 2014). These authors also mention that learning between projects is just one side of the coin, the other is learning within projects. Storm & Savelsbergh (2014) looked at the research streams concerning the topic of learning in projects and defined the following three areas:

1. Operational learning: used to illustrate the learning curve that occurs when doing repetitive tasks (Eden et al., 1998; Arditi et al., 2001; Lam et al., 2001; Cooper et al., 2002).
2. Managerial learning: aimed at finding lessons learned after the project is finished, to be applied in future projects (Busby, 1999; Cooper et al., 2002; Schindler and Eppler, 2003).
3. Project-based learning: used as a tool to implement objectives of organizational learning (Rhodes and Garrick, 2003).

Project-based organizations (like Fluor) work on project life cycles, which are long, non-repetitive, developmental, and based upon special assembled teams that are disbanded upon the project’s completion. Members of the project teams often sit together for the first time, which means it is difficult to create an appropriate ‘organizational learning’ culture, access and internalize previous learnings, and

locate knowledge assets. However, the long life cycles and its gated process do offer a good framework to organize learning opportunities in a disciplined manner (Morris, 2003).

Li & Love (1998) classified research in managerial problem solving into two categories: cognitive processing models and decision support systems. Both approaches have led to models that increase the understanding of construction problem-solving. In this manner, cognitivism focusses on explaining the human behavior in construction problem solving, while decision support system focusses on providing a rational basis for investigating the step-by-step performance of problem-solving activities (Li & Love, 1998).

4.1.3 AN ALTERNATIVE APPROACH TO PROJECT MANAGEMENT: PROJECT DESIGN SCHOOL

Heintz et al. (2015) state that a new approach to project management education is required when taking into account all the critique of current traditional project management practices. Recent research findings of Svejvig (2015) and O’leary (2013) highlight the importance of understanding construction projects as social system in which different goals, perspectives and meanings are aligned and interplayed in a complex manner. Due to the increased complexity of projects, current approaches to project management are not sufficient anymore to support project managers carrying out their function (Heintz et al., 2016).

As earlier discussed by Morris (2013), an alternative approach should focus on the client’s strategy and goals. This new approach should centralize the social and environmental needs into project management practice, which entails that the project manager must focus on the early phases (front-end loading) of the project. Heintz et al. (2015) adds that this alternative approach should be designed around Ahern’s et al. (2014a) notion, in which project management is seen as a problem-solving practice, rather than gaining competence in using pre-defined project management tools. Also, this alternative approach should incorporate learning as fundamental element in project management.

Heintz et al. (2015) conclude that design thinking is a necessary tool when the problem of the project manager includes the determination of a course of action, which changes the present state into a more desirable one. Furthermore, Heintz et al. (2015) state that this approach should be built around a framework that provides project managers the ability to understand the problem situation, in order to determine an effective course of action by drawing upon the entire repository of project management research, knowledge and tools.

The core purpose of Heintz et al. (2016) research is to change project management education, by focusing on ‘how to be a project manager’ instead of ‘how to use the systems of a project manager’. In this new approach, project management is seen as a process of designing and enacting courses of action and preferred situations. As project managers are found in many roles in construction projects, the use of tools and insights of traditional projects management still remains important. Thus, project managers still have to be able to apply a wide range of project management approaches to solve many types of problems. It is important that project managers continue to learn to adapt and improve their skills (Heintz et al, 2015).

4.2 DESIGN THINKING IN PROJECT MANAGEMENT

The alternative approach to project management research by the Project Design School is elaborated in this sub-chapter. First, management as design is described, followed by design thinking theory. Then, the essence of design thinking is determined, and finally design problems are given, which can be found in project management practice.

4.2.1 PROJECT MANAGEMENT AS DESIGN

Various researchers have looked into the application of design thinking with the aim to approach the general types of complex problems encountered in management due to its ‘liquid and open character’ (Boland, 2004; Martin, 2009; Brown, 2008). Boland and Collopy (2004) describe the advantages of design thinking in management contexts by comparing the ‘decision attitude’ with the ‘design attitude’ in problem-solving. They state that in a decision attitude towards problem-solving it is assumed that alternatives are easily formed, while the decision to choose the best option is difficult. In contrast, the design attitude assumes it is difficult to create good alternatives, but once you have developed a great option, the decision is easily made.

Many business and management communities have expressed their interest in ‘design thinking’ to address complex and open-ended challenges (Stacey, Griffin, & Shaw, 2000). Dealing with these open and complex problems leads to a particular interest in the ways designers create ‘frames’, and the way designers deal with frames in their field of practice (Heintz et al., 2016). This sudden interest to adopt and apply design thinking practices in other fields calls for a clear definition, definite knowledge, and a toolbox. Dorst (2011) fulfills this demand by writing the paper *“the core of design thinking and its application”*. In this paper, Dorst (2011) explains the basics of problem-solving reasoning, the creation of frames, and the complex relationship between framing practices and problem-solving. The content of this paper is summarized in the following sub-chapter.

4.2.2 THE CORE OF DESIGN THINKING AND ITS APPLICATION

Dorst (2011) states that it is important to realize that designs are developed as a response to a particular need in order to understand the complex and puzzling field of design practices. The core challenge of design can be found in basic reasoning patterns, which are used by humans to solve problems. In a basic reasoning pattern, different ‘settings’ of known and unknowns are compared in an equation to find a result (figure 20, left). This equation changes in design (and other productive) professions as the result is not a matter of fact, but rather the acquisition of a certain value (figure 20, right).



Figure 20: Standard problem-solving reasoning (left) and Design problem-solving reasoning (right)

Depending on the form of problem-solving, different reasoning equations are used. Dorst (2011) describes deduction, induction, abduction-1 and abduction-2. In each equation the focus shifts between ‘what’ (a thing), ‘how’ (a working principle), and a ‘result’ (something observed) or a ‘value’ (aspired). These reasoning equations and the topic of framing are elaborated below, based on Dorst (2011).

- Deduction (figure 21, left): it is known what is required and how one can get to there, which allows for the result to be predicted. For example: stars are in the sky (what), and it’s known how fast they move (how), then it can be predicted what their positions are in one hour (result).
- Induction (figure 21, right): it is known what is required and what the result is. By thinking backwards, it is possible to find the working principle. For example: stars are in the sky (what),

one hour later change in position is observed (result), then an equation to find how fast they moved is created (how). Proposing working principles that could explain observed behavior (a hypothesis) is seen as a creative act.

- Abduction-1 (figure 22, left): it is known what the aspired value is (value), and what working principle (how) would help to achieve the aspired value. The what (object, service, system), which gives definition to both the problem and the potential solution, is missing. This is often what designers and engineers do. For example: create a design that operates with a known working principle, and within a set scenario of value creation. The final drawings of the design will serve as the ‘what’. This is a form of closed problem-solving, which is applied on daily basis by organizations in various fields (Dorst, 2006).
- Abduction-2 (figure 22, right): it is only known what the aspired end value is. The challenge is to find out ‘what’ to create, whilst there is no known or chosen working principle that can be trusted to deliver the aspired value. This is a more complex and open form of problem-solving reasoning, which is closely associated with conceptual design.
- Framing: in a problem situation like abduction-2, experienced designers create a frame to tackle the complex creative challenge of coming up with both a thing and its working principle to obtain the aspired value. The reasoning behind framing is (Dorst, 2011): *“if we look at the problem situation from this viewpoint, and adopt the working principle associated with that position, then we will create the value we are striving for”*.



Figure 21: Deductive problem-solving (left) and Inductive problem-solving (right)



Figure 22: Abductive-1 problem-solving (left) and Abductive-2 problem-solving (right)

4.2.3 THE ESSENCE OF DESIGN THINKING

As described by Dorst (2011), the core of design thinking is characterized by abduction, which implicates that design thinking is solution-oriented (Lousberg et al., 2015). In abduction, searching and experimenting is required to get to the desired situation. In this process the problem has to be reframed, after which it is experimented with a number of possible solutions in order to see if the desired outcome (aspired value) is indeed achieved. This searching and experimenting is a distinctive feature for applying design thinking in management practices, in order to approach complex situations (Lousberg et al., 2015)

The framing step distinguishes design thinking from conventional problem-solving such as induction, deduction and abduction-1. According to Dorst (2011), framing is the core thing that design practices could bring to other organizations to approach open and complex problem situations. Even though the design reasoning process looks quite complex, it can be a simple routine process. If the designer (or problem-solver) dealt with a problem before and is familiar with the situation, a frame can be an integral part of the way the designer is reading the situation.

The core challenge of design thinking is about the performance of a complex creative feat in which a thing (object, service, system) and a working principle is created simultaneously. Due to this double creative step, designers are required to come up with concepts for the ‘what’ and ‘how’ and test them

in conjunction (Dorst, 2011). By doing so, the problem and solution are developed at the same time Lousberg et al. (2015) describe the application of the abstract process of design thinking in four sequential steps:

1. An understanding of the problem situation is created, by which the complexity of the issue is recognized. This allows the project manager to define the aspired value.
2. The complex issue can best be approached by working backwards, in which the project manager starts working from the aspired value that needs to be created. After reasoning backwards from consequences, the project manager develops an initial frame. This framing process is actually a form of induction.
3. When a promising or credible frame is created, the project manager can move from induction to abduction-1. By creating a thing (object, system, service) in order to complete the equation. This is an important step, since it is only possible to test the design's value when the equation is completed.
4. After the creation of a thing and a working principle, the value is tested by reasoning forward. This is actually part of deduction, in which it is assessed whether the thing and working principle together perform well enough to create the aspired value. Only after the performance of this assessment, the proposed frame can be accepted as definitive. Until this point, the frame was only a possible way forward. When the design has shown to lead to the aspired value, the frame becomes definitive.

4.2.4 DESIGN PROBLEMS IN PROJECT MANAGEMENT

Design problems in project management come in several scales, in which the largest can be seen as the design of the project and its processes, and many smaller ones concerning designing intervention to keep the process on track. Some main activities include (Heintz et al., 2015; Heintz et al., 2016):

- Overall organization of the project and shaping the project team
- Creating construction schedules
- Stage-gate reviews
- Forms of contracts, tendering, and selection of partners
- Developing briefs and budgets
- Structures of reporting
- Composing the design teams

Even though this list mainly concerns strategic decisions, design is also applicable for construction project managers when solving day-to-day problems (Heintz et al., 2016). Some of these day-to-day problems consist of unpredictable events caused by either members of the project team or by exogenous events that must be dealt with (Heintz et al., 2016). All can be seen as design problems, as the construction project manager must inform himself about the current situation and determine a course of action which will lead to the desired result or aspired value. Both kinds of design problems (mapping the future course of the project and solving daily problems) occur under high uncertainty and in dynamic situations in which exogenous factors will likely play a significant role. (Heintz et al., 2016)

The multiplicity and ambiguity of project goals and resources (differently perceived by different actors), and the interrelation between several choices to be made (each containing a different frame), raises the complexity of some project management problems to the level of a wicked problem (Heintz et al., 2015). A wicked problem (table 1) is described as a problem where there is no (mathematical) optimized solution available for decision making (Coyne, 2005; Rittel & Webber, 1973), and therefore a problem type in which design thinking could be very useful.

4.3 THE PROJECT DESIGN CYCLE

As described in the chapter 1.2 and 4.1.3, the Project Design School proposes an alternative approach to project management research. In order to educate project managers and students in the field of project management they have created the Project Design Cycle. The elements of the Project Design Cycle and its educational purpose is elaborated below.

4.3.1 CHARACTERISTICS OF THE PROJECT DESIGN CYCLE

A big advantage of approaching complex problems in a design thinking way, is the processes of looking for the actual problem. Situations, project team members and other actors are often not transparent, which makes it difficult to find a solution that actually solves the problem situation. By applying design thinking, the situation is understood first, after which its underlying nature and problem owner are determined. Only then, a solution is designed (Heintz et al., 2015). Various design thinking models are described in relevant literature (Lousberg et al., 2015). All have the following three activities in common (Van Doorn, 2004; Van Doorn, 2012):

- Analyze the problem
- Synthesize a solution to the problem
- Evaluate and test the solution against the problem

Based on literature research, Lousberg et al. (2015) developed a cyclic design model, which is applied within the Project Design School. The Project Design Cycle enables and educate project managers and (graduate) students in project management to apply design thinking practices in order to cope with complex situations, which are often unexpected, insecure, unstable and unique.

The foundation of the cycle is based on generating and testing (Newell & Simon, 1970). However, the Project Design Cycle is also quite similar and comparable to the *'Plan-Do-Check-Act'* cycle of Deming (1952), and to the learning cycle of Kolb (2000), consisting of the elements *'Concrete Experience-Reflective Observation-Abstract Conceptualization-Active experimentation'*. The key in Kolb's learning cycle is experimental learning, which enables people to achieve the highest stages of learning (Moon, 1999). Also, fundamental in this learning cycle is reflection as a reflective habit (Smith, 2001), which is seen as inherent to design thinking by Lousberg et al. (2015). As described in chapter 4.1.2, both design and management rely on learning and feedback from previous situations, in order to arrive at better outcomes than otherwise would have been realized.

The Project Design Cycle elements and its characteristics are shown in figure 23 (next page) and further elaborated below. This figure and the description are based on the papers of Lousberg et al. (2015) and Heintz et al. (2016).

AWARENESS

The first element of the cycle is awareness. As the word implies, the aim is to establish awareness of the current situation by recognizing the problem. Both the formal project (as captured in the project information) and the informal social situation (status and state of actors and stakeholders) are encompassed in this element. Awareness has to be created of 'what is going on', 'who's doing what', the goals, plans, and intentions. In other words, it's about recognizing that something needs to be done. A significant component of awareness is sense-making, in which the project manager considers what metaphor (or project management perspective) best illustrates the problem situation. This metaphor can then be used by the project manager to describe the current situation.

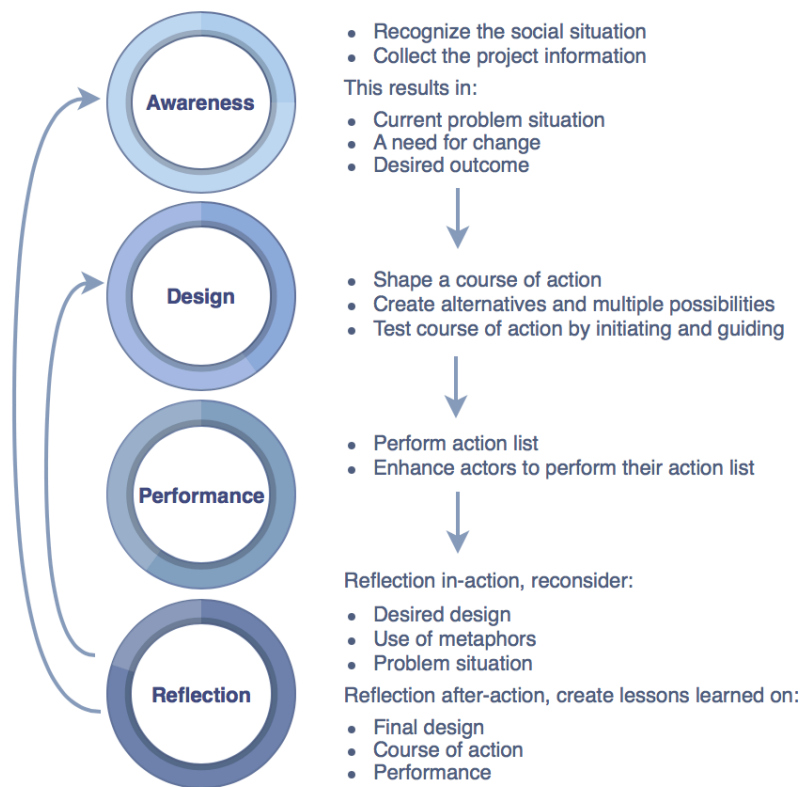


Figure 23: Characteristics Project Design Cycle (own figure)

DESIGN

The design element refers to the shaping of a course of action, which is based on the outcome of the awareness element and contains: an understanding of the current state, a need for change, and (perhaps) a desired outcome. The course of action contains a set of actions for the actors in the project to do, but also includes tasks which the project manager must perform in order to initiate and guide other actors to carry out their required actions. The open and free approach of design thinking is important in this matter in order to generate multiple alternatives and possibilities. Besides generating ideas, the design element should also include testing of the ideas. A designed course of action also has to be tested in some sense. The principles of design thinking are incorporated in this element.

PERFORMANCE

The third element is performance. This element refers to the performative aspect of management and presents the set of actions the project manager has to perform himself in order to reach the desired situation. As a project manager it is not just a matter of creating the design, in design and construction management a performance is required to change people’s minds and actions. In this context, performance can be seen as acting in order to change one’s behavior and actions.

REFLECTION (IN-ACTION AND AFTER-ACTION)

The fourth element is reflection, which can be either in-action or after-action. In the first sense, reflection refers to reflection while performing, which is introduced by Schön (1983) and defined as “*thinking about doing something, while doing it*”. Reflection after-action refers to reflection as a separate moment after the performance is completed. This type is recognized in both Deming’s management cycle (1952) and Kolb’s experiential learning cycle (2000). The aim of this element is to reflect on the designed course of action and its performance to draw any lessons learned.

By reflecting, the project manager might consider changing the choice of metaphor or the initial description of the situation, which indicates the cycle starts over and repeats itself. Incorporating this element in the cycle ensures that reflection and learning becomes integrated into the daily functioning of project management. This provides both project managers and students with the opportunity to both improve their knowledge and skills over time and to gain increased insights of the current project situation.

4.3.2 EDUCATIONAL PURPOSES OF THE PROJECT DESIGN CYCLE

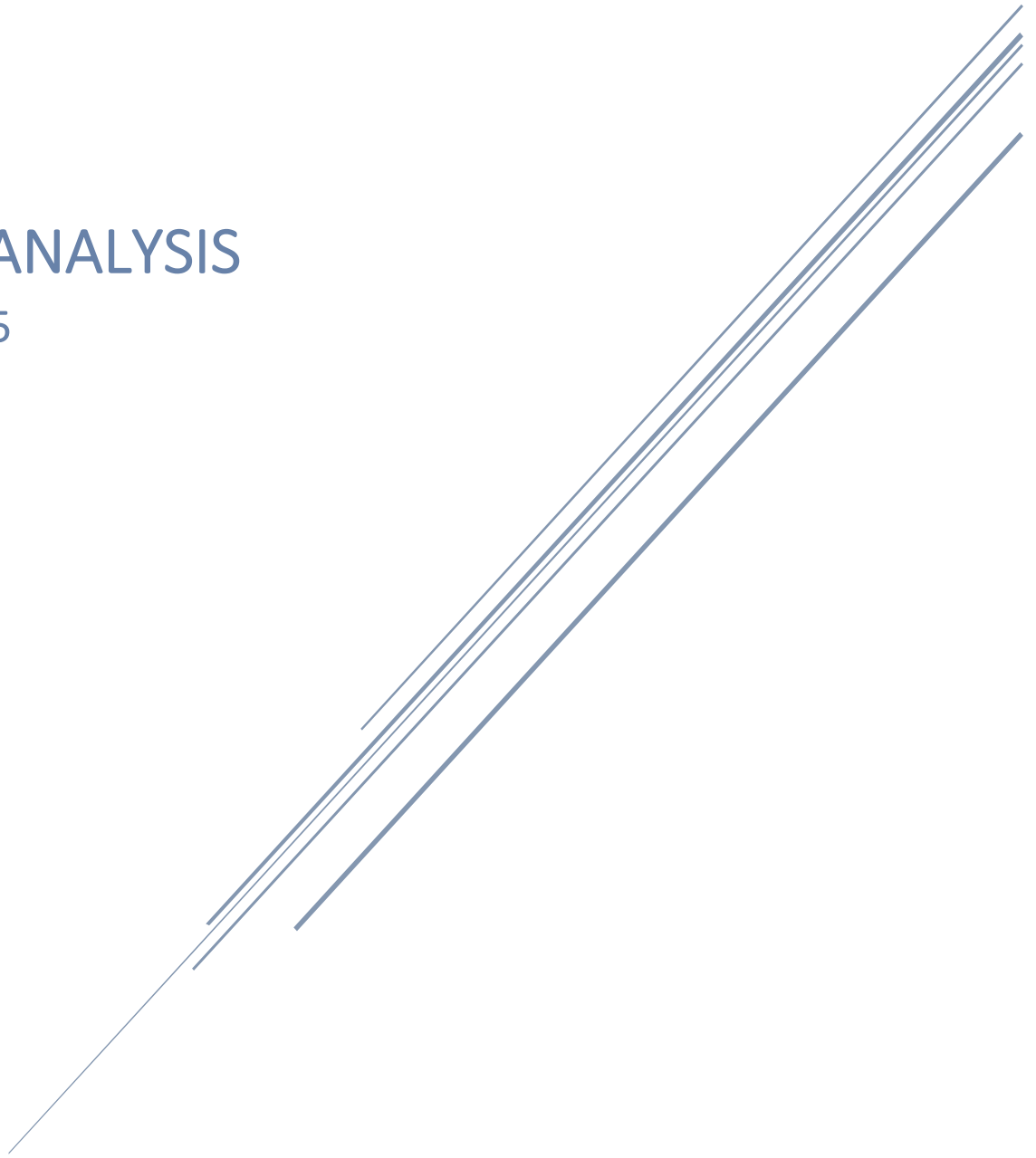
When facilitating learning in projects, soft management-skills are just as important as hard system-skills (Berggren & Söderlund, 2008; Davies & Hobday, 2005). This process perspective for projects with intrinsic learning, could have implication for the education of project management students (Ahern et al., 2014b). Heintz et al. (2015) adds to this, that not only project managers need to use this design thinking approach with awareness to learn from their performance, but project management students will also have to be trained in order to learn from their own performance as a project manager. Heintz et al. (2015) propose that management games and training related to cases would be most suitable to train people with these skills.

To become a fully-fledged project manager, it is an important pre-requisite to (1) have knowledge of and having worked with project management systems, and (2) develop the capabilities highlighted in the Project Design Cycle. By this, graduate project managers do not only learn how to be employed as a junior project manager, but also learn how to be able to successfully grow into more senior roles (Heintz et al., 2016). The Project Design School believes that education practices in project management should address the elements of the Project Design Cycle as integral to project management. Importantly, the focus does not lay on training project managers to use the cycle step-by-step in practice, but rather to incorporate the cycle into their practices in which project managers approach the issues of the separate elements in a more considered and professional manner.

Heintz et al. (2015) state that students get lost in chasing the ever-changing project management tools and techniques when focusing on the lower-level actions of a project manager. Therefore, they describe it is particular important to educate (future) construction project managers to focus on the higher-levels actions of the individuals. As these higher-level actions concentrate more on the cognitive and social skills, the focus on personal awareness, design, performance and reflection makes the Project Design Cycle an ideal approach for the education of students and professionals (Heintz et al., 2015).

CASE ANALYSIS

Chapter 5



Chapter 5 concerns the empirical data collection and case-study analysis. First, the selection process of the case-studies and related respondents is described in sub-chapter 5.1. Then, methodology of the empirical data collection is described in sub-chapter 5.2. The empirical research consists of two semi-structured interviews with five respondents, in which the first interview serves as a base for the second interview. The organization and analysis of the collected data of the interview transcripts is determined in sub-chapter 5.3. Finally, the case-studies are analyzed in respectively sub-chapters 5.4 (case A), 5.5 (case B) and 5.6 (case C). Each case-study is analyzed by identifying potential complex issues in the first interview, discussing these complex issues in the second interview, analyzing whether the Project Design Cycle elements are recognized in the respondent's approaches, and comparing the findings of respondents in the same case-study project. This chapter delivers data to answer sub-question 3 and serves as input for chapter 6.

5.1 CASE-STUDIES AND RESPONDENTS

The empirical research contains three case-study projects and five respondents, which are part of the related construction management teams. This sub-chapter describes the selection process of the case-studies and related respondents and gives their main characteristics.

5.1.1 SELECTION CASE-STUDIES AND RESPONDENTS

CASE-STUDY PROJECTS

The characteristics of each case-study project needs to be similar in order to keep the collected data comparable. Each project is characterized by five topics; region, business line, size (TIC), contract type during FEED and EPC, and project phase (figure 24). Obviously, one of the main requirements is that all projects should apply the Construction-Driven Execution philosophy as described in chapter 3. The case-study projects are chosen in consultation with the Regional Construction & Fabrication manager in the Hoofddorp office.

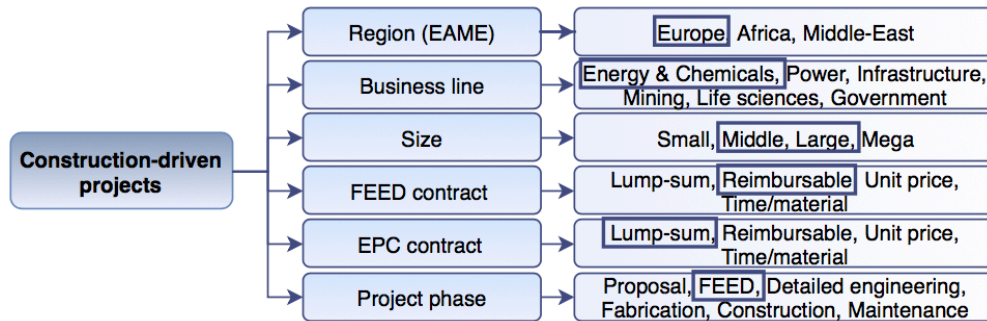


Figure 24: Characteristics & demarcations case-study projects

- All case-study projects are all engineered and constructed in Europe, which is part of the EAME region (Europe, Africa and Middle-East). This demarcation is important because of potential diversity between different regions. As all projects are in Europe, less attention has to be paid to differences such as culture, diversity, craftsman skills, and organizational structures.
- All projects are within the business line energy & chemicals (i.e. oil & gas and petrochemicals).
- The size of the projects is medium to large, which means the total installed costs (TIC) will range from one hundred-million to one-billion euros.
- All projects currently have a reimbursable FEED contract, which are converted to an EPC lump-sum contract when the projects advance to later stages of the project life-cycle.
- The current stage of each project ranges from pre-FEED (FEL 2) to FEED (FEL 3) at the time of this research. From a design thinking point of view, these phases are most interesting for this research since problem situations are more complex as they have to be solved upfront and concern multiple phases and disciplines.

The case-study projects that are selected for this research are shown in table 2. Due to confidentiality reasons, the names of the project and respondents have been censored.

Table 2: Information case-study projects

Project	Project type	Design	Build	TIC (€)	Contract FEED	Contract EPC	Phase
Case A	Ammonia plant	NL	POR	800 million	Reimbursable	Lump-sum	FEL 3
Case B	Hydrocracker	NL	NL	400 million	Reimbursable	Lump-sum	FEL 3
Case C	Hydrogenation plant	UK	UK	450 million	Reimbursable	Lump-sum	FEL 2

RESPONDENTS

Criteria for the respondents within the cases are based on their function, background, years of experience in construction, and availability. In total five respondents are selected for the empirical research. The details of the selected respondents are given in table 3. Again, the names of the project and respondents have been censored. To summarize, all respondents should at least:

- hold a position as a site- or construction manager at one of the case-study projects,
- have 15 years of experience in construction of which a considerable amount is spent in the field,
- have obtained a bachelor's degree,
- be available during the time of this research.

Since site managers are in fact more senior and experienced construction managers, and the difference in function only shows in hierarchy and not in functional content, both are referred to as construction managers. This done to prevent confusion throughout the research.

Table 3: Details respondents

Respondents	Nationality	Education	Experience in construction	Years in the field
Case-study A				
Respondent A1	English	BSc Construction management	18	10
Respondent A2	American	BSc in Civil, Architectural & Construction Engineering	37	-
Case-study B				
Respondent B1	Dutch	BSc Civil engineering	30	-
Respondent B2	Dutch	BSc Mechanical engineering	23	15
Case-study C				
Respondent C1	English	BSc Industrial technology	15	8

5.1.2 DESCRIPTION OF CASE-STUDIES AND RESPONDENTS

The case-studies and respondents are explained in more detail below. First, the characteristics and drivers of the projects are described, followed by a brief description of the construction managers that are interviewed. This information is extracted and retrieved from project documentation and preliminary conversations with higher management of the construction management department.

CASE-STUDY A – RESPONDENTS A1 & A2

Case-study A's scope contains the design and construction of an ammonia plant, which is part of a larger existing plant in Portugal. The project will be designed in Fluor's Hoofddorp office and eventually constructed on the current plot in Portugal. The total installed costs are approximately 800 million euro. Fluor is on a reimbursable contract for the front-end engineering and design (FEED). After FEED, the contract will be converted into an EPC lump-sum contract.

The main project driver for the client is cost. Time is less of an issue as the project is an extension of an existing plant that is already in production. Because the contract is on lump-sum terms, all profit and losses are Fluor's. Therefore, from a Fluor perspective the main drivers are schedule and cost. Fluor's main execution strategy with regards to this project is modularization. The goal of modularization is to reduce the required manpower on-site. This is one of the main drivers as it increases safety (by moving work off the site) and because of expected resourcing problems due to several competitive sites nearby.

Two construction members of Project A are interviewed, namely respondent A1 and respondent A2. These construction members perform a crucial role in a construction-driven FEED phase as they are responsible for the construction execution strategy, leading the constructability program, and alignment of engineering, procurement and construction disciplines.

CASE-STUDY B – RESPONDENTS B1 & B2

Case B represents the design and construction of a hydrocracker plant. This hydrocracker will be part of a larger existing plant in the Netherlands. The design will also be developed in the Netherlands as Fluor Hoofddorp is awarded with the reimbursable FEED contract. Fluor will also be responsible for the EPC lump-sum contract. The total installed cost of this project is approximately 400 million euro.

The main driver of this project is schedule. Environmental regulations require the client to adapt their current plant in order to meet new standards before September 2020. The entire project is scheduled to be built in no more than 28 months. Modular solutions are not possible because the current jetties could not be used for heavy lifting and because the Port of Rotterdam denied using the current quay wall for offloading. Even though modularization is not possible, reducing working at height and scaffolding are still construction's main objectives.

Two construction members of Project B are interviewed, namely respondent B1 and respondent B2. Respondent B1 performed a crucial role in the construction-driven FEED phase as he is responsible for the construction execution strategy, leading the constructability program, and alignment of engineering, procurement and construction disciplines. The construction manager (respondent B2) joined the project later just before the completion of FEED.

CASE-STUDY C – RESPONDENT C1

Project C is part of an existing plant located in the UK. The scope of this project includes a hydrogenation plant with total installed costs of approx. 450 million euro. This project will be designed and constructed in the UK. Fluor is currently in the pre-FEED phase on a reimbursable contract, in which the conceptual design and an initial construction execution strategy of the hydrogenation plant is developed.

Because the key driver of this project is cost, efficiency in the construction phase is of great importance. Advanced Work Packaging (AWP) and Work Face Planning (WFP) are applied to increase the productivity on-site. Also, modular execution is applied to eliminate some of the productivity issues and man-hour requirements from site. Furthermore, the constructability program is installed right from the beginning of FEED to make sure all ideas of the project team are captured.

At the time of this research, the only person within the construction management team was respondent C1. Therefore, only one respondent is interviewed in Project C. Interviewing a construction manager of a different project, or someone of a different discipline, would not be feasible for the empirical research as it wouldn't be possible to compare the data. The main role of respondent C1 in the construction-driven FEED phase is to support constructability, and to set up the project for the next phase of execution. By working with the engineers, procurement and the designers it's aimed to set-up the plot to be constructible and to work on the construction execution aspects of it like planning and the procedures.

5.2 SEMI-STRUCTURED INTERVIEWS

The empirical data collection consists of two rounds of interviews with all five respondents. The aim of the first interview is to define ‘potential’ complex issues, which are then used to structure the second interview in order to analyze how the respondent approaches these complex issues. This analysis is done in a specific chosen software tool named Atlas.TI.

An important side note is that the respondents are not made aware of, nor have any specific knowledge of the objective of this research, design thinking, or the Project Design Cycle during the length of the empirical data collection. The respondents will not be informed until the final part of the second interview. This enables a high-level of objectivity to be preserved throughout the entire empirical research.

5.2.1 FIRST INTERVIEW: IDENTIFY POTENTIAL COMPLEX ISSUES

The theoretical framework of chapter 3 serves as a basis to define the topics of the first interview. Also, project documentation is gathered and analyzed to find background information of project specific topics. The topics and problem situations discussed during the first interview concern the role and responsibility of the respondent (Q1-Q8), Construction-Driven Execution (Q9-Q14), modularization (Q15-Q19) and constructability (Q20-Q22). These themes are extracted from the theoretical framework in chapter 3 and either represent complex (problem) situations or contribute to the complexity of other situations. Questions asked regarding these topics concern the:

- Role and responsibilities
- Handling unexpected situations
- Identifying complex issues
- Solving complex issues
- Using previous experiences
- Reflecting practices

The questions of the first interview are listed in Appendix A. The transcriptions of the first interview can be found in a separate appendix, which is available on request. The transcripts are analyzed to identify potential complex issues in the answers of the respondents. Three to five potential complex issues are determined per respondent, resulting in a total of twenty issues among all respondents. Each issue is compared to the TOE-Model of Bosch-Rekvelde et al. (2011) to define elements that contribute to the technical (T), organizational (O) and external (E) complexity of an issue. Furthermore, the problem situations (as defined by the respondents) are summarized to describe the problem situation.

5.2.2 SECOND INTERVIEW: IDENTIFY PROJECT DESIGN CYCLE ELEMENTS

The potential complex issues defined in the first interview are applied as a framework for the second interview. The objective of the second interview is to get in-depth information and a better understanding of how the respondents approached the problem situations.

Additional information is gathered by observing some of the respondents during constructability meetings. In these meeting several disciplines sit together to discuss and solve (complex) problem areas. Since construction managers lead these multidisciplinary meetings, it is an opportunity to observe and evaluate their behavior in day-to-day activities. The main goal of these observations is to get a better understanding of the problem situations that occur in their daily practice and to detect any problem-solving approaches. The information gathered in these meetings is used to provide guidance in the second interview. By being able to ask more specific and directing questions, it is expected to obtain

more workable data. Since the sole purpose of the information obtained in these meetings is processed in the questions of the second interview, no further attention will be paid to the content of these meetings.

The aim of the second interview is to assess whether the respondents apply design thinking when performing their daily function. Thus, whether they are focused on analyzing the problem by developing various solutions, as this determines the searching and experimenting nature of managing as design, contrary to the common view on managing as choosing between ready-made options presented (Lousberg et al., 2015). Also, the focus lays on the application of the Project Design Cycle elements. Therefore, per potential complex issue it is questioned:

- Whether the respondent considers the issues as complex and why (Q1),
- What his approach was to approach the problem situation and find a solution (Q2),
- Whether he reflected on his approach or retrieved any lessons learned (Q3).

The objective of the first question is to evaluate the complexity behind the issue; is the issue also perceived as complex by the respondent, and if so, what makes it complex. This question also serves as a check to determine whether the issue is correctly defined as complex. The objective of the second question is to evaluate the process the respondent went through when approaching the issue. This is used to assess whether the respondent incorporated design thinking principles by applying the Project Design Cycle elements. The aim of the third question is to evaluate whether the respondent reflects during or after solving the issue. Again, these three questions are repeated for each individual issue.

After discussing all complex issues, the reflection practices at Fluor are questioned (Q4-Q6). In order to get a better understanding of the reflection practices, it is asked what the current standard is, what the respondent's opinion is about this standard, and how the reflection practice could be improved.

Finally, the principles of design thinking and the Project Design Cycle are explained to the respondents. After the respondent is made aware of the research objective, it is asked whether he recognizes the Project Design Cycle elements in his daily functioning (Q7-Q8), and whether he recognizes them in the office during FEED, or also on-site during construction (Q9). Furthermore, it is questioned if the respondent recognizes the application of design thinking when solving complex issues (Q10). Finally, a potential tool based on the Project Design Cycle (ADAPT) as described in chapter 6.2.2, is presented to the respondent to collect feedback (Q11).

Appendix B presents the questionnaire that is used in the second interview. The transcripts of these interviews can be found in a separate appendix, which is available on request.

5.3 ORGANIZING AND ANALYZING INTERVIEW TRANSCRIPTS

In order to extract practical data from the interview transcripts, the information has to be organized first. The activities undertaken to organize and analyze the data are described in the sub-chapters below.

5.3.1 ORGANIZING INTERVIEW TRANSCRIPTS

The transcripts of both interviews are converted into workable data before the case analysis is performed. This conversion from raw to usable data is done by a method called ‘coding’. The coding process is conducted in five sequential activities and is summarized below.

The first activity performed to identify the complex issues (first interview) and the Project Design Cycle elements (second interview), is to print the transcriptions of the interviews and highlight meaningful quotations that might be of any use to the case analysis. Also, initial impressions and potential patterns are noted.

The second activity is to simulate the highlights, remarks and quotations of the hardcopy version into a digital version of the transcription. This digital version is processed in a qualitative data analysis software tool named Atlas.TI. This is a software tool that simplifies the qualitative analysis of large bodies of textual data. This tool is used to arrange, reassemble and manage the empirical data in a creative and systematic way (ATLAS.ti GmbH, n.d.). After selecting quotations in the digital file, codes are added in order to organize and retrieve the data. The codes are named in a structured way to preserve a clear overview throughout the analyzing process. The codes used in the analysis are shown in figure 25. Further, in figure 26 one of the codes is decomposed to display how the codes are clustered and grouped per case-study, respondent and issue.

Codes

- Complexity
- Awareness
- Design (generating & testing)
- Performance
- Reflection

Figure 25: Codes overview

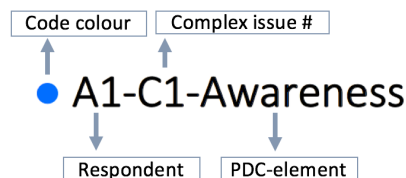


Figure 26: Components of a code

The third activity is to go through all quotations again and to reflect upon the assigned codes. This is done by writing down comments and memos to each selected code. These memo’s serve as explanation on why the particular code is assigned and what the relation with other quotations or codes is.

The fourth activity only concerns the second interview, in which each complex issue is summarized by answering eight questions. The aim of these summarizing questions is to describe the identified codes, design thinking patterns, and any other patterns among the elements. This step is further elaborated in the following sub-chapter.

The fifth activity is to transform the generated data into organized reports. The following reports are generated, clustered and added to the appendices:

- Appendix D: Complex issues defined in the first interview
- Appendix E to appendix I: Summary and coding per issue as discussed in the second interview
- Appendix J: Opinion of the Project Design Cycle by the respondents
- Appendix K: Opinion of reflection practices by the respondents

5.3.2 ANALYZING INTERVIEW TRANSCRIPTS

The case-studies are analyzed in sub-chapters 5.4, 5.5 and 5.6. Below is elaborated how the empirical data is analyzed and structured. The headers used below match the headers the case analysis.

INTERVIEW 1: IDENTIFY POTENTIAL COMPLEX ISSUES

After defining potential complex issues in the transcripts of the first interview, each issue is briefly compared to the TOE-model of Bosch-Rekvelde et al. (2011). This model can be found in figure 30 in appendix C and serves as a tool to determine the technical, organizational and external complexity of issues. The TOE-model contains 47 elements, which all contribute to the complexity. For each issue it is determined what the main complexity is, and which elements contribute to this complexity.

Furthermore, the potential complex issues as defined by the respondents, are briefly summarized in the case analysis. Quotations of the first interview that relate to the identified issues are clustered in Appendix D. The quotations of the associated statements are added as reference and are displayed by an 🗨️-icon. For instance, with “🗨️ 1:1” is meant: ‘quote document#1 : quotation#1’.

SECOND INTERVIEW: IDENTIFY PROJECT DESIGN CYCLE ELEMENTS

The Atlas.TI reports of the complex issues discussed in the second interview (appendix E to appendix I), are summarized in a set of tables to present a clear overview. Based on these tables, a case analysis is performed to assess whether the respondents apply design thinking practices in their daily functioning. An ‘example table’ that is used in the case analysis is given below.

Example table case analysis

Respondent #	1	2	3	4	5	6	7	8
Complex issue #1	●	●	●	●	●	●	●	●
Complex issue #2	●	●	●	●	●	●	●	●
Complex issue #...	●	●	●	●	●	●	●	-

Bulletins (grading)

- Recognized
- Partially recognized
- Not recognized
- Not applicable (only column 8)

Columns (questions)

1. Is the issue determined as **Complex**?
2. Is the **Awareness**-element recognized?
3. Is the **Design**-element recognized?
4. Is the **Performance**-element recognized?
5. Is the **Reflection**-element recognized?
6. Are **All elements** recognized?
7. Are the elements performed in **Correct sequence**?
8. Is there a **Distinction** between **generate and test**?

By defining whether an issue is indeed complex (column 1), and (more importantly) conceived as complex by the respondents, connections and patterns between complexity and the application of design thinking principles are identified. If complexity is fully recognized, both organizational and technical ● is assigned. If the issue is not fully defined as complex (either organizational or technical) ● is assigned. Finally, if the respondent did not recognize any complexity of the issue or if it was not able to retrieve an answer regarding complexity ● is assigned.

Columns 2 to 6 concerns the recognition of the Project Design Cycle elements in the described approach of the respondents. All elements are graded separately (column 2 to 5), after which a summarizing question (column 6) determines if all elements were recognized in the complex issue. ● is assigned if the elements are recognized. ● is assigned if an element is partially recognized or when it was debatable what the element actually was (it could be that the issue is part of a larger cycle). ● is assigned if the element was clearly not recognized. For the grading of column 6 an average is taken.

Column 7 aims to define whether the recognized elements are performed in the correct sequence. ● is assigned when all elements were present and conducted in the correct sequence. ● is assigned either when the elements are performed in the correct sequence even though some elements are missing, or when it is uncertain whether a respondent applied the current sequence in practice. Finally, a ● is assigned when the elements are conducted in the wrong order.

Column 8 verifies that a clear distinction is made between the generating and testing sub-element within design. As construction management is often just one of many involved disciplines, it is expected that the testing/ verification is carried out by other (more specialist) disciplines. ● is awarded when a clear distinction between generating and testing alternatives is observed. ● is assigned when there is little distinction visible. ● is assigned when there is no distinction. If question 3 (design) is assigned by a yellow or red bulletin, a dash (-) is assigned to this column as no observation is possible.

Furthermore, after explaining design thinking and the Project Design Cycle to the respondents, they were asked about their opinion of the Project Design Cycle, if they recognize these themes in their daily functioning, and about their personal opinion of a potential design thinking tool (ADAPT). These findings are briefly summarized under header 'Respondent's opinion about the Project Design Cycle'. All findings with regard to this topic are put in a separate Atlas.TI report, which can be found in [Appendix J](#).

Moreover, the opinion of the respondents with regards to the reflection practices at Fluor are collected. In the interviews it is questioned what the current reflection practice looks like, what their opinion is, and how they would improve it. These findings are put together in a separate Atlas.TI report, which can be found in [Appendix K](#). These findings are further discussed and summarized in the cross-case analysis.

CASE ANALYSIS (RESPONDENT 1 VS RESPONDENT 2)

The findings of the respondents are summarized and compared to each other in order to draw any conclusions with regards to the case-studies. The respondents are compared to each other by analyzing their approach to similar issues. Since the issues of two respondents do not always match, the individual issues are clustered into general categories. By doing so, it has been made possible to observe additional differences and similarities in the approach of both respondents.

General remark

Nevertheless the intentions of the author to reflect on the outcome of the beforementioned topics as objective as possible, the findings remain subject to his interpretation. Additionally, the results rely upon the ability of the author to 'recognize' the Project Design Cycle elements. The respondents are not able to assess the Project Design Cycle elements, as they are not made aware of cycle or design thinking until the end of the second interview. Furthermore, it's important to note that the respondents reflect on their project after the events occurred. This could imply that the answers of the respondents are biased compared to what actually happened at the time of the problem situation. It is important for the reader to consider this when reviewing the case analysis.

5.4 CASE A - ANALYSIS

The case analysis of project A concerns two objects of research: respondent A1 and respondent A2. Both are interviewed twice in order to identify (complex) issues, and to analyze the approach the respondents used to identify and solve these issues. Lastly, both respondents are compared by analyzing their approach to 'similar' issue. Citations of the respondents are added as reference and displayed by an 🗨️-icon. These citations can be found in the related Atlas.TI reports in the appendix.

5.4.1 FINDINGS RESPONDENT A1

FIRST INTERVIEW: IDENTIFY POTENTIAL COMPLEX ISSUES

Four potential complex issues are identified in the first interview. The citations (🗨️) used to determine these complex issues can be found in **Appendix D**. The following four issues are used as a basis for the second interview:

➤ C1: Modularization of pre-dressed columns

This issue contains complexities from all TOE areas. The main complexity elements recognized are: dependencies between tasks, involvement of different technical disciplines, technical risks, lack of resources and skill availability, size of the project team, company internal strategic pressure, remoteness of location and interference with existing site.

Respondent A1 confirms that Project A is fully modularized and explains that the complexity behind the choice for modularization depends on many factors, including: location, site attributes, labor availability, schedule, safety, access and environmental and regulatory factors (🗨️ 1:64). He further elaborates that the choice to select modularization as a strategy demands an objective analysis and business case to support it (🗨️ 1:64). Therefore, the modularization of pre-dressed columns is chosen as a complex issue.

➤ C2: Revising the plot plan

This issue mainly concerns technical and organizational complexity of the TOE-model. The main complexities recognized are: variety and dependencies of tasks, involvement of different technical disciplines, high project schedule drive, interfaces between disciplines, and lack of trust in construction.

Respondent A1 describes that revising the plot plan during FEED creates a complex situation, since he had to confront five engineering managers who all have invested interests in getting the engineering phase closed (🗨️ 2:69). Respondent A1 further states that these changes are complex as it is a much wider consideration, which are the most difficult ones because there is a conflicting interest with engineering to get the job finished (🗨️ 1:65). He finishes by stating that the difficult issues are the ones where he has to request others to redo their work for benefits (value) they will never see (🗨️ 1:30).

➤ C3: Aligning engineering and construction disciplines

This issue mainly contains organizational complexity elements. Elements of the TOE-model recognized are: dependencies between tasks, involvement and interfaces between different technical disciplines, size of project team, and lack of trust in construction.

Respondent A1 describes alignment as an important element in order to build in a most efficiently and safe manner (🗨️ 1:67). He states that there is enough knowledge and expertise in the office to solve technical issues, however the complexity lays in the communication, in which he aims to get his wishes known, understood and supported in order to get them implemented (🗨️ 1:68). He adds that most issues are viewed through a technical lens in which most problems get a technical problem stamp straight away, while it might not be a technical problem but a commercial problem for which technical solution is applied. In that case, it is important to get the distance and perspective (🗨️ 1:69). Respondent A1 continues by stating that the main problem that he experienced up to now is the resistance from engineering (🗨️ 1:70).

➤ C4: Pre-assembled pipe racks

This issue is primarily technical complex. TOE elements recognized are: high number, variety and dependencies of tasks, involvement and interfaces of different technical disciplines, technical risks, size of the project team and the interfaces with the existing site.

Respondent A1 describes that ‘construction’ prefers pre-assembled pipe racks over a stick-built approach. However, when FEED is advanced, going back beginning would result in extra engineering costs and also delay other disciplines, such as: piping, structural steel, electrical instrumentation, civil foundation design (☺ 1:71). The interfaces between all these discipline displays the complexity of this issue.

SECOND INTERVIEW: IDENTIFY PROJECT DESIGN CYCLE ELEMENTS

The Atlas.TI reports of the complex issues related to respondent A1 are collected in Appendix E. These reports contain a summary of the analysis, the codes found in the transcriptions, and memo’s written during the coding process. The findings per issue are displayed in a smaller table in Appendix E. These tables are combined and presented in table 4. The content of this table is further elaborated below.

Table 4: Summary findings - Respondent A1

Complex issues respondent A1	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
A1-C1: Modularization of pre-dressed columns	●	●	●	●	●	●	●	●
A1-C2: Revising the plot plan	●	●	●	●	●	●	●	●
A1-C3: Aligning engineering and construction disciplines	●	●	●	●	●	●	●	-
A1-C4: Pre-assembled pipe racks	●	●	●	●	●	●	●	-

➤ Column 1: Complexity

Respondent A1 recognizes complex problems mostly as organizational problems, or problems with far reaching consequences. Not necessarily financial or technically, but across project phases (☺ 1:22). He continues that the tough ones are where you have to ask others to redo their work for benefits they will never see (☺ 1:30). All four issues were defined by the respondent as complex in the second interview. This indicates the issues were selected correctly.

➤ Column 2-6: Project Design Cycle elements

Most of the elements were recognized in all four complex issues, except for issues C3 and C4. In issue C3, respondent A1 first creates awareness of the problem by analyzing the situation (☺ 2:47) and by reflecting back on its previous experiences (☺ 2:48, ☺ 2:50). Then, to create the alignment, he goes straight into action by applying a method known as the 5-why’s (☺ 2:53). Finally, he reflects again on this approach (☺ 2:56). In C4 all elements were recognized. However, it was not entirely clear if the design element was present. As the design was only generated and not tested (☺ 2:34, ☺ 2:36), it could also be part of the performance element, which means the respondent went from awareness to performance, and then to reflection. This would exclude the application of design thinking.

An example where respondent A1 applied all elements in the correct order is issue C1. First, the respondent creates awareness by creating an understanding of the problem situation (☺ 2:2). By looking at possible solutions he gains more awareness of the entire problem situation and the complexity of the issue (☺ 2:2). Secondly, he comes up with several alternatives (☺ 2:3) and confirms the creation of multiple alternatives (☺ 2:6). After generating ideas, he tests them by evaluation the drivers (☺ 2:5). Thirdly, after testing the alternatives a solution is chosen and performed by analyzing the requirements and limitations for the execution of the solution (☺ 2:7). Finally, respondent A1 describes how he reflects upon the alternatives in several constructability sessions (☺ 2:9).

➤ Colum 7: Sequence of the PDC-elements

The correct sequence was found in issues C1 and C4. As described in the example above, the elements in issue C1 were applied in the correct order. Interesting to see is that respondent A1 reflected in-action on his previous experiences to create awareness of the problem situation. In C2 the elements were not performed in the correct order. In this problem situation, there were multiple smaller cycles: in the first cycle respondent A1 tried to find a solution until he received resistance of engineering disciplines (☺ 2:15-2:18, ☺ 2:58), after which he reflects on the situation (☺ 2:21) to create new awareness (☺ 2:59). Then, respondent A1 tried a different approach (☺ 2:22-2:27) and performs most of the elements again (☺ 2:28-2:32). Even though the design element was not recognized in C3, the other elements were performed in the correct order: awareness of the problem situation was created by reflecting in-action on previous experiences (☺ 2:47-2:50). After which respondent A1 executed a solution (☺ 2:53) and reflected on it (☺ 2:56). In C4 all elements were applied in the correct sequence. An interesting feature is that after the design element is conducted (☺ 2:34), respondent A1 reflects in-action (☺ 2:34) to create new awareness (☺ 2:37), after which he executed the solution (☺ 2:41, ☺ 2:42) and reflects upon the outcome (☺ 2:43).

➤ Column 8: Distinction generating and testing

In issues C1 and C2 a distinction between generating and testing has been found. In C1, respondent A1 first designed multiple alternatives (☺ 2:3, ☺ 2:5) and tested them in cooperation with other disciplines in order to verify if the preferred alternative was indeed doable (☺ 2:6). In C2 it was quite difficult to conclude whether a solution was generated before it was tested, or whether the respondent tested assumptions created by awareness (☺ 2:17, ☺ 2:18, ☺ 2:58). As the design element was not recognized in C3, nothing can be said about the distinction between the design-generate and design-test sub elements. However, if this is indeed part of a larger cycle (as explained above), the smaller cycle represents the ‘generate’ step, which is followed by the ‘testing’ step when applied in practice. Finetuning this approach appeared to be an interactive process. In C4 no distinction was noticed; the approach was designed (☺ 2:34, ☺ 2:36) and performed (☺ 2:42), but not tested in between.

5.4.2 FINDINGS RESPONDENT A2

FIRST INTERVIEW: IDENTIFY POTENTIAL COMPLEX ISSUES

In the first interview five potential complex issues are defined. The citations used to determine these complex issues can be found in [Appendix D](#). The following issues are used as a basis for the 2nd interview:

➤ C1: Modularization pre-dressed columns

This issue concerns technical and external complexity. The TOE-elements recognized in this issue are: uncertainties in scope, dependencies between tasks, lack of resource availability, external risks, number and dependencies on external stakeholders, required local content, remoteness of location, and the company’s internal strategic pressure.

Modularization of pre-dressed columns is seen as a complex issue by respondent A2, as it involves multiple nationalities, locations, long distances (☺ 3:13). He adds that is important to involve process engineering in the modules and pass their knowledge on to other engineering disciplines (☺ 3:40). According to respondent A2, the objective of modularization is to reduce resources and schedule requirements (☺ 3:13).

➤ C2: Aligning engineering and construction disciplines

Only organizational complexity is recognized in this issue. The TOE-elements recognized in this issue are: dependencies between tasks, involvement and interfaces between different technical disciplines, size of project team, and lack of trust between construction and engineering.

Respondent A2 describes the importance of involving construction early in the process: get everybody on the same page, get them communicated, discuss problems, mitigate the risks, and define solutions (☺ 3:44). He states that the office is moving slowly to understand the importance of CDE, however that some people still talk about making Fluor an engineering office again (☺ 3:43). This illustrates that the alignment of engineering and construction disciplines is still an issue to be solved.

➤ C3: Fit-for-purpose applying the CDE playbook

This issue primarily concerns organizational and external complexity. The TOE-elements recognized in this issue are: uncertainty in methods, lack of experience with parties involved, incompatibility between different pm tools, lack of experience in the office, and company internal strategic pressure.

The CDE-playbook standard is based on a couple of projects. However, as every project is unique and has different clients, respondent A2 sometimes has to waver from the main directive (☺ 3:36). Even though it is important to stay within the core value and concept (as it has proven effective), some flexibility is required to effectively apply it at a specific project (☺ 3:36). How respondent A2 comes up with this fit-for-purpose application of the CDE-playbook has been determined as a potential complex issue.

➤ C4: Logistics study

Issue C4 mainly concerns organizational and external complexity. The TOE-elements recognized in this issue are: number of locations, high number of tasks, number of different nationalities and languages, organizational and external risks, number and dependencies of external stakeholders, required local content, interfaces with existing site, and remoteness of location.

Respondent A2 states that a modular execution approach opens up a whole new door from a logistic standpoint; infrastructure, upfront planning, etc. (☺ 3:13). He states that there are some problems with the logistics study as they cannot get the logistics study assigned, which impacts constructability, construction sequence, the size of equipment, and the amount of resources. He further states that increasing the window would be more effective as larger modules can be used (☺ 3:37). Respondent A2 confirms this is very complex (☺ 3:38), since not only Fluor has to be aligned but also the subcontractors and vendors need to be involved early on (☺ 3:39).

➤ C5: Sequencing of work

Technical and external complexity is recognized with regards to this issue. The TOE-elements recognized in this issue are: project duration, number of locations, high number and dependencies of tasks, involvement and interfaces between different disciplines, dependencies on external stakeholders, and company internal strategic pressure.

Sequencing of work is seen as a complex issue by respondent A2: it's about making sure that the work progress is in sequence in order to prevent other work fronts from blocking as it is important to always keep additional work fronts open (☺ 3:11). He continues that from a construction point of view, it is more organizational complexity because engineering takes care of the more technical side. The goal of sequencing is to establish production targets while maintaining safety on-site (☺ 3:12).

SECOND INTERVIEW: IDENTIFY PROJECT DESIGN CYCLE ELEMENTS

The Atlas.TI reports of the complex issues related to respondent A2 are collected in Appendix F. These reports contain a summary of the analysis, the codes found in the transcriptions, and memo's written during the coding process. The findings per issue are collected in a table in Appendix F. These tables are combined and presented in table 5. The content of the table is further elaborated below.

Table 5: Summary findings - Respondent A2

Complex issues respondent A2	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
A2-C1: Modularization pre-dressed columns	●	●	●	●	●	●	●	●
A2-C2: Aligning all disciplines	●	●	●	●	●	●	●	-
A2-C3: Fit-for-purpose applying the CDE playbook	●	●	●	●	●	●	●	●
A2-C4: Logistics study	●	●	●	●	●	●	●	-
A2-C5: Sequencing of work	●	●	●	●	●	●	●	●

➤ Column 1: Complexity

Issues C1 and C5 were defined as complex (⌚11:88, ⌚3:11). Both C2 and C3 were not defined as complex or difficult, but rather as a new situation construction management has to cope with in Construction-Driven Execution (⌚11:89). Even though respondent A2 does state that flexibility is required “based on the complexity of these items” (⌚11:57), the application of the CDE-playbook was not further defined as complex. Issue C4 was defined as difficult instead of complex (⌚11:44).

➤ Column 2-6: Project Design Cycle elements

All elements were noticed in issues C1 and C5. In C1, two cycles are recognized by respondent A2; a larger cycle that includes multiple alternatives (modularization, cutting the columns, pre-assembly, and stick-build), and a smaller cycle that just focusses on one of the alternatives. The smaller cycle is actually part of the Design/ testing element of the larger cycle and only consist of the elements: awareness, performance and reflection (⌚11:6, ⌚11:9, ⌚11:11, ⌚11:16). In C2 the design element is not recognized. Since issue C3 is still in progress (⌚11:32), no performance has taken place, rendering reflection (after-action) isn’t possible. In C4 only the elements of awareness and performance are recognized (⌚11:43, ⌚11:45). This could be explained by the fact this issue is one of the alternatives of a larger cycle, namely that of modularization (⌚11:13). In this case, the elements of the smaller cycle are part of the design-test element of the larger cycle. In C5 all elements are recognized, however the performance and reflection (after-action) elements were barely recognized (⌚11:47, ⌚11:66). This can be explained by the fact the issue is still in progress.

➤ Column 7: Sequence of the PDC-elements

It can be concluded that the majority of elements were not conducted in the correct sequence; only the issues C1 and C4 are partially recognized in the right order. In C1, awareness of the entire situation is created first (⌚11:12), followed by the development of four alternatives (modularization, cutting the columns, pre-assembly, stick-build (⌚11:15). The modularization alternative is then tested in a separate cycle. In this smaller cycle awareness is created by performing a preliminary site walk (⌚11:19). Then, ideas are generated, such as: increase window, improve infrastructure, pre-dress columns (⌚11:2, ⌚11:15). These ideas are then ‘tested’ by talking to the competitor, vendors and specialists (⌚11:3, ⌚11:4, ⌚11:11). Finally, the respondent reflects back to the larger cycle by comparing the alternatives in order to decide which option is most suitable (⌚11:19).

In C2, the respondent goes back and forth between reflection (⌚11:55, ⌚11:25) and performance (⌚11:22, ⌚11:27), in order to create awareness of the problem situation. In C3, the respondent starts with explaining the design options and how he tests them (⌚11:32, ⌚11:33). After which he reflects (⌚11:34) and created awareness (⌚11:57). In C4 awareness of the problem situation was created (⌚11:43), after which the solution is performed (⌚11:45). This issue is only partially applied in the correct sequence since the design and reflection element are missing. In C5 the elements are also not conducted in the correct order. First, respondent A2 explains how he is going to perform his solution by

discussing it with planning specialists (🗨️ 11:47), then he creates awareness of the project drivers and problems (🗨️ 11:48, 🗨️ 11:65), followed by explaining how he generates and tests the alternatives (🗨️ 11:49-11:52), in between he reflects to increase the awareness and to create objectives within the design (🗨️ 11:53, 🗨️ 11:66).

➤ Column 8: Distinction generating and testing

In two out of five complex issues a clear distinction between generating and testing was recognized. In C1 the distinction could be made, however the difference in the smaller cycle between ‘test and perform’ or ‘test and reflect’ is less clear. In C2 and C4 the design element was not recognized, which means nothing could be stated about the distinction of generate and test. However, in issue C2 the respondent does describe the structure which he applies in these meetings: he creates a design (scope), test the methods together with others to identify risks, generate ideas together with other to mitigate these risks, and then repeats this cycle if needed (🗨️ 11:27). This represents searching and experimenting which indicates design thinking principles. In C3 there is a clear distinction between both generating and testing: the respondent describes the alternatives he developed together with others (🗨️ 11:32, after which he describes how he tests and compare them (🗨️ 11:33). In C5 both sub-elements are hard to distinguish when looking at the coding. As the design is still in progress, the generate sub-element contains the objectives (🗨️ 11:49, 🗨️ 11:51) and the testing element contains the assessing requirements (🗨️ 11:50). However, one could also state this is all part of the awareness element, as it is about creating awareness of the entire problem situation, its objectives and requirements. In the end, no ‘real’ alternatives are generated or tested in issue C5.

5.4.3 CASE ANALYSIS (RESPONDENT A1 VS RESPONDENT A2)

The findings of both respondents are analyzed and compared to each other in order to determine whether the construction managers within case A applied the Project Design Cycle. It can be observed that respondent A1 recognized all issues as complex, and also applied most of Project Design Cycle elements in his approach to solve these issues. Based on this, it can be concluded that respondent A1 applies design thinking when approaching complex issues. Respondent A2 perceived less issues as complex, which could be explained by the fact that respondent A2 is more experienced than A1, and therefore doesn’t perceive the same level of complexity. Subsequently, respondent A2 often did not apply all four elements in his approach issues. This could either be because he didn’t perceive the issue as complex and therefore thought it was not required to solve the issue, or because he is used to the typical ‘firefighting’ practice on-site and has difficulties adapting to this new form of problem-solving.

The approach of both respondents can be compared by analyzing the ‘similar’ issues. By categorizing the issues, it is possible to compare more issues between the respondents. Three categories are found:

➤ Modularization, pre-assembly and logistics (A1-C1, A2-C1, A2-C4)

When studying the modularization and pre-assembly issues, it is found that in both issues the complexity and all Project Design Cycle elements were recognized. This indicates that both respondents recognized the complexity of the problem situation and determined that they needed to approach it in a thoughtful manner. The logistics study is part of this category since it concerns the logistics of the modules, which is part of the decision to apply a modular approach. However, in contrast to the other issues in this category, this issue is just partially recognized as complex and does not cover all four elements. It is assumed that as the logistics study represents the test-element of the alternative to go modular, only awareness of the situation is created, after which a solution is performed. As both design and reflection are missing, the approach regarding the logistics study looks quite similar to the typical ‘firefighting’ approach.

➤ Plot plan and sequence of work (A1-C2, A2-C5)

Issues A1-C2 and A2-C5 are interrelated since both aim to optimize the schedule. In A1-C2 this is done by revising the plot plan layout, and in A2-C5 by pre-fabricating certain components. When comparing both issues some similarities can be observed: both issues are perceived as complex, contain all elements, and are not applied in sequence. The respondents first create awareness of the problem situation by defining ‘what is needed’ and ‘who is required’ to change the current plan. Then, both try to design a solution and test it with either colleagues or vendors. Respondent A1 has to persuade the engineering disciplines as he tries to change their work upon completion, while respondent A2 is dependent on the client to accept the change. The main difference is that respondent A2 only partially applied performance and reflection. This can be explained by the fact that the issue is still in progress.

➤ Alignment of disciplines (A1-C3, A2-C2)

Aligning engineering and construction disciplines has been discussed by both respondents. It is noteworthy that the same PDC-elements are recognized and missing, while only one of the respondents perceived the issue as complex. Respondent A1 perceives the alignment as complex since *“each individual has a different opinion of what the best solution could be”*. His approach to test the alternative solutions is by checking whether the actor purely based the solution on previous experiences or whether the actor approached it in an objective way. Respondent A1 does this by keep asking ‘why’ and looking at the pros and cons of each alternative. He states the importance of not attacking someone, but to change their minds by approaching it in an objective way. Even though respondent A2 doesn’t perceive the alignment as complex, the approach is quite similar. First, he defines the agenda (scope) of the meeting. Then in collaboration with the related disciplines, he identifies risk factors and limitations that could potentially impact engineering and construction, after which they work together to mitigate these factors. He incorporates the lessons learned and experiences of all actors to identify the limitations.

5.5 CASE B - ANALYSIS

The case analysis of project B concerns two objects of research: respondent B1 and respondent B2. Both are interviewed twice in order to identify potential complex issues, and to analyze the approach the respondents used to identify and solve these issues. Lastly, both respondents are compared by comparing their approach to ‘similar’ issue categories. Citations of the respondents are added as reference and displayed by an 🗨️-icon. These citations can be found in the related Atlas.TI reports in the appendix.

5.5.1 FINDINGS RESPONDENT B1

FIRST INTERVIEW: IDENTIFY POTENTIAL COMPLEX ISSUES

In the first interview four issues are defined. The citations used to determine these complex issues can be found in **Appendix D**. The following four issues provide the framework in the second interview:

➤ C1: Modular, pre-assembly or stick-built

This issue is mainly technical and organizational complex. The TOE-elements recognized in this issue are: high number of tasks, dependencies between tasks, uncertainty in method, involvement and interfaces between different technical disciplines, high project schedule drive and size of project team.

Since time is the main driver in this project, special attention had to be paid to the construction execution plan (🗨️ 5:15). Respondent B1 states that three execution strategies were available: modular, pre-assembly or stick-built (🗨️ 5:7). Also, this decision has large consequences and involves many stakeholders and depends on several departments (🗨️ 5:10, 🗨️ 5:15).

➤ C2: Resourcing, staffing and contracting in FEED

Issue C2 is organizational and external complex. The TOE-elements recognized in this issue are: type of contract, size of project team, lack of company internal support, lack of experience in the office, and instability of project environment.

Respondent B1 describes the biggest challenge in FEED was the lack of construction management resources (☹5:3). Therefore, the respondent could only rely on his own experiences (☹5:1). Besides that, the final investment decision was delayed by the client, which influenced the starting dates of extra resources (☹5:5). This also meant that any decisions made for new staffing had to go through the client as the project was still on reimbursable terms (☹5:17). Internally, there was also not enough budget made available for extra resources, which made this issue extra difficult (☹5:6).

➤ C3: Changing plot plan due to contaminated soil

This issue contains all TOE complexities. The TOE-elements recognized in this issue are: high number and dependencies of tasks, involvement and interfaces between different disciplines, technical risks, type of contract, dependencies on external stakeholders, and interference with existing site.

The client provided a “clean” construction area, which later on appeared to have existing piles underground (☹5:8). The geotechnical and topographical surveys were not performed during pre-FEED because the client didn’t want to spend money on it in that stage (☹5:13). As the new piles had to be driven next to the old piles, the piles had to be extended from 30m to 35m length. Not only did this require a different piling contractor, the plot plan also had to be revised (☹5:8). Respondent B1 states that everything that can have consequences for the civil component is seen as a complex issue (☹5:11). Therefore, this issue is selected for the second interview.

➤ C4: Aligning construction, engineering and procurement disciplines

Issue C4 primarily concerns organizational complexity. The TOE-elements recognized in this issue are: lack of experience with disciplines involved, interfaces between different disciplines, size of the project team, lack of trust between engineering and construction, and company internal strategic pressure.

During constructability in FEED, the plot plan and the execution strategy was reviewed together with the other disciplines (☹5:18). Respondent B1 describes that engineering was not engaging construction management because of conflicts they had in the past (☹5:19). The image of construction managers didn’t motivate engineering and procurement disciplines to talk to construction. Furthermore, he states that still a huge learning curve is required to get construction up to the level where it needs to be (☹5:19). He finally states that the interaction between engineering and construction has improved a lot during the course of the project.

SECOND INTERVIEW: IDENTIFY PROJECT DESIGN CYCLE ELEMENTS

The Atlas.TI reports of the issues related to respondent B1 are collected in Appendix G. These reports contain a summary of the analysis, the codes found in the transcriptions, and memo’s written during the coding process. The findings per issue are collected in a table in Appendix G. These tables are combined and presented in table 6. The content of this table is further elaborated below.

Table 6: Summary findings - Respondent B1

Complex issues respondent B1	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
B1-C1: Pre-assembled pipe racks	●	●	●	●	●	●	●	●
B1-C2: Resourcing and staffing in FEED	●	●	●	●	●	●	●	-
B1-C3: Contaminated soil / piling	●	●	●	●	●	●	●	●
B1-C4: Aligning engineering and construction disciplines	●	●	●	●	●	●	●	●

➤ Column 1: Complexity

Respondent B1 recognizes issues C1 and C3 as complex (☺6:1, ☺6:29). Both C2 and C4 were only partially recognized as complex. In issue C2, respondent B1 only recognizes the organizational complexity, and states this is mainly because of the contracts between Fluor and the client (☺6:16). Respondent B1 recognizes the organizational complexity of issue C4 (☺6:40). Interesting to observe is the fact that both issues that were perceived as complex by respondent B1, also contained all elements., while the contrary can be observed of issues C2 and C4 (both are missing elements).

➤ Column 2-6: Project Design Cycle elements

As described, all elements were recognized in issues C1 and C3. In C2 the design element was missing and in C4 the performance element was missing. Also, the awareness element was partially recognized as it only contained the recognition of the complexity (☺6:4), but there was no awareness of any problem situation. An example where respondent B1 applied all elements is issue C3. First, he creates awareness of the problem situation by concluding the as-built information was incorrect (☺6:30). Then, the plot plan was designed, tested, re-adjusted and tested again (☺6:31). This is a good example of searching and experimenting until a solution with the highest value is designed. After design, the piling is performed (☺6:33) and the reflected upon (☺6:34), which created new awareness (☺6:35). To solve the issue respondent B1 designed a new plan and executed it (☺6:38). However, it is unclear whether the design element also included testing. Finally, lessons learned are drawn by reflection upon the situation (☺6:39).

➤ Column 7: Sequence of the PDC-elements

In C1, respondent B1 first explains how he performs his solution by discussing it with planning specialists (☺6:2), then he creates awareness of the project drivers and the problem situation (☺6:4), followed by an explanation of how he generates and tests the alternatives (☺6:5), in between he reflects to increase the awareness (☺6:46) and to create objectives within the design (☺6:9, ☺6:10, ☺6:11). In C2 the recognized elements were performed in the correct sequence, however the design element was missing. Issue C3 is the only issue in which all elements were performed in the correct sequence. First, a plot plan was created by generating and testing alternatives. Then, when a new problem occurred, the applied the same elements again. In fact, there were two smaller cycles within this issue. C4 was not performed in sequence: after defining it as partially complex (☺6:40), the respondent reflects on the situation (☺6:41), after which he briefly describes how he tried to create alignment (☺6:42, ☺6:41).

➤ Column 8: Distinction generating and testing

Only in issue C4 a distinction could be made between generating and testing. In C1 the difference between generating and testing is difficult to recognize. Because the design is still in progress, the generate elements contain the objectives and the testing element the assessing requirements (☺6:5). However, one could also say this is all part of the awareness element, as it is about creating awareness of the entire problem situation, its objectives and requirements. No real alternatives are generated or tested in this example. It is unable to conclude anything about the distinction in issue C2 since the design element was recognized. In C3 the respondent talks about designing and testing alternatives. However, because it is unclear if this is done separately (☺6:31), a yellow bulletin is assigned to this box. In C4 a distinction has been found as the respondent first explains how he creates a new approach to integrate construction and engineering disciplines (6:42), and then tests this approach by requesting feedback by a colleague of another discipline (☺6:43).

5.5.2 FINDINGS RESPONDENT B2

FIRST INTERVIEW: IDENTIFY POTENTIAL COMPLEX ISSUES

In the first interview three potential complex issues are defined. The citations used to determine these complex issues can be found in Appendix D. The following four issues are defined in the first interview and used as a basis for the second interview:

➤ C1: Unexpected situations

This issue contains both technical and organizational complexity. The TOE-elements recognized in this issue are: uncertainty in methods, dependencies between tasks, conflicting norms and standards, technical and organizational risks, high project schedule drive and interfaces between different disciplines.

When asked how respondent B2 treats unexpected situations in his daily work, he responded that it depends on when, how and what the surprise is and also on the complexity of the issue (☺ 7:1). If it is something new (unforeseen), he first receives the surprise, after which he analyzes it and decides whether he acts on it or whether he requires others to solve it (☺ 7:1). This topic has been selected for the second interview in order to = further analyze the applied approach. Several unexpected situations are sketched and presented to respondent B2 in order to observe how he would approach them.

➤ C2: Aligning engineering and construction disciplines

Issue C2 primarily concerns organizational complexity. The TOE-elements recognized in this issue are: interfaces between different disciplines, lack of experience with disciplines involved, size of the project team, lack of trust between engineering and construction, and company internal strategic pressure.

Respondent B2 introduced interactive planning sessions for both construction and engineering during the FEED phase (☺ 7:3), to get everyone on the same page with regards to milestones, requirements, objectives, barriers and opportunities (☺ 7:4). Respondent B2 aligns construction and engineering disciplines in order to develop the best solution by making sure the right people are involved in the discussions, showing examples, making sketches and suggestions, and come up with a solution (☺ 7:14). As respondent B2 has not been involved until the end of FEED, he was not confronted with any issues with regards to the application of Construction-Driven Execution (☺ 7:6). He defines the alignment, in order to work and act according the schedule, as one of the biggest challenges (☺ 7:2)

➤ C3: Sequencing of work

This issue mainly concerns technical and organizational complexity. The TOE-elements recognized in this issue are: high number of project goals, high variety of tasks, dependencies between tasks, uncertainty in methods, involvement of different technical disciplines, high project schedule drive, interfaces between different disciplines and size of the project team.

Respondent B2 defines sequencing of work in the FEED phase as a complex issue (☺ 7:2). He states that even though construction can define what the schedule and milestones should be, the trick is to get everybody alignment on the schedule and work according to it. His main focus and objective for scheduling is to minimize work on-site, working on height and use of scaffolding (☺ 7:5).

Modularization & pre-assembly

As modularization and pre-assembly was defined as a complex issue by most of the other respondents, it was also asked whether respondent B2 perceives this as complex. He states that the creation of modular solutions is not a complex issue, but 'just a structured way of working' and that it's about making sure that teams are elaborating (☺ 7:9). When asked whether he perceived the design of pre-assembled pipe racks as complex, respondent B2 replied that it is not complex to him because of his experiences in the past. He further explains that coming to the solution is not complex, but the alignment of all disciplines is (☺ 7:13). For these reasons, modularization & pre-assembly is not further discussed as a 'complex' issue in the second interview.

SECOND INTERVIEW: IDENTIFY PROJECT DESIGN CYCLE ELEMENTS

The Atlas.TI reports of the complex issues related to respondent B2 are collected in Appendix H. These reports contain a summary of the analysis, the codes found in the transcriptions, and memo’s written during the coding process. The findings per issue are collected in a table in Appendix H. These tables are combined and presented in table 7. The content of this table is further elaborated below.

Table 7: Summary findings - Respondent B2

Complex issues respondent B2	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
B2-C1: Unexpected situations onsite	●	●	●	●	●	●	●	-
B2-C2: Aligning all disciplines	●	●	●	●	●	●	●	-
B2-C3: Sequencing of work	●	●	●	●	●	●	●	●

➤ Column 1: Complexity

Issues C1 and C2 were not recognized as complex by respondent B2 in the second interview, as he experienced these issues as standard working practices (⌚12:10). However, a yellow bulletin is assigned since issue C2 was recognized as complex in the first interview (⌚7:13). Issue C3 was recognized as both technical and organizational complex by respondent B2 (⌚12:32). Additionally, he explained that the main complexity of early involvement is the creation of awareness and the recognition of all potential issues upfront (⌚12:16).

➤ Column 2-6: Project Design Cycle elements

In C1 the elements of awareness (⌚12:1, ⌚12:2) and performance (⌚12:3, ⌚12:4) were fully recognized, while the design element was only partially recognized as the respondent only describes the generating part of design (⌚12:6). Reflection was also partially recognized as he briefly reflects on his approach but doesn’t draw any lessons learned (⌚12:7). Remarkable of issue C2 is that all elements were recognized in the first interview by answered the question “How do you align the disciplines during these meetings to come up with the best solution?”. His response was “Make sure the right people are involved in the discussions, show them examples, make some sketches and suggestions, and then come up with a solution” (⌚7:13). In this answer all elements are recognized, however, respondent B2 doesn’t elaborate this approach in the second interview (⌚12:10). In C3 the design (⌚12:11) and reflection element (⌚12:17) were recognized. Awareness was only partially recognized since there wasn’t a clear problem defined, and the performance element was not observed (⌚12:11, ⌚12:16).

➤ Column 7: Sequence of the PDC-elements

In issues C2 and C3 the elements were partially performed in the correct order. In C1 the elements were not performed in the right sequence as the respondent starts with awareness and performance (⌚12:1-12:4), after which he designs (⌚12:6) and reflects (⌚12:7). As described in the previous paragraph, it is quite debatable whether respondent B2 applied the elements in the correct order in issue C2, as he didn’t elaborate on his approach in the second interview. In C3 the elements that were present, were conducted in the correct sequence. However, since the performance element is missing, this issue is assigned with a yellow bulletin.

➤ Column 8: Distinction generating and testing

As the design element is missing in issue C1 and C2, nothing could be stated about the distinction between generate and test. In C3 the respondent does discuss an iterative process in which he generates and tests ideas by looking at the main drivers (costs, schedule, interfaces, etc.). However, in this explanation there is no clear distinction made (⌚12:11). Therefore, a red bulletin is assigned.

5.5.3 CASE ANALYSIS (RESPONDENT B1 VS RESPONDENT B2)

To determine whether the construction managers within case B applied the Project Design Cycle, the findings of both respondents are analyzed and compared to each other. When comparing both respondents, it can be observed that the elements of the Project Design Cycle are more frequently recognized in the approach of respondent B1 than in the approach of respondent B2. Remarkable is that respondent B2 didn't conceive the same issues as complex as respondent B1. The alignment (organizational complexity) was seen as the main complexity by respondent B2, while the creation of modular and pre-assembly solutions was not perceived as complex. Also, most findings of respondent B2 were retrieved from the first interview. Even though it was asked to elaborate on the issues determined in the first interview, not much was added in the second interview. This resulted in many yellow bullets in respondent B2's table. As a consequence, it is made very difficult to compare both respondents.

The approach of both respondents can be compared by analyzing the 'similar' issues. By categorizing the issues, it is possible to compare more issues between the respondents. Two categories are found:


- Sequencing of work (B1-C3, B2-C3)

This category consists of two issues which not seem to be related on first sight. However, both concern optimizing the plot plan in order to improve the sequencing of work during construction. In issue B1-C3 the construction sequence is uncertain as the soil is contaminated with old piles. In order to prevent piling issues during construction, the plot plan had to be revised multiple times. When comparing both issues, some differences and similarities can be observed. Even though both issues are recognized as complex, in issue B2-C3 little awareness is created and also no solution is performed. This could be caused by the fact that issue B2-C3 was still in progress, and no real problem situation could be defined by the respondent.

- Alignment of disciplines (B1-C4, B2-C2)

The alignment and integration of disciplines was discussed by both respondents. Both state that this issue is primarily about the organizational complexity instead of the technical aspects of the problems. Respondent B1 tries to approach this organizational problem by 'a lot of listening and not too much pushing', realizing his idea is not always the best, and asking feedback of other disciplines. Respondent B2 highlights the importance of getting all disciplines on the same page to make sure that everybody understands why, how and what is needed to deliver the project successfully. Furthermore, respondent B2 states that it is important to make sure everybody is buying straight from the beginning. Even though respondents B1 and B2 apply a slightly different approach, both agree that it's important to listen and make sure the other disciplines want to be part of the team, instead of just pushing top-down.

5.6 CASE C - ANALYSIS



The case analysis of project C contains one object of research. Respondent C1 is interviewed twice in order to identify (complex) issues and to analyze his approach used to identify and solve these issues. Citations of the respondents are added as reference and displayed by an -icon. These citations can be found in the related Atlas.TI reports in the appendix.

FIRST INTERVIEW: IDENTIFY POTENTIAL COMPLEX ISSUES

In the first interview four issues are defined. The citations used to determine these complex issues can be found in [Appendix D](#). The following four issues provide a framework for the second interview:





➤ C1: Unexpected situations

This issue is primarily technical complex. The TOE-elements recognized in this issue are: strict quality requirements, high number and dependencies between tasks, involvement of different technical disciplines, technical risks, high project schedule drive, and dependencies on external stakeholders.

Respondent C1 states that it is important to be adaptable and flexible in order to deal with unexpected situations in his daily functioning. As the project is dynamic, situations change, and new things come up which weren't planned for (9:2). Furthermore, he defines a complex issue as any problem that cannot be solved in a short amount of time and with a limited amount of people. Especially anything that changes the process, which results in delays on the schedule or delivery dates. For example, (unexpected) delivery or safety issues on-site (9:5)




➤ C2: Modularization and pre-assembly

This issue contains technical, organizational and external complexity. The TOE-elements recognized in this issue are: high variety and dependencies of tasks, technical risks, involvement and interfaces between (technical) disciplines, size in CAPEX, type of contract, dependencies on external stakeholders, and interference with existing site.

Respondent C1 performed a modularization evaluation to decide what modules can be used on the project to eliminate productivity issues from site and to reduce man-hour requirements (9:8). The aim of the project is to maximize the use of modules to the point it makes sense (9:12). As the project is located in an existing refinery, respondent C1 is also looking in to pre-fabrication and pre-assemble as much as possible (9:12). The respondent recognizes modularization and pre-assembly as complex issues (9:13).



➤ C3: Alignment of construction and engineering disciplines

This issue mainly concerns technical and organizational complexity. The TOE-elements recognized in this issue are: non-alignment of project goals, dependencies between tasks, involvement and interfaces between different (technical) disciplines, and lack of skills availability.

The constructability program in FEED aims to capture the great and bright ideas of the project team to create a solid construction execution plan (9:9). Respondent C1 states that it is important to have reviews with the different disciplines and try to get integrated with the project team (9:10). He continues that the integration and alignment of these disciplines can be a large issue, since every project is different and includes different types of people. Whether these alignment issues are complex, often depends on what it is (9:11).

➤ C4: Logistics study

Issue C4 is primarily organizational and external complex. The TOE-elements recognized in this issue are: number of locations, dependencies between tasks, interfaces between different disciplines, number of different nationalities and languages, organizations and external risks, dependencies on external stakeholders, and interference with existing site.

When discussing modularization, respondent C1 stated that the logistics behind the modules is a complex endeavor (9:13). This logistics study involves the choice where the module is going to be build, how they are shipped, and how they are moved to site. The whole operation involves many actors and disciplines as it has a major impact on the supply-chain (9:13). Therefore, this issue has been selected for the second interview.

SECOND INTERVIEW: IDENTIFY PROJECT DESIGN CYCLE ELEMENTS

The Atlas.TI reports of the complex issues related to respondent C1 are collected in Appendix I. These reports contain a summary of the analysis, the codes found in the transcriptions, and memo’s written during the coding process. The findings per issue are collected in a table in Appendix I. These tables are combined and presented in table 8. The content of this table is further elaborated below.

Table 8: Summary findings - Respondent C1

Complex issues respondent C1	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
C1-C1: Unexpected situations	●	●	●	●	●	●	●	●
C1-C2: Modularization and pre-assembly	●	●	●	●	●	●	●	●
C1-C3: Alignment of construction and engineering disciplines	●	●	●	●	●	●	●	-
C1-C4: Logistics study modules	●	●	●	●	●	●	●	-

➤ Column 1: Complexity

Issue C1 was only defined as technical complex (☺13:11), therefore a yellow bulletin has been assigned. Issue C2 and C4 were both recognized by the respondent as complex, both in the first and second interview (☺9:13, ☺13:22, ☺13:52). The alignment of construction and engineering (C3) is not described as complex and therefore assigned with a red bullet.

➤ Column 2-6: Project Design Cycle elements

All elements were recognized in C1 and also in C2. In C2 the majority of the elements were recognized, only the presence of the performance element is debatable (☺13:25). On the one hand, the respondent explains that he performs a study after generating and testing several alternatives. On the other hand, this could also be part of the test sub-element (☺13:19). In C3 the design-element is not recognized, and also reflection barely takes place (☺13:28). This might be because the issue is not defined as complex by the respondent. In C4 only awareness, performance and reflection are recognized. It could be that this issue (the logistics study) is part of a larger decision-making cycle, namely the decision to go for modules instead of stick-build. If this is the case, the logistics study is merely the testing part of one of the alternatives, which insinuates that there is a clear objective (assess the alternative). This would explain the iterative process of creating awareness and performing the solution (☺13:31-13:38).

➤ Column 7: Sequence of the PDC-elements

In issue C1, the elements are partially recognized in the correct order; the chronological order of the elements is correct, but the explanation of the respondent during the interview is not. The respondent first creates awareness of the situation that is created (☺13:2, ☺13:4), then he comes up with several solutions and tests them on cost and schedule impact (☺13:5). Eventually a solution is chosen and performed (☺13:6). Finally, the respondent reflects on the situation in constructability meetings in order to in draw any lessons learned from the situation (☺13:9). In C2 the respondent first creates awareness of the problem situation (☺13:16), followed by generating and testing of alternatives (☺13:14, ☺13:18, ☺13:19). Then, he performs a study after which the project manager makes the final call (☺13:25). Respondent C1 also reflects after-action by using his lessons learned as input in the design process (☺13:20). In C3 the elements that are recognized are applied in the correct sequence. However, since some elements were not recognized, it is debatable whether the correct sequence is performed. In C4, the elements are practically performed in sequence; it goes back and forth between awareness and performance (☺13:31-13:38), in which reflection of previous experiences is used in-action to create awareness of the entire problem situation (☺13:38).

➤ Column 8: Distinction generating and testing

In issues C3 and C4 there is no design element recognized, which makes it impossible to conclude whether the sub-elements occurred separately of each other. In C1 the respondent talks about creating several alternatives and then testing them on cost and schedule (🗨️13:5). However, this distinction is not clear enough to conclude whether the sub-elements are performed independently of each other. In C2 a clear distinction between generating and testing is recognized. First, respondent C1 comes up with several alternatives (🗨️13:14, 🗨️13:18, 🗨️13:21), after which he assesses them together with other disciplines by area (🗨️13:15, 🗨️13:19, 🗨️13:23).

CASE ANALYSIS (RESPONDENT C1)

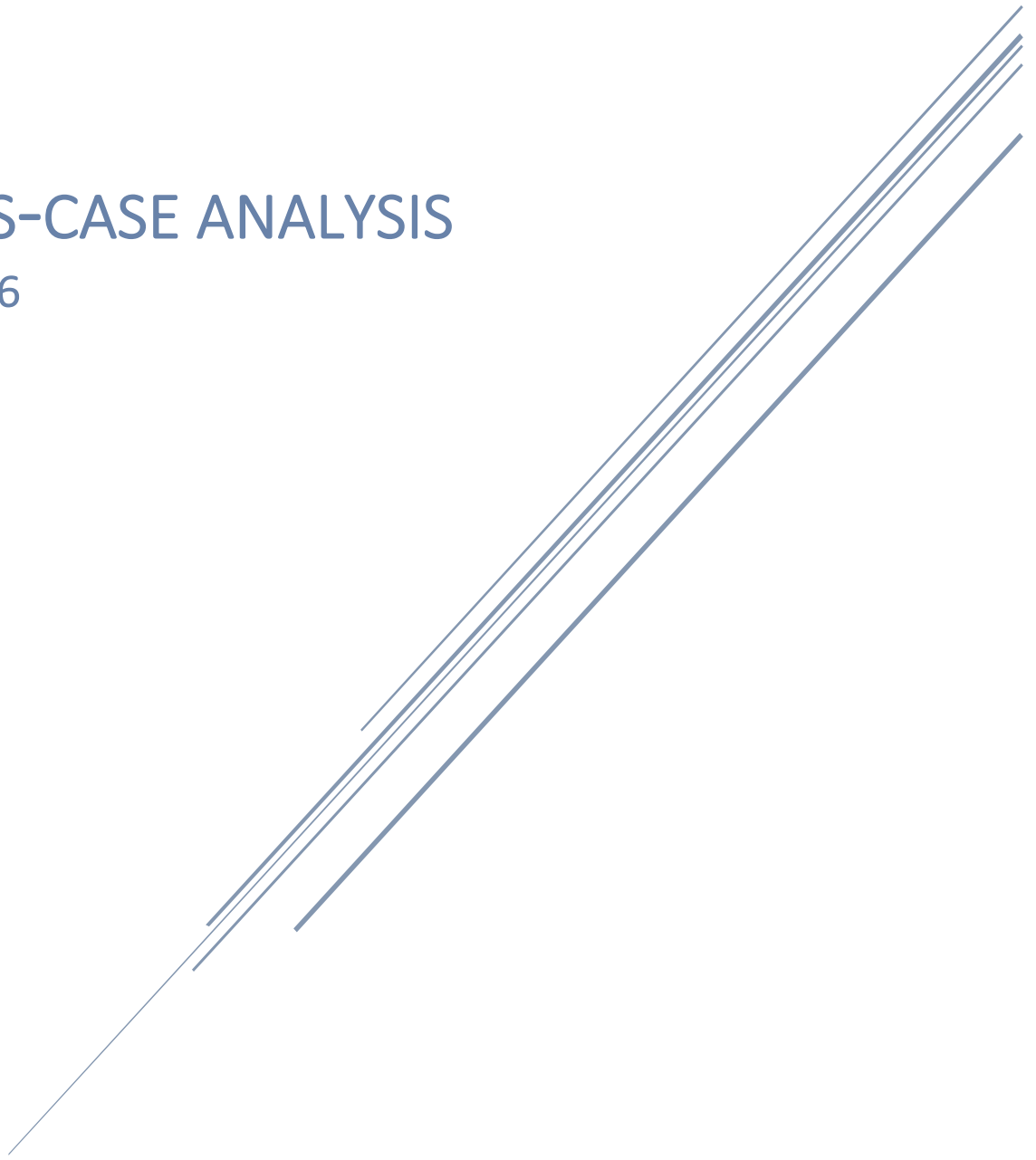
Since case-study C only contains one respondent, no comparison can be made. However, respondent C1 is briefly discussed in order to summarize case C. It can be observed that respondent C1 recognizes most of the issues as complex, only the alignment is not perceived as complex. Furthermore, the respondent applied most of Project Design Cycle elements, but mainly when the issue was recognized as complex. Similar to respondent A2, the logistics study is part of a larger cycle; namely the decision to apply a modular approach instead of stick-built.

Even though no comparison can be made within this case, when observing the categories of the other two cases, the issues of respondent C1 could be placed in the following categories:

- The categories of modularization, pre-assembly and logistic study (issue C1-C2 and C1-C4)
- The category of the alignment of disciplines (issue C1-C3)

CROSS-CASE ANALYSIS

Chapter 6



In chapter 6, the case analysis findings of chapter 5 are compared to each other in a cross-case analysis. This cross-case analysis is discussed in sub-chapter 6.1 and concerns the categorization of complex issues, the application of the Project Design Cycle, and design thinking in construction management. Based on the theoretical framework and the empirical research, a practical tool (ADAPT) is created and presented in sub-chapter 6.2. Finally, the findings of the cross-case analysis and the practical tool are discussed and validated by an external panel in sub-chapter 6.3. This chapter answers sub-question 3 and 4 and provides the knowledge to answer the main research question in chapter 7.

6.1 CROSS-CASE ANALYSIS

A cross-case analysis is performed to analyze and define any occurring patterns when comparing the observed complex issues, the respondents, and the case-studies. Firstly, the defined complex issues are categorized by topic in order to compare the approach of various respondents. Secondly, the application of the Project Design Cycle elements by the respondents is analyzed. Thirdly, the application of design thinking in construction management is discussed by comparing the findings of complex and non-complex issues, the respondents, the opinion of the individual respondents regarding the Project Design Cycle in their daily functioning, and their opinion regarding the current reflection practices.

6.1.1 CATEGORIZATION OF COMPLEX ISSUES

Three issue-categories are determined in the case analysis by comparing the findings of the respondents of case-studies A, B and C. The remaining issues are put in a fourth category 'IV. Others'. When considering all twenty issues, another category 'Unexpected situations' seem to be present, which was discussed by respondents B2 and C1. However, these issues cannot be compared since only one of the two respondents recognized the complexity. Therefore, both issues have been put in the category 'Others'. The categories and the related respondents are shown in table 9 and further analyzed below.

Table 9: Overview issue categories

Issue categories	Case A		Case B		Case C
	A1	A2	B1	B2	C1
I. Modularization & pre-assembly	●	●	●	-	●
II. Aligning all disciplines	●	●	●	●	●
III. Sequencing of work / plot plan	●	●	●	●	-
IV. Others	-	●	●	●	●

I. MODULARIZATION, PRE-ASSEMBLY AND LOGISTICS

This category contains all issues that concern modularization and pre-assembly solutions. The issue 'logistics study' is also part of this category as it relates to the logistics of the modules from the fabrication-yard to the construction site. The issues included in this category are listed in table 10.

Table 10: Category I

	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
I. Modularization, pre-assembly and logistics								
A1-C1: Modularization of pre-dressed columns	●	●	●	●	●	●	●	●
A1-C4: Pre-assembled pipe racks	●	●	●	●	●	●	●	-
A2-C1: Modularization pre-dressed columns	●	●	●	●	●	●	●	●
B1-C1: Pre-assembled pipe racks	●	●	●	●	●	●	●	●
C1-C2: Modularization and pre-assembly	●	●	●	●	●	●	●	●
A2-C4: Logistics study modules	●	●	●	●	●	●	●	-
C1-C4: Logistics study modules	●	●	●	●	●	●	●	-

It is remarkable that all issues related to modular and pre-assembly solution are identified as complex, include all Project Design Cycle elements, and are often in the correct sequence. Based on this information one could say that respondents A1, A2, B1 and C1 did apply design thinking principles with regard to modular execution: they recognized the complexity, created awareness of the problem situation, generated and tested several alternatives, performed a solution and reflected upon the

approach. Only respondent B2 did not perceive this topic as complex. A reason for this might be that respondent B2 was barely involved during pre-FEED and FEED, and therefore only perceived modular execution on an operational level, but not on a tactical or strategic decision-making level.

On the other hand, it is noteworthy that both issues related to the logistics study are partially complex and exclude the design and reflection elements. As described in the previous sub-chapters, this could be explained by the fact that the execution approach is determined in FEED, which means that all alternative execution approaches (modular, pre-assembly and stick-built) need to be reviewed. With regards to the modularization alternative, this is (among other things) done by the performance of a logistics study. In this sense, the logistics study is not about designing a value, but about testing an alternative by creating awareness of restrictions (awareness) and by removing them (perform).

II. ALIGNMENT OF VARIOUS DISCIPLINES

The alignment of engineering, procurement and construction disciplines was discussed by all respondents in the second interview. An overview of the findings of this category is given in table 11.

Table 11: Category II

	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
II. Aligning of various disciplines								
A1-C3: Aligning engineering and construction disciplines	●	●	●	●	●	●	●	-
A2-C2: Aligning all disciplines	●	●	●	●	●	●	●	-
B1-C4: Aligning engineering and construction disciplines	●	●	●	●	●	●	●	●
B2-C2: Aligning all disciplines	●	●	●	●	●	●	●	-
C1-C3: Aligning all disciplines	●	●	●	●	●	●	●	-

This category is either partially or not recognized by the respondents as complex. Only respondent A1 recognizes the alignment of engineering and construction disciplines as complex. Another significant feature of this category is that each issue excludes at least one element of the Project Design Cycle elements (the design element in most cases). This illustrates a clear pattern and implies that the alignment of various disciplines might not be a ‘complex’ issue. Even respondent A1 who recognized it as complex, does not apply the design element. For this reason, this issue should not have been determined as complex in the first interview.

On the other hand, these findings could serve as a good example of the traditional ‘firefighting’ mode, in which an issue (problem) is observed, a solution is created and performed. As the respondents didn’t perceive this issue as complex, it could very well be that they did not presume ‘design’ (generating and testing of alternatives) and reflection element was required.

III. REVISING PLOT PLAN AND SEQUENCING OF WORK

This category contains three comparable topics: revising the plot plan, sequencing of work, and contaminated soil conditions (as shown in table 12). These issues are combined as they all concern the optimization of the plot plan in order to enhance the sequencing of work. Issue B1-C3 is also part of this category as the contaminated soil required the plot plan to be revised.

Table 12: Category III

	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
III. Plot plan review and sequencing								
A1-C2: Revising the plot plan	●	●	●	●	●	●	●	●
A2-C5: Sequencing of work	●	●	●	●	●	●	●	●
B1-C3: Contaminated soil / piling	●	●	●	●	●	●	●	●
B2-C3: Sequencing of work	●	●	●	●	●	●	●	●

The complexity of this category is recognized by all respondents. Interesting to see is that most of the elements are recognized by all respondents. However, performance is not applied in some cases. This could be explained by the fact that the sequencing of work is an ongoing event, which is not finished at FEED. In this case, there might not be a clear problem, or the final solution is not performed yet. Since issues A1-C2 and B1-C3 are indirectly related to the sequencing of work, they do contain all elements.

IV. OTHERS

Table 13 includes all issues that couldn't be placed in one of the above categories. Only issue C1-C1 is defined as complex and contains all PDC-elements. Therefore, only this issue will be used to analyze the application of the Project Design Cycle in the next sub-chapter. No further observations can be made as all issues concern different topics, complexities and respondents.

Table 13: Category IV

	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
IV. Others								
A2-C3: Fit-for-purpose applying the CDE playbook	●	●	●	●	●	●	●	●
B1-C2: Resourcing and staffing in FEED	●	●	●	●	●	●	●	-
B2-C1: Unexpected situations on-site	●	●	●	●	●	●	●	-
C1-C1: Unexpected situations on-site	●	●	●	●	●	●	●	●

6.1.2 APPLICATION OF THE PROJECT DESIGN CYCLE

A notable observation when looking at the case analysis findings is that many issues are not perceived or described as complex by the respondents. This indicates that some of the identified issues from the first interview were not or partially recognized by the respondents in the second interview. However, this also shows that the recognition of complexity has a major influence on the way respondents approach issues. Therefore, it has been determined to separate the 'complex' from the 'non-complex' issues in order to properly compare the findings and determine the application of the Project Design Cycle.

From the twenty issues which were defined in the first interview, twelve were confirmed to be complex by the respondents, three partially complex and five not complex. By categorizing these twenty issues, two more issues turned out not to be complex. The ten remaining complex issues are shown in table 14 and concern the following issue-categories: modularization & pre-assembly, sequencing of work, and plot plan review. The twelve non-complex issues can be found in table 15 and concern the issue-categories: logistics study and the alignment of various disciplines.

The sole purpose of these tables is to present an overview whether the Project Design Cycle elements are recognized or not. No quantified conclusions can be drawn from the table. However, the table does serve as a useful tool that can be used to make observations and highlight occurring patterns.

Table 14: Cross-case analysis complex issues

Cross-case analysis: Complex issues	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
I. Modularization, pre-assembly and logistics	●	●	●	●	●	●	●	●
A1-C1: Modularization of pre-dressed columns	●	●	●	●	●	●	●	●
A1-C4: Pre-assembled pipe racks	●	●	●	●	●	●	●	-
A2-C1: Modularization pre-dressed columns	●	●	●	●	●	●	●	●
B1-C1: Pre-assembled pipe racks	●	●	●	●	●	●	●	●
C1-C2: Modularization and pre-assembly	●	●	●	●	●	●	●	●
III. Plot plan review and sequencing	●	●	●	●	●	●	●	●
A1-C2: Revising the plot plan	●	●	●	●	●	●	●	●
A2-C5: Sequencing of work	●	●	●	●	●	●	●	●
B1-C3: Contaminated soil / piling	●	●	●	●	●	●	●	●
B2-C3: Sequencing of work	●	●	●	●	●	●	●	●
IV. Others	●	●	●	●	●	●	●	●
C1-C1: Unexpected situations on-site	●	●	●	●	●	●	●	●

By analyzing the complex issues in table 14, it can be observed that the elements of the Project Design Cycle were practically always applied when the issue was recognized as complex by the respondents. Looking at the individual Project Design Cycle elements of the complex issues, it can be observed that the awareness, design and reflection elements were practically always recognized. The performance element was sporadically absent, but this seems to be the case in issues that still in progress, such as the sequencing of work (B2-C3 and A2-C5) and the execution plan of modules (C1-C2). These problem situations are often ongoing and concern multiple project stages. This indicates that the design or solution could not have been fully performed yet.

As the searching and experimenting nature of design is incorporated in the design element, it can be concluded that the respondents often applied design thinking principles when an issue is perceived as complex. An example of this conclusion is issue A1-C1 as described below. During the generation and testing of the alternatives, respondent A1 created more awareness of the actual problem situation. In this way, the respondent developed the problem and solution simultaneously.

Respondent A1 creates awareness by creating an understanding of the problem situation (☺ 2:2). By looking at possible solutions he gains more awareness of the entire problem situation and the complexity of the issue (☺ 2:2). Then, he comes up with several alternatives (☺ 2:3) and confirms the creation of multiple alternatives (☺ 2:6). After generating ideas, he tests them by evaluating the project drivers (☺ 2:5). Moreover, a solution is chosen and performed by analyzing the requirements and limitations for the execution of the solution (☺ 2:7). Finally, respondent A1 describes how he reflects upon the alternatives in several constructability sessions (☺ 2:9).

Furthermore, it can be observed that the elements were rarely applied in the correct sequence. This reflects that either the sequence was correct even though some elements were missing (issue A2-C1), or the sequence was explained in a different order by the respondent while it might have occurred in the correct sequence (issue C1-C1). However, the sequence might also depend on the reflective skills of the respondent to describe his own approach in a structured and clear way. Also, the human mind often doesn't work in a structured way as proposed in the framework of the Project Design Cycle.

When looking at the distinction between generating and testing, it can be observed that these sub-elements occurred separately a couple of times. Since the design element wasn't recognized in some issues, little results could be retrieved regarding the distinction of generate and test. However, the distinction was present in issue C1-C2 as described below. This example represents the searching and experimenting nature of design thinking, as the problem and solution were developed simultaneously.

Respondent C1 first generates ideas to create extra value on-site (🗣️13:14), then he tests these ideas by performing an analysis (🗣️13:15). Secondly, the respondent goes through all problem areas to create several alternatives in an open multi-disciplinarily brainstorm session (🗣️13:18). The alternatives are assessed by the disciplines and captured in a log. Respondent C1 adds that some decisions can be performed straight away, while others have to go back to the drawing table or has to be studied by an analysis (🗣️13:19). Thirdly, the previous experiences and lessons learned of other disciplines are used to create new awareness of the problem situation and as new input for the designing process (🗣️13:21). Finally, the alternatives are tested again by performing an analysis, in which the alternatives are assessed on costs, productivity, logistics and schedule (🗣️13:23).

Table 15: Cross-case analysis non/ partially complex issues

	Complexity	Awareness	Design	Performance	Reflection	All elements	Sequence	Distinction G-T
Cross-case analysis: Non-complex issues								
I. Modularization, pre-assembly and logistics								
A2-C4: Logistics study	●	●	●	●	●	●	●	-
C1-C4: Logistics study modules	●	●	●	●	●	●	●	-
II. Alignment of various disciplines								
A1-C3: Aligning engineering and construction disciplines	●	●	●	●	●	●	●	-
A2-C2: Aligning all disciplines	●	●	●	●	●	●	●	-
B1-C4: Aligning engineering and construction disciplines	●	●	●	●	●	●	●	●
B2-C2: Aligning all disciplines	●	●	●	●	●	●	●	-
C1-C3: Alignment process	●	●	●	●	●	●	●	-
IV. Others								
A2-C3: Fit-for-purpose applying the CDE playbook	●	●	●	●	●	●	●	●
B1-C2: Resourcing and staffing in FEED	●	●	●	●	●	●	●	-
B2-C1: Unexpected situations on-site	●	●	●	●	●	●	●	-

By analyzing the non-complex issues in table 15, contrary conclusions can be drawn. First of all, it is noteworthy that none of the issues, which are not or partially recognized as complex, contain all Project Design Cycle elements: either the design or performance element is missing. Furthermore, it is interesting to observe that the design and performance were never missing in the same issue. Since always one of the elements were missing when an issue is not recognized as complex, the elements are never performed in the correct sequence.

Additionally, it is interesting to notice that in two issues in which the design element was only partially recognized (A2-C3 and B1-B4), the generating and testing of ideas was conducted separately of each other. For instance, in A2-C3 as described below. Unfortunately, nothing could be stated about the other issues, since most of them didn't contain the design element at all.

The respondent starts with explaining the design options and the alternatives he develops in cooperation with other disciplines (🗣️11:32, 🗣️11:40), then he describes how he tests and compares them, and reflects on the dynamic situation (🗣️11:33, 🗣️11:41).

Since the design element is often missing when the issue is not perceived or recognized as complex, it can be concluded that the respondents barely applied design thinking principles when approaching non-complex issues. Even in issue A2-C3 and B1-C4 where the design element was partially recognized, the respondents did not create multiple alternatives, which is a main characteristics of design thinking.

Even though the Project Design Cycle and design thinking principles were barely recognized in these issues, many of the individual elements are still recognized. This can be explained by the fact that a traditional 'firefighting' approach also contain some similar elements, such as awareness and performance for instance. As a consequence, it can be observed that most of the non-complex issues were approached and solved by traditional 'firefighting' problem-solving. This is shown in issues A1-C3, A2-C4, C1-C3, and C1-C4. The latter is further explained below.

The logistics study discussed in issue C1-C4 is part of a larger decision-making cycle, namely the decision to apply modularization. In this occasion, the issue is merely the testing part of one of the alternatives, which insinuates that there is a clear objective: assess whether this alternative is feasible. This would explain the iterative process of creating awareness and performing the solution (testing): it goes back and forth between awareness and performance (🗣️13:31 to 🗣️13:38), in which awareness of the entire problem situation is created by reflection in-action.

6.1.3 DESIGN THINKING IN CONSTRUCTION MANAGEMENT

To determine whether design thinking and the Project Design Cycle is applied by construction managers in a construction-driven FEED phase, the findings of the previous sub-chapters are reviewed. First, the differences between complex and non-complex issues are discussed. Secondly, the approach of construction managers is compared to the approach of site managers. Thirdly, the findings of all three case-studies are compared. Fourthly, the opinion of the respondents with regards to the Project Design Cycle, and with regards to the reflection practices are discussed.

COMPLEXITY OF ISSUES

Based on the findings, it can be determined that the design element is often missing when an issue is not recognized as complex. Since the searching and experimenting nature of design is incorporated in the design element, it can be concluded that the application of design thinking by the respondents often depend on their perspective of the level of complexity of the related issue.

Of course, one could argue what the significance is with regards to the final solution when an experienced construction manager does not perceive an issue complex, and therefore, doesn't apply the elements of the Project Design. It could very well be, that the firefighting approach is the best approach for certain issues that are not complex. As it is not measured (or known) whether the approach of the respondents resulted in the highest value for the concerning issues, it is hard to comprehend whether the application of the Project Design Cycle would indeed resolve in a 'better and well-thought through' solution.

ROLE OF THE CONSTRUCTION MANAGERS

To prevent misunderstandings throughout the research, the role of both the site- and construction manager have both been referred to as construction manager (as a site manager is in fact a more experienced construction manager). However, in daily practice site managers (respondents A2, B1, C1) have seniority over construction managers (A1, B2). Logically, one could argue that due to this seniority, the site manager would recognize the complexity of issues earlier and also approach the issue in a more considerable way in comparison to the construction manager. Nevertheless, this can hardly be noticed in the findings.

When comparing construction manager A1 and site manager A2, it can actually be observed that respondent A1 recognized more complexity elements in the issues, and also applied the elements of the Project Design Cycle more often. On the other hand, one could also say that due to the seniority, the site manager doesn't perceive the same level of complexity as he might have much more experience with these issues. When comparing site manager B1 and construction manager B2, the opposite can be observed. Respondent B1 recognizes much more complexity elements and also approaches the issues in a more considered manner. In this case, one could say the construction manager doesn't have the same level of experience to recognize the complexities, and therefore apply a simpler (more straightforward) problem-solving approach.

Altogether, it can be concluded that there are too many variables that might have influenced the differences in the findings. For instance, it could depend on: education, experience in construction, experience in office, age, previous employee, or nationality. But also, the moment of involvement in the project, or their experience with Construction-Driven Execution, modularization, sequencing, and constructability.

CASE-STUDIES

By comparing the findings of the three case-studies in the previous sub-chapters, it's aimed to observe some differences and similarities. When looking at the issue-categories, the following can be observed. Regarding category I, both case A and case C aimed to apply full modularization solutions in order to reduce man-power and working on height on-site, while Case B only concerns pre-assembly solutions due to client restrictions. However, no differences could be observed in the findings of the case-studies. With regards to the findings of category II (alignment), no distinct differences could be noticed. Furthermore, the issues in category III (plot plan review) only concern case A and case B. Since case C was still in FEL 2, no issues regarding the sequencing of work were detected or solved yet. Interesting is that the respondents in both cases apply all Project Design Cycle elements when the problem is clearly defined (A1-C2, B1-C3) and do not apply the performance element when the problem is not clearly defined, or when the issue is still in progress (A2-C5, B2-C3).

Remarkable is that no differences are observed when analyzing the findings of application of the Project Design Cycle between the cases. Similar patterns seem to be present between the cases in both complex as non-complex issues.

RECOGNITION OF THE PROJECT DESIGN CYCLE BY THE RESPONDENTS

Interesting to observe during the interviews, is that all respondents claim to be familiar with the elements of the Project Design Cycle in their daily functioning (appendix J). This is in contradiction with some of the findings of the cross-case analysis, which indicate that the respondents occasionally apply all elements. This could be explained by the assumption that the respondents are familiar with the elements due to previous training sessions for other (quite similar) decision-making tools, but never had to apply these methods to a full extend since they were always on-site. Additionally, they might not be aware of the complexity of issues in FEED or of their own approach to solve these issues.

Table 16 shows that all respondents recognized the elements of the Project Design Cycle but did not always perceive the elements in the same way. Especially the design and reflection elements mentioned under a different name by the respondents (☎2:81, ☎11:80, ☎6:50, ☎12:33, ☎13:47). Additionally, respondents A1 and B2 state that the reflection element is also applied during the design element to ‘check’ or evaluate with other disciplines whether the chosen solution is indeed doable and creates more value (☎11:82, ☎12:26). This can be seen as a separate ‘test’ step in the design element. Furthermore, the reflection element is perceived as lessons learned by multiple respondents (☎11:80, ☎12:33).

Table 16: Recognition of the Project Design Cycle elements (appendix J)

	Awareness	Design	Performance	Reflection
Respondent A1	Aware and empowered	Design & reflect	Performance	Reflection
Respondent A2	Identify problem	Create a solution	Construct or execute	Lesson learned and reflect back
Respondent B1	Identify issue	Collect data	Report data	Analyze report and reflect
Respondent B2	Awareness	Design & check	Perform	Lessons learned / Check
Respondent C1	Awareness by reflection	Design	Perform	Reflect

The respondents do state that they particular recognize these elements when solving issues in FEED and less during the construction stage on-site. They all acknowledged that issues in FEED require a different problem-solving approach compared to what they are used to on-site (☎2:76, ☎11:77, ☎11:78, ☎12:24, ☎12:25, ☎13:50). As stated by case A1 *“if the solution is quick, safe and of acceptable quality, then it will likely be cost effective as-well”* (☎2:76). This shows that the main driver during construction is schedule and therefore require a simplified approach (identify the problem, find a solution and perform it), when compared to the Project Design Cycle.

Based on this, it can be concluded that construction managers often fall short on the design and reflection elements due to the constant time pressure on-site, and because there is little time reserved for generating and testing several alternatives, or for any reflection of the final solution. Additionally, case B1 states: *“it is also dependent on the education of the construction manager; someone who came of the tools has never learned to approach problems in this way”* (☎6:52). This indicates that some construction managers are not trained or educated to approach problems in a more design thinking way. Therefore, it can be concluded that construction managers require education to approach issues in FEED in a more considerate manner.

REFLECTION PRACTICES IN CONSTRUCTION MANAGEMENT

Furthermore, special focus was put on the reflection element throughout the interviews. The respondents were asked about formal reflection practices at Fluor, their personal reflection moments, and improvements. The answers are summarized in table 18 and can be found in appendix K. It can be noticed that formal and informal reflection practices vary a lot per respondent. Formal reflection practices consist mostly of the lessons learned database and ‘KnowledgeOnline’ forum. Personal reflection practices are diverse: some are taking it seriously and keep a diary, while others only reflect their solutions with colleagues.

The respondents state that reflection practices can be improved both formally and informally. Formally it is suggested by the respondents to conduct monthly meetings between all construction management teams assigned at various projects. These meetings can be specific focus sessions to address a specific issue or can be used to share and discuss experiences, problems and solutions that occurred. In this way, time is scheduled to properly reflect on experiences. Informally, it is suggested by the respondents to incorporate reflection in the day-to-day practices of construction managers when they are in FEED.

6.2 PRACTICAL APPLICATION OF THE PROJECT DESIGN CYCLE

In the previous sub-chapter, the (complex) issues, application of the Project Design Cycle elements and design thinking by the respondents is evaluated in a cross-case analysis. The next step is to determine how the Project Design Cycle can be transformed into practical tool that can be used in the case-study projects. First, it is explained why a tool is needed by combining the theoretical framework with the findings of the empirical research. Then, based on the elements of the Project Design Cycle and the findings of the cross-case a tool is presented. Finally, it is elaborated how this tool can be applied by the construction managers to enable them to approach complex issues they are confronted with in a construction-driven FEED phase.

6.2.1 APPROACHING COMPLEX ISSUES DURING FEED

In a construction-driven project, construction managers are involved early in the process to provide input to office departments in order to prevent mistakes from happening in later stages of the project. The role of construction managers in FEED can be compared to that of project managers. In order to tackle the complex issues that occur during FEED, it is found that construction managers need to learn how to think and solve problems like an experienced project manager would do. Since the Project Design Cycle framework is used to educate and support (future) project managers in order to approach complex problem situation in a design thinking way (Lousberg et al., 2015), it is considered to be a useful framework for construction management as-well.

In the previous sub-chapter, it is researched to what extend construction managers already apply the elements of the Project Design Cycle when approaching complex issues. It is found that construction manager typically falls short on the design and reflect element, since little time is reserved for generating and testing several alternatives or for any reflection of the final solution. When construction managers do not reflect and share knowledge, they do not give themselves the opportunity to find the best solution with the highest value. Fundamentally, it is about identifying, recognizing and acknowledging complex situations. Otherwise, when decisions are made merely on experience, the solution with the highest value is often missed. This identification is based on previous experience and could be improved by correctly reflecting on old experiences and sharing this with other colleagues, disciplines, and projects.

It is observed that the respondents primarily apply the elements of the Project Design Cycle when they perceive the complexity of issues. Therefore, it is determined that they require a practical tool to guide and support them to identify and approach complex issues in FEED. To create acceptance and support within the construction management community, the Project Design Cycle has to be adjusted. The new tool and the transformation of the Project Design Cycle is elaborated below.

6.2.2 TRANSFORMING THE PROJECT DESIGN CYCLE

The Project Design Cycle by the Project Design School is transformed to the 'ADAPT – Decision-making cycle'. ADAPT is an abbreviation of the elements Awareness, Development, Assessment, Performance, and Throw-back. It represents the steps a construction manager has to go through in cooperation with other disciplines, in order to identify complexities and find the solution with the highest value to solve these issues.

As shown in figure 27, the individual elements of the Project Design Cycle have been transformed in order to make it more suitable and acceptable for the implementation within Fluor's construction management department.

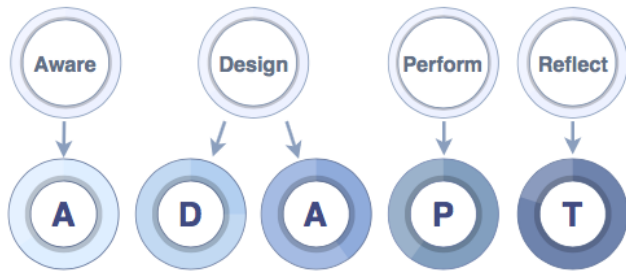


Figure 27: Transition Project Design Cycle to ADAPT

The first element Awareness remains the same in ADAPT. In the cross-case analysis (table 14 & 15, sub-chapter 6.1.2) it is determined that the respondents sometimes perform the sub-elements of design (generate and test) in separate steps. Therefore, it has been decided to split up the design element into Develop and Assess, in which Develop represents the generating step and Assess the testing step. Assess is in fact another reflection step that is placed between design and perform (table 16, sub-chapter 6.1.3) and could be seen as Reflection-in-action. The third element Performance will remain the same. The fourth element Reflection is replaced by Throw-back, because the majority of the respondents perceived this element as lessons learned (table 16, sub-chapter 6.1.3). By throwing-back lessons learned and previous experiences, additional awareness is created in new projects. This final element has resemblance to Reflection-after-action.

As defined by the Cambridge English Dictionary (n.d.), the word ADAPT stands for “to change something to suit different conditions or uses”, and also as “to become familiar with a new situation”. In this research context, the essence of ADAPT is precisely that: construction managers have to adapt in order to change something (their approach) to suit different conditions (construction-driven FEED). By doing so, they “have to become familiar with a new situation”, which represents the new role and responsibilities they have to fulfill in order to solve complex issues in the early stages of the project.

The ADAPT decision-making cycle (figure 28) represent a design thinking framework that can be applied in practice by Fluor’s construction management. ADAPT is a decision-making cycle that enables construction managers to approach complex issues which occur in a construction-driven FEED-phase. This cycle is based on the elements of the Project Design Cycle and could serve as a useful tool to educate and assist construction managers in this manner. This framework could support and educate construction management by improving their capabilities and skills. The application of the cycle is further elaborated in the following sub-chapter.

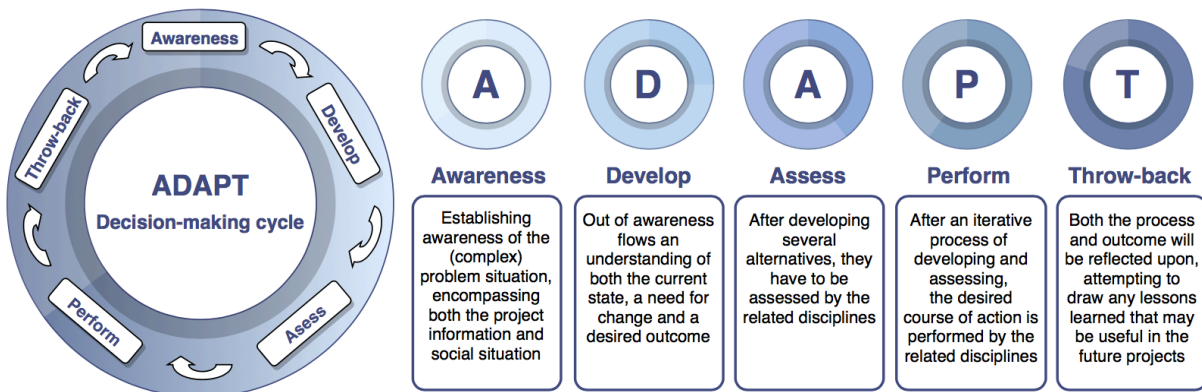


Figure 28: ADAPT – Decision-making cycle (own figure)

6.2.3 APPLICATION OF ADAPT

This sub-chapter elaborates what the elements of ADAPT consist of and how the framework could be applied in construction management practice. The elements of ADAPT are defined step-by-step in figure 29. This figure provides a framework which can be used in construction management practice.

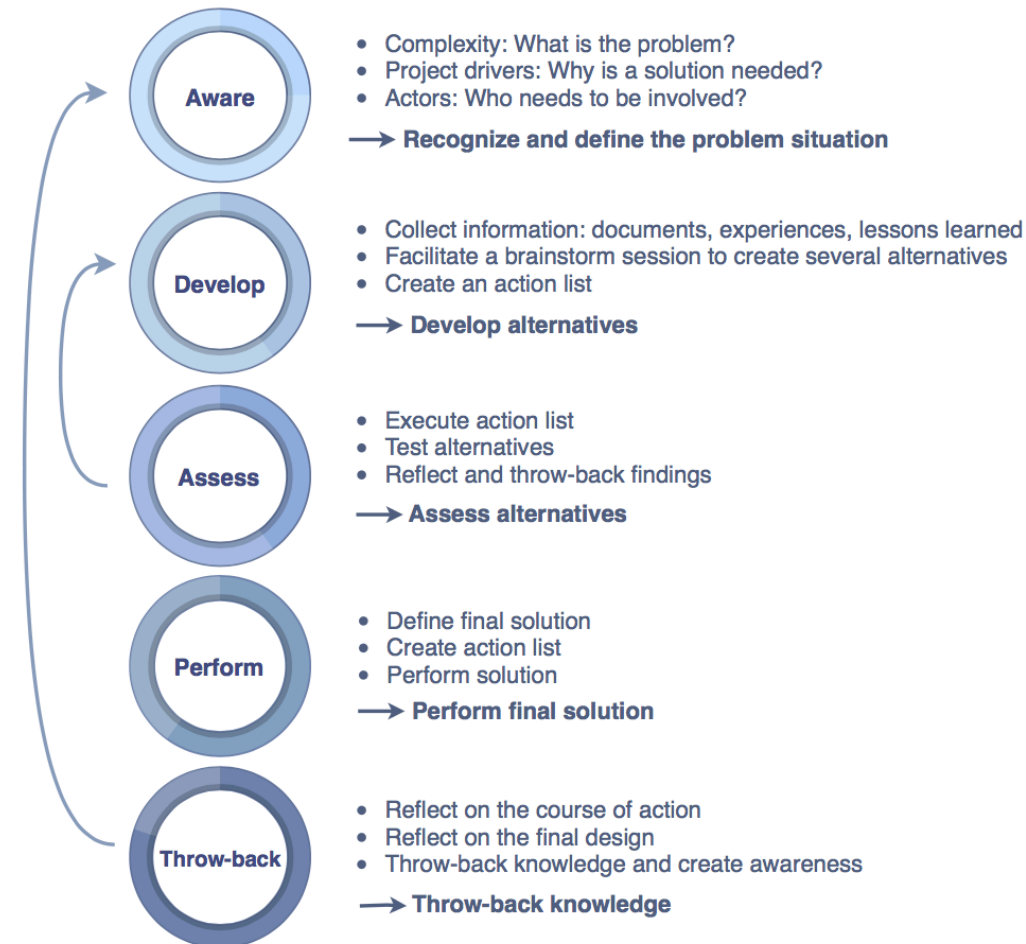


Figure 29: ADAPT – Elements and characteristics

First, awareness is created by defining the complexities in the situation, the project drivers that influence the final decision, and the actors and disciplines that need to be involved. This information allows the team to define the problem situation and to determine the aspired value.

Secondly, alternatives are developed. It is crucial that the related information is gathered, this consist of project documents and drawings, previous experiences of actors, lessons learned that are applicable to this problem situation. This will provide the basis of a brainstorm session. This session is facilitated by the construction manager and aims to develop several alternatives. At the end of each session an action list is created for all actors.

Thirdly, the action list is conducted by the individual disciplines, by which the alternative solutions are tested and reflected upon. Any new information that has come up is thrown-back to re-define the problem situation and serve as input for a second brainstorming session. This interactive process of development and assessment is focused on finding a solution that will lead to the aspired value.

Fourthly, after choosing a solution that is expected to deliver the aspired value, the solution is performed. This is done by first defining the final solution in more detail together with the other disciplines. After which an action list is created for the individual disciplines, as-well as the construction manager to enable the disciplines to do their work. Finally, the solution is created by performing the action lists.

Fifthly, the final solution is reflected upon. Any lessons learned are drawn of both the course of action and the final product. These lessons and new knowledge are thrown-back to create awareness for other issues. It is important that relevant new information and knowledge is also shared with other construction management teams in order to prevent the same situation happening over and over again.

ADAPT serves a double purpose in construction management practices and could be applied in the form of a cognitive processing model and in the form of a decision support system:

- Cognitive processing model: remind and support construction managers not to make decision merely based on old experiences, but to take their time to properly reflect on situations and share their knowledge in order to identify, recognize and acknowledge complex situations.
- Decision support system: structure constructability meetings to approach complex issues in a multi-disciplinary way and to provide construction managers the ability to get an understanding of the problem situation, in order to determine an effective course of action by drawing upon the entire repository of construction management research, knowledge and tools.

ADAPT should not be implemented top-down by too many new procedures as Fluor is already flooded with new innovations and procedures. In comparison to other tools (like CDE), ADAPT should be implemented and driven by the construction managers from bottom-up. This can be done by making the individual construction managers aware of their lack of skill to solve complex issues the FEED phase, and by proving the cycle's added value. By providing a clear framework and structure, construction managers are learning how to approach complex issues in FEED and find solutions with higher values. Additionally, by being aware of the elements, and in special 'Throw-back', construction managers learn to share their knowledge with other construction management teams and other disciplines. This creates new awareness in other situations and enables others to identify and solve complex situations in an early stage.

Constructability is a perfect example where construction, engineering and procurement disciplines work together to create integrated solutions in order to prevent 'fires' from happening on-site. Awareness can be created by identifying the complex situations in the constructability program in cooperation with other disciplines. The identified complex issues can then be discussed in so called 'constructability focus' sessions. As the name already predicts, these sessions are about focusing on a specific component or area of the design with high complexity, in which a multidisciplinary team dives into the issue in several meetings. These sessions are led by construction manager, and therefore provide an excellent opportunity to implement the ADAPT decision-making cycle from bottom-up. The elements can be used to shape and structure these sessions by presenting a framework. This platform also creates a great opportunity to design base-cases and standardize certain components of the plant, especially for modular solutions. These base-cases can then be 'Thrown-back' and used in other/ future projects.

ADAPT has been discussed with the respondents in the final question of the second interview. After explaining; what ADAPT is about, why a tool is required, and how it could be applied in construction management, their opinions of the concept are collected and put in table 17 in [appendix J](#). These reflections by the respondents are used to validate the acceptance of ADAPT within Fluor's construction management. It is important to note that the magnitude of this validation is relatively small, since it is possible that the respondents have answered biased after explaining the tool.

6.3 EXTERNAL VALIDATION

Findings of sub-chapters 6.1 and 6.2 are presented to an independent expert panel, in order to perform an external validation. The selected experts are independent since they have had no influence, input or knowledge of this research. The expert panel consists of two high-level managers (expert A & expert B) which are active within Fluor's energy and chemicals (O&G) business line. These two experts are briefly introduced in appendix K. Both experts have extensive knowledge of oil and gas projects, are familiar with the current application of Construction-Driven Execution, and work closely with construction managers in their daily functioning.

The validation is conducted in the form of an open discussion between the experts. First, the theoretical framework, empirical research process, and the results are presented in order to provide the experts with background information and argumentation of the statements. Then, it was asked whether the experts recognize themselves in the findings of cross-case analysis. Furthermore, ADAPT is presented and explained to the panel, after which the tool is discussed by presenting three statements related to the application of ADAPT. Finally, the current role of construction management in Construction-Driven Execution is discussed.

In this sub-chapter the validation session is summarized and discussed. Of each topic the discussion points are mentioned first, after which quotations are used to summarize the experts panel statements. Finally, new findings and perspectives are listed in a clear overview.

6.3.1 COMPLEX PROBLEM-SOLVING BY CONSTRUCTION MANAGEMENT IN FEED

Discussion points validation:

- *Construction managers often do not recognize the complexity of issues in FEED,*
- *Construction managers often skip elements of the Project Design Cycle when the issue is not recognized as complex,*
- *Construction managers barely apply the elements in the correct sequence,*
- *Construction managers often apply the generate and test components of design separately.*

After explaining the research methodology, the experts were asked whether they recognized themselves in these findings and if they think they are valid. Both experts agreed with these statements and stated they do not recognize design thinking practices within construction management. However, they do mention that these statements do not apply for project managers, as they are used to the process of doing complex analysis and decision-making.

Expert A adds that construction managers *“traditionally are field orientated and have a hands-on problem solving in the field, rather than the complex theoretical problem solving that you're looking at here”*, while project managers *“expect a level of detailed analysis and testing, to make sure that you provide the data that they need to make informed decisions”*. Construction managers are normally at the back-end of the process, act reactive and are good in problem solving, but they are not good at preventing problems. To prevent the problem, it is required to perform a complex analysis before an event happens, while construction managers traditionally apply post-event reaction to fix problems.

Expert B confirms that the findings drawn from table 14 & 15 (cross-case analysis) are rightfully concluded, and states *“construction managers always find a solution for something, however it is rarely the right solution”*. Expert B adds that construction managers are really good in problem solving but are not always able to handle the complex decisions in FEED. He continues that construction managers solve problems whatever the costs as they are only fixated on the completion, however *“they fall short in understanding the commercial side of processes or don't have the knowledge or skills to understand all the things that are involved in the decision-making.”*

(New) findings and perspectives:

- Construction managers are field orientated and have a hands-on problem solving in the field, rather than the complex theoretical problem solving.
- It is recognized that project managers do apply the elements of the Project Design Cycle.
- Construction managers fall short in understanding the commercial side of the decisions

6.3.2 IMPLEMENTATION AND APPLICATION OF ADAPT

Discussion points validation:

- ADAPT can provide a structure to constructability
- ADAPT can support the cognitive process
- ADAPT should be implemented bottom-up

Expert B agrees that construction managers need a platform. However, he disagrees with the statement that construction managers do not have enough time to reflect. He is of the opinion that *“they are just the type of people we have in our resource pool that just love the action, the firefighting, to make the decisions and move forward. They do not want to do develop and assess; they want to go from Aware to Perform in the same five minutes”*. By investing more in the front-end and influence the issues in the first place, construction managers can generate time in the end to actually execute their plan, and also have time to reflect on it. The current problem is that not enough time is invested in the front-end to identify potential risks, alternatives and methods. Therefore, when going to site the problems are not identified yet and construction managers have to go straight into problem-solving mode.

With regards to the last statement (bottom-up implementation), both experts agree and disagree. Expert A states that on the hand, it should be implemented bottom-up as an integrated approach in which the construction managers have to be pro-active and take it upon themselves to drive this, adopt it, and move it forward. However, on the other hand, they need to have resources available to really put such a framework into place. This has to be done top-down by setting-up the budgets and estimates for man-hours in FEED. Expert A states that these man-hours are often not accounted for.

Expert B adds that ADAPT is a nice structure which he understands. However, he also states most construction managers of the current population would not have the flexibility of mind to actually be able to work with ADAPT. As most of the construction resource pool is over fifty, they are used to executing their work in a certain way and are not going to run an ADAPT-framework to make decisions. The focus should be top-down on selecting the right people that would be able to work with a framework like ADAPT and understand the necessity of doing it this manner.

(New) findings and perspectives:

- The problem with the current construction management resource pool is that most construction managers actually wants to fight fires and do not want to develop and assess.
- ADAPT should be implemented bottom-up as an integrated approach in which construction management is pro-active and take it upon themselves to drive, adopt, and move it forward.
- ADAPT should have top-down support by providing enough man-hours for construction management in FEED, and by selecting the right people that are able to approach these complex issues.

6.3.3 CULTURAL PROBLEM REGARDING CONSTRUCTION-DRIVEN EXECUTION

Discussion point validation:

- *Cultural problem within Fluor: construction managers are reviewed and rewarded based on their ability to fight fires, while in FEED it is expected that they approach complex issues in a different way. How can we tackle this cultural problem within Fluor and how can we support current construction management?*

Expert A and expert B both recognize this cultural problem. Fluor went from EPCm to EPC, but the departments have not grown that way: *“the cultural problem is that the mind shift that construction is part of the overall process does not only concern construction, but also engineering and procurement disciplines: it is a mind shift change from an organizational perspective”*. With regards to construction, expert A concludes that *“construction managers often have the feeling they're a separate entity and some kind of client receiving deliverables or materials from somebody else, and then just solve the problems. Not only do construction managers not invest at the front, they want to get to site as quick as they can. They feel they are in the office under duress and want to get to site because that's where they get the power and their up-lifts and everything else”*. Expert A also states that the term ‘Construction-Driven’ should change to ‘Execution-Driven’, as it is not only construction who has to execute the project successfully. It is important to do it together as a team with engineering and procurement.

Both expert A and B are of the opinion that this position should not be filled by the traditional construction manager. Expert B do state that construction managers should be part of the leadership team who jointly runs the project and be an integral part of the front-end in order to take strategic decisions and performing what-if scenarios. However, a small side-note is made; *“I also recognize that it is not possible to have this function fulfilled by every construction director we have in our resource pool. That's why we have to select the right people”*. Expert B adds to this *“the construction manager has excellent visibility of the site, but often misses the visibility of the client contract relationship and external activities like procurement”*. Therefore, expert B thinks that this position should be filled by someone who stands in between the construction manager and project director and have construction, contract and commercial awareness and focus.

Expert A finishes the discussion by stating *“the problem is that the construction organization has been neglected for many years. Fluor has been rewarding construction managers for the wrong things. Involving them in the beginning doesn't solve the problem in projects because they have been rewarded for something else for 30 years, and they cannot change in a day”*. Expert B complements that it can be difficult to change a 60-year-old construction manager. Therefore, the focus should be on training and educating the next generation of construction managers to make them aware of how they fit into the overall process and apply the system.

(New) findings and perspectives:

- Construction has been neglected for too long; an organizational mind shift is required to realize that construction is part of the overall process.
- Construction managers have to change their mindset: be aware of their position in the overall process and be willing to make a difference in the office.
- Fluor's current resource pool mostly consists of traditional construction managers, which are rewarded for the wrong things.
- This position in FEED should be filled by newly selected construction managers that both have extensive construction knowledge and contractual and commercial awareness and focus.
- The focus should be on educating the next generation of construction management since experienced construction managers of late age are not going to change quickly.

RESULTS

Chapter 7



In chapter 7 the results are concluded, discussed and recommended. First, the research question and related sub-questions are answered in sub-chapter 7.1. Secondly, in sub chapter 7.2 the methodology, results and validation are discussed and complimented with limitations. Additionally, the scientific and practical implication of the results are determined. Thirdly, scientific recommendations for future research and practical recommendations to Fluor are presented in sub-chapter 7.4. Finally, the research thesis is reflected upon by the author in sub-chapter 7.4.

7.1 CONCLUSION

Based on the theoretical framework and the empirical research, conclusions are drawn to answers the research questions. The main research question “*How can the Project Design Cycle enable construction managers to identify and approach complex situations in a construction-driven FEED phase?*” will be answered in this sub-chapter. Four consecutive sub-questions are answered in order to answer the main question. Combining the answers of all sub-questions provides the knowledge and information required to answer the main research question.

1. *What is the influence of Construction-Driven Execution on construction management practices?*

The purpose of Construction-Driven Execution is to take construction from a reactive process in the end to a more pro-active process in the beginning, in order to reduce potential probabilities of issues occurring in the end. This is done by involving construction managers early in the process. The influence of Construction-Driven Execution on the role and responsibilities of construction management practices can be observed on several levels.

The construction manager’s focus shifts from firefighting (on-site) towards fire prevention (FEED). This transition has a major impact on the way construction managers should approach issues in their daily functioning. Issues on-site require a direct and traditional problem-solving approach (identify problem – create solution – execute solution). While issues in FEED are more complex, as they concern multiple phases, disciplines, and locations (office, modular yard, construction site, harbour). Missing one component on one of these areas could have large consequences for others. Additionally, the aspired end-result is often unknown, which causes actors to be cautious and reactive to others in the process.

In Construction-Driven Execution, the prescribed role and responsibilities of the construction manager can be compared to that of the project manager. In fact, the construction manager is the ‘project manager’ of the execution portion of the project, in which construction managers have to lead and align multiple disciplines in order to create an integrated construction execution plan. Furthermore, their level of decision-making changes from operational to tactical and strategical. Tactical and strategical decisions are infrequent, have a large scope, include uncertainty, and should be based on different alternatives. Instead of solely focusing on schedule when making operational decisions on-site, the construction manager should also consider the commercial and contractual aspects of the project when making tactical and strategical decisions in FEED.

2. *What is the essence of design thinking and the Project Design Cycle?*

The basic reasoning pattern of design thinking can be comprised to: “*a thing (what) + a working principle (how) leads to an observed result*”. In design practices, the result cannot be defined upfront and is therefore presented by an aspired value (Dorst, 2011). The core challenge of design thinking concerns the performance of a complex creative feat in which a thing (object, service, system) and a working principle is created simultaneously. In other words, the essence of design thinking comes down to the simultaneous development of problem and solution (Dorst, 2011). Design thinking is characterized by abductive reasoning, which can be explained in four sequential steps (Lousberg et al., 2015):

1. Define the aspired value by recognizing the problem situation;
2. Use inductive reasoning to work backwards from the aspired value and create a frame to determine a working principle;
3. Use abductive-1 reasoning to create a thing to complete the equation.
4. Use deductive reasoning to work forward and test whether the thing and the working principle result in the aspired value. If this is the case, the proposed frame can be accepted as definitive.

The Project Design Cycle is created by the Project Design School and in order to provide a framework to educate and guide project managers to apply design thinking principles when approaching complex issues. It educates project managers the ability to understand the problem situation, in order to determine an effective course of action by drawing upon the entire repertory of project management research, knowledge and tools. The Project Design Cycle consists of the element's awareness, design, performance and reflection. The Project Design Cycle elements are explained as follows:

- Awareness is created to define the current problem situation, a need for change, and a desired outcome. At this stage, it is important for the construction project manager to take time to enable himself to observe the entire situation and not move into action too quickly.
- In design, the construction project manager defines a course of action by moving backwards in order to create a frame. This frame allows the project team to create and test several alternatives. By doing so, an object, system or service is created, which results in a solution that would lead to the aspired value.
- In performance, the construction project manager initiates and guides the project team to execute the developed course of action. The goal of this step is to confirm whether the design does indeed lead to the aspired value.
- After performance, the result is reflected in order to assess whether the proposed frame can be accepted as definitive. If the frame is accepted, the project manager can move on and derive any lessons learned from this approach (reflection after-action). If the frame is declined, the project managers has to go back to design, in which the new knowledge is used to create awareness to adjust the proposed frame (reflection-in action).

3. To what extent are the elements of the Project Design Cycle currently applied by construction managers when approaching complex issues in a construction-driven FEED phase?

An empirical research is performed in which five construction managers of three case-study projects are all interviewed twice. The transcripts of the interviews are analyzed in a case- and cross-case analysis. In the cross-case analysis it is analyzed to what extend the elements of the Project Design Cycle are incorporated in the daily practice of construction managers. The following findings are obtained from the cross-case analysis to answer this sub-question:

- The respondents often did not recognize or perceive the complexity of the issues. It is observed that the recognition of complexities influences the approach of the respondents to solve the issues to a large extend. The issue-categories that were perceived as complex concern modularization, pre-assembly, sequencing of work and revising the plot plan. Alignment of disciplines is not recognized as complex by the respondents. From the twenty issues identified in the first interview, ten were defined as complex in the cross-case analysis.
- When an issue is recognized as complex, nearly all Project Design Cycle elements were applied most of the times by the respondent. However, the sequence of the elements was often not correct. The design element was conducted separately (generate and test) sometimes.
- When an issue is not recognized as complex, it is observed that practically always one or two Project Design Cycle elements were not applied by the respondents. Moreover, it is found that the sequence is most likely not to be performed in the correct order. This is also in line with the statement made above; some elements are missing when complexity is not recognized, which indicates the elements are not performed in the correct sequence. It is observed that the design element is recognized the least, followed by performance.

To conclude, a clear coherence is observed between the application of the elements and the recognition of complexity with regard to the identified issues. It can be concluded that construction managers do apply the elements of the Project Design Cycle in their daily function in FEED. However, only when the issue is recognized as complex. Thus, the approach of the construction manager strongly on their ability to identify and recognize complexity elements within issues.

Furthermore, it is found that the design element is most likely not to be applied when the issue is not recognized as complex. This indicates that the searching and experimenting nature of design thinking is often not used by the respondents in this situation. Furthermore, it is observed that the construction managers fall back in their on-site problem-solving mode when they do not recognize the complexity of the issue. In this simplified problem-solving approach, the respondents go straight from awareness of the problem to the performance of a solution. The design and reflection elements are often skipped in the traditional on-site problem-solving approach.

4. How can the Project Design Cycle be transformed to serve as a practical tool for construction managers in a construction-driven FEED phase?

It is determined that the Project Design Cycle provides a suitable framework to both educate and support construction managers to approach complex issues in FEED. However, the Project Design Cycle needs to be adjusted in order to create acceptance and support within the construction management community. Based on the empirical research the following findings should be included the new tool:

- The design and reflection elements are often mentioned by a different name,
- A separate reflection step is recognized between design and perform,
- The 'generate' and 'test' steps within the design element are sometimes applied separately,
- The respondents are familiar with the framework of the Project Design Cycle.

The Project Design Cycle has been transformed to the ADAPT – decision-making cycle, by incorporating the findings of the empirical research. ADAPT is an abbreviation of the elements Awareness, Development, Assessment, Performance, and Throw-back.

The individual elements of the Project Design Cycle have been transformed in order to make it more suitable within construction management. The first element Awareness remains the same. In the cross-case analysis it is determined that the respondents sometimes perform the sub-elements of design (generate and test) in separate steps. Therefore, it has been decided that the design element is split up. Respectively into Develop and Assess, in which Develop represents the generating step, and Assess the testing step. Assess is in fact another reflection step, which is placed between design and perform, and could be seen as Reflection-in-action. The third element Performance will remain the same. The fourth element Reflection is replaced by Throw-back, as the majority of the respondents perceived this element as lessons learned. By throwing-back lessons learned and previous experiences, additional awareness is created in new projects. This final element is equal to Reflection-after-action.

As defined by the Cambridge English Dictionary (n.d.), the word ADAPT stands for “*to change something to suit different conditions or uses*”, and also as “*to become familiar with a new situation*”. In this research context, the essence of ADAPT is precisely that: construction managers have to adapt in order to change something (their approach) to suit different conditions (construction-driven FEED). By doing so, they “*have to become familiar with a new situation*”, which represents the new role and responsibilities they have to fulfill in order to solve complex issues in the early stages of the project.

RQ. How can the Project Design Cycle enable construction managers to identify and approach complex situations in a construction-driven FEED phase?

The Project Design Cycle, which incorporates the essence of design thinking, provides a useful framework to support and enhance construction managers to identify and solve the complex issues that occur in FEED. The ADAPT – Decision-making cycle is based on the Project Design Cycle and developed to provide construction managers with a framework. ADAPT incorporates the identification of complexities, development and assessment of alternatives, creation of a solution with the highest value, and a reflection upon the outcome. This framework can be used to educate and support construction managers by improving their capabilities and skills that are required to approach complex issues during FEED. ADAPT provides both a structure for decision making, and a supportive model for cognitive reasoning and reflection practices.

➤ Decision support system:

ADAPT can serve as framework to structure constructability meetings in order to approach complex issues in a multi-disciplinary way. Also, it provides construction managers the ability to get an understanding of the problem situation in order to determine an effective course of action by drawing upon the entire repertory of construction management research, knowledge and tools.

Constructability is a perfect example where construction, engineering and procurement disciplines work together to create integrated solutions in order to prevent ‘fires’ from happening on-site. Awareness can be created by identifying the complex situations in the constructability program in cooperation with other disciplines. The elements can be applied to shape and structure these sessions by presenting a useful framework. This platform also creates a great opportunity to design base-cases and standardize certain components of the plant, especially for modular solutions. These base-cases can then be ‘Thrown-back’ and used in other/ future projects.

➤ Cognitive processing model:

ADAPT can serve as a cognitive processing model to remind and support construction managers not to make decisions merely based on old experiences, but to take their time to properly reflect on situations and share their knowledge in order to identify, recognize and acknowledge complex situations. In the empirical research it is found that the main focus should be about the identification and recognition of complexities before a decision is made. When the complexities are not identified, construction managers apply their standard ‘firefighting’ approach in which they solely use their experience to solve the problem. By doing so, they often miss the opportunity to find the solution with the highest value.

The integrated reflection component of the Project Design Cycle can be very useful for construction managers. It is observed that when reflection is skipped, the construction managers do not allow themselves to find the solution with the highest value. In this sense, reflection enhances the determination of complexities and the sharing of important knowledge to prevent mistake from happening time after time.

7.2 DISCUSSION

In this chapter the methodology, results and validation method are discussed and complimented with limitations in sub-chapter 7.2.1. Furthermore, both the scientific and practical implications of the results are discussed in sub-chapter 7.2.2.

7.2.1 DISCUSSION & LIMITATIONS

This sub-chapter discusses the research methodology, results and validation method. The advantages and limitations of these subjects are mentioned. Subsequently, the influence and consequences of these limitations are elaborated.

METHODOLOGY

An advantage of the applied research methodology is that each respondent in interviewed twice. First of all, it provided more in-depth information that could be used for the analysis. Secondly, by interviewing the same person again, the respondent was already familiar with the research and was more willing to be open and honest in his answers. Another advantage of the applied methodology was that the respondents were not made aware of the research objectives, design thinking, or the elements of the Project Design Cycle until the end of the second interview. By doing so, the respondents maintained a high level of objectivity throughout the interviews. If they would have been made aware of the elements, it is expected that the they would have answered in line with the elements. Furthermore, the use of Atlas.TI qualitative data analysis software enabled a structured and well-organized case analysis, which made it a simple activity to extract the data by use of pre-defined codes. Additionally, by performing this approach a high-level of transparency and reliability is maintained throughout the empirical research by performing this approach.

However, during the execution of this research methodology also some limitations occurred. These limitations mostly relate to the respondents and case-study projects. To summarize:

- Project A and Project B have been put on hold during the research. This limited the research on three levels: (1) no further correspondence was possible with the respondents as they were sent to another construction site, (2) no other construction managers were available for any additional interviews, and (3) the ADAPT tool could not be implemented in practice.
- Respondent B2 was interviewed after Project B was put on hold. This influenced his answers drastically: only short and superficial answers were given. Additionally, during the interview it became clear that case A2 wasn't involved during FEED. Therefore, many of the complex issues did not apply on him.
- Project C was in the pre-FEED phase, which implies that only the construction manager of the construction management team was involved in the project. Therefore, it was only possible to interview one person instead of two. Also, many issues (such as sequencing of work) were still ongoing, which indicates that some Project Design Cycle elements (performance and reflection after-action) could not have been applied yet.

RESULTS

It can be concluded that the research objectives are achieved for the most part. Firstly, empirical data is collected by performing qualitative case-study research. The findings of this empirical research serve its purpose as it contributes to the establishment of the ubiquity of the Project Design Cycle elements, their cyclic relationship, and the degree to which managers use these elements as an explicit method. Secondly, a theoretical framework is performed to research the core themes of this research: design thinking, the Project Design School, Construction-Driven Execution and construction management.

Combining this theoretical framework with the empirical data retrieved to reach the first objective, an advice was created in the form of a practical tool that can be used by construction managers to approach complex issues in a construction-driven FEED phase.

The findings of the cross-case analysis are validated and discussed with an external panel. The key finding of the validation session is that a practical tool for construction management is insufficient to enhance the Construction-Driven Execution philosophy within the entire organization. On the contrary, it is found that a mind shift is required to solve a cultural problem within the organization. On the one hand, construction managers often do not have the skills and commercial knowledge to make complex decisions, are not able to change their way of working, or prefer not to be involved in FEED and want to stay on-site. On the other hand, other disciplines like engineering and procurement also have to adapt and accept the involvement of construction management. Also, project management should estimate enough man-hours to allow construction managers to get familiar with a new approach, in which they base their decision by including design and reflection. Finally, project directors should not select the construction managers solely based on their traditional problem-solving skills.

It is found that conclusions related to management research are never black or white. Therefore, some limitations have to be accounted for when discussing the results of this research:

- Nevertheless the intentions of the author to reflect on the answers of the respondents as objective as possible, the findings remain subject to his interpretation.
- Additionally, the results rely upon the ability of the author to 'recognize' the Project Design Cycle elements. The respondents were not able to assess the Project Design Cycle elements, as they were not made aware of cycle or design thinking until the end of the second interview.
- Furthermore, it's important to note that the respondents reflected on their project after the events occurred. This could imply that the answers of the respondents are biased compared to what actually happened at the time of the problem situation. It is important for the reader to consider this when reviewing the results.
- Due to a little number of data (twenty complex issues of five respondents), it was not possible to quantify the results. Additionally, because semi-structured interviews are subjective, the results are abstract which makes the conclusion open for interpretation.

VALIDATION

The external validation also contained some limitations. The initial goal was to validate this research in two ways: by an external expert panel, and by implementing the ADAPT tool in one of the case-study projects and ask participants for feedback. During the external validation session, the results of this research were presented to an expert panel and discussed in an open setting. Unfortunately, the second validation method was not fully executed. Together with respondent A1 it was organized to implement and apply the tool in one of the constructability focus-sessions. However, shortly after defining the plan, the project got cancelled and respondent A1 got send to another project. Other limitations that occurred are:

- Both experts did not have a construction background. Because of this, they could not evaluate the results of the empirical research and compare it to their own approach. However, as they are both senior managers and worked with construction management on a daily basis, they were able to compare the problem-solving ability of the respondents to that of project managers.
- Both experts were Fluor employees. Even though they were not involved in the research before, they were not completely external and could have incorporated political views in their reactions.

7.2.2 IMPLICATION OF THE RESULTS

The results of this research have both scientific and practical implications. The scientific implication concerns the Project Design School, which aims to fill a literature gap in project management research. The practical implication affects Fluor, which have the ambition to further embed the Construction-Driven Execution philosophy in its organization. Both implications will be discussed below.

SCIENTIFIC IMPLICATION

As discussed in chapter 1, the first objective of this research is to provide empirical data to firmly establish the ubiquity of the Project Design Cycle elements, their cyclic relationship, and the degree to which managers use these elements as an explicit method. This framework has been created by the Project Design School in order to fill a knowledge gap in project management research, which concerns the subject of how project managers create ‘management frameworks’ to approach complex problems. It can be stated that this goal is reached to a large extent, since the application of the Project Design Cycle has been researched amongst construction managers.

The results show that the current application of the Project Design Cycle by construction managers is highly dependent on the recognition of the complexity of an issue. When an issue is recognized as complex, the Project Design Cycle elements are applied most of the times. In contrast, when an issue is not recognized as complex, the Project Design Cycle is practically never applied as a whole; often one or two elements are missing. Therefore, it can be concluded that the identification and recognition of complexity is a necessary skill for problem-solvers. Especially for construction managers, which are typically used to and have become specialists in fighting fires on-site. The observation that the Project Design Cycle elements are rarely applied in sequence, is in line with the studies of the Project Design School, and also illustrates that the Project Design Cycle serves as a high-level framework instead of a clearly defined and structured. However, it might be required for education and training purposes of (future) construction managers that they first become aware of the elements and its structure, before being able to apply its essence in practice.

PRACTICAL IMPLICATION

The second objective of this research is to use the principle of the Project Design Cycle to provide Fluor with advice on how to enhance the CDE philosophy within the construction management department. This advice is based on the theoretical framework of the influence of Construction-Driven Execution on construction management practice, the application of Project Design Cycle by the construction managers, and the ADAPT decision-making cycle.

The results support the statement that construction managers have to approach complex issues in a more considered manner compared to issues on-site. Instead of fighting fires during construction, construction management is put in an advisory role to provide input in order to prevent the fires from happening in later stages. As construction managers are not trained or educated to fulfil this type of position, it is not unusual that they are not able to approach complex issues in a correct manner. It has been determined that ADAPT would be a useful tool to assist construction managers in educating them to solve complex problems in FEED. ADAPT would serve as a starting point to identify complexities, provide a structure to approach issues, and provides a framework that highlights reflection practices. In doing so, ADAPT enables construction managers to approach complex issues in FEED in a more considerate way, and by doing so, enhance the CDE philosophy within Fluor’s organization.

Furthermore, in the validation sessions some barriers for the implementation and application of ADAPT within Fluor were discussed. The following barriers are found:

- Construction has been neglected in the organization for too long; an organizational mind shift is required to realize that construction is part of the overall process. Also, construction-management have to become aware of their position in the overall process.

- Resistance by construction managers to work in the office instead of on-site, as they miss out on certain benefits and prefer a different working atmosphere;
- Fluor's current resource pool mostly consists of traditional construction managers, which are rewarded firefighting instead of fire preventing, and therefore fall short in understanding the commercial side of the decisions.
- The focus should be on educating the next generation of construction management since experienced construction managers of late age are not going to change quickly.
- Resistance by engineering and procurement disciplines to be driven by construction, the name of Construction-Driven Execution contributes in a negative way.

These findings of the validation session confirm the cultural problem within Fluor with regards to the implementation of Construction-Driven Execution. While Fluor pushes the Construction-Driven Execution philosophy top-down, as it is proved to be of value in other Fluor offices, the implementation of Construction-Driven Execution on the lower levels of the organization is limited. This supports the statement that it's not only construction management that has to 'adapt' in order to enhance construction-driven project Execution. On the contrary, the entire organization requires a mind shift. Furthermore, it is found that as long as construction managers are reviewed by their problem-solving efficiency (find a solution as quick as possible), in which no appreciation is awarded to the creation of several alternatives or reflection practices, the implication of design thinking principles in construction management will be limited since the current generation does not have the skill-set.

To conclude, the actual change required to solve this cultural problem within Fluor comes down to the following. On the one hand, construction managers which are placed in a 'project management' function during FEED should change their mind-set by recognizing the importance of being involved early in the process in order to prevent mistakes from happening. They have to be willing to break the 'cycle' and stop the same mistakes from happening again and again. On the other hand, the entire oil & gas business line organization need to change their mind-set, accept the involvement and influence of construction management in FEED, and adapt an integrated approach to solve increasingly complex issues.

The ADAPT Decision-making cycle can influence this cultural problem to a certain extend. ADAPT provides a framework to construction managers to solve these complex issues in a design thinking way. The framework also promotes to work in a multi-disciplinary manner, which contributes to the alignment and integration of the construction, engineering and procurement disciplines. However, the influence of ADAPT as a tool is only limited with regards to changing the mind-set of both construction managers and other disciplines.

7.3 RECOMMENDATIONS

The recommendations consist of a scientific and practical part. Scientific recommendations concern future research opportunities, while the practical recommendations relate to an advice to Fluor to further enhance Construction-Driven Execution in oil and gas projects.

7.3.1 SCIENTIFIC RECOMMENDATION

Scientific recommendations are provided to determine further research. These recommendations could be used as a starting point for future researchers or graduates. Based on the research findings, the following recommendations for further research are identified:

- If more research time was available, it would be interesting to further investigate the underlying reasons *why* and *when* construction managers perceive issues as complex. There might be more implicit or secondary reasons. Secondly, further research could be performed to understand *how* construction managers could identify complex situations in the FEED phase. Thirdly, it would be very useful to further investigate required qualifications of construction management to properly function in a construction-driven FEED phase.
- Further research needs to examine more closely the relationship between the recognition of complexity and the occurrence of the design element. Since this conclusion is solely based on the words of the respondents it can be seen as a weak link of this research. This is also due to the fact that the amount of data found in the investigated case-studies seems to be limited. Objective measurements should be used based on project documentation, observations in daily practice, and by interviewing more respondents. By performing more interviews, the occurrence of design thinking (in combination with complexity) can be researched in a more statistically significant way. Such a study would also provide data to make further distinctions between the 'firefighting' and 'fire preventing' approaches applied by construction managers.
- It would be interesting to create a theoretical framework to evaluate the application of other type of decision-models in construction management. Questions that should be answered in such a framework are: (1) *what kind of decision-making models are suited for construction managers to approach different kind of problems in FEED?* And (2) *How can a construction manager decide what kind of approach is required to solve issues with different levels of complexity?*
- Further research could also be conducted to determine the effectiveness of the application of the Project Design Cycle (in the form of ADAPT) in construction management. As two case-study projects got cancelled, the option to implement and apply the tool was not available. By first educating construction managers with the principles of the tool, the tool can be implemented to provide a framework and a structure to approach complex issues in an integrated team effort. By observing these sessions, it can be determined if the ADAPT framework does indeed support construction managers in their day-to-day practice.

7.3.2 PRACTICAL RECOMMENDATION

Practical recommendations are set to provide an advice to host company Fluor. Most of these recommendations could also be used for other EPC contractors in the oil and gas industry when involving construction disciplines early on in the project. The following recommendations are made to further embed the Construction-Driven Execution philosophy within Fluor's Hoofddorp office:

- An organizational mind shift is required to realize construction as part of the overall process and can help to prevent mistakes in later stages by sharing their knowledge. It could help to change the name of Construction-Driven Execution, as 'construction-driven' creates resistance with engineering and procurement disciplines.
- Construction managers should be reviewed and rewarded on their ability to solve problems on-site, but also on their commercial and contractual decision-making skills in order to properly perform their function in FEED. Additionally, they have to change their mindset when being involved early in the process and be aware of their position in the overall process. Finally, they should be trained to become aware of the commercial and contractual side of decisions, and also to properly reflect and share their knowledge in order to prevent the same mistakes happening over and over again.
- Based on the research findings, it is recommended to implement and apply the ADAPT decision-making cycle in construction management practice. This tool provides a framework to approach the complex issues that construction managers are confronted with when involved early in the project during FEED. In the end, the objective of ADAPT is not to train construction managers to apply the cycle step-by-step in practice, but to incorporate the cycle into their daily practices to approach complex issues in a more considered and professional manner.
- In order to implement ADAPT it should have top-down support by providing enough man-hours for construction management in FEED, and by selecting the right people that are able to approach these complex issues.
- ADAPT should be implemented bottom-up as an integrated approach in which construction management is pro-active and take it upon themselves to drive, adopt, and move it forward. This can be done by making individual construction managers aware of the cycle and its added value.
- The constructability program serves as a perfect platform to implement and test the application of ADAPT. The framework can serve as a structure to identify complex situations in the constructability program. These identified complex issues can then be discussed in so called 'constructability focus' sessions. As construction management lead these sessions, it is a perfect opportunity to implement the ADAPT decision-making cycle and use its elements to shape and formalize these sessions in a structured way.

7.4 REFLECTION

I would like to add a personal reflection to this research on the past six months. I've started with my research proposal on the 3rd of April 2018. Four weeks later on the 1st of May, this proposal was approved by my graduation commission, consisting of TU Delft representatives H. Bakker, L. Lousberg and M. Leijten, and company representatives A. McCarthy and D. Goodall. From this moment on, the research officially started. Below I will reflect on the research process and lessons learned, research results and personal objectives, and overall opinion.

RESEARCH PROCESS AND LESSONS LEARNED

From the kick-off on, the process went pretty well in my opinion. My goal was set clearly: finish in six months by researching the application of the Project Design Cycle in Fluor's construction management department. Based on my previous HBO experience I knew what to do and which steps I had to take in order to deliver a good research.

Contrary to my initial expectations, I quickly discovered that CDE was not a strategy but rather a philosophy. Getting a grip of oil and gas projects and the construction industry took many weeks. I had to figure out what CDE is really about, how the construction managers deviate from the standard in order to make a fit-for-purpose execution strategy, and whether they use design thinking in this process. Since this was not clearly outlined, I looked into complex situations, like modularization, constructability, sequencing of work, alignment of other disciplines, etc.

After defining what to research, I conducted interviews and described the results. In anticipation of the midterm I was comfortable with my research so far and assumed (I thought I was on track and) it wouldn't take me a lot of time to finish the research. However, after the midterm presentation, I realized that I was quite behind on my theoretical framework, but (even) more importantly; my research methodology for the empirical research was too vague and unclear due to the fact (since) I didn't have not yet elaborated on how I was going to analyze the transcripts and what my results would look like.

I tried to apply all lessons learned of my previous HBO thesis, such as: start on time, clearly define the objective, don't wait to the last moment with the interviews, keep close contact to both the university and company supervisors. And compared to that thesis, I thought I really applied a well thought through methodology. However, it turned out I wasn't fully aware of what a scientific methodology and qualitative case-study research should look like. In the end, this was one of the largest barriers in my research. It took me quite some time to understand and implement the feedback of the midterm. This setback and moving places made July a very hectic month, which resulted in two weeks delay. Fortunately, since my original schedule was really tight I was still on track in comparison to fellow students who started in the same period.

Prior to my green light meeting, I was quite confident my thesis was complete and good enough to defend it. However, it turned out I was too focused on the results, while the methodology was unclear and not transparent. This came as a total surprise to me which I didn't expect. I've realized in a qualitative research; the whole point is to discuss the situation in which the results are found. It is important to sketch the entire situation and discuss it from different angles. In this way, a nuanced conclusion can be drawn up which is not black or white. This was the biggest barrier I came across during the entire process. To revolve this barrier, I had to elaborate on my methodology, and show all the little steps in between the results and conclusions, in order to come to a nuanced conclusion that includes multiple perspectives and clearly displays the angles in the situation. In consultation with the committee, it was agreed to extend the research period with two weeks in order to adjust the beforementioned points.

Not passing the green light made me a quite insecure with regards to my 'scientific capabilities'. As Fluor already offered me a job which would start the 5th of November, I felt a lot of pressure to do it correct this time. Therefore, I acted pro-actively and consulted many people. Not only my company and university supervisors, but also my parents, girlfriend and fellow graduate students. Interesting enough, it was the conversation with my girlfriend that made me realize what my actual problem was: I'm always focused on results and therefore jump to conclusions too quickly (apparently not only in this research but also in my personal life). Since my girlfriend is a lawyer, she explained to me that all she does in her work is to describe and sort all details and complications of a certain situation, including all perspectives to exclude any ambiguities or uncertainties. This was something I had to learn in a short period of time. Therefore, my most important lessons learned is 'how to perform a qualitative research': in which it's not about the results, but how I incorporate all perspectives when describing the situation. It's about giving insights in a certain situation, not just about giving a good or wrong answer. To conclude, the last two weeks I've learned to include nuances into my findings and results, and I hope I have succeeded.

RESEARCH RESULTS AND PERSONAL OBJECTIVES

When looking at the results of the research, it's difficult to say whether I'm pleased or not. On the one hand, I am: the research objectives are accomplished by providing empirical data to the Project Design School and by providing Fluor with insights in the current application of Construction-Driven Execution.

On the other hand, I would have loved to implement and apply the ADAPT cycle into practice, by educating construction managers and making sure they apply the framework to approach complex issues in a multidisciplinary setting. Unfortunately, this was not possible because the projects were put on hold. Also, it was not the main objective of my research and would therefore only distract me.

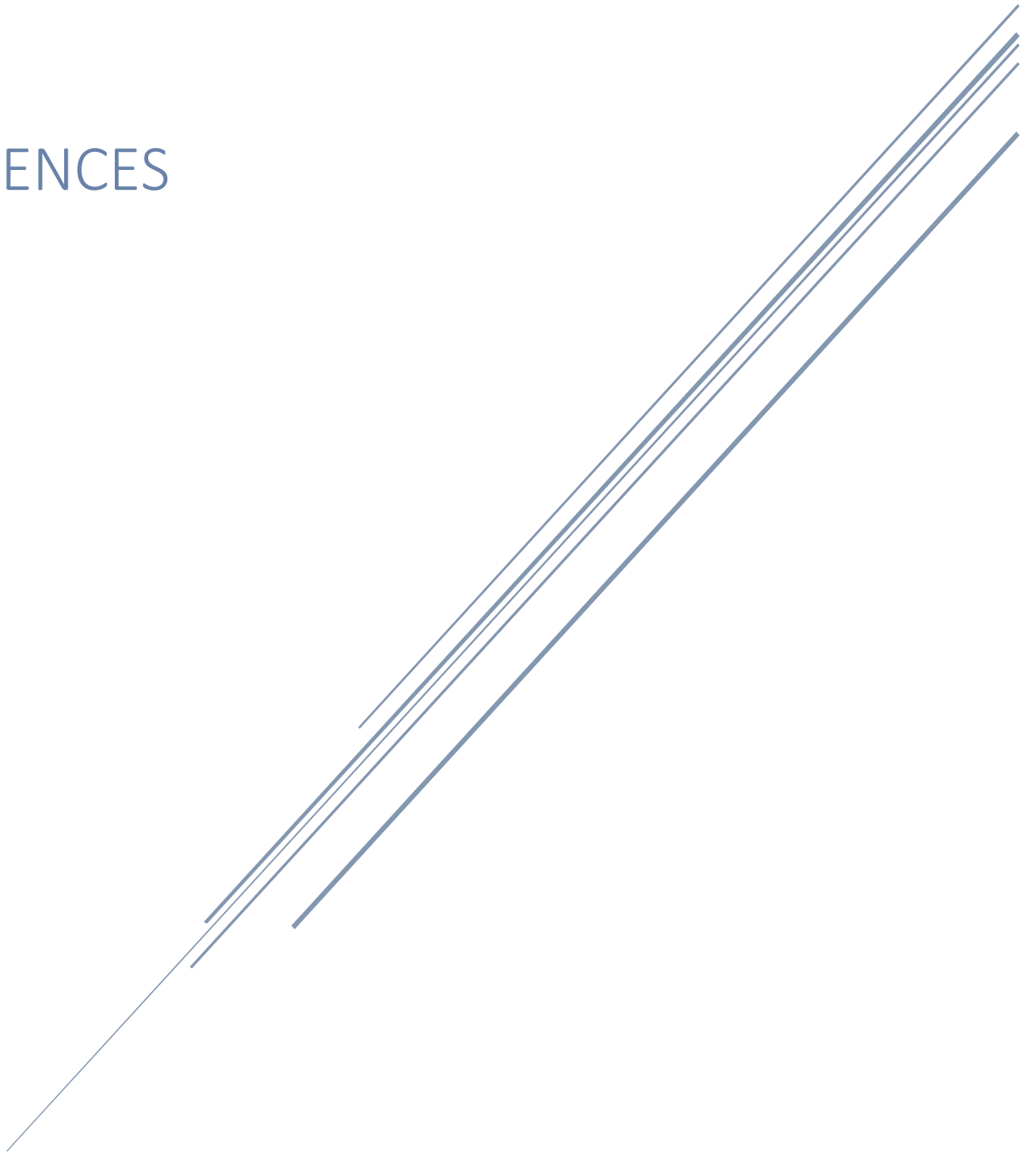
Instead of moving forward with my results, I had to hit the brake and go into more depth with regards to the results itself. This switch was difficult, but in the end I'm content with the research results. I reached my objectives and give insight in the combination of the two worlds of 'construction management in the oil and gas industry' and 'design thinking'. Of course, I would have rather delivered a thesis that changed the entire construction industry, but I have to be realistic that this is not doable in a six-month research.

Furthermore, I've achieved all my personal goals. First of all, I've learned a lot about design thinking, construction management, early involvement of construction, the oil and gas industry, and approaching complex issues. I consider this as very useful knowledge for my future career. Secondly, maybe even more important, the objective of doing a master study has been accomplished: I've found really nice job at Fluor Infra as a Junior Project Engineer.

OVERALL OPINION

Reflecting back, I think not passing the green light was the main lesson learned for me: I was too focused on the results and had put too little attention to the road towards the results and what these results could mean from different angles. Overall, I really enjoyed the last six months of writing my thesis at Fluor: to work on a daily basis with colleagues, but also discussing with my university and company supervisors. I've learned a lot from their advice, and also from all the stories I came across during the interviews with the respondents. Of course, the last couple of weeks were quite hard: I had to dig deep, make long days and nights, and cancel all social activities. Especially after the green light; I had to rely on myself to get over the setback, rebuild myself, and give everything I had to graduate in order to be able start my first job in November. I'm very pleased I've accomplished this.

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Appendices



- A. Questionnaire interview 1
- B. Questionnaire interview 2
- C. TOE-model for complexity
- D. Potential complex issues – Atlas.TI report (1st interview)
- E. Respondent A1 – Atlas.TI report (2nd interview)
- F. Respondent A2 – Atlas.TI report (2nd interview)
- G. Respondent B1 – Atlas.TI report (2nd interview)
- H. Respondent B2 – Atlas.TI report (2nd interview)
- I. Respondent C1 – Atlas.TI report (2nd interview)
- J. Opinion Project Design Cycle – Atlas.TI report (2nd interview)
- K. Opinion reflection practices – Atlas.TI report (2nd interview)
- L. Expert panel details

A. INTERVIEW 1 – QUESTIONNAIRE

Role and responsibilities:

1. What do you do as a site/ construction manager at your project during the FEED phase?
2. How do you perform/ act out your role as construction manager?
3. How do you treat a 'surprise' (unexpected situation) in your daily work?
4. What do you see as complex issues (unknown knowns)?
5. How would you describe the process you go through when solving complex issues?
6. To what extent did you apply your previous experiences in this project?
7. Do you have moments of reflection (e.g. at the end of the day)?
8. What do you do with the learned lessons of these reflections?

Construction-Driven Execution:

9. What were your main 'Construction-Driven Execution' considerations?
10. To what extent did you apply the 'prescribed' CDE playbook in this project?
11. What did you do differently and why (AWP, Mod, Auto tools, CB, etc.)?
12. What were the main problems you were confronted with due to the application of CDE?
13. Did you consider these problems as complex?
14. How did you cope with these problems and how did you come to this solution?

Modularization:

15. To what extent did you apply modularization at the project and why?
16. How did you come to this solution, what were the steps that you took?
17. Do you see this (modularization) as a complex problem to solve?
18. Is it eventually the best solution? What would you have done differently?
19. When reflecting back on this solution, how do you process the lessons learned?

Constructability:

20. What does constructability mean to you?
21. How do you manage/ lead constructability meetings?
22. How do you align the disciplines during these meetings?

B. INTERVIEW 2 – QUESTIONNAIRE

Complex problem-solving:

During the first interview the following issues and problem situations were brought to attention (*complex issue 1 tm 4*):

1. Do you see this event as a complex problem?
2. How would you describe the process you went through when approaching this issue?
3. Did you have a moment of reflection during or after getting to the solution and what did you do with these lessons learned?

→ Repeat these questions for each complex issue

Reflection practice at Fluor:

4. What does the current reflection practice/ lessons learned/ knowledge sharing program look like at Fluor?
5. What do you think of the current reflection practices at Fluor?
6. How could this reflection practice within Fluor be improved in your perspective?

Project Design Cycle:

7. Do you recognize elements that you used the PDC cycle in the problems discussed before?
8. Do you recognize the elements of the PDC in other day-to-day practices? Or strategically?
9. Do you perform these elements in this sequence?
10. To what extent do you think that construction managers apply design thinking when solving complex construction problems?
11. Do you think these names/steps are suited for construction management? Would you change the names of the steps?
12. What do you think of ADAPT?

C. TOE-MODEL FOR COMPLEXITY

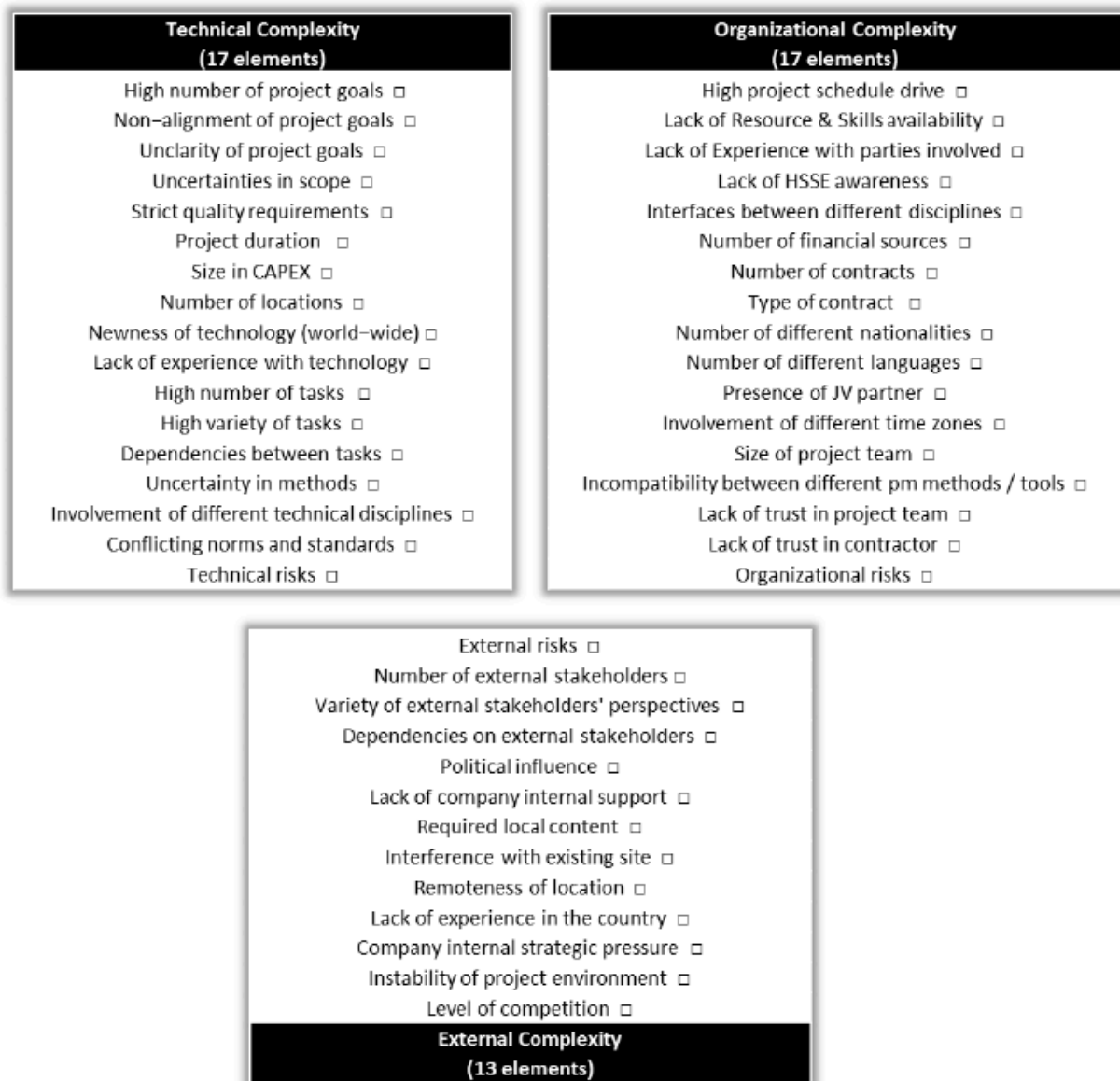
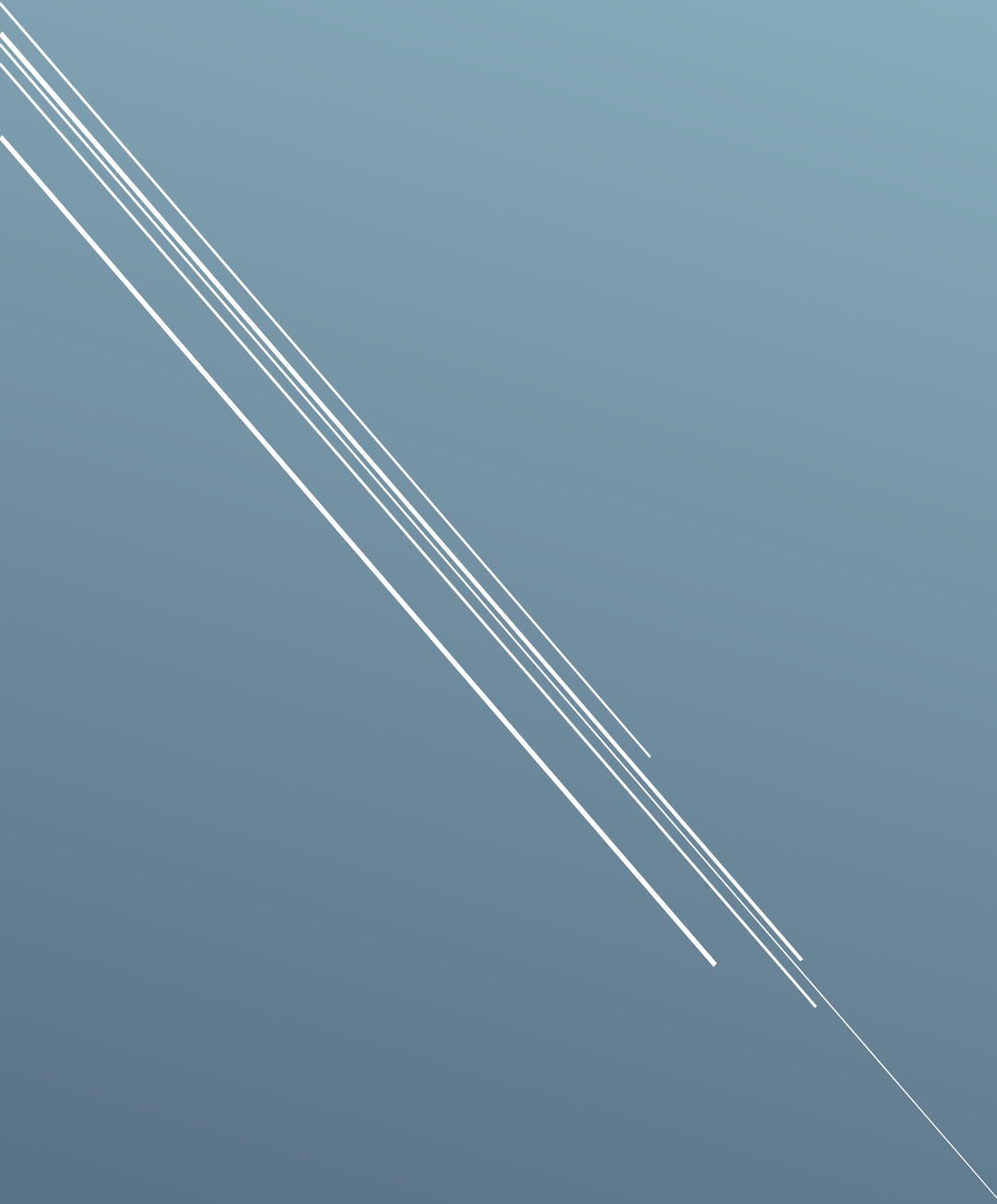


Figure 30: TOE-model for complexity (Bosch-Rekvelde et al., 2011)




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