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"Study without desire spoils the memory, and it retains nothing that it takes in."

Leonardo da Vinci

Abstract

It is widely recognized that research regarding complexity in projects has been inspired by Baccarini through his publication in 1996. Since then, research on this topic has been developing to other areas such as healthcare, IT, military, manufacturing, engineering, construction, and more. From theory point of view, the topic has also been researched in relation to various theories such as organization theory, PMI (Project Management Institute) view, system theory, complexity theory, among others. Interestingly, there is currently still no agreement among the researchers regarding the definition of complexity itself. Despite of this fact, studying complexity is important and will potentially improve project management practices, including in *brownfield* projects, where research has not much been pursued.

Brownfield projects are important in securing sustained energy supply, as well as in realizing the transformation within the energy industry. This master's thesis explores complexity in large oil and gas modification projects and aims to classify the complexity encountered by the individuals participating in such projects. A new framework for classifying project complexity is proposed by implementing *grounded theory* methodology over the data gathered through interviews and observations.

Acknowledgements

One of the inspirational moments I had in life was when I met my former colleague **Fred** in 2008. He was at that time just finished his master's study and was at the age of around 60 when he started the study. **Fred** has been truly inspirational in demonstrating the spirit of continuous learning.

It took me several years after that encounter until in 2020 I was finally being able to start the master's study at the University of Stavanger. The completion of this master's thesis marks the achievement of one important goal. Yet, the journey still continues: learning throughout life.

I want to express my sincere gratitude to my supervisor **Prof. Eric Christian Brun** for his guidance in writing this master's thesis. I highly appreciate his support and dedication in sharing his expertise and insights which makes writing this master's thesis a very valuable learning experience for myself.

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Chapter 1

Introduction

1.1 Background

Size and scope have been identified as some of the characteristics of project complexity (Baccarini, 1996; Bosch-Rekveldt et al., 2011). In *brownfield* projects, another unique characteristic is that they are executed on live production facilities, exposing the project team to several other types of complexity. Several publications argue that proper understanding of project complexity is important for an effective project management (Geraldi and Adlbrecht, 2008; Rad et al., 2017; Vidal and Marle, 2008; Williams, 1999). Some also argue that project complexity can lead to cost overruns and poor project performance when necessary measures are not in place (Gao et al., 2018; Ahn et al., 2017; Luo et al., 2017; Williams, 1999), making it an important aspect to be considered when managing a project.

This master's thesis focuses on project complexity in modification projects of existing oil and gas facilities, usually referred to as *brownfield* projects. There are in general two types of modification project. The first one is related to corrective and preventive maintenance of the facility, often small in size, and incurred as part of operational costs (OPEX). Such projects can be for example: replacement of a pump, relocation of some field instrumentation, etc. The other type is larger in size and has a goal in supporting medium/long term business targets, such as increasing production capacity of an oil field and lifetime extension of a facility. These larger projects are usually funded through dedicated investment budget (CAPEX) and managed by a separate project organization within the oil and gas company.

Brownfield projects have an important role in supporting the energy production business, making them as an interesting subject to be explored. *Brownfield* projects are important in two ways:

1. In the era of energy transition as per today, oil and gas production is still an important business for the energy producers as currently their incomes are mainly generated from sales of oil and gas. *Brownfield* projects contribute in ensuring high availability of the production facilities and securing continued production of oil and gas in the medium/long term, which enable the companies to sustain their business and gradually increase their investments in renewable energy sources, as part of their strategy in facing the energy transition.

2. *Brownfield* projects are contributing directly to the energy transition process by reducing carbon footprints from existing oil and gas facilities, for example through electrification projects. When this master's thesis is being written, there are multiple electrification projects which are currently under execution in Norway. Typically in these projects, the main power supplies to the platforms are being replaced by electrical power produced through renewable sources, allowing for partial/complete dismantling of the platforms' gas turbine generators. There are also several more offshore platforms currently being evaluated for receiving electrical power supplied by renewable energy sources in near future.

1.2 Motivation

Although project complexity has been a research topic for many years, search on databases (Scopus, Web of Science) did not reveal any publication aimed specifically to classifying complexity in oil and gas *brownfield* projects. As argued by Geraldi and Adlbrecht (2008), comprehension of project complexity is important for an effective project management. With the classification provided in this master's thesis, the practitioners in *brownfield* projects would be equipped with a tool specifically tailored for their field of industry, which can improve their project management practices. Project managers will become more effective in focusing their attention to the aspects that are relevant and setting the team's priorities accordingly. The intention to provide such information has motivated this research in exploring this particular topic.

1.3 Objective

The objective of this master's thesis is to answer the research question: *"How project complexity in brownfield oil and gas projects can be classified?"*. The term *classifying* used in this research refers to the process in discovering different types of project complexity and then grouping them under several common themes.

The findings from this research are analyzed in order to provide a comprehensive description (Mikkelsen, 2020) for project complexity encountered by project participants in *brownfield* projects. The result is not intended to be used as predictor of any law-like relationships nor defining an explanation for project complexity itself.

1.4 Approach

The research is designed using qualitative approach, employing a holistic multiple-case study. There are three large *brownfield* projects included in the case study, where data are being compared within each project and against other project cases.

In classifying project complexity, the collected data are analyzed by implementing *grounded theory* methodology.

1.5 Contribution

This master's thesis seeks to provide insights both to the community of research and the industry.

To the community of research, this master's thesis seeks to fill the knowledge gap in research on project complexity, specifically in establishing a classification for project complexity within *brownfield* oil and gas projects.

Industry practitioners would also benefit from the result of this research. The information presented in this master's thesis may be used in improving project management practices which will lead to better project performance. Contractors and engineering companies make more profit when they deliver projects with good performance. They also gain better reputation and trust, which makes them more attractive for future projects. Energy producing companies, on the other hand, will also gain benefit from cost-effective *brownfield* projects. Not only they will be able to sustain their oil and gas production, they will also have more capital to invest in the renewable energy sources and realize their energy transition strategy.

Chapter 2

Related Work

This chapter begins with providing an overview of the development in research on project complexity from historical perspective, followed by the definition of project complexity proposed by various research. Several research that inspire this master's thesis are then presented in further sections in this chapter.

2.1 Overview of Research Development in Project Complexity

Among the latest research on project complexity, the paper by Mikkelsen (2020) has been identified as the one providing a thorough historical overview on how research on this topic has been developing. This section mainly reflects on the finding he presented in his publication.

Mikkelsen (2020), like many other researchers, regarded Baccarini's paper (1996) as the initiator for research on project complexity, proposing a definition: "consisting of many varied interrelated part", which later on referred to as structural complexity. Baccarini (1996) proposed that components of project complexity are organizational and technological, which can be operationalized in terms of interdependency and differentiation.

Mikkelsen (2020) further described that about a decade after Baccarini's publication, project complexity became one of the five top topics pursued in the 'Rethinking Project Management' (RPM) research-network funded by UK Government. This was followed by the occurrence of a 'spark' in the post-RPM era, although the relationship between the RPM movement and this 'spark' has not been confirmed. However, this 'spark' is worth mentioning, because it marks the starting of diversification in research regarding project complexity. This diversification arises only about a decade ago, which has not entered its final stage yet. Mikkelsen believes there is also indication that diversification may still come in the future, diverging the definition of project complexity.

Mikkelsen (2020) furthermore elaborated that prior to the 'spark', the research by Williams (1999) appeared to be as one of the earliest diversifications responding to Baccarini (1996). Williams (1999) proposed to include uncertainty into the dimensions of project complexity with the definition: "Project complexity can be characterized by two dimensions, each of which has two subdimensions: structural complexity (number of elements and interdependence of elements) and uncertainty (uncertainty in goals and uncertainty in methods)". In 2008, Remington and Pollack proposed four project complexity dimensions: structural, technical, directorial, and temporal. Three years later, Maylor et al. (2011) argued that the concept of project complexity had developed and included new dimensions: structural complexity, uncertainty, dynamic, pace, and sociopolitical dimension. In 2016, a structured literature review by Bakhshi et al. concluded a further development of project complexity, while reflecting on the previously mentioned diversification. Bakhshi et al. (2016) argued that project complexity has now the dimensions of: emergence, autonomy, belonging, connectivity, diversity, size, and the element of context.

In terms of operationalization, as shown by Mikkelsen (2020), research has also been developing. Since 'complexity' itself is a rather abstract concept and is not directly measurable, identification of the existence of its components could help to understand and define the concept of 'complexity'. Such process is referred to as operationalization. Some research in this area presented a few dimensions of project complexity, while others came with large numbers such as Rad (2016), with 51 project complexity indicators, Dao et al. (2017) with their 11 categories, 35 complexity attributes, and 101 indicators in total, and Bakhshi et al. (2016) who identified 128 project complexity factors as a result of a literature review covering the period between 1990 to 2015. One of the preferred methods of operationalization is Analytical Hierarchy Process (AHP), which is often used in combination with the Delphi method, utilizing the practitioners' evaluations of the suggested dimensions as input, for example in Vidal et al. (2011). Another preferred method is Structural Equation Modeling (SEM), exemplified by Qureshi and Kang (2015), and Bueno and Gallego (2017).

Research on complexity theory is being regarded by Mikkelsen (2020) as the pursuit of the explanation for complexity. One of the important work in this area is the one by Jaafari (2003), dated from the pre-RPM era. However, the use of complexity theory in project management has gained momentum with studies such as Cooke-Davies et al. (2008).

In regards to the levels of project complexity, Mikkelsen (2020) argues that research has been orthogonal to the previously mentioned dimensions of project complexity. The most simple form is the duality of being a complex project or not, having two levels of complexity. Whitty and Maylor (2009) differentiates project in two categories: complicated or complex. Snowden and Boone (2007) further developed this idea through the sense-making Cynefin framework, which covers four domains: simple, complicated, complex and chaotic. Bakhshi et al. (2016) regards Cynefin as an example of research belonging to system-of-systems (SoS). The other two schools of thought they identified are PMI view and complexity theory view. Some latest papers on the foundation of complexity theory have contributed stratification concepts, for example Kiridena and Sense (2016) and Daniel and Daniel (2018). Mikkelsen (2020) concluded that based on these two research, the complexity theory and the SoS school of thought have merged.

Another recent publication is the research by Morcov et al. (2020). Attempting to consolidate the different views, they propose two dimensions: subjective and objective complexity, where the latter consists of two sub-dimensions: structural and dynamic complexity.

The paper by Bolzan de Rezende and Blackwell (2019) is also one of the most recent work in this area. Building upon previous framework, they propose to include new dimension to project complexity, resulting in 7 dimensions of project complexity: structural, uncertainty, pace, dynamic, novelty, social-political, and institutional.

2.2 Definition of Project Complexity

Many research, including the most recent ones, have found that currently there is no agreement regarding the definition of project complexity.(Bakhshi et al., 2016; Morcov et al., 2020; Mikkelsen, 2020).

Mikkelsen (2020) argues this situation is caused by different motivations in researching this topic, leading to different results. He concluded there are five main motivations: 1) search for prediction based on law-like relations, 2) search for an explanation of the unpredictable behavior of projects, 3) search for a comprehensive description of project complexity, 4) designing prescriptive theory for handling project complexity, and 5) understanding project cases, without the intention of generalization. This master's thesis reflects a combination between the third and fifth type of the motivations according to Mikkelsen (2020).

Table 2.1 and 2.2 show how various research differ in their definition on project complexity.

Study	Study type	Industry	Project complexity definition	Characteristics/keywords
Turner and Cochrane (1993)	Conceptual	Construction	Degree of whether the goals and methods of achieving them are well defined	Uncertainty of goals, uncertainty of methods
Baccarini (1996)	Review	General	Consisting of many varied interrelated parts and can be operationalised in terms of differentiation and interdependency	Operational interdependencies, multiorganizational structure, technological complexity
Cicmil and Marshall (2005)	Empirical study	Construction	Invokes ambiguity, paradox and the dimensions of time, space and power of the organizing processes in project settings	Flux and change, radical unpredictability, conversational and power relating, ambiguity of process, social interaction
Hatch and Cunliffe (2012)	Conceptual	General	Consists of many different elements with multiple interactions and feedback loops between elements	Nonlinear, multiple components and interactions, change and evolve constantly, emergence
Vidal et al. (2011a, 2011b)	Case study	Manufacturing	The property of a project which makes it difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system	Organizational complexity, technological complexity, interdependencies, property of project, project difficulty
Tatikonda and Rosenthal (2000)	Case study	Product development	The nature, quantity and magnitude of organizational subtasks and subtask interactions posed by the project	Technology interdependence, objectives novelty, project difficulty
Ribbers and Schoo (2002)	Case study	Information systems	Variety, variability and integration of system	Variety, variability, integration
Maier (1998)	Conceptual	General	Operational and managerial inter-dependence of the elements, evolutionary development, emergent behaviour, geographic distribution	Open systems, chaos, interdependence, self-organization
Benbya and McKelvey (2006)	Conceptual/ interviews	Information systems	(empty)	Structural, organizational, dynamic
Remington et al. (2009) Remington and Pollack (2007)	Conceptual/ interviews	General	A number of characteristics to a degree, or level of severity, that makes it extremely difficult to predict project outcomes, to control or manage project	Hierarchy, communication, addictiveness, fitness landscape, edge of chaos

Table 2.1: Definitions of project complexity summarized by Bakhshi et al. (2016)

Study	**Study type**	**Industry**	**Project complexity definition**	**Characteristics/keywords**
Geraldi and Adlbrecht (2007)	Empirical study	Plant engineering	Complexity of fact, faith and interaction	Dynamics, uniqueness & customisation, immaturity interdependence, size, sources, transparency, reference, empathy
Grisogono (2006)	Report	Defence	The ratio of the number of ways of getting the wrong outcome to the number of ways of getting it right	Coherent behaviour, networked causality, vast options, unpredictable, unfixed rules
DeRosa et al. (2008)	Conceptual	Defence	The complexity of a problem situation stems from its openness, interdependence of contributing factors and multi-scalarity	Autonomous agents, adaptation, self organization, phase changes

Table 2.2: Definitions of project complexity summarized by Bakhshi et al. (2016) - continued

There are however some common themes characterizing project complexity which are shared between those publications (see Table 2.3): interdependency, variety, and uncertainty. These three keywords have been considered as relevant to *brownfield* projects, and therefore this master's thesis has defined project complexity as "concerning the variety and interdependency of many project parts where there are some forms of uncertainty being involved." In this context, uncertainty covers also ambiguity, the difficulty to predict, and unknowns. This definition of project complexity will further guide the data collection process.

Theme	Keywords used in various research
Interdependency	Interdependency: Baccarini (1996), Vidal et al.(2011a, 2011b), Tatikonda and Rosenthal (2000), Maier (1998), Geraldi and Adlbrecht (2007), DeRosa et al.(2008) Feedback loops: Hatch and Cunliffe (2012) Interaction: Geraldi and Adlbrecht (2007) Networked causality: Grisogono (2006)
Variety	Consisting of many varied interrelated parts: Baccarini (1996) Multiple interactions: Hatch and Cunliffe (2012) Quantity, magnitude: Tatikonda and Rosenthal (2000) Variety: Ribbers and Schoo (2002) Size: Geraldi and Adlbrecht (2007)
Uncertainty	Uncertainty in goals and in methods: Turner and Cochrane (1993) Ambiguity, unpredictability: Cicmil and Marshall (2005) Difficult to understand, foresee: Vidal et al. (2011a, 2011b) Difficulty to predict the project outcome: Remington et al. (2009), Remington and Pollack (2007) Unpredictability: Grisogono (2006)

Table 2.3: The common themes shared by various project complexity definition

2.3 TOE Framework

Bosch-Rekveldt et al. (2011) conducted case study involving 6 large engineering projects within process industry between 2002-2010. Their research is of inductive nature, where the main purpose is to describe project complexity based upon observation in the study case. This also means that their framework is not intended to test the theory nor to predict project complexity. Rather than focusing on the “predict and control” aspect in project management, they aim to contribute on the “commit and prepare” strand.

What they found is that the existing framework at that time put more weight upon technological complexity. Bosch-Rekveldt et al. (2011) identify that organizational complexity has also significant impact to complexity in projects, highlighting the importance of managerial skills for project managers. They included “project management complexity” as part of project complexity, belonging to organizational complexity.

The framework is shown Table 2.4, capturing 3 main categories: Technical, Organizational, and Environmental, as well as their respective sub-categories.

Technical	Organizational	Environment
Goals	Size	Stakeholders
Scope	Resources	Location
Tasks	Project team	Market conditions
Experience	Trust	Risk
Risk	Risk	

Table 2.4: The sub-categories in TOE framework introduced by Bosch-Rekveldt et al. (2011)

Bosch-Rekveldt et al. (2011) explains that the TOE framework includes elements related to both structural complexity and uncertainty. They explicitly included technical complexity and organizational complexity in their framework as main categories of project complexity. Most of the elements in the technical category have a structural character, such as number of goals, size of scope, number of tasks, and dependencies between tasks. They also included uncertainties in goals and methods into the technical category. There are some structural elements they choose to include in the organizational category such as the number of project management methods, tools, amount of different disciplines. Bosch-Rekveldt et al. (2011) also explicitly include softer aspects and environment. The softer aspects appears in the organizational category, such as trust, availability of resources and skills, experience with parties involved, and interfaces between disciplines. The environmental category covers influences from outside of the project like political situation, level of competition, strategic pressure, required local content, and weather.

The element of risk is considered as contributor to project complexity and given a special attention by Bosch-Rekveldt et al. (2011) by being included in all the three categories They further explain that aspects of risk are also covered in other elements of all three categories, especially topics related to uncertainty, including weather condition, political situation, among others.

2.4 Three Different Schools of Thought

Bakhshi et al. (2016) contend that there are in principle three main schools of thought in research on project complexity: the Project Management Institute (PMI) view, System of Systems (SoS) view, and Complexity Theorists view. Their finding is the result of an extensive literature review covering various publications between 1990 to 2015.

2.4.1 Project Management Institute (PMI) view

Bakhshi et al. (2016) argue that the PMI-view puts more focus on structural complexity (such as variety, size, and interdependence), uncertainty, and socio-political situation. They believe one of the earliest research in this school of thought was Baccarini (1996), who introduced Technological and Organizational complexity, and proposed that structural complexity and project complexity could be inferred based on integrity of communication, coordination, and control. Continuing Baccarini's footsteps, Williams (1999) proposed a new description of project complexity which included the structural dimension, such as numbers of activities and interdependencies of elements, as well as the uncertainty of objectives and methods. Bakhshi et al. (2016) point out that the research by Shenhar (2001) suggested some projects, such as those in construction, have a lower degree of uncertainty, while projects requiring innovation like IT and defence have a higher degree of uncertainty. Bakhshi et al. (2016) further argue that the Project Management Institute attention upon project complexity was on multiple stakeholders and ambiguity, disregarding other aspects of complexity, and similar approach was also followed by a large number of researchers belonging to this school of thought.

2.4.2 System of Systems view

System of Systems are "large-scale integrated systems that are heterogeneous and independently operable on their own, but are networked together for a common goal" (Jamshidi, 2008: p.2). Bakhshi et al. (2016) found there were not many research that defined and distinguished complex project before 2002. They take the study result from Norman and Kuras (2006) Air Operations Support as an example of system of systems, whereas there are 80 autonomous and independent systems which have their own design purposes. At the same time, they are interacting together in order to achieve the functionality of the SoS they belong to. All of these autonomous independent systems serve different purpose, but they still satisfy the original purpose. Bakhshi et al. (2016) explained further that many researchers: Braha et al. (2006), Ireland (2015), Sauser et al. (2008), among others, regarded autonomy and independence, belonging, connectivity, diversity, and emergence as foundations and characteristics of the System of Systems. In SoS, the agents in complex projects spontaneously organize themselves to cope with various internal and external perturbations and conflicts. This allows them to evolve and adapt.

2.4.3 Project Complexity Theory view

Bakhshi et al. (2016) argue this third scholar group regards project complexity from the theory point of view. There are various theories linked to examining project complexity that they have discovered through their literature review, such as: complexity theory (Shenhar and Dvir, 1996; Whitty and Maylor, 2009), co-evolutionary theory (Benbya and McKelvey, 2006), organizational theory (Cicmil and Marshall, 2005), contingency theory (Baccarini, 1996), theory of constraints (Rand, 2000), systems theory (Checkland, 1999), network theory (Pryke, 2005), and adaptive self-organization theory (Jaafari, 2003).

Bakhshi et al. (2016) underline that most contributors to this group have focused solely on a single functional aspect of the project. In addition, they also found that all the features and characteristics discussed in theories are time-dependent, observer-dependent and problem-dependent, which require further exploration in order to understand how these characteristics operate in various types of projects.

PMI View	SoS View	Complexity Theory View
	Self organization	
Difficulty	Autonomous systems	
Ambiguity of features	Non linear	
Changing project governance	Emergent	
Technology newness	Chaotic behaviour	Scale laws
Non linear	Share and acquisition	Control parameters
Flexible	environment	Coarse-graining
Uniqueness	Fractals	Contingency
Mega projects	Unclear and unfixed	Tiny initiating events
Indirect communication	boundaries	Edge of chaos
Context dependence	Fitness landscape	Power laws and
Uncertainty	Adaptive cycles	Paretian distributions
Capability	Not built for	
Trust	the same purpose	
Multiple stakeholders	Uniqueness	
	Flexible	

Table 2.5: Characteristics of project complexity according to the three different schools identified by Bakhshi et al. (2016)

2.5 The Project Complexity Profile

Kiridena and Sense (2016) attempt to synthesize what they found in the literature regarding project complexity, and propose a new framework which divides complexity into three

<table>
<tr><th></th><th>Technical</th><th>Environmental</th><th>Organizational</th></tr>
<tr><td>Dynamic (emphasis on temporal aspect)</td><td colspan="3">Complex Adaptive Systems
Learning and adapting to align with/respond to the environment leading to self-organization and evolution

Sustained shifts in project goals, scope, methods, management structure, team composition, and performance arising out of:
Learning and experimentation by project team; cooperation and information sharing among stakeholders; cumulative experience and know-how; and reactive and proactive responses/adjustments to environmental influences</td></tr>
<tr><td rowspan="3">Interactional (emphasis on spatial aspect)</td><td colspan="3">Complex Systems
Nonlinear interactions between elements within and outside the project system leading to emergent behavior

Spontaneous changes in project goals, scope, methods, management structure, team composition and performance resulting from the sequential, reciprocal and cascading effects of:

technical–organizational interactions:
e.g., misalignment and/or lack of know-how, personal interests/goals/expectations, cultural fit and leadership style</td></tr>
<tr><td colspan="2">technical–environmental interactions:
e.g., changing compliance requirements, technological adjustments, socio-cultural constraints, and environmental conditions</td><td></td></tr>
<tr><td></td><td colspan="2">organizational–environmental interactions:
e.g., misalignments and/or changes in goals and expectations, conflicts, negotiations, and arbitrations</td></tr>
<tr><td rowspan="2">Structural (emphasis on static aspect)</td><td colspan="3">Complicated Systems
The presence of any combinations of the attributes (listed below) beyond a certain threshold leading to intricacy, messiness, ambiguity, unpredictability, and being constrained</td></tr>
<tr><td>project size; number of different interdependent parts; product configuration; site characteristics
novelty of the technologies involved and methods used
ambiguity around project goals and/or final product attributes
the number of technical, structural, and information interfaces</td><td>institutional frameworks
social interfaces, processes, constraints, and hierarchies
geographical and climatic conditions
market and competitive setting
political and regulatory realms
social and cultural norms</td><td>governance framework; project management structure and team composition
expertise and experience of the project team
nature and expectations of stakeholders
organization culture and leadership style</td></tr>
</table>

Table 2.6: Project Complexity Profile proposed by Kiridena and Sense (2016)

levels and link them into the previously identified categories: technical, environmental, and organizational. The levels of systems they have proposed are complicated, complex, and complex-adaptive systems. Projects with lowest complexity level are identified as complicated projects, whereas the elements of complexity in such projects can be clearly distinguished as either of technical, environmental, or organizational aspect. The next level of complexity, the complex project, is being characterized by interactions between some project complexity elements belonging to several of the technical, environmental, or organizational aspects. On the highest level, complex-adaptive projects are being characterized by the interactions between the project elements belonging to all of the technical, environmental, and organizational aspects.

Chapter 3

Research Design and Data Analysis

3.1 Methodology

3.1.1 The Argument for Choosing Qualitative Approach

As being pointed out by experienced researchers (Castell et al., 2021) it is important for a researcher to understand the difference in ontological and epistemological perspectives forming the different research methodologies out there. Ontology is the view on what knowledge is. Is it external to the researcher, waiting to be discovered? Or constructed by the researcher through more understanding? Epistemology is the view on how knowledge is being obtained. Is the researcher standing external to the research 'object', and only picking up information during data collection and analysis? Or is the researcher being actively involved in construction of knowledge? The research methodologies are constructed upon these different views and therefore must be carefully selected in order to support the research purpose.

There are various paradigms concerning ontology and epistemology which are widely accepted today, among others "the five figured worlds": positivism, post-positivism, critical theory, constructivism, and participatory, proposed by Lincoln, Lynham, and Guba in (Denzin and Lincoln, 2018: ch. 5). Another example is the paradigms proposed by Burrell and Morgan (1979). As discussed by Brun (2010: p. 8) in his PhD dissertation, the latter is in particular relevant for organizational studies, proposing 4 paradigms: functionalist, interpretivist, radical humanist, and radical structuralist. Another publication, Goles and Hirschheim (2000), recognizes the significant contribution of Burrell and Morgan (1979) paradigm, and its relevance towards other scientific field than social science, such as information system.

Interpretivism intention is to build knowledge from understanding individuals' unique perspectives and the meaning attached to those perspectives (Burrell and Morgan, 1979). Constructivism views knowledge as constructed as people work to make sense of their experience (Denzin and Lincoln, 2018: p.98). In contrast, functionalists (also often called positivist) seek to discover law-like relationships and intend to provide a tool for predicting similar behaviour through empirical models.

Corbin and Strauss (2015) describe qualitative research as "a form of research in which the researcher collects and interprets data, making the researcher as much a part of the research process as the participants and the data they provide", clearly adopting the interpretivist and constructivist paradigms. They explain further that the most common reasons that researchers select qualitative over quantitative approach are:

- "To explore the inner experiences of participants
- To explore areas not yet thoroughly researched
- To explore how meanings are formed and transformed
- To discover relevant variables that later can be tested through quantitative forms of research
- To take a holistic and comprehensive approach to the study of phenomena" (Corbin and Strauss, 2015: p. 5)

The objective in this master's thesis is to provide a classification of project complexity encountered in *brownfield* projects within oil and gas industry. The intention is not to explain any cause and effect relationship which can be used for predicting complexity nor to make empirical model for project complexity, therefore functionalist/positivist paradigm is not suitable for approaching this research. Since complexity can be viewed from a rather subjective perspective where different people experience different situation and give different meanings towards project complexity, interpretivist and constructivist paradigm are considered to be the most relevant views in approaching this research, and therefore qualitative research approach is selected.

3.1.2 Grounded Theory Methodology

Grounded theory methodology was first introduced by Glaser and Strauss in 1967 for the purpose of constructing theory grounded in data. Their work "Discovery of Grounded Theory" has a significant impact to the scientific community. Although they are both sociologists by discipline, the method they introduced is also applicable for other disciplines since it enables "identification of general concepts, the development of theoretical explanations that reach beyond the known, and offers new insights into a variety of experiences and phenomena." (Corbin and Strauss, 2015: p.6).

Glaser	Strauss and Corbin	Charmaz
Beginning with general wonderment	Having a general idea of where to begin	Concious about personal/ subjective standpoint
Emerging theory/neutral questions	Forcing the theory/ structured questions	Gathered information guides the subsequent data collection
Development of a conceptual theory	Conceptual description	Conceptual description.
Theoretical sensitivity (the ability to perceive variables and relationships) comes from immersion in the data	Theoretical sensitivity comes from methods and tools	Theoretical sensitivity achieved by theoretical saturation/ immersion in data
The theory is grounded in the data	The theory is interpreted by an observer	The theory is interpreted by an observer
Credibility, or verification, of theory is derived from its grounding in the data	Credibility of theory comes from the rigour of the method	Credibility of the theory comes from explicating personal/subjective standpoint of the researcher
A basic social process should be identified	Basic social processes need not be identified	Social context needs to be identified
The researcher is passive	The researcher is active	The researcher is active
Data reveals the theory	Data is structured to reveal the theory	Data is structured reveal the theory

Table 3.1: The three most widely accepted versions of *grounded theory*, summarized from Edwina and McDonald (2019) and Charmaz (2017)

Corbin and Strauss (2015) point out that *grounded theory* is unique in comparison to other methods in qualitative research due to:

- The concepts are derived from data collected during the research and not selected prior to starting the research. This feature is the one that gives the methodology its name. A theory is then constructed out of these concepts.
- In grounded theory, research analysis and data collection are interrelated. After initial data collection, analysis being conducted upon that data. The concepts derived from the analysis form the basis for the subsequent data collection. Data collection and analysis goes in a continuous cycle throughout the research process.

Currently, the following three primary versions of *grounded theory*: Glaser, Strauss and Corbin, and Charmaz are the most accepted and recognized methodologies (Edwina and McDonald, 2019). Comparison between Glaser's version and Strauss and Corbin's version of *grounded theory* summarized by Edwina and McDonald (2019) is replicated in Table 3.1. The summary of Charmaz's version is included in the same table by the author of this master's thesis.

3.1.2.1 Choosing The Most Suitable *Grounded Theory* Version for This Research

As shown on Table 3.1, one of the main differences between Glaser's and the other two versions of *grounded theory* is how a researcher should position himself when conducting research. Glaser emphasizes on eliminating the researcher's influence in planning the direction of data collection process, putting the researcher in a rather passive position. This is, according to Glaser's version, essential in order to ensure that data will be the main driver in the emergence of theory. In contrast, Corbin and Strauss recognize the importance of creativity of the researcher, including in planning what information to be pursued in the next process of data collection, as well as in the process of forming a theory out from data. They claim that being able to connect to one's creative-self is important in producing a research with good quality (Corbin and Strauss, 2015: p.349).

Traditionally, Corbin and Strauss' version has been recognized as the one that emphasizes on certain procedures such as open, axial, and selective coding. In their 2015 book edition, however, the authors are no longer putting the focus on such procedural details (in fact, 'selective coding' was not mentioned at all), but rather on the rigorous process of planning the data collection and performing thorough analysis, reminding researchers that they really should prepare for a long haul (p. 83).

Charmaz's contribution to the development of *grounded theory* is through her persistence on adopting constructivist paradigm towards the method. When comparing between

Corbin and Strauss' against Charmaz's version, there seems to be little difference between the two. In their 2015 book edition, Corbin and Strauss put equal weight both towards the interpretivist and constructivist perspectives in their methodology, blurring the distinction between the two versions.

Strauss and Corbin's version has been chosen as the most suitable *grounded theory* version to be implemented in this master's thesis due to following reasons:

- Considering my professional background as an engineer working in oil and gas industry, I have reflected about my position as a researcher in the context of writing this master's thesis. I have participated in several projects and have an "already formed" world view regarding the topic being researched in this master's thesis, which brings myself into an interpretivist and constructivist position, as opposed to a purely interpretivist as required in Glaser's version
- I do have some idea where to start this research and how to gather information in a rather structured manner at the beginning of this research. These are the characteristics of constructivist approach, which also are reflected by Corbin and Strauss' version
- The time-frame given for completing this master's thesis has also been another point of considerations. Selecting a more structured methodology, such as Corbin and Strauss', will likely support in completing this research on the given time period.

3.2 Research Design

3.2.1 Steps in This Research

The research is started by gathering the most recent literature regarding complexity in projects. The search were performed across Scopus and Web of Science databases, using keywords: "project complexity", resulting in 846 documents (468 articles, 301 conference papers, 37 reviews, 27 book chapters, 3 books, and a few number of other types of documents). A few relevant articles were studied, and using snowballing technique more literature were identified. Searches were also performed using keywords "modification project", "brownfield project", and "oil and gas project" which respectively were resulting in 284, 160, and 710 documents. During this stage, the literature are not yet studied in detail since the idea is rather to gather an overview of what have been done in this area of research.

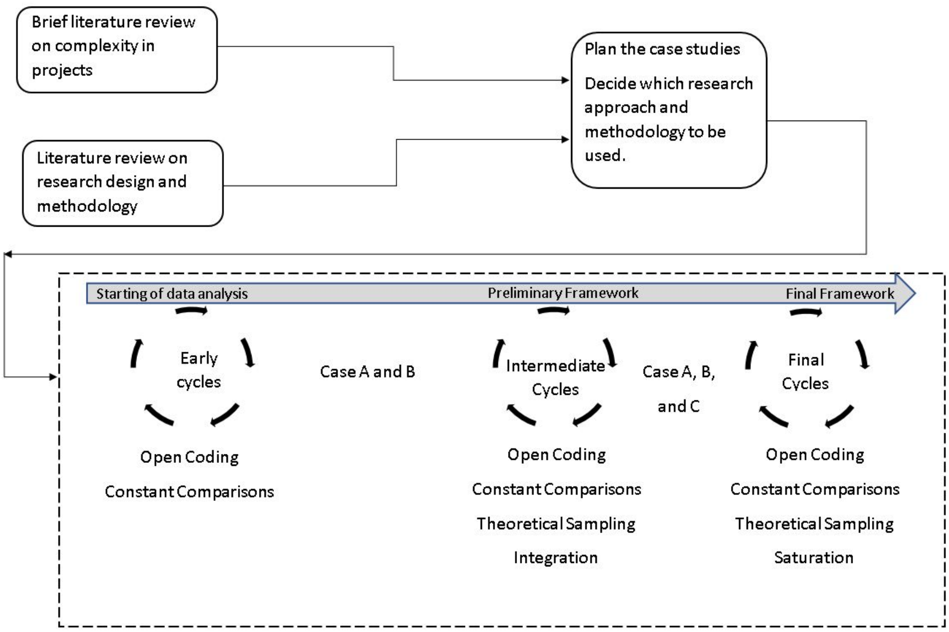

Figure 3.1: The research design for this master's thesis. See Figure 3.3 for details on *grounded theory* method

At the same time, literature review of various research approach was being performed in a rather detailed manner. Similarly, database search was performed (Scopus, Web of Science), using keywords "qualitative research design" (resulting in 3192 documents), and "introduction to grounded theory" (resulting in 5 documents). A few relevant articles were selected and studied, and then using snowballing technique more literature were discovered. This was to give foundation for the selection of the research design and methodology for this master's thesis.

After the most suitable research method is selected, first pieces of data are collected, followed by data analysis. Section 3.3 describes the data collection, while the analysis process is described in Section 3.4.

Figure 3.1 illustrates the entire process.

3.2.2 The Case Studies

Three oil and gas modification projects are used in the case study. In term of size and investment value, Project A is significantly larger compared to project B and C. Both Project A and B are completed when this master's thesis is written, therefore the participants had to rely on their memory when answering interview questions. Project C consists of two contractually separate projects which have similar goals. Those are, however, managed by the same manager, where several engineers are being shared on both projects. Furthermore, the two use a common methodology and tools in producing engineering products, and therefore they are considered as one project in this case study.

	Project A	Project B	Project C
Personnel	260	160	100
Building blocks	36	10	4 + 8
Work packages	5984	2647	332 + 917
Purchase packages	113	77	24 + 39
Engineering documents	15808	4719	244 + 396
Supplier's documents	4277	2208	202 + 631

Table 3.2: Overview of the projects used in case study

Figure 3.2 provides the perspective of the typical work breakdown structure in all the project cases. Several building blocks are assigned in correspondence to the dedicated construction areas, for example: 'BB01 - Wellhead Inlet Area', 'BB02 - Transformer Area'. Every building blocks consist of work packages, where specific tasks are collected into manageable-size packages, such as 'cable pulling in wellhead area', 'demolition of piping supports.'

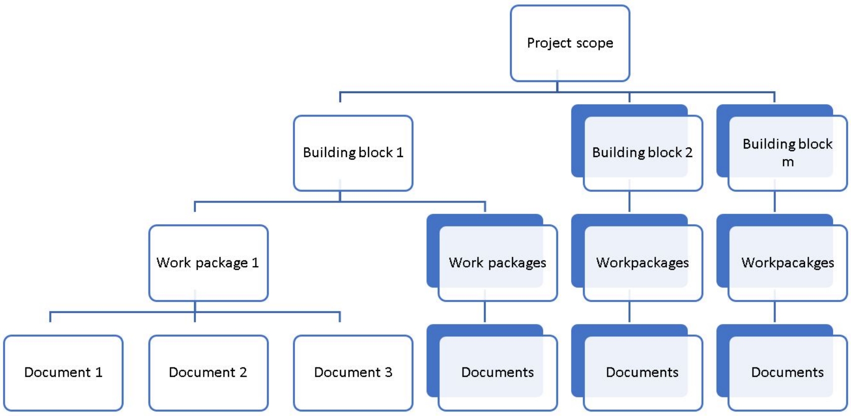

Figure 3.2: Typical work breakdown structure of the projects used in the case study

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3.3 Data Collection

3.3.1 Analytical Questions in Preparing Data Collection

Based on the definition of project complexity chosen for this master's thesis (ref. Section 2.2), the following analytical questions are employed when designing the interviews:

1. How can information about interdependency be obtained?
2. How can information about variety be obtained?
3. How can information about uncertainty be obtained?

When applying these questions, the synonyms to these keywords are also being considered. Table 2.3 shows various synonyms which researchers relate towards "interdependency", "variety", and "uncertainty", for example: "interdependency" is another terminology for interaction, feedback-loop, or networked causality. Some consider "variety" as consisting of many interrelated parts, multiple interaction, quantity, size, etc. "Uncertainty" is referred to when they consider ambiguity, unpredictability, difficulty to understand, and uncertainty itself. These three keywords and their synonyms are used for capturing elements of complexity through the interviews.

3.3.2 Interviews

Semi-structured one-to-one interviews are conducted and recorded in Microsoft Teams. They are fully transcribed and made anonymous both in terms of the project and the participants themselves. Each interviews are started by short introduction on this research, followed by brief introduction of the participants and their roles in the project. They are asked to tell what they did on the projects chronologically, and to describe any complexity they experience. With this type of open question, most participants are able to provide information fulfilling the analytical questions previously mentioned in Section 3.3.1. More specific questions are only given when they ask for guided discussion, and when information of certain type of complexity is being pursued, reflecting to the questions described in Section 3.3.1. Some examples of interview guides:

- Can you tell about various elements of the project? Please describe.
- Do you recognize any interrelation between various parts of the project? Please describe.
- Do you have experience concerning uncertainty in the project? Please describe.

People with more than ten years experience in *brownfield* projects were selected. The participants represent the engineering disciplines which have exposure towards multiple systems as well as against many other disciplines in the project.

Project A	Project B	Project C
Technical Safety, 2	Automation Lead, 1	Technical Safety, 1
Automation, 2	Engineering Lead, 1	System Engineer, 1
Engineering Lead, 1	Electrical, 1	Engineering Lead, 1
Process, 1	Technical Safety, 1	

Table 3.3: The overview of various disciplines and the number of interview participants per discipline

3.3.3 Project Documentation

Besides through interviews, data were also collected through observation of several project documentations. The observation were then documented in memos in NVIVO, in order to keep the cases anonymous. These observation memos were coded and analyzed in the same manner as the interview transcriptions. There have been one document per each project included in Project A and B. From Project C, two documents were included.

Project A	Project B	Project C
Engineering Study Report	Project Lesson Learn	Project Meeting Action Log
		Design Review Presentation

Table 3.4: Documentation used in observations

3.4 Analysis

3.4.1 The Methodology According to Corbin and Strauss

This master's thesis uses Corbin and Strauss' version of *grounded theory* described in their 2015 book. Unlike other research methods where analysis are performed after completing data collection, in *grounded theory* data collection and analysis process are performed simultaneously throughout the research. Once the first piece of data is being gathered, analysis is performed immediately. Then the second piece of data is collected, also followed by analysis over now the larger size of data. This iterative process of data collection and analysis lasts throughout the entire research period.

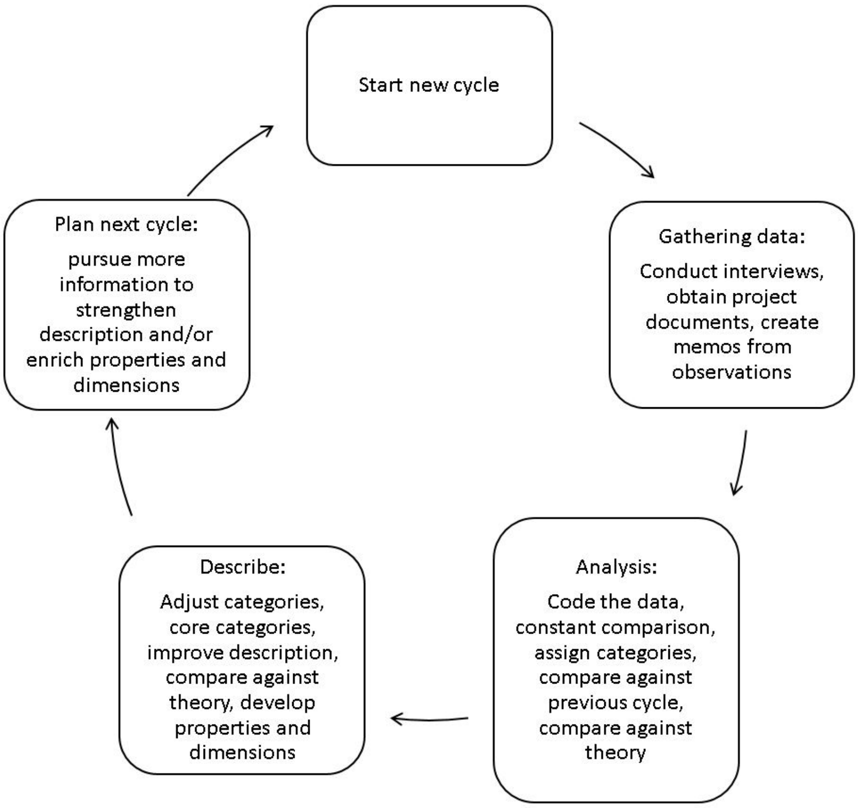

Figure 3.3: The Iterative Process in Data Collection and Analysis according to Corbin and Strauss (2015)

Corbin and Strauss' (2015) describe that data may be collected in various forms. Interviews and observations are the most frequently used approaches in data collection. However, any type of written, observed, or recorded material can also be used (for example: journals, videos, drawings, diaries, internal documents and memos, Internet postings, memoirs, and historical records.) (Corbin and Strauss, 2015: p.7).

Coding is the activity for developing concepts through interpreting the meanings from the data and assigning "conceptual headings" to them. The data analysis process begins with open coding. First, data are segregated into smaller sections, for example an interview transcription is divided into several sections containing several sentences. The sentences contained in each section should refer to the same context. "Conceptual headings" are then assigned for each section, these are referred to as "codes". In the beginning of the analysis process, open coding is applied to several interviews in order to collect several different codes. After a few interviews are being coded, usually some codes start showing relationships between one another. Codes which belong to the same theme are then being grouped together under a higher order code, called a "category". Sorting and grouping the codes is previously referred to as axial coding, whereas in the latest edition of their book, Corbin and Strauss (2015) called this process as "constant comparison".

The process continues with coding the next interview data. New codes may be obtained, and some new codes may be able to be put under existing categories. There is also a possibility that a new category emerges. The data from previous analysis are then being re-analyzed (i.e., being compared to the most recent codes and categories, and then being sorted accordingly in order to support the concept). During this process, some categories may be removed if the data do not support them. Some others maybe combined with one another, or being restructured in a different hierarchy.

"Integration" is the process of pulling the concept together based on the result of several cycles of data collection and analysis. This process is traditionally being referred to as selective coding. This can be done once the categories become stable. The result from this process is a conceptual framework (i.e., the theory constructed from data). The terminology framework is widely used in qualitative study, which represents similar concept to a model obtained in quantitative approach. From this point, new data collection and coding are still continued, followed with constant comparison and theoretical sampling. The aim is to test the validity of the framework against more data.

Corbin and Strauss underline the importance of "theoretical sampling" during the continued analysis. What they mean is that the questions prepared for the subsequent interview should be planned in order to enrich the concept that has been formed throughout the previous data analysis. With this, a more rich characteristics about a category can be formed, which Corbin and Strauss referred to as dimensions and properties. This process can also be used for testing whether the preliminary concept is adequately firm. Some negative case may occur. They should also be analyzed, however, it does not necessarily mean that they rule out a category. Sometimes, data from a different group or case study are used to test the framework. Further adjustment and refinement are carried out through out the process. This is continued until "saturation" is reached (i.e., no more new concept can be developed). (Corbin and Strauss, 2015)

In the first edition of their book, Corbin and Strauss used the terminologies "open coding", "axial coding", and "selective coding". These terminologies, except for the first one, are no longer being emphasized in their 2015 edition, however the same principle remains.

In this master's thesis, "axial coding" or "constant comparison" were performed continuously since the very beginning of the analysis process, together with open coding over the data each time new information is being collected, as suggested in 2015 Corbin and Strauss book edition.

The "integration" stage explained in Section 3.4.4 is comparable to what traditionally referred to as "selective coding".

The analysis process in this master's thesis is designed in such way that data from Project A and B are used in the process of integrating the theory, while data from Project C are purposely used in theoretical sampling and saturation.

3.4.2 Analytical Questions for Identifying Complexity from Data

Reflecting upon the definition of project complexity described in Section 2.2, the following analytical questions were applied:

1. Does the information describe interdependency?
2. Does the information describe variety?
3. Does the information describe uncertainty?

These three keywords and their synonyms are used for capturing elements of complexity through the gathered data.

3.4.3 Open Coding and Constant Comparison

Two interviews from Project A were the first being coded, followed by 4 interviews from Project B and 2 more interviews from Project A. The summary of open coding result from this stage is shown in table 3.5 below, while the complete codes can be found in Table A.1, Through constant comparison, some preliminary core categories emerged: "Achieving the goal of the project", "Clarity", "Impact to the project", "Knowledge", "Non-Technical", and "Project Size". At this stage, they seem to be supported by a variety of codes. Each preliminary core category has in average about 10 codes. One category "Impact to the project" had only 3 codes, while another code "Non-Technical" had more than 30 codes under itself.

Core categories	Number of subcategories (including second order subcategories)
Achieving the goal of the project	18
Causes of incidents	0
Clarity	6
Common challenges in brownfield projects,	0
Definition of complexity	2
Impact to the project	3
Knowledge	8
Non-technical	31
Project size	0
Tasks of a technical safety engineer,	0
Tasks of an automation engineer.	0

Table 3.5: Summary of core categories obtained very early in the analysis

The further developed open coding summary is presented in Table 3.6, while the complete codes from this stage are shown in Table A.2. The codes are being constantly compared with data and result from previous analysis. The data are obtained from 6 interviews from Project A and 4 from Project B. In addition, observations towards project documentations are also included. These observations are documented in memos and they are coded in similar way as the interviews. One memo for Project A and one for Project B are included.

Core categories	Number of subcategories (including all lower level subcategories)
Causes of incidents	0
Clarity	6
Common challenges in brownfield projects	2
Definition of complexity	2
Impact to the project	4
Organizational	67
Project size	3
Task of a Technical Safety Engineer	0

Task of an Automation Engineer	0
Technical	17
Unknown	1

Table 3.6: Summary of core categories obtained further in early analysis

3.4.4 Integration and Formation of Theory

During “theory integration”, also referred to as “selective coding”, the codes are constantly being compared against each other and towards the preliminary code structure, and against the literature on project complexity. Some codes were renamed in order to give more precise description. Some other codes were redundant and therefore being combined towards existing codes. The coding structure were also revised several times in order to ensure relevance and richness in codes supporting each core category. Several codes such as tasks of engineers were discarded since they were not supporting the theory formation. Some participants were asked to define project complexity using their own words, however most of them were struggled to provide such definition. In previous analysis, their answer were coded, however within the integration stage it was decided to discard this code since it did not provide valuable information.

Some participants mentioned Technical and Organizational complexity spontaneously as the dimensions of complexity in *brownfield* projects without receiving any guided question. Continued analysis found that a large portion of the elements from the data is related to Organizational aspect, such as communication, coordination, and planning. This was compared against the literature, and Organizational became a part of the preliminary core categories of this master’s thesis, replacing the Non-Technical category.

Further analysis identified that the remaining elements shared a common theme, that they resides outside of the project. A new preliminary core category External was added, and the relevant codes were now relocated under this core category.

Later on, several elements which relate to unknown, uncertainty or ambiguity are relocated under Clarity Assurance. These elements may relate to one of the three other core categories, however they show also relevance towards other core category at the same time. For example: installation sequence (T) which must be clarified together with Operations (O), or new safety regulation (E) which needs to be clarified with the client (O) on how to implement in the solution (T).

Analysis and comparison towards various frameworks proposed in several literature were conducted as part of the process of formation of the new framework, such as against:

- structural complexity, uncertainty, dynamic, pace, and sociopolitical dimension (Maylor et al., 2011),
- structural, technical, directorial, and temporal (Remington and Pollack, 2008)
- technical, organizational, environmental (Bosch-Rekveldt et al., 2011)
- project complexity profile (Kiridena and Sense, 2016)
- subjective, objective (Morcov et al., 2020)
- emergence, autonomy, belonging, connectivity, diversity, size, and the element of context (Bakhshi et al., 2016).
- structural complexity, uncertainty, pace, dynamic complexity, novelty, socio-political, institutional (Bolzan de Rezende and Blackwell, 2019)

Some participants voluntarily brought up Technical and Organizational as complexity dimensions, indicating that they are familiar with these themes. Meanwhile, most participants showed difficulty to answer questions such as "The literature mentioned about perceived and objective complexity, can you recall any example of these from the project?". This is aligned with Gao et al. (2018: p.3) who argue that the Technical, Organizational, and Environmental is a framework which can be easily and correctly understood by practitioners in construction projects. By reflecting on the information provided by interview participants and the work by Gao et al. (2018: p.3), in order to provide the project practitioners in *brownfield* projects with a framework that can be easily and correctly understood, this master's thesis proposes a new framework which is built upon Bosch-Rekveldt et al.'s (2011) TOE framework, by introducing a new category Clarity Assurance.

The result from this integration stage is a framework consisting of categories Technical, Organizational, External, and Clarity Assurance. This framework is formed based upon data from 6 interviews in Project A and 4 in Project B, as well as one project documentation per each project. The coding structure from this stage showed richness in terms of the numbers of sub-categories and codes. The summary of coding result from this stage is shown in Table 3.7, while the complete code structure can be found in Table A.3.

Core categories	Number of subcategories	Number of Codes
Clarity Assurance	3	11
External	1	3
Organizational	5	49
Technical	4	16

Table 3.7: Summary of core categories obtained after integration

3.4.5 Saturation Phase

More data were coded and analyzed after the theory integration. Three interviews and two project documents from Project C were included. Theoretical sampling, or also referred to as "selective coding" were conducted in order to enrich dimensions and properties of the core categories. The core categories have been stable since the theory integration and until all data from Project C were coded. Most data from the theoretical sampling were able to be linked to existing codes, indicating that saturation has been reached. Table 3.8 shows the summary of the core categories obtained from this stage, while the complete code structure can be found in Table A.4.

Core categories	Number of subcategories	Number of Codes
Clarity Assurance	3	14
External	0	5
Organizational	5	47
Technical	2	18

Table 3.8: Summary of core categories obtained after saturation

3.5 Ensuring Quality in Qualitative Research

The main aspect that positivists see as a flaw in qualitative research is the quality of its research process. Corbin and Strauss mentioned several criteria which have been widely debated in the research community, those can be utilized in determining the quality of a qualitative research, such as validity, reliability, credibility, truthfulness, rigor, and applicability (2015: ch.18). Corbin and Strauss consider reliability and validity as the terms which contain much of the sentiments from quantitative research and therefore they have considered not to use those terms (p. 345). They also consider the word "truth" as containing a certain extent of dogmatism, therefore they do not prefer using truthfulness. They conclude that "credibility" is the most suitable term, which they consider as the indication "that findings are trustworthy and believable in that they reflect participants', researchers', and readers' experiences with phenomena, but at the same time, the explanation the theory provides is only one of many possible"plausible" interpretations from data." (p. 345). They further argue that the same judgment criteria can not be applied across the different qualitative methodologies because each methodology is based on a different theoretical foundation and has different procedures.

To ensure credibility and quality of their research, Corbin and Strauss (2015: p.347-349) suggest researchers to apply the following strategy, which they argue is specifically applicable for their version of *grounded theory* methodology:

1. Methodological consistency: the research should follow all the procedures required in the selected method. Any step in the procedure should not be skipped. Procedures between different methods should not be mixed together.
2. Clarity of purpose: The researcher should be acutely clear on the purpose of the research across the entire research period. For example, is the research is to describe phenomena or is it to draw a theory?
3. Self awareness: Researchers to recognize their own biases and assumptions. Making journals regularly as well as performing self reflections during data collection and analysis will help to document researchers' position relative to the research. When presented together with the research result, observer can judge the quality of the process.
4. Training in how to conduct qualitative research: Adequate information about the methods and practice is one success factor in qualitative research
5. Sensitivity to participants and data: Be aware to non-verbal messages during interviews, as well as context on what the participants are implying to through their responses
6. Willingness to work hard: Spend the time necessary in each process, and put attention to details
7. Connecting with the creative self: The researcher should try looking at the data from different perspectives, address information from different direction, and brainstorm all possible explanations

8. Methodological awareness: Researchers should possess awareness of implications from the decisions they made during the research process

9. Strong motivation to perform the research

3.5.1 Explicating the Researcher's Position

Explicating the position of the performing researcher relative to the research activity he is conducting has been an important topic discussed by Charmaz (2017) and Corbin and Strauss (2015). This section provides a brief summary of professional background of the researcher writing this master's thesis.

The researcher has been working for several years within oil and gas industry, and have participated in more than five projects, including in two projects used as study case in this master's thesis. The researcher's roles in the projects are within Automation discipline with both technical and coordinator responsibilities.

When working on this master's thesis, the researcher took a full-time educational leave from his work as an engineer. During the research, he positioned himself as a person residing outside of the projects. Own experience were not included as data in this research. When conducting interviews, the researcher always ask open questions and let the participants guide the flow of the interviews.

3.5.2 Measures Taken for Ensuring Credibility of This Research

Reflecting upon the suggestion given by Corbin and Strauss (2015) as discussed in Section 3.5, the following measures have been taken in order to support the credibility of this research.

- Raw data, transcription and memos are kept in a secure location in order to enable tracing when required
- An individual file was created for each stage in the analysis cycle to enable traceability, as well as to show how the analysis have developed
- Continuous self reflection about own subjective interpretation and internalization of various project complexity experienced by the performing researcher. See also Section 3.5.1
- The final analysis result was presented to a couple of interview participants in order to seek feedback

- Revisiting the methodological procedures regularly in order to ensure consistency against the chosen methodology
- Reflecting upon the objective of the research regularly in order to maintain the focus of this research
- To provide transparency, complete codes are presented in Chapter 4, including the reasons for coding

Chapter 4

Findings

4.1 The Framework Constructed from the Data

The framework proposed in this master's thesis is shown on Figure 4.1, while the final code structure is presented further in this chapter. The final code structure is also shown in Table A.4. The core categories are: Technical, Organizational, External, and Clarity Assurance. The fourth core category Clarity Assurance emphasizes on the importance of *ensuring clarity.* At the same time, it is overarching the three other categories, indicating there is interrelationship between that element towards some or all of the three other core categories.

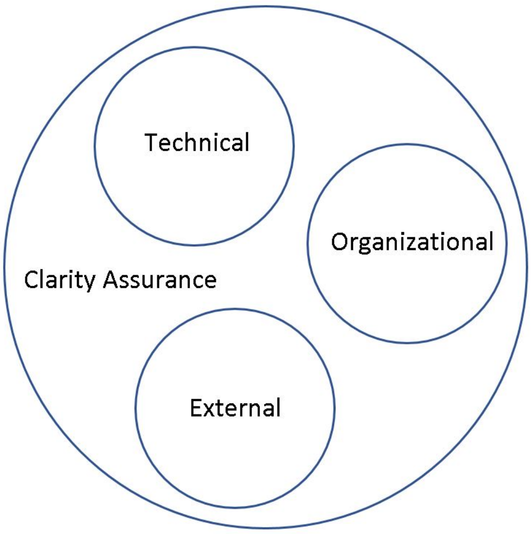

Figure 4.1: Project Complexity Framework for *Brownfield* Oil and Gas Projects proposed by this master's thesis

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The following sections describe the categories and codes obtained from the data, including reason for coding and the corresponding excerpts from the data.

4.1.1 Technical

This core category is dominated by codes related to variety within a project. The elements in Technical category are related to the *product* that the project is aiming to deliver or the *method* that the project is implementing in order to achieve its goals.

4.1.1.1 Method

Method is the approach being used in order to achieve the solution which in general involves the use of technology, technical skills, and technical experience. The list of codes supporting this category can be found in sections 4.1.1.1.1 to 4.1.1.1.11.

4.1.1.1.1 Avoid disturbance to live systems which can disrupt production

Coding reason: handling interdependency of project elements and reduce risk of disrupting the production.

Document: Project C interview 2, 22/04/2022 14:46
"Today we received a lot of alarms and trips that we are verifying and we are redesigning to avoid spurious trips and the interruption of normal production, ... (deleted detailed technical information to keep the project anonymous)... interrupt normal production because of course that is not desired"

4.1.1.1.2 Design verification

Coding reason: The products are part of variety of project elements.

Document: Project A Interview 4, 01/03/2022 13:47
"...so I think for as long as you know that you're doing the right thing at the right time, it's not a bad way to go. It will probably make products cheaper if you can. The only thing it won't is if you start making faults. It will make you more expensive because you've already produced a lot of things. So small quality checks along the way were critical."

Document: Project B interview 01, 23/02/2022 11:02
"Another one we kind of face, umm it was because we were doing modification of new wells so it was supposed to be kind of like the same type of wells that the existing

and then we were putting more oil producers, then another fact that sometimes can be dangerous and can cause problem is the copy and paste effect. Because we even have some issues with when we did the design for example, and then the SCD was showing modification in the design and because it was so similar well as the existing, the SAS vendor took the logic from before and then they didn't implement the SCD modification for example. So that copy and paste factor for Brownfield can be as well a tricky one, at that time then it didn't cause any big problem, but when it was discovered then we got a kind of like an NCR for let's say."

Document: Project B interview 04, 04/05/2022 13:51
"If you think of, because in the modification project you are going into an existing system, um, you have from the start of, um, normally you are depending on the existing documentation. And, um, to say that, normally the existing documentation is maybe not detailed enough, maybe there are something that's wrong with the update. So you often have to go offshore to verify this."

4.1.1.1.3 Different modification projects follow the same company guidelines

Coding reason: company guidelines describe how to handle multiple project elements (variety), as well as interdependency between some of those.

Document: Project B interview 04, 23/02/2022 11:02
"It's nearly the same procedure because we need to follow the our company guideline. And that's how we deal with it. Even if the procedure called in different names. Yeah on the platform, but it's only a small or minor differences in the company guideline. It's the process that describes how you normally follow the sequence in where you are in the project. So, it's in every project you have a start up, you have a verification reports and systems which should be followed to secure that you get the deliverables according to the sequence we want to deliver, and what also requirements is to get the documentation sent out for information, and acceptance at the customer. So. If we follow our own process, it's actually very good even if it's not down in detail, so it's good to have a lot of tools that we use as a helper on this."

4.1.1.1.4 Ensure adequate level of detail achieved before proceeding to next stage

Coding reason: handling multiple project elements (variety) and interdependency between them.

Document: Project B interview 04, 04/05/2022 13:53
"But that's that's why that should not be in normally know too much changes in after a

FEED, because that takes time and especially when you have a time limit in plan to deliver.”

Document: Project C interview 3, 04/05/2022 10:43
“So of course, always in Brownfield project work on existing installation can be challenges. From the FEED phase it was picked up, maybe it was done in rush, um it was picked up very simple, a very kind of, at that time, thought that very easy route for the cable tray, the cable ladders and cable tray, and the cables. But at some point, it was identified that was not the most best solution and we have to redo that one during the engineering phase. And these redo of course lead to much spent time hours use. But at the end it was kind of a more safe, how can I say, design solution that was implemented in the project. But yeah, so. facilitate in a way the the construction as well.”

4.1.1.1.5 Keep the design simple

Coding reason: activity related to handling multiple project elements (variety) or interdependency between them.

Document: Project B interview 02, 23/02/2022 11:02
“...and also I think you probably heard about this KISS philosophy, um, keep it simple and stupid. So in the design, when things project become more complex, engineers also need to think about. Keep the simple and stupid which well functioning I could give you. One example is in Project B, we had a tie in point for the fire water and somebody have took a firewater tie in from long, far away here. But there’s somewhere else closer here. They then it’s really simple thing but, people should think twice. You might make things simpler and less work.”

4.1.1.1.6 Preventing human error

Coding reason: handling multiple project elements.

Document: Project B interview 02, 23/02/2022 11:02
“...in our project, we have human factor specialist. They conduct workshops with the people to brainstorm the scenarios. Human error can happen in the control room, right? So we analyzed this critical tasks, ff there’s potential for human error can happen. So there is this kind of workshop, but they are very specialized/narrow in terms of the scope, it’s more for operators, like people who operate the platform to join this meeting. And not a lot of people, for example interface with other.. So this is one of the solutions, you have the workshop you get people who use this to brainstorm. But not many of the people who designed this think about what error can cause a major accident. Not

one thing, many things had to be together for causing a major accident, but of course we have lot of reviews in the project. People talk about things. Pick up the risks and consequences. But we are talking about, how could we do better? It's very difficult to be better. Very challenging."

Document: Project B interview 02, 23/02/2022 11:02
"First, it could be the design, there's some hidden factors which could cause human error. Second one also the user. How do you use this? Right, how to use it during the operation. We're not talking about, you know things are designed, as to a perfect level, we're not talking about that. We criticize other people. We're talking about 0.1 percentage of the possibility which things might go wrong, Right? So very very high consequence, but very low possibility."

4.1.1.1.7 Understanding the applicable technical requirement

Coding reason: knowledge required in order to handle multiple project elements (variety).

Document: Project A Interview 1, 28/02/2022 13:16
"So then you've got to learn how they do it and then trying to apply your knowledge to the way that they do it."

Document: Project A Interview 2, 28/02/2022 14:32
"...to get all these subsea scope defined properly"

Document: Project A Interview 4, 28/02/2022 18:44
"So we struggled, or we worked quite a lot with identifying what's the actual demands compared to what the actual limitations were.. and also to understand what the different.., what do you call it. . . ., namings meant for the different companies, so you could have one abbreviation in subsea meaning one thing, and the same abbreviation in SAS meant something totally different. So, you had sort of call it language barriers as well as technical barriers for being the first ones off."

Document: Project A Interview 3, 28/02/2022 18:15
"...we experienced these challenges when we are required also to comply with new standards that they're not available or applicable at the time the installation was built. So this is the main challenge in the technical issue I have experienced there now."

Document: Project B interview 04, 23/02/2022 11:02
"...the work you're gonna do have to be done by normally the latest revision of the standard and specifications that's operated by the company. "

4.1.1.1.8 Understanding the applicable technical requirement, Applicable regulation

Coding reason: knowledge required in order to handle multiple project elements (variety).

Document: Project A Interview 3, 28/02/2022 18:15
"...we are required also to comply with new standards that they're not available or applicable at the time the installation was built."

4.1.1.1.9 Understanding the applicable technical requirement, Applicable standard

Coding reason: knowledge required in order to handle multiple project elements (variety).

Document: Project A Interview 3, 28/02/2022 18:15
"...we are required also to comply with new standards that they're not available or applicable at the time the installation was built."

4.1.1.1.10 Use of technology

Coding reason: action related to handling of various project elements (variety).

Document: Project A Interview 6, 17/03/2022 15:19
"PDLA1: And tools like you know you're familiar (software name), this tool allows you as you are in the platform looking at the equipment. Even though it could be not 100% updated, it's a very good tool to have an understanding of where you are and what you have, it's a very good start point. And also all these – how it's called – measurement surveys where there is a particular team that goes offshore to do scanning of lines dimension, that's super important also to have, from as early as possible in the project. So Piping can base the design all the lines, support or equipment layout, as exact as possible according to the real dimensions of the the platform, something that obviously doesn't happen in the Greenfield projects because in the Greenfield project everything is from zero, so you can have as you wish."

Document: Project B interview 02, 23/02/2022 11:02
"Another complexity. I would say the technology development for example artificial intelligence/software that are used. For example this software for detecting leakage on pipelines,"

Document: Project B interview 03, 23/02/2022 11:02
"But, from for example electro point of view, we have a complicated activity because we had we managed a high voltage. Both high voltage machine and, like transformer, VSD.."

4.1.1.1.11 Use of workshop

Coding reason: action related to handling variety in project elements.

Document: Project C interview 2, 22/04/2022 15:41
The interviewee described development of shutdown hierarchy document which was involving multidisciplinary team.

Document: Project C Memo 1, 25/04/2022 15:03
"Engineering activities such as workshops and completion of documents which are requiring input and participation from various disciplines are followed up in the meeting. Action responsible and required date are assigned for each topics."

4.1.1.2 Product

The reason that product is considered as Technical is due to the nature of the product of a *brownfield* project itself, which generally is a technical solution involving design, fabrication, installation, and commissioning of the product. The list of codes supporting this category can be found in sections 4.1.1.2.1 to 4.1.1.2.6.

4.1.1.2.1 Capacity of existing equipment or system

Coding reason: interdependency between new solution and existing equipment.

Document: Project B interview 01, 23/02/2022 11:02
"...specially because we are going into very old facilities, is capacity constraints. So, because when you come with the modification then not necessarily on the capacity that you need is there (available) and not necessarily it's easy to increase that capacity as well. We are talking about utilities or in the control system for growing. If there's any big bottleneck. For example, if it's a legacy control system that can be a big issue to come with modification and and to have enough capacity available. So that's another kind of like complexity that are a brown field project could have. Again this three last ones I'm speaking more now in the early concept that we are doing because we come with big modification, even electrification, and so on. And then we found a facilities that are still old with old control systems. So there's a risk of needed to upgrade. And then it's the network having not enough capacity, so you need to go into all this detail to see if it's feasible."

4.1.1.2.2 Establish complicated functionalities involving various systems

Coding reason: handling variety and interdependency in project elements.

Document: Project C interview 2, 22/04/2022 14:48
“Yeah, there is a lot of work behind the main transformer. We need to reestablish the design again and straighten it out. Umm. up also. Also, there are new functionalities. The client have requested for automated functions that we are also spending a lot of time between electro and automation to build up a single push button functions. ...(deleted some detailed technical description to keep the project anonymous) As I said, we are spending a lot of time to build up this. Lot of signals, lot of preconditions, lot of different steps to consider. It’s actually an interesting part in the project to develop this.”

Document: Project C interview 3, 04/05/2022 09:40
“Of course, as well as part of the procurement, we also have you know that the SAS supplier. The time needed for the SAS supplier depend on the information to be received, make longer the delivery time and of course it affects the whole procurement and delivery process. Also, there are dependent from some information we have to start with some I/O list, correct? But then the development of the packages, the engineering of the packages in the procurement process. the maturing information increase the number of signals and that will affect the original, yeah. basis that was made for.. um specifying the equipment, but this also affect procurement. So basically I think there has been one of the most complex process and complexity with regard to Project C related to high voltage equipment.”

4.1.1.2.3 Establish interface between various systems

Coding reason: handling variety and interdependency in project elements.

Document: Project C interview 2, 22/04/2022 13:51
“So we also have several interfaces there to the platform modified by Project C2. So actually the the shutdown hierarchy modification is affecting both platform modified by Project C1 and the nearby platforms. So it’s an important part.. what I will gonna say.”

Document: Project C interview 2, 22/04/2022 14:40
The interviewee described interfaces between various electrical switchboards. The interface is both against other electrical equipment and control system equipment of various functionalities.

4.1.1.2.4 Establish technical solution

Coding reason: handling multiple project elements (variety) and interdependency between them.

Document: Project A Interview 2, 28/02/2022 14:31
"...to get all these subsea scope defined properly..."

Document: Project A Interview 4, 28/02/2022 18:42
"...technical difficulties where we constantly were figuring out together with the subsea vendors the, well, the solution and how to do this, how is this interpreted"

Document: Project C interview 2, 04/05/2022 13:36
The electrical system engineer described the detailed electrical scope which needed to be delivered by the project. Detail information regarding that scope is not presented here in order to keep the project anonymous.

4.1.1.2.5 Establishing complicated functionalities

Coding reason: handling multiple project elements (variety) and interdependency between them.

Document: Project C interview 2, 22/04/2022 14:13
The electrical system engineer described implementation of complicated functionalities required to be delivered by the project. This functionality involved many different electrical system, automation and instrumentation system. Specific sequence must be fulfilled in order to achieve the functionality. Safety protection are also involved in order to secure operation of this new functionality.

Document: Project A Interview 1, 27/01/2022 13:50
The technical safety engineer described that integrating new equipment to existing system can be more complicated than building something completely new.

Document: Project C interview 2, 22/04/2022 14:57
"...it's a complex process. It's. Umm, sometimes much easier to just design from new instead of modify and find all the different challenges because there is always a risk, continuously..."

4.1.1.2.6 Understand the project scope

Coding reason: understanding the project scope is required to handle multiple project elements (variety) properly.

Document: Project A Interview 1, 27/01/2022 13:30
"So I guess it's a little bit of a challenge when you're just come into a project you haven't got the history maybe as some of the others have had, don't have. They had a little bit longer to look at it. They've got the connections there you come in and have a job to do,

but I I guess I had worked at this company before so I knew a lot of the people, And but he will move around as well. So I had a new senior leader, whatever it was called at that time, So I knew some of the people, but you're coming a little bit later than the project started, so you're just catching up, always but... You catch up quite quickly. You got a job to do so. From that perspective, you do the best you can."

Document: Project A Interview 2, 28/02/2022 14:31
"...to get all these subsea scope defined properly the subsea vendor was not decided, so we needed to do lots of interface with the different possible vendor and go through the different possible scenarios"

4.1.2 Organizational

The core category Organizational is related to organizing the variety, interdependency, and uncertainty in project elements, such as tasks, interaction between the team members, suppliers, project stakeholders, and more. Under this core category, there has been identified 5 sub-categories: Communication, Constraints, Coordination, Learning, and Planning, all of which are related to organizational aspects of a project. Communication, Coordination, and Planning are related to the activities in managing people, tasks, and products, for example: "Maintain clear and trustworthy communication in the team", "Interface coordination", and "Plan the resources required in the organization". Learning is also identified as part of the Organizational core category. To some extent, learning may be subjective to each individual, for example an Automation engineer needed to learn about subsea control technology he has not yet encountered in previous projects. On the other hand, learning can also be organized collectively on the organizational level, such as in "Ensure good understanding of the applicable engineering methods" and "Acquire new knowledge: related to new client" which must be complied by all the project team members. For either individual or organizational context, learning is mainly about improving and managing knowledge residing inside each participants of the project, therefore it is included under the core category Organizational. The category Constraints is related to organizational limitations which must be responded by the project, for example: "Acquire resource with required skills and knowledge" and "Limited time available".

4.1.2.1 Communication

The category Communication is related to the activities in managing people, tasks, and products. The list of codes supporting this category can be found in sections 4.1.2.1.1 to 4.1.2.1.8.

4.1.2.1.1 Culture awareness in communication

Coding reason: ambiguity caused by different culture background.

Document: Project B interview 02, 04/05/2022 13:47
"Other complexity I would say is culture awareness because when the company becomes more international and engineers become very international as well, people have a different background. For example (country name) culture, like you are from other country, I'm from (a country name) and we also have people from Venezuela, Spain, Norwegian, English, so.. Cultural awareness about communicating technically to make the communication more effective. I don't know what you yourself have experience about communication.

Yeah, and also I think this communication for the cultural awareness I I've found when I'm in Norway and never had this kind of course. But when I started with the previous company we had this three days training where we only talking about, we are people who talk, think, communicate, show body language. So like to have a cultural awareness will not change you, but at least it gives you more awareness of. I'm talking to somebody he thinks a different way as me and communicate different way from me. And also, I think in some cultures people talk, they don't look into your eyes right? So. when they have this kind of course, they will be more aware of looking at other people into the eyes and communicate. It's a small things but. Well, yeah."

4.1.2.1.2 Ensure clear understanding of what to deliver and when

Coding reason: ambiguity or uncertainty about the goal

Document Project A Interview 6, 16/03/2022 14:14
"And the key issue is of course in all these, not only for this particular task, but also for the normal building blocks and normal project is to make sure that everybody have a clear understanding of milestones, what to deliver, that's the key. Because it's easy to say "OK, we have this milestone, everybody have to comply", but not necessarily all disciplines have a clear scope for each milestone. So one of the main task is to make sure that everybody have a clear understanding of their deliverables to each one of the milestones. And a special focus on the work packages and the materials. That was actually a key factor for success of this project."

Document Project A Interview 6, 17/03/2022 14:01
"But the thing is it's more related to have a clear understanding of the scope more than anything else. Because at the end, all are professionals, not everybody knows everything technically, but everybody is able to find a technical solution always. I haven't seen any

technical solution that cannot be solved at all. I don't believe that the complexity is related to any technical issue per sae. It's more related to have a good communication and good understanding between the team member on what needs to be delivered and when. And that's where the complexity could be sometimes arises because other things that can make things complex at the end. Engineering works for Construction to have everything ready to start the installation, and complexity could be not having material on time. And how to start solving that? Be prepared to find materials in other projects or start looking other suppliers or be ready to pay additional fees in order to get what you need faster. Also make sure that all the input is ready for construction and to start."

Document Project A Interview 6, 17/03/2022 14:03
"But the most important part is to have – from the beginning – a clear understanding of what have to be solved and when. And work in advance. One of the things that helped us a lot was to prepare – to be ready – with all the input to the work packages and all the materials available in the storage six weeks before the installation start date. Because then everybody is focused. To have OK, if you have, in your mind a clear understanding what do you need to be ready in the next 6-10-12 weeks, you can focus on that medium short term, of course, without forgetting the long term, because you have to look into that also. But things goes, in my opinion, more smooth."

Document Project A Interview 6, 17/03/2022 15:09
"DI: ...the more challenging part, if I understand, it's probably to get this different individual people work together, maybe having their own style and personalities, do you have any practical experience on what the practical things that work or?

PDLA1: Yeah, one of the main things that always came on the table to solve was, you know, that normally in our company we have a team working from engineering. We have work packages that is, you know, the main document that is used offshore to build things, to make that work package, there are a lot of input from Engineering and input from the Construction team. They have to provide that. And sometimes, there were a lot of discussions on who do what. For example, several things Engineering was arguing: no no this is Construction scope and Construction say: no, they (Engineering) must have that in scope, and things get stuck. And that's the kind of things that can delay the final product and need to be fixed 100% from the very beginning."

Document: Project B interview 04, 04/05/2022 13:48
"...so it's that we need to follow up, with the plan we have, have meetings with the internal engineers and also with the customer. Often discipline-wise to secure that we have the same understanding of the deliverables."

Document: Project B Memo 1, 03/03/2022 20:38
"The Engineering Lead ensure the Discipline Leaders understand about the deliverables expected from each discipline through close communication, workshop with the Client, and establishing the guideline for the methods to be followed."

4.1.2.1.3 Establish and maintain good communication with the client

Coding reason: eliminate uncertainty or ambiguity.

Document: Project A Interview 4, 01/03/2022 13:27
"...the idea that we had when we went to the client or we had almost hourly communication with the client. There were basically sitting on our desks with us."

Document: Project A Interview 5, 04/03/2022 14:01
"DI: Yes people, or the organization.. more on how the teams are, what you call it, inform and interface. PEA1: Actually, I'm quite a.. I think it works fine.. because, unlike other project, where we can not contact the client directly. We need our discipline lead. DI: Ah. Right PEA1: This project, because the client's Process people, he was sitting at our premise, so we can just go there and talk to him, and was very good."

Document: Project A Interview 6, 16/03/2022 14:02
"And of course the client was absolutely involved on this because they were absolutely interested."

Document: Project C interview 2, 22/04/2022 15:09
"...sometimes depends on the time, but the project but. The client sometimes go goes more into details on some particular topics.. sometimes it leaves the control purely on our side. We have the full responsibility, of course, for everything to be OK in the end. Ohh believe I would say we get the support from client. So it's OK, I cannot complain, but sometimes client complain a lot that some processes on our side are taking way too much time so so so their main focus in this project to some degree on technical level they are participating, but the main focus is that things will happen on time and that the money they have spent on, especially for the integration tests will be well used."

Document: Project C interview 2, 22/04/2022 15:16
"...so we have a the there is a risk there. The client is also very focused on that. So whenever we have decisions that we want to buy something new especially at this stage of the project. The They will try to push us into another direction to avoid it. So, so, so not to. So to avoid that risk, the delivery of equipment."

4.1.2.1.4 Client availability and involvement

Coding reason: client availability and involvement reduces uncertainty or ambiguity.

Document: Project A Interview 1, 27/01/2022 13:42
"It was quite nice. We had the the client on site. I think 100% of the time. So that was very valuable. That was not a challenge. That was a challenge over common other really.. I think. Maybe on some other projects that the client isn't on the contractors premise 100%. So. That was good that our discipline was on site at the (company) office."

Document: Project A Interview 6, 17/03/2022 13:35
"PDLA1: They were located with us. The client was in the same building with us, in the same of officers area, and in this particular project, the client was absolutely cooperative. They were part of the of the team, definitely. And they helped as much as possible to solve the problems, when it was possible for them. Of course, maybe it's not all the time, but they were willing to cooperate, and that was also one of the key factors for this project to succeed. I have been employed where the client is just looking at arrows text like signals that in a in a in a drawing and I don't know if because lack of involvement or. I don't know. I don't know how to say that, but that was not the case in this particular project. And the commitment of the customer to solve the issues was important."

4.1.2.1.5 Access to Client

Coding reason: better access towards the client can reduce ambiguity or uncertainty.

Document: Project A Interview 5, 04/03/2022 14:06
"PEA1: And then we can also write the email to him directly, but we will, like expected to copy to our discipline lead."

4.1.2.1.6 Client and contractor in same location

Coding reason: co-located team can reduce ambiguity.

Document: Project A Interview 1, 27/01/2022 13:43
"It was quite nice. We had the the client on site. I think 100% of the time. So that was very valuable. That was not a challenge. That was a challenge over common other really.. I think. Maybe on some other projects that the client isn't on the contractors premise 100%. So. That was good that our discipline was on site at the (company) office."

Document: Project A Interview 4, 01/03/2022 13:25
"...the idea that we had when we went to the client or we had almost hourly communication with the client. There were basically sitting on our desks with us."

Document: Project A Interview 5, 04/03/2022 14:01
"This project, because the client's Process people, he was sitting at our premise, so we can just go there and talk to him, and was very good.

Yeah, yeah, and also because that's a before the corona, right? I mean we had a physical meeting together. I mean, if I can take this other project I'm in now, it is a challenge because I just jumped in. And half of the people are in Bergen, yeah, it is corona, and we have never met them, so it is very strange to start working with them, you know. Cause you don't know the people personally.. I don't know, but slightly different or difficult. But in Project A, from my perspective it is a quite good project."

4.1.2.1.7 Establish trust

Coding reason: trust can reduce uncertainty.

Document: Project A Interview 4, 28/02/2022 18:59
"...We were talking to each other. So there was a what are your organizational complexity towards establishing trust. That we as (company name) were, well basically able to communicate with all of these without enforcing the other company to increase their scope. So part of the trust that we had to establish was that we were capable of maintaining both our wants and wishes for the interface as well as maintaining the contractual agreements and the contractual limitations for all the parties."

Document: Project A Interview 4, 28/02/2022 20:10
"I was well, if you look at what I was actually responsible for, it was the technical details. But in order to start solving them.. we had to participate in getting the organizational parts together and that trust that we created that was created on the technical level and then used as proof up on the organizational level that we're doing the right thing and we have to do it like this to make it work."

Document: Project A Interview 4, 01/03/2022 10:53
"I think so that that we learned as we went along and we had sort of a common understanding, I think throughout the whole interface, I tried at least to say that quite some time that we have to establish a interface truth and then follow that. If that's wrong, well then we move it to something else, and then this is the true, so that we just we sort of got everybody on board discussed then we came up with the solution for the interface for us, but then if it later was wrong, it didn't matter if it's it was me who wrote it, or supplier 1 or supplier 2. We just change this as a group to something else that's now right"

Document: Project A Interview 4, 01/03/2022 11:13
"So the automation engineer in FEED established communication with both the subsea providers 'cause it was two, who was struggling for the contract. And then when I came in, they were still not decided on the project or which one was going to be chosen. So ah, there we started with sort of simple deliveries, and then that communication and that level of detail going back and forth sort of evolved, as we understood, I wish we got to know each other and understood what we stood for and stuff like that. Especially that part where the most difficult things I think, was to support and protect that the idea that we are allowed to be wrong, that we can choose something. Now when we were allowed to move it there and nobody will blame anybody. And I said a couple of times quite often. Yeah, if you want to blame somebody then blame me. So there is in some of the MOMs. It says, "(AEA1) said it's supposed to be like this. And then when somebody read it afterwards, I got confronted. And then said, well, yes, 'cause we had to choose something, then it's better to choose something 'cause it's a lot easier to rip a page apart then to create the page itself. So as long as your written something, it's a lot easier to then go back and say, well, "this point is wrong in this point is wrong"." Change this to that." Change this to that rather than sitting and writing the whole thing from scratch. But I think to answer what you're asking, I think it was a development over time that it just we just sort of matched in personalities, I think it's the best answer for it."

4.1.2.1.8 Maintain clear and trustworthy communication in the team

Coding reason: clear and trustworthy communication reduces ambiguity and uncertainty.

Document: Project A Interview 4, 01/03/2022 10:55
"I think so that that we learned as we went along and we had sort of a common understanding, I think throughout the whole interface, I tried at least to say that quite some time that we have to establish a interface truth and then follow that. If that's wrong, well then we move it to something else, and then this is the true, so that we just we sort of got everybody on board discussed then we came up with the solution for the interface for us, but then if it later was wrong, it didn't matter if it's it was me who wrote it, or supplier 1 or supplier 2. We just change this as a group to something else that's now right"

Document: Project A Interview 4, 01/03/2022 11:13
"So the automation engineer in FEED established communication with both the subsea providers 'cause it was two, who was struggling for the contract. And then when I came in, they were still not decided on the project or which one was going to be chosen. So ah, there we started with sort of simple deliveries, and then that communication and

that level of detail going back and forth sort of evolved, as we understood, I wish we got to know each other and understood what we stood for and stuff like that. Especially that part where the most difficult things I think, was to support and protect that the idea that we are allowed to be wrong, that we can choose something. Now when we were allowed to move it there and nobody will blame anybody. And I said a couple of times quite often. Yeah, if you want to blame somebody then blame me. So there is in some of the MOMs. It says, "(AEA1) said it's supposed to be like this. And then when somebody read it afterwards, I got confronted. And then said, well, yes, 'cause we had to choose something, then it's better to choose something 'cause it's a lot easier to rip a page apart then to create the page itself. So as long as your written something, it's a lot easier to then go back and say, well, "this point is wrong in this point is wrong"." Change this to that." Change this to that rather than sitting and writing the whole thing from scratch. But I think to answer what you're asking, I think it was a development over time that it just we just sort of matched in personalities, I think it's the best answer for it."

Document: Project A Interview 4, 01/03/2022 13:23
"It's very important to have a communication all the way through. And that understanding and level of understanding that we'll do whatever it takes to reach our milestone, and that trust."

Document: Project A Interview 4, 01/03/2022 13:46
"We've gotten feedback from technical umm, say and supplier themselves that they've never yet worked and I'm more productive companionship with open dialogue and understanding across the different phases."

Document: Project B interview 02, 04/05/2022 13:38
"Also a challenge is communication between the multi disciplines. Should be communicated in advance, or on time... thoroughly... so people have more effective progress on the schedule. I would say these are challenge."

Document: Project B Memo 1, 03/03/2022 21:08
"Communication between various coordinators (Discipline Lead, Procurement Lead, Change Lead, etc) need to be maintained. It is one of the challenges in a large modification project."

4.1.2.2 Constraints

The category Constraints is related to organizing various limitations encountered by the project. The obtained codes supporting this category are listed in section 4.1.2.2.1 to 4.1.2.2.5.

4.1.2.2.1 Acquire resource with required skills and knowledge

Coding reason: interdependency between engineering disciplines in reaching the project's goal, where people with the right competencies are required.

Document: Project A Interview 5, 04/03/2022 13:59
"PEA1: Yeah, but some of the consultants, 'cause we get quite a good consultant. Maybe they work with (client name) before from other projects.

DI: OK. So one of the way to get this knowledge or competency is to add resources who has previous knowledge with the customer?

PEA1: Yeah."

4.1.2.2.2 Lack of Resources with specific competence

Coding reason: interdependency between engineering disciplines in reaching the project's goal, where people with the right competencies are required.

Document: Project A Interview 2, 28/02/2022 14:35
"...subsea was new for (company name) at that time, so there was not a lot of in build knowledge or inhouse knowledge, so there was not many people to ask at that time."

Document: Project A Interview 4, 28/02/2022 18:39
"The subsea integration part was complicated due to nobody has done done it before."

Document: Project B interview 03, 23/02/2022 11:02
"...also this high voltage, there's not a lot of people have knowledge for that. This also make it complicated in that way because, we need people in design and people offshore who has knowledge of high voltage, that could be another challenge for electro discipline."

Document: Project C interview 3, 04/05/2022 10:51
"And it took us at the beginning, during the FEED phase, we didn't manage to get the correct resources and this in a way affect that we didn't have a very good FEED phase with a good, um input for the execution phase and that leads to an execution phase to extend all the clarifications and definition with regard to power system philosophy affecting the execution of the project. So we are reaching and you know that we're reaching the point in which due to the late input, we have a delayed input to SAS supplier and the input from automation to do the necessary work. And we are affecting or close to impact the final milestone of the project."

4.1.2.2.3 Limited capacity of resources

Coding reason: interdependency between engineering disciplines in reaching the project's goal, where delayed delivery by one discipline causes late delivery of other discipline(s).

Document: Project B interview 02, 29/03/2022 11:01
"...that some people are stressed by the schedule, time, so people don't have time to go into the details"

Document: Project B Memo 1, 03/03/2022 20:51
"Some activities such as following up weight report were not completely followed up due to the speed of the project. Resources didn't have time to follow up properly."

Document: Project C interview 2, 22/04/2022 15:48
"...the responsible is very responsibility is quite high actually. And the problem is that. The the project is underestimated both scope and resources-wise you know, so I am really I am really having a hard time jumping from a lot in between different topics. Even now, for many weeks I am delaying some processes somewhere else because. I am too much in and out to review something and I cannot finalize it due to too many other activities."

4.1.2.2.4 Limited time available

Coding reason: availability of time affects the handling of variety and interdependent project elements.

Document: Project B interview 02, 04/05/2022 13:23
"...that some people are stressed by the schedule, time, so people don't have time to go into the details"

Document: Project B interview 04, 23/02/2022 11:02
"...it's normally the time limit that's, that we are or working against us"

Document: Project B Memo 1, 03/03/2022 20:50
"Some activities such as following up weight report were not completely followed up due to the speed of the project. Resources didn't have time to follow up properly."

4.1.2.2.5 Tasks requiring competencies which the project do not have

Coding reason: Relevant competencies are required when dealing with the variety and interdependent project elements.

Document: Project C interview 3, 04/05/2022 10:50
"But in this case was that we need to incorporate a new power source to the platform and we need to in a way and synchronize with existing system. To provide a common solution for the platform. And then the competence of resources is not so easy to find."

4.1.2.3 Coordination

The category Coordination is related to organizing various elements of the project, including resources, activities, and stakeholder participation. The codes obtained from the data which are supporting this category are listed in section 4.1.2.3.1 to 4.1.2.3.22.

4.1.2.3.1 Change Management

Coding reason: management of change on the multiple or interdependent project elements

Document: Project A Interview 5, 04/03/2022 14:19
"Yeah. As always, there will be some change, but, I think it's a smooth. It's fine if we any change, we always write to change flag 'cause we don't want to... well, we we were told by the company, that we don't want to work for free. So if there are any changes and like extra scope, we always done through change flag, so yeah."

Document: Project A Interview 6, 17/03/2022 13:28
"For example, we have we used software for managing change flags. It's a very good tool to keep track of absolutely all changes. The changes could be as small as modify one PID with a line or a new transmitter, or a change in the text. Something as simple as that to something as complex as include new ESV or a modification of a big line or something like that. So keep a good system to track all the changes where all disciplines are familiar with the change and are involved the change is also super important."

Document: Project A Interview 6, 17/03/2022 13:33
"But, well, we handled. We had maybe because we had a good system for keeping track of the changes. And of course there was a very good team work in in that project."

Document: Project A interview 03, 23/02/2022 11:02
"In both project. Yeah, well I can say that in Project A, we had several clients, and I mean the counterpart. And it was a difficult sometimes because you just, if the counterpart is changed, or the company of the client change personnel, sometimes it's difficult because, sometimes we have had agreement, and we have this style, you know, just working with someone and we have a challenge in that way, because sometimes you have an agreement, but we if you don't have very good documented this agreement, it could be a a challenge on that. Yeah, because the new person who is coming and maybe he or she doesn't recognize this agreement. I think it now and we are thinking on the new project that the agreement had to be officially agreed. Because you don't know maybe tomorrow they will change again the counterpart. That is important."

Document: Project B interview 03, 23/02/2022 11:02
"Yeah, I think it is. I say now to my leader that maybe now we have to use this because

the problem is that when you have an agreement. it was maybe one year ago. And also not only because the new person is coming also offshore. The client from offshore say" no, but I don't agree with this", and we say no, well, it is agreement with the, you know the client (project personnel). But the problem is, if you don't find any official, you know. document where you have this agreement, that could be a problem, that could be a challenge also."

Document: Project B interview 03, 23/02/2022 11:02
"Well, fortunately we have.. it as the email system and also all those have been solved with this. But that I say again, it's not really official, but works. At least."

Document: Project B interview 03, 23/02/2022 11:02
"Normally we discuss it with the engineering management and meetings, but to do it well you have to have a change management system. We're using it"

Document: Project B interview 03, 04/05/2022 13:53
"Yeah, there is a clear guidance.. Yeah, but it's just who is the owner of everything and has to be set up in the project. Yeah, so it's very, yeah, because engineering only a small part of that actually costs hours. And plan. Our Planner also get information if it's accepted by the customer or not. And if they don't see it as a change or instructed to do things, yeah, we just have to implement anyway or upgrade. But that's that's why that should not be in normally know too much changes in after a FEED, because that takes time and especially when you have a time limit in plan to deliver."

Document: Project B interview 03, 23/02/2022 11:02
"...and also the complexity with the discussion with.. that not our company who had all the responsibility. I think there were a lot of strong meanings from the customer. And how to secure, umm, not by only email agreements that we've done. Because then and then also to get everyone, yeah, or included in the same umm.. so everyone can get the same information. Yeah, that's also is, because everyone have their own meetings and then to secure that everything is correctly (documented) . . . (long pause)"

Document: Project B Memo 1, 03/03/2022 21:02
"The project learned that it is important to have a dedicated Change Manager in order to keep track all the changes that came during the project, document the reason, the cost estimation for the additional scope, and approval from the Client."

4.1.2.3.2 Coordination of procurement packages

Coding reason: Procurement packages are project elements (variety) and having interdependency with other elements.

Document: Project A Memo 1, 02/03/2022 21:16
“There are planned for 75 procurement packages in total, whereas 28 procurement packages identified as long lead item. They are the equipment/material which have 26 weeks or more delivery time. Purchase order must be placed in timely manner to meet installation time.”

Document: Project A Memo 1, 02/03/2022 21:17
“Half part of the entire procurement is bulk material. Coordination between the building-block teams inside the project must be made in order to ensure efficient use of total bulk material.”

Document: Project C interview 3, 04/05/2022 09:41
“...Of course, as well as part of the procurement, we also have you know that the SAS supplier. The time needed for the SAS supplier depend on the information to be received, make longer the delivery time and of course it affects the whole procurement and delivery process. Also, there are dependent from some information we have to start with some I/O list, correct? But then the development of the packages, the engineering of the packages in the procurement process.. the maturing information increase the number of signals and that will affect the original basis that was made for specifying the equipment, but this also affect procurement. So basically I think there has been one of the most complex process and complexity with regard to Project C related to high voltage equipment.”

4.1.2.3.3 Coordination of the project

Coding reason: coordination of various elements in the project, which involve variety or interdependency.

Document: Project A Interview 5, 04/03/2022 13:53
“And also, how we cooperate with each building block. I mean, if we change the line up stream, line number, size, how we inform the next (building block) because that’s done by another engineer, and another (personell in the) project”

Document: Project A Interview 6, 16/03/2022 14:15
“And the key issue is of course in all these, not only for this particular task, but also for the normal building blocks and normal project is to make sure that everybody have a clear understanding of milestones, what to deliver, that’s the key. Because it’s easy to say “OK, we have this milestone, everybody have to comply”, but not necessarily all disciplines have a clear scope for each milestone. So one of the main task is to make sure that everybody have a clear understanding of their deliverables to each one of the milestones. And a special focus on the work packages and the materials. That was actually a key factor for success of this project.”

Document: Project A Memo 1, 02/03/2022 21:14
"There are planned for 75 procurement packages in total, whereas 28 procurement packages identified as long lead item. They are the equipment/material which have 26 weeks or more delivery time. Purchase order must be placed in timely manner to meet installation time."

Document: Project A Memo 1, 02/03/2022 21:17
"Half part of the entire procurement is bulk material. Coordination between the building-block teams inside the project must be made in order to ensure efficient use of total bulk material."

Document: Project B Memo 1, 03/03/2022 20:36
"The Engineering Lead ensure the Discipline Leaders understand about the deliverables expected from each discipline through close communication, workshop with the Client, and establishing the guideline for the methods to be followed."

Document: Project C interview 2, 22/04/2022 14:53
"...the biggest complexity, it's the interfacing between electro and automation. We might say that electrical discipline is a leading one. We have to continuously follow up everything, of both safety discipline for the upgrade of the shutdown systems and also with automation for developing, called this, the fully automated logics. There is also another complexity, a part of the scope, and this project is also to do the integration on the platform modified by Project C1, The thing is that on that platform there are two independent control systems today "

Document: Project C interview 2, 22/04/2022 15:02
"And the more we go into details, the the even closer follow up between electric and automation, well, we need to have. So just to give an example for all this automation logics for instance, the SCD's are being continuously developed by automation engineer."

Document: Project C interview 2, 22/04/2022 15:07
"The big part in this project will be also the integration test, so the the main objective, because the the complexity is high and the risk is also high, things will not go well enough on time. And there is not so much time offshore, we cannot allow ourselves for a long shutdowns to test. It's not like when we do a new build. That we have more time, we can have better planning to test and retest and redo. It's not that easy here because the platform is in normal operation still and it will continue further.. so the high focus is to perform integration test onshore to the farthest extent possible. So we are building test racks. Two to four, the most important parts of the system that we are going to control, and we will do the integration between electrical and control systems. Both

PMS PDCS. And we will try to retest it to the furthest extent possible before we start commissioning offshore.”

Document: Project C interview 3, 04/05/2022 09:33
“...but I would say that with regard to procurement side. Yeah. OK. It’s also at some point as well umm, combined a bit with also with engineering because it’s a complex process with regard to what comes first.. you know, we have to specify some equipment, correct? That we need to order and buy. But this equipment as well needs some technical information in order to order them accordingly, correct? And that requires some calculation, but to to have some values (of the calculation) you have let’s say in this case we, I don’t know if you remember, we have (third party electrical study company) which is the engineering company that did the calculations, correct? And they need some information from (electrical equipment supplier) as well for them to to calculate. So it’s kind of I don’t know how to say, it is kind of a it’s a circular, where you need one company, need information from that one. But the other one need information from the other one. So it’s kind of OK at some point we need to start assuming some values and that need to be adjusted and calculation to be made in order to reach the the final values or parameters that are the one that require for make the procurement process. So that’s where in a way. Yeah, it is one of the complexities of of, of, of, of this job. Went to get the correct information and the correct data to specify the equipment and for example to avoid the changes in the scope of the work or change flag from the from the different suppliers. And at some point, once the for example, (third party electrical study company) completed the calculation with the information that was used by (electrical equipment supplier) then this value can be adjusted and then information have to come back again to (third party electrical study company) to perform new calculations or it’s a that’s part of the complex process and especially affect the procurement process because can make the the the procurement of the process and the how can I say the fabrication time at the engineering time a bit longer that. What we could expect. so I think that this is one of the the key at least in Project C and this type of the project, one of the complex process with regard to to procurement.”

Document: Project C interview 3, 04/05/2022 10:00
“And basically we didn’t have so many delays and I mean we kind of keep the milestone. Where we intended to install the equipment and in a way the design was went well.We have very few queries and most of the equipment and all the input that, for example white discipline electro telecom instrument needed to give to structural for making all the starters, steel and support and connection of equipment into the two rooms. We’re provided in a good way with very few issues or challenges. So it was OK, but of course we always need to see the input from the supplier to us to perform the drawings for prefab shall be taking care as a critical line to not delay construction phase.”

Document: Project C Memo 1, 25/04/2022 14:58
"The document records various issues which must be solved by the project, either by one or multiple disciplines, who shall follow up, and when they are targeted to be resolved."

4.1.2.3.4 A dedicated coordinator for a complicated building block

Coding reason: handling variety or interdependency of project elements.

Document: Project B interview 03, 04/05/2022 13:48
"Organizational, I can say something about that. I can give an example, with the two projects A and B, the organizational point of view, we have Project Delivery Leads in Project A, but not in Project B. That's also could be a problem because it's just, um, there is no (person who ensure) to share information, because when you have Project Delivery Leads specific for example the building block, the PDL can just meet the people, and different discipline, and just analyze barrier, analyze and share information and communicate. But if you don't have this PDL in Project B, that could be a more difficult. Just to, you know, share and communicate, that is a difference I can see that, in a big project like Project B and A, you need a PDL or project delivery lead. That, this is a difference I can see on both project. And can result on the one in success, and the other one may be some delay."

Document: Project B Memo 1, 03/03/2022 21:07
"For delivery of a separate module, it is suggested to have a dedicate coordinator such as PDL (Project Delivery Lead), to ensure coordination between various disciplines, ensuring all materials are ordered and delivered, ensure correct sequence, and that information are communicated towards each disciplines."

4.1.2.3.5 Adapt the method

Coding reason: approach used in handling variety or interdependency of project elements.

Document Project A Interview 4, 29/03/2022 12:14
"If we're gonna follow that system, it will take too much time. And then the discussions were like going on that no, you have to follow the system, 'cause it's the obligated system by all contractors and stuff like that. And that's where the discussions were. Our way of working started.. And also that I think that the communication and the and the bond inside the company or inside that interface was created when we, or when the other saw that the we as (company name), did what we were supposed to do."

Document Project A Interview 4, 29/03/2022 12:16
"But we discussed that instead of being dependent on anybody else, we need to put money

into it, so we need we bought a whole system that is just for us. So the nodes that were going to be installing offshore, we bought 2 instead of 1. So that we created our system onshore. To match what was going to be installed offshore, that meant that we were so independent of all the topside stuff that had to be looked after, well, operations is going to do maintenance on this and this pump, so they need the node and stuff like that. We were completely separated from that, 'cause we know we installed new nodes and in the separate part of the system. And we were only communicating with one subsystem and not the rest of the platform. So we created sort of a post on test. We created our own island where we were sitting in. And then also in the in a when implementing offshore. They were, they were sitting on a separate place with the separate control, operator station that wasn't connected to the control room. So the guys who are doing the commissioning when that went on the control room didn't, wasn't involved in the commissioning testing because it's just between two offline systems."

Document Project A Interview 4, 01/03/2022 13:20
"But we know that that function will be used, so instead we sort of skipped a couple of steps and then you could integrate that thing early instead of waiting for the IDC for it."

Document Project A Interview 4, 01/03/2022 13:49
"And it's also critical to understand the involvement of the other disciplines like we were working on something that was just automation to automation, and that's why we could say that, well, you don't need IDC. Because Process can't possibly say anything about this. It's not technical safety. An electrical doesn't care."

Document Project A Interview 4, 01/03/2022 13:51
"But it's important then when you do that adoption that you stick by your. Yeah. Well decision."

Document: Project C interview 2, 22/04/2022 15:04
"And I am not accepting, let's say that I am just getting it on the review and sit alone myself and comment it, to me it's insufficient process."

4.1.2.3.6 Align the team

Coding reason: handling variety or interdependency of project elements.

Document: Project A Interview 5, 04/03/2022 13:57
"...like it's different way to show, like, in a PID, the valve and maybe we have different way to show for each building block. I think we got commented from the client. So later we had someone like, eh, how to say, make the cookbook. Before that we didn't have

any, like, guidelines, but we transformed some guideline from Oslo, some project. So we use that at the beginning."

Document: Project A Interview 6, 17/03/2022 14:02
"PDLA1: But the thing is it's more related to have a clear understanding of the scope more than anything else. Because at the end, all are professionals, not everybody knows everything technically, but everybody is able to find a technical solution always. I haven't seen any technical solution that cannot be solved at all. I don't believe that the complexity is related to any technical issue per sae. It's more related to have a good communication and good understanding between the team member on what needs to be delivered and when. And that's where the complexity could be sometimes arises because other things that can make things complex at the end. Engineering works for Construction to have everything ready to start the installation, and complexity could be not having material on time. And how to start solving that? Be prepared to find materials in other projects or start looking other suppliers or be ready to pay additional fees in order to get what you need faster. Also make sure that all the input is ready for construction and to start. Once you are able to have all the input and all materials. Yeah, we don't have any, well, I mean, technically all our projects could be complex, but the technical complexity is something that everybody can handle. I don't know if you agree with that. And even if it's a rocket that we have to build, we'll we know how to build it, so that's not the problem.

DI: Yeah now. So, the more challenging part, if I understand, it's probably to get this different individual people work together.. maybe having their own style and personalities, do you have any practical experience on what the practical things that work or?

PDLA1: Yeah, one of the main things that always came on the table to solve was, you know, that normally in our company we have a team working from engineering. We have work packages that is, you know, the main document that is used offshore to build things, to make that work package, there are a lot of input from Engineering and input from the Construction team. They have to provide that. And sometimes, there were a lot of discussions on who do what. For example, several things Engineering was arguing: no no this is Construction scope and Construction say: no, they (Engineering) must have that in scope, and things get stuck. And that's the kind of things that can delay the final product and need to be fixed 100% from the very beginning."

Document: Project A Interview 6, 17/03/2022 15:13
"PDLA1: And yeah, because the main task of any position of coordinator, leader, as you want to call, is to make sure that there is good communication. Even though it seems to be a very – I don't want to say the word stupid – but it's something logical, people have to communicate, but that's not that happens, I don't know, sometimes you need

to force that communication. And having meetings all the times, not either a solution because too many meetings then people don't have time to work, because if you spend half of your time in meetings then you don't have time to prepare the documentation and drawings and so on. But to have the proper amount of meetings, you need to reach out to the team, share information between them and clarify "what is the scope of who", that's a key factor. And also I need to reach a lot to so people have a good understanding of when things have to be ready."

Document: Project C interview 2, 22/04/2022 15:46
"So yeah, in a way, based on my experience, to summarize the many things where actually driven by electrical all of the things were actually in the end driven by Electro discipline. So we were pinpointing things we need to do this we need to do that, we need to improve the shutdown hierarchy, we need to even for automation we need to reshuffle the whole communication topology. Due to the shutdown hierarchy the way it is going to work in the end. So we are in the driver seat"

Document: Project C Memo 1, 25/04/2022 14:59
"Topics covered in the minutes of meeting: Project milestones and Plan, multidiscipline activities (such as HAZOP, design review, constructability review) follow up by each engineering disciplines, mechanical completion, construction, and commissioning."

Document: Project C Memo 1, 25/04/2022 15:00
"The document shows each Discipline Leader need to maintain overview of who work from the office and who work from home."

Document: Project C Memo 1, 25/04/2022 15:02
"Technical: The minutes of meeting records the technical topics requiring follow up, especially due to the nature of their criticality and that they are requiring coordination between several engineering disciplines, as well as towards various equipment and service suppliers."

4.1.2.3.7 Depending upon input from other disciplines

Coding reason: interdependency between various disciplines.

Document: Project B interview 03, 23/02/2022 11:02
"...but also from electro point of view, also we depend on other discipline. That means that sometimes we need to just wait for the inputs.., heat tracing. Heat tracing is a very difficult, even though you say it's just for heating. And it's just a fitting cable. It's a. It's also complex activity because it's not only dependent of Electro, it depends on Process and Piping disciplines.. also you have to do calculation for that. And also have many

factor also, Insulation discipline or Material. And you had to consider a lot of factor and on the calculation.. Piping input, Process input, Insulation inputs to the calculations, and also you have to consider all parameters and temperature application. is it for protection, your process protection. And sometimes we have to just do re-calculation and sometimes It's very complex really. It's a lot of, I think in Project B we have about 100 activities with heat tracing around the project."

Document: Project B interview 03, 23/02/2022 11:02
"Because this is a new module and you know you don't have this information or the PDMS model and you don't have the information on the isometric piping isometric as difficult for an electro to identify where we have this fire wall, we need to go through on different level, I mean. Yes, that that that is a challenge, also because it that's just, you can't see that we depend on other discipline for information, is it right or not."

Document: Project C Memo 1, 25/04/2022 15:00
"The document shows there are input required from various discipline for meeting various milestones. Four milestones require input from all engineering disciplines. Two milestones requiring input from Process and Electrical. One milestone requires input from Automation and Technical Safety. The document records also weekly progress on the development of the documentations, as well as the issues currently encountered and who are responsible for following up."

Document: Project C Memo 1, 25/04/2022 15:02
"Technical: The minutes of meeting records the technical topics requiring follow up, especially due to the nature of their criticality and that they are requiring coordination between several engineering disciplines, as well as towards various equipment and service suppliers."

4.1.2.3.8 To resolve ongoing issues

Coding reason: handling multiple or interdependent project elements.

Document: Project B Memo 1, 03/03/2022 21:03
"There was established a dedicated Task Force for communicating issues around engineering application tools. This task force include IT personnel, engineers, and personnel from fabrication. Issues around the use of engineering tools and how to solve them are discussed in daily meetings."

4.1.2.3.9 Coordination with 3rd party

Coding reason: handling variety or interdependency of project elements.

Document: Project B interview 01, 23/02/2022 11:02
“...the other one I remember from. Project B is the concurrent project coordination as well. Because there was some ummm.. since we were coming with our new project and it was as MM as well done by another engineering company, then there was some issues when it comes to how do we modify the fire and gas cabinet in this case specifically. So we were needed to do, (control system supplier) was kind of like the middle men there and we needed to come with some modification and the this project from another EPC company needed to coordinate in between. companies to try to see how do we do this job, and when and who does what, so that was as well a bit of umm.. and then before that we needed to do it politically correct. Because you cannot just go even though it was a person you knew from before. and we know each other quite well, yes, so that that easy up. The first contact with him and we need to sort this out, but we could not just sort it out with him. I need to involve the interface people just to make sure that things were doing correctly, and in the best benefit of the client.”

4.1.2.3.10 Coordination with Drilling and Wells

Coding reason: handling variety or interdependency of project elements.

Document: Project B interview 04, 23/02/2022 11:02
“Yeah, in Project B for instance, we had the interface with drilling and well. And there were a lot of wells that was involved coming into the project that we were going to do, and they changed the plan all the time. That was a very difficult, to see the consequences, what that had to do with the main scope for Project B. Because they changed that all the time and what impact that had on the original scope.”

4.1.2.3.11 Coordination with neighbouring platform

Coding reason: handling variety or interdependency of project elements.

Document: Project A Memo 1, 02/03/2022 21:12
“The produced oil and gas are further sent to 2 other different platforms. The modification related to these transport lines need to be coordinated with the other installations.”

4.1.2.3.12 Coordination with Operation

Coding reason: handling variety or interdependency of project elements.

Document: Project B interview 01, 23/02/2022 11:02
“The other one, it’s a general one. We did not speak this stuff, but I would say that was

always with this kind of like when you modify for also automation when you modify existing system you always have a risk of unplanned production as stop. So that's as well always the risk when you do a modification, especially if you're going to touch ESD and PSD nodes and things like that, you can have kind of like that risk., and as well need to plan the work for in shut down. So when you do your plan identification you need to make sure that if there's such down job you identify with time so it get properly planned whether in the project shutdown or in the general shutdown of the project. But you never want to get into is that you get to find out too late that you have a shutdown job that it wasn't planned, because then it's like cost them money and nobody will like."

4.1.2.3.13 Lack of involvement of the Operators (end users)

Coding reason: handling variety or interdependency of project stakeholders.

Document: Project B interview 04, 23/02/2022 11:02
"Also for modification we, umm, Operation and those users, it's normally maybe too late involved in the project, because, um, the customer don't have time for it. You gonna have the operation that's on land or in the project to discuss with up front and then when the operators come in sometimes, they say it can't be done like this and you see it everything together, because they are the one working with the system every day."

4.1.2.3.14 Coordination with supplier

Coding reason: handling variety or interdependency of project stakeholders.

Document: Project A Interview 2, 28/02/2022 14:34
the subsea vendor was not decided, so we needed to do lots of interface with the different possible vendor and go through the different possible scenarios

Document: Project A Interview 4, 28/02/2022 18:57
"...then there's the oh human factor where we were a lot of people from different businesses. It was four or five companies involved in that interface not directly, the direct link was Supplier 1, Supplier 2, and Supplier 3, but they had contract owners and we had contract owners and everybody had to be in the loop to be able to legalize that. We were talking to each other. So there was a what are your organizational complexity towards establishing trust"

Document: Project A Interview 4, 01/03/2022 10:11
"...we needed control system vendor provide their understanding, subsea vendor to provide their understanding, and then we use me, based on my experience and also based on his two sort of bridge those two together, so that we sort of not always, but sometimes at

least, understood that even though they're talking about the same apples, he's are red, but he's are green. So you need that middle part who can sort of, he doesn't have to understand the details of each system, but he has to sort of pick up when, when they're diverting in the explanation, so to speak."

Document: Project B interview 01, 23/02/2022 11:02
"...then there was some issues when it comes to how do we modify the fire and gas cabinet in this case specifically. So we were needed to do, (control system supplier) was kind of like the middle men there and we needed to come with some modification and the this project from another EPC company needed to coordinate in between. companies to try to see how do we do this job, and when and who does what.."

Document: Project B interview 03, 23/02/2022 14:07
"...we need to size the circuit, MCBs, or Circuit breaker for Electro valve. But it's difficult to get that from the start.. because a it's a long process to get the, you know, the calculation from the manufacturer from the valve manufacturer especially. And it's taking a lot of time to get that, and this is a challenge for the electrical discipline because, you know, is not only to size MCB or the circuit breaker, also the, umm Also, we need to size the cables. And.. it's activity that could be on delay"

Document: Project B Memo 1, 03/03/2022 20:58
"For some Suppliers, this is the first time they deliver such equipment, so it took longer time for them to deliver."

Document: Project C interview 2, 22/04/2022 14:55
"So we deal a lot with that supplier. Majority of equipment is actually delivered by that supplier from original design as well so. That was the advantage also to choose the same equipment brand to continue further for new deliveries plus all relevant upgrades."

Document: Project C interview 3, 04/05/2022 09:41
"Of course, as well as part of the procurement, we also have you know that the SAS supplier. The time needed for the SAS supplier depend on the information to be received, make longer the delivery time and of course it affects the whole procurement and delivery process. Also, there are dependent from some information we have to start with some I/O list, correct? But then the development of the packages, the engineering of the packages in the procurement process.. the maturing information increase the number of signals and that will affect the original basis that was made for specifying the equipment, but this also affect procurement. So basically I think there has been one of the most complex process and complexity with regard to Project C related to high voltage equipment."

4.1.2.3.15 Difficult to get input from supplier

Coding reason: interdependency between various disciplines and the supplier.

Document: Project B interview 03, 23/02/2022 11:02
"...we need to size the circuit, MCBs, or Circuit breaker for Electro valve. But it's difficult to get that from the start.. because a it's a long process to get the, you know, the calculation from the manufacturer from the valve manufacturer especially. And it's taking a lot of time to get that, and this is a challenge for the electrical discipline because, you know,is not only to size MCB or the circuit breaker, also the, umm Also, we need to size the cables. And.. it's activity that could be on delay"

4.1.2.3.16 Coordination with various project stakeholders

Coding reason: stakeholders are identified as variety in project.

Document: Project A Interview 4, 01/03/2022 08:43
"...we're including, keep the personnel that has sort of a technical leg and a contractual leg in both sides. And that's how we sort of established that trust. It's not like just because we say we need this function, it is not expected that the function will be delivered if it's outside of subsea scope, for instance, and vice versa. It's not automatic that things that you decide can be decided without having a economical parts on the side."

Document: Project A Interview 4, 01/03/2022 09:01
"I think we've faced different clients and a client within the client. We we had our automation counterpart who was very involved and very supportive of our work. And then we had the interface management position."

Document: Project C Memo 2, 25/04/2022 15:08
"The project involves 3 different platforms. The project is responsible in design, installation and commissioning on 2 platforms, and design for required interface on the third platform, leaving installation as the scope of another project organization."

4.1.2.3.17 Ensure adequate equipment testing onshore to avoid a lot of troubleshootings offshore

Coding reason: handling variety or interdependency of the project elements.

Document: Project C interview 2, 22/04/2022 15:08
"The big part in this project will be also the integration test, so the the main objective, because the the complexity is high and the risk is also high, things will not go well enough on time. And there is not so much time offshore, we cannot allow ourselves for a long shutdowns to test. It's not like when we do a new build. That we have more time,

we can have better planning to test and retest and redo. It's not that easy here because the platform is in normal operation still and it will continue further. so the the high focus is to perform integration test onshore to the farthest extent possible. So we are building test racks. Two to four, the most important parts of the system that we are going to control, and we will do the integration between electrical and control systems. Both PMS PDCS. And we will try to retest it to the furthest extent possible before we start commissioning offshore."

4.1.2.3.18 Interface coordination

Coding reason: handling variety or interdependency of project elements.

Document: Project A Interview 4, 28/02/2022 18:57
"...then there's the oh human factor where we were a lot of people from different businesses. It was, four or five companies involved in that interface not directly, the direct link was Supplier 1, Supplier 2, and Supplier 3, but they had contract owners and we had contract owners and everybody had to be in the loop to be able to legalize that. We were talking to each other. So there was a what are your organizational complexity towards establishing trust"

Document: Project A Interview 4, 01/03/2022 11:09
"Everybody was on the same, just it was Supplier 1 and ourselves and our counterpart on our side, subsea vendor and then subsea counterpart on their side in one sort of, well, the yeah interface unity, talking about these things and agreeing on this and that."

Document: Project C interview 1, 21/03/2022 12:10
"...it was a little bit complex in this project because, actually we have, we had maybe three organization in that project, we have the one for (older platform's name) and we have different people for (name of the newer platform), specially for those who are connected to operation. Also, sometimes we had contact with the organization from (the other ongoing project), which is connected to (newer platform's name), (deleted some project detailed activity to anonymize) So yes, it was a challenge, from the organizational level especially when it comes to organizing meeting. If you want to have a meeting with all of these people and on that time that was really a challenge that was at a complex task. Yes. This is the challenge for from the organizational point of view."

4.1.2.3.19 Challenge for getting required information

Coding reason: handling interdependency of project elements.

Document: Project C interview 1, 21/03/2022 12:21
“when I started preparation for example, the safety requirements specification for the SIL levels for the safety function. Yeah, at the beginning I was, because the project is mainly (older platform name and newer platform name) and (deleted detailed activity to anonymize the project), but at a later stage of preparing the SRS I was stuck with information from (the other ongoing project). ...(deleted)... But then we discovered that without this information from (the other existing platform interfaced to the project) we cannot proceed in our work. DI: Right, So we need to get.. TSA2: Yeah or we cannot. Yeah produce the proper work. DI: Yeah. I see. TSA2: Which is why we can summarize it with.. when you, when you have interfaces in the projects you have many interfaces, several interface here.. this is the challenge.”

4.1.2.3.20 Interface management

Coding reason: handling variety or interdependency of project elements.

Document: Project B interview 01, 23/02/2022 11:02
“...involve the interface people just to make sure that things were doing correctly”

Document: Project C Memo 2, 25/04/2022 15:08
“The project involves 3 different platforms. The project is responsible in design, installation and commissioning on 2 platforms, and design for required interface on the third platform, leaving installation as the scope of another project organization.”

4.1.2.3.21 Planning for offshore implementation, POB capacity

Coding reason: handling variety or interdependency of project elements.

Document: Project A Memo 1, 02/03/2022 21:13
“There are capacity limits on allowed persons onboard the platform (POB), this will limit the capacity in progressing the construction offshore.”

Document: Project B interview 01, 23/02/2022 11:02
“So one of them is that the installation was dependent on POB (Personnel On Board) so there was a limitation on capacity of people that could be, and doing the job and because the platform, It’s a small platform with very small capacity POB”

4.1.2.3.22 Planning for offshore implementation, Scheduling for installation

Coding reason: handling variety or interdependency of project elements.

Document: Project B interview 01, 23/02/2022 11:02
The interviewee described that in Project B, since the platform has a small capacity for allowed personnel on board (POB), the project had to plan accordingly for the implementation offshore.

4.1.2.4 Learning

The category Learning is concerning knowledge-improvement and knowledge-management of both the individuals within the project and the project itself as an organization. The codes constructing this category can be found in section 4.1.2.4.1 to 4.1.2.4.7.

4.1.2.4.1 Acquire new knowledge

Coding reason: new knowledge required to complete a task, which is part of variety in project elements.

Document: Project A Interview 1, 28/02/2022 13:30
"...one of the things I was looking at was flare radiation for example, which was that was brand new to me. But, so that was a challenge in the sense that I had to learn. What had to be done as well as learn the way that or the client wanted it done, 'cause they had their own custom software, That was fun to learn that and, do flare radiation calculations. That was nice."

Document: Project A Interview 2, 28/02/2022 14:36
"subsea was new for Company T at that time, so there was not a lot of in build knowledge or inhouse knowledge, so there was not many people to ask at that time."

4.1.2.4.2 Collaborate to acquire new knowledge

Coding reason: handling interdependency of project element.

Document: Project A Interview 4, 01/03/2022 10:05
"...you can get information of all the pieces and bits and stuff like that and that you can read from paper. But understanding how it's put together requires collaboration and cooperation. So I think as least for our subsea part there were we can, you can easily like read it. You can Google what a Christmas tree is, and subsea production system works on the general level. But to understand how or at least to understand the limitations of it, which was the important part of what we were trying to establish, you have to have a sort of detailed experience from both sides, so you need at least for our sake, we needed control system vendor provide their understanding, subsea vendor to provide

their understanding, and then we use me, based on my experience and also based on his two sort of bridge those two together...”

4.1.2.4.3 Learning new technology

Coding reason: Learning is required in order to complete a task, which is part of variety in project elements.

Document: Project A Interview 4, 28/02/2022 18:45
“It’s first for at least modification parts over the company. I think they’ve had subsea projects in Oslo previously or somewhere but this specific interface protocol was never used before or utilized. So Project A the first project utilizing that and making it work.”

Document: Project A Interview 5, 04/03/2022 14:13
“PEA1: ..before I worked only in VM project like changing the lines same or changing the valve. But here, it’s MEG and that we have to use pilot PSV. That’s a new thing for me. Yeah. So we learned a lot about the challenge to use the pilot PSV. It’s because, you know,‘Cause I supply MEG to subsea, and they need temperat-, eh, pressure as high as possible, but at the same time the flow line, because the weight, -weight problem- so they cannot have some material very heavy, so can handle very high pressure.. that’s why we need the pilot PSV because it allow the operation pressure and the design pressure is 5% different, like, in contrast, with the traditional PSV which withstand 10% differential so, so that’s where we can get higher operation pressure as high as possible with this pilot PSV. Yeah, we this same design pressure.”

4.1.2.4.4 Acquire new knowledge, Related to new client

Coding reason: Learning is required in order to complete a task (which is part of variety and interdependency of project elements).

Document: Project A Interview 3, 28/02/2022 18:32
“...it is when you are working for different clients. This is one of the complexity also and yeah, if you are used to work for example for X, client for three or four years, and then you shift to another client actually this add to the complexity. Yeah, so if you shift to an old installation with another client this will be more complex and you’re yeah, and for me for example. Personally I need to spend too much time to just to get tuned to the new system, yeah- Yeah, maybe this is, maybe this is common for anyone, but really I suffer from this. So when I am shifting to switch and working with a new client...”

4.1.2.4.5 Curiosity supports learning

Coding reason: Learning is required in order to complete a task, which is part of variety.

Document: Project A Interview 4, 01/03/2022 10:30
"I may be a lot more humbled. there's a, I don't know, you sort of see the way, or we're all then at your tasks in a certain way. And you feel that after quite some time in the industry that you have certain control of certain aspects, but then you're open up to there's 10,000 people working on stuff you have never understood or heard about was an issue. Of course everybody has heard about subsea in our industry and everybody has heard about, yeah, it's wells connected to topside. But the, it makes you humble when you see all of this equipment and stuff that is created Just for that one task and all the people involved. And I think that's sort of helped me, at least 'cause it's a lot easier to teach somebody who's a well curious and a bit thin, or rather than being stubborn and and persistent. So I think it sort of made me learn and understand that there's a lot more going on than what you think you know. I think that's what I've taken away from. This is that you can learn a lot and you can have steep learning curves and stuff like that like. When I started in Project A with subsea, the first thing I had to Google was Subsea Christmas tree, 'cause I didn't know what it was. And then a couple of months later I'm invited to discuss a functional safety inside the P ID is over the subsea x-mas tree, so it's sort of you're, you're invited and I think that's only because I was humble. You're invited into sort of worlds of decisions for a lot of things."

4.1.2.4.6 Ensure good understanding of the applicable engineering methods

Coding reason: Method is something that being used for handling project task (variety) and interdependency between them.

Document: Project A Interview 5, 04/03/2022 12:16
"...there were many challenges, because it's a very big project and because before in Stavanger we've normally done the VM project or small scope. So at the beginning we have problem like how we, like, divide the scope. That could be divided to different building blocks.. but have a challenge like how we divide the building block, is it by the physical area, like yeah, this module, yeah, what the interface there? Or should we divide like per system, like, yeah, system 40, system 23, and the yeah, there are lot of confusion, and especially when you see the interface."

Document: Project B Memo 1, 03/03/2022 20:41
"Ensure the use of resources who understand/have familiarity with engineering methods in modification projects. At the beginning of Project B, there was only a handful people who had this competency, so the Project established learning sessions with another department who can teach the methods."

Document: Project B Memo 1, 03/03/2022 20:56
"Some challenge related to Engineering for Procurement (management of purchase packages). One of the main causes is the PRE unfamiliarity with the project execution method."

Document: Project B Memo 1, 03/03/2022 21:05
"One slide in the presentation file shows the comment from Structural discipline, that there was challenges due to lack of training on the work methods, reported issues with poorly configured tools for engineering design as well as progress reporting. The issues around the software/tools consume time which should have been dedicated to producing the engineering products."

Document: Project C Memo 1, 25/04/2022 15:04
"The minutes of meeting highlights the some of the details on the engineering methods which require focus and prioritization by the disciplines."

4.1.2.4.7 Learning to use engineering tools properly

Coding reason: Learning about engineering tools are required in order to handle various project task (variety).

Document: Project A Interview 1, 29/03/2022 18:41
"...'cause they had their own custom software, That was fun to learn that and, do flare radiation calculations. That was nice. Alright. That was more of a personal challenge, and nothing really technical, although there's a technical aspect of it to to learn."

Document: Project B Memo 1, 03/03/2022 19:54
"During FEED, not all engineering tools which are design to support detail engineering and execution activities are needed to be used. However, experience show that a good preparation in setting up/configuring those tools already in FEED phase will help the smooth start on the next project phase. It will also be beneficial for personnel who will continue to the next phase that she understands the functionality of the tools as well as the method which will be used. Again this is to ensure smooth start of the next project phase."

Document: Project B Memo 1, 03/03/2022 21:09
"The project also suggest familiarization towards the engineering tools used for creating and documenting offshore work packages. Understanding how this tool works and how the information relates to the documentation tool is important to ensure progress."

4.1.2.5 Planning

The category Planning is concerning organizing interdependent resources and activities in the project. The codes obtained from the data which support this category are listed in section 4.1.2.5.1 to 4.1.2.5.6.

4.1.2.5.1 Identify amount of work packages

Coding reason: work packages are considered as variety, which can also have interdependency towards other work package or activities in the project.

Document: Project B Memo 1, 03/03/2022 20:33
"Identification of the amount of engineering workpackages for each discipline, subsystems, prefabrication, and commissioning packages should already done during the FEED phase, in order to plan the construction activities better. Sequence for installation of the packages should also be planned. Activities offshore (installation/demolition/modification) which require platform shutdown need to be identified early."

4.1.2.5.2 Identify requirement for platform shutdown

Coding reason: offshore implementations which require shutting down of the platform should be identified, so that the other interdependent work packages or activities can be planned accordingly in order to meet the plan.

Document: Project A Interview 6, 17/03/2022 15:27
"PDLA1: ...always with high focus on the planned shutdowns. Because for the shutdowns, you need to be absolutely ready.

DI: That's also typical to Brownfield project I guess because yeah.

PDLA1: Yeah, yeah yeah yeah because in a in a Greenfield there are no shutdowns we are building everything and then is when do you do you do the tie in, and all done"

Document: Project B Memo 1, 03/03/2022 20:34
"Identification of the amount of engineering workpackages for each discipline, subsystems, prefabrication, and commissioning packages should already done during the FEED phase, in order to plan the construction activities better. Sequence for installation of the packages should also be planned. Activities offshore (installation/demolition/modification) which require platform shutdown need to be identified early."

4.1.2.5.3 Plan the resources required in the organization

Coding reason: resources needed to handle multiple project elements and their interdependencies.

Document: Project C interview 2, 22/04/2022 15:50
"And it's hard at this phase of the project just to you know, get someone to help you because. We have gone through such a long process and we are getting closer and closer to the end to the forecast that end at least. So it's now becoming too late to just upsize the team. That should be planned better from beginning to be honest. Then from beginning you have more people involved, with more history. And then it's topped better and then. But that didn't happen. So I am often finding myself with a lot of information. But no one else know about."

4.1.2.5.4 Prepare installation sequence

Coding reason: identifying implementation sequence of multiple work packages (variety), as well as any interdependency between them.

Document: Project B Memo 1, 03/03/2022 20:34
"Identification of the amount of engineering workpackages for each discipline, subsystems, prefabrication, and commissioning packages should already done during the FEED phase, in order to plan the construction activities better. Sequence for installation of the packages should also be planned. Activities offshore (installation/demolition/modification) which require platform shutdown need to be identified early."

Document: Project C interview 3, 04/05/2022 09:55
"I would say that more the construction is 3 part. The first one is what I mentioned, all the main main equipment. The second part is more the all the cable trays and cables that this one can be done kind of in parallel. But of course you need to wait until some point to pull the cables when the main equipment turn installed and terminate the cable.. these also went in a in a good way, not big challenges. And the last part will be all the implementation of the logic together with the pre-commissioning and commissioning phase"

4.1.2.5.5 Prepare required spare parts

Coding reason: handling uncertainty. When starting up new installed equipment, there is a risk that some important component do not work. Available spare parts support smooth delivery of the solution produced by the project.

Document: Project A Memo 1, 04/05/2022 13:57
"Necessary spare part must be prepared to ensure smooth commissioning and start up of the completed equipment packages."

4.1.2.5.6 Preparing engineering tools

Coding reason: engineering tools are required for producing various products of the project (variety). Some other engineering tools like planning tool and risk register deal with interdependency of the project elements.

Document: Project B Memo 1, 03/03/2022 19:51
"During FEED, not all engineering tools which are design to support detail engineering and execution activities are needed to be used. However, experience show that a good preparation in setting up/configuring those tools already in FEED phase will help the smooth start on the next project phase. It will also be beneficial for personnel who will continue to the next phase that she understands the functionality of the tools as well as the method which will be used. Again this is to ensure smooth start of the next project phase."

Document: Project B Memo 1, 03/03/2022 20:32
"Engineering tools configuration is including access for personnel, inclusion of necessary software module, linking towards the Client's database and data synchronization mechanism."

4.1.3 External

Factors or influences from outside of the project are being sorted under this core category, since the project does not have access to control the source of influence. The project can only respond to them. Such factors are among others the job market situation, changes in regulation, and the COVID-19 pandemic. On their proposed framework, Bosch-Rekveldt et al. (2011) use Environmental to describe such factors. This master's thesis chooses to use the terminology External instead, since in the context of oil and gas industry, Environmental has been referred towards the object of nature which physically surrounds a production facility, such as the ocean, air, land, etc. Furthermore, from the context of a project, the terminology External provides a clearer meaning, that an External factor is something that resides outside of the project.

The codes obtained from the data which support this category are listed in section 4.1.3.1 to 4.1.3.5.

4.1.3.1 Influence from External organization

Coding reason: interdependency with external organization. Uncertainty caused by external organization.

Document: Project B interview 04, 23/02/2022 11:02
"Yeah, in Project B for instance, we had the interface with drilling and well. And there were a lot of wells that was involved coming into the project that we were going to do, and they changed the plan all the time. That was a very difficult, to see the consequences, what that had to do with the main scope for Project B. Because they changed that all the time and what impact that had on the original scope."

4.1.3.2 Lots of people leaving the project due to high demand on the job market

Coding reason: uncertainty caused by external situation.

Document: Project C interview 2, 22/04/2022 15:52
"And we lost a lot of people in the process also unfortunately. Leaving the project.

DI: Right. That's also. This also hurt a little bit I guess.

EEC1: That also. And that is also kind of a kind of, I don't know if you would call it can call it external call, but this is kind of beyond the any planning you don't normally you don't normally forecast. This kind of things to happen. But but on safety discipline level. I I think (person name) and you in the end. (person name), I think, a third safety discipline engineer I had to deal with. So there was a lot of back and forth due to that and also now automation we we lost the few people who already. And now I have a I don't know third or fourth one to deal with. So and you know when you are in a driving seat and then people around we are swapped all the time then you feel like it's again more on you because then you have a new people to again explain and follow up."

Document: Project C interview 3, 04/05/2022 10:58
"...we have a important key personnel leaving the project, from Electrical, from Automation that were kind of the key. I think that with regard to other disciplines was kind of more stable. But the two main disciplines in this project, Electro and Automation suffer from from this yeah. from market condition that's called it in that way."

4.1.3.3 New regulation

Coding reason: Interrelationship between new requirement in new regulation and the technical solution.

Document: Project A Interview 1, 28/03/2022 21:23
"The other complexity you've got from safety at least, but I think it goes on across other disciplines is the age of the platform that you're installing a project on. We've got two projects just now going that I'm working on ones on and then installation from 2005 startup or 2004 and the other one is from 2015. And in those not 10 year gap, There's been some, let's say, significant changes in standards and what have you. So you're trying to say, For your modification, you should be applying the new standards of course, but then you're trying to put it in a platform that designed on old standard, for example fire loads. That's a.. It's basically going up from 250 kilowatts per meter squared up to 350 kilowatts per meter squared as a jet fire fire load. So you try and install something for 350 next summer, that's 250, and then you want to connect to pipe between the two. And then you, yeah? It it adds extra conversations that needs to be needs to be hard to see. Where does the boundary go.. How much extra cost is it there… Is it gonna take to to do this… And do you actually spend that extra cost? What you gain from that extra cost? And really, what is the requirement when PTIL come knocking on the door anyway? Is that a an old part of the platform that's regulated by the 2005 regulations, or is it something new that's gone in so it should be regulated by the 2021 regulations or 2022 regulations now so. There's a bit of complexity there."

Document: Project A Interview 3, 28/03/2022 21:21
"...we experienced these challenges when we are required also to comply with new standards that they're not available or applicable at the time the installation was built. So this is the main challenge in the technical issue I have experienced there now."

Document: Project A Interview 6, 28/03/2022 21:24
"That was not the case in Project A, I don't have any in my memory an example, but that could happen. And that could be a risk, but that should be addressed as a risk, and it's up to the customer to agree how to solve it. But the identification of that is very important of course."

Document: Project B interview 01, 28/03/2022 21:21
"But when you are in brownfield projects you have as well some standard compliance issues let's say because if depending on how old is the platform, then sometime the new standard are hard to comply. So then you need to add to deviations and then you need to see how important is to for safety or any factor to comply with this regulation and then see if it's possible and if not then do the deviation accordingly."

Document: Project B interview 04, 28/03/2022 21:22
"...the work you're gonna do have to be done by normally the latest revision of the standard and specifications that's operated by the company. And, um, and that may be different for what the equipment was made of earlier, but you have to secure that

the existing you've tie into, it's not, yeah or will not be broken for what you are coming with, so, so it's, um, normally more complex that you have thought of. Even if it's... because there are rules you need to know about and you follow it. But it's not easy to estimate for all these things, even if you know 'cause you based your estimation on, that everything is OK."

4.1.3.4 Performance of Suppliers

Coding reason: interrelation between supplier's delivery and the project result.

Document: Project C interview 3, 04/05/2022 10:57
"EMC1: Which other external impact you can have? Well, input from supplier is one of them"

4.1.3.5 The pandemic causing delays

Coding reason: Uncertainty caused by the pandemic.

Document: Project C interview 2, 22/04/2022 15:14
"I have one thing in mind. I'm not sure if it is with in the within the category you are after, but I will mention it anyway. What we what we see we are struggling more and more these days especially. We especially you know we are executing this project through a pandemic. What our suppliers are actually. struggled with is the deliveries. Often we are told this a certain lead time for a delivery. But. Later on we find out it is extended much more and much more."

Document: Project C interview 3, 04/05/2022 10:55
"The the COVID could be an external factor, but I think that we managed to do it in a good way. I think that in a way we achieve milestones could have been better, but I think that it was not as worst as it could have been, could have been worse"

4.1.4 Clarity Assurance

Several interview participants mentioned about the importance of Clarity in the project. For example, an Electrical Engineer from Project C highlighted the importance of adequate detail development during FEED (Front End Engineering Design) phase, in order to provide clear scope for the next project phase. This statement was supported by the Engineering Manager in the same project. Another example is that in Project A, the Project Delivery Lead underlined the importance of clear understanding from each project team member about what they were required to deliver and when their delivery should have been completed. Misunderstanding about this will cause delay due to re-work or late input towards other disciplines. In Project B, the Engineering Manager pointed out the importance that the engineers understand the methods used in the project to ensure quality and on-time delivery.

As explained earlier, this core category is emphasizing on ensuring clear understanding. At the same time, this core category is also overarching all the three other core categories (Technical, Organizational, and External) mentioned above, as Clarity may concern one or combination of them. The elements which fall under this core category can be recognized as having a certain form of unknown, uncertainty, or ambiguity. For example: a new safety regulation (External) requires that a specific method to be fulfilled for documenting the probability of failure on demand for SAS (Safety and Automation System) equipment. However, the platform was built according to the previous revision of the safety regulation, and complying to the new one will require complete replacement of the entire system. To resolve this, coordination between relevant engineering disciplines (Organizational) is required in order to provide the acceptable solution (Technical).

4.1.4.1 Ambiguity

The list of obtained codes which support the category Ambiguity can be found in section 4.1.4.1.1 to 4.1.4.1.6.

4.1.4.1.1 Different supplier or product can have different terminologies

Coding reason: ambiguity regarding the terminology and definition used by topside control system vs. subsea control system was identified from the data.

Document: Project A Interview 4, 01/03/2022 10:14
"We needed control system vendor provide their understanding, subsea vendor to provide their understanding, and then we use me, based on my experience and also based on his two sort of bridge those two together, so that we sort of not always, but sometimes at least, understood that even though they're talking about the same apples, he's are red, but he's are green. So you need that middle part who can sort of, he doesn't have to understand the details of each system, but he has to sort of pick up when, when they're diverting in the explanation, so to speak."

Document: Project A Interview 4, 28/02/2022 18:41
"...and also to understand what the different.., what do you call it. . . ., namings meant for the different companies, so you could have one abbreviation in subsea meaning one

thing, and the same abbreviation in SAS meant something totally different. So, you had sort of call it language barriers as well as technical barriers for being the first ones off."

4.1.4.1.2 Ensure clear understanding of what to deliver and when

Coding reason: ambiguity in the context that different person/department have different understanding of what was required from them to deliver.

Document: Project A Interview 6, 16/03/2022 14:14
"So one of the main task is to make sure that everybody have a clear understanding of their deliverables to each one of the milestones. And a special focus on the work packages and the materials. That was actually a key factor for success of this project."

Document: Project A Interview 6,17/03/2022 14:01
"It's more related to have a good communication and good understanding between the team member on what needs to be delivered and when."

Document: Project A Interview 6, 17/03/2022 14:03
"But the most important part is to have – from the beginning – a clear understanding of what have to be solved and when. And work in advance."

Document: Project A Interview 6, 17/03/2022 15:09
"We have work packages that is, you know, the main document that is used offshore to build things, to make that work package, there are a lot of input from Engineering and input from the Construction team. They have to provide that. And sometimes, there were a lot of discussions on who do what. For example, several things Engineering was arguing: no no this is Construction scope and Construction say: no, they (Engineering) must have that in scope, and things get stuck. And that's the kind of things that can delay the final product and need to be fixed 100 from the very beginning."

Document: Project B Memo 1, 03/03/2022 20:38
"The Engineering Lead ensure the Discipline Leaders understand about the deliverables expected from each discipline through close communication, workshop with the Client, and establishing the guideline for the methods to be followed."

4.1.4.1.3 Ensure good understanding of the applicable engineering methods

Coding reason: ambiguity on how to approach the tasks.

Document: Project A Interview 5, 04/03/2022 12:16
"Yeah yeah there were many challenges, because it's a very big project and because before in Stavanger we've normally done the VM project or small scope. So at the beginning

we have problem like how we, like, divide the scope. That could be divided to different building blocks, but have a challenge like how we divide the building block, is it by the physical area, like yeah, this module, yeah, what the interface there? Or should we divide like per system, like, yeah, system 40, system 23, and the yeah, there are lot of confusion, and especially when you see the interface."

Document: Project B Memo 1, 03/03/2022 20:41
"Ensure the use of resources who understand/have familiarity with engineering methods in modification projects. At the beginning of Project B, there was only a handful people who had this competency, so the Project established learning sessions with another department who can teach the methods."

Document: Project B Memo 1, 03/03/2022 20:56
"Some challenge related to Engineering for Procurement (management of purchase packages). One of the main causes is the PRE unfamiliarity with the project execution method."

Document: Project B, Memo 1,03/03/2022 21:05
"One slide in the presentation file shows the comment from Structural discipline, that there was challenges due to lack of training on the work methods, reported issues with poorly configured tools for engineering design as well as progress reporting. The issues around the software/tools consume time which should have been dedicated to producing the engineering products."

4.1.4.1.4 Establish solution which complies to various drivers in the project

Coding reason: ambiguity about the driver for the project goal.

Document: Project A Interview 1, 29/03/2022 10:57
"...and I guess the client has a driver to have a lower cost or... Maybe they've got a different end goal as well. Maybe now that I'm trying to make things more expensive, people you got to try and understand, and what they have to accept, what they're doing as well."

4.1.4.1.5 Subjectivity in interpreting the requirement

Coding reason: ambiguity in interpreting the requirement.

Document: Project A Interview 1, 27/01/2022 13:14
"And I guess in technical safety with a lot of evaluations, that can be very subjective to either your own personal interpretation of standards, your experience on how it's been

done in the past, And trying to interpret how the client has done this previously, and how they want to do it now."

Document: Project A Interview 1, 27/01/2022 13:23
"And Area classification was another thing that I was doing. And that's a very subjective topic I guess as well. I mean we had lots of discussions over the use of compact flanges and versus welding, and the consequence on the area classification. Whether it's acceptable or not, and it's. Yeah, that's the that was quite challenging because you've got different drivers you're trying to from my perspective versus trying to interpret the standards the best I could"

Document: Project A Interview 4, 28/02/2022 18:41
"The communication standards were developed and written but they were interpreted differently from one subsea vendor to another and also from one sub-vendor to another. So we struggled, or we worked quite a lot with identifying what's the actual demands compared to what the actual limitations were."

4.1.4.1.6 Understand client requirement

Coding reason: ambiguity in understanding of client requirement due to previous experience performing similar activity towards a different client.

Document: Project A Interview 1, 27/01/2022 13:05
"Or it's done in a different way, Because of the client that you have, because at that time it was (company name) and they say it should be done this way. So then you've got to learn how they do it and then trying to apply your knowledge to the way that they do it."

Document: Project A Interview 1, 27/01/2022 13:16
"I was just trying to see what are some of the things I was doing so I was one of the things I was looking at was flare radiation for example, which was that was brand new to me. But, so that was a challenge in the sense that I had to learn. What had to be done as well as learn the way that or (client company name) wanted it done, 'cause they had their own custom software, That was fun to learn that and, do flare radiation calculations. That was nice."

Document: Project A Interview 1, 27/01/2022 13:23
"And Area classification was another thing that I was doing. And that's a very subjective topic I guess as well. I mean we had lots of discussions over the use of compact flanges and versus welding, and the consequence on the area classification. Whether it's acceptable or not, and it's. Yeah, that's the that was quite challenging because you've got different

drivers you're trying to from my perspective versus trying to interpret the standards the best I could, and I guess the client has a driver to have a lower cost or... Maybe they've got a different end goal as well. Maybe now that I'm trying to make things more expensive, people you got to try and understand, and what they have to accept, what they're doing as well. So you want to train to present that the best you can, and they can make an exception they want. Couple of examples there."

Document: Project C interview 2, 22/04/2022 15:44
"We were focused on how to do it safely, but in the end it from the client perspective it was a bit of spaghetti on the shutdown hierarchy. So again the client requested a simplification process. But simplification process meant that we will trip a bit more equipment than we really need to, but this was done in order to simplify the the hierarchy document. So when you look at it here, it's easier to understand what is going to happen, but not necessarily. Not necessarily."

4.1.4.2 Uncertainty

The codes obtained from the data, which support the category Uncertainty are listed in section 4.1.4.2.1 to 4.1.4.2.6.

4.1.4.2.1 Ensure achievement of adequate level of details when moving the project to the next stage

Coding reason: inadequate details causes uncertainty to the next stage of the project.

Document: Project C interview 2, 22/04/2022 15:18
"The problem is that the way I see it, you know I I came into this project by the end of the FEED stage more or less so the FEED, The. The. It was almost a slightly less than it lasted. Slightly less than one year and in the FEED stage ... (deleted) ... Not really good conclusions"

Document: Project C interview 2, 22/04/2022 15:44
"But you know in FEED state, actually all this was not properly addressed. That is one of the good example. No one. No one really knew. We will actually do such a high modification in the end for the shutdown hierarchy"

Document: Project C interview 2, 22/04/2022 15:45
"I remember in the execution state state there were some mails from the client. No one really answered and. I picked them up and started going around and. From that, in the end, we we found out, OK, we need to do much, much, much more"

Document: Project C interview 3, 04/05/2022 10:54
"If you have a good FEED phase with a good report with a clear understanding, what we should do in the execution phase, that will make simpler things. But if we have not performed a good definition study, we have so many items. It kind of say open in the air that that can lead to a yeah. And that that can lead to to challenges that basically I would say that the in Project C that was one of the main reason we didn't have a good definition of the power system philosophy. It was very simple, very rough, we didn't use enough time to do that and that create all the current consequences that we face along the project. Yes well it's important to have a clear definition of the scope of the work when we start and engineering phase or detailed engineering phase."

4.1.4.2.2 Ensure reliable information for supporting the basis for engineering design

Coding reason: uncertainty due to unreliable information.

Document: Project C interview 2, 22/04/2022 14:04
"So that in a way that is actually increasing a complexity from electrical perspective because we are dealing with existing systems which were never alive and we cannot rely so well on the documentation. The quality of it is poor. It was never brought into the asbuilt level as it should be. So that is giving us a lot of challenges."

Document: Project C interview 2, 22/04/2022 15:01
"I see that we should have (offshore) trips more often because in the process we are more and more focused on different areas in details and, the more in details we go to, the more we rediscover, the more challenges we rediscover and then it is a benefit to again go out and verify it how it is."

4.1.4.2.3 Problem caused by unreliable information in existing documentation

Coding reason: uncertainty due to unreliable documentation.

Document: Project A Interview 3, 28/02/2022 17:58
"When it comes to technical complexity, maybe the main issue is lack of information for the existing systems. We cannot find everything that we need, especially for such old installations"

Document: Project A Interview 5, 04/03/2022 14:15
"Yeah, yeah, yeah, it's like, I think as the client's process engineer said, yeah, (platform name) is quite old platform so, some documents were not well developed and defined like from when you start the platform like in the 80's."

Document: Project A Interview 5, 04/03/2022 14:16
“Yeah. The same with like when we update the design report or system manual. And the existing is not well updated.”

Document: Project A Interview 6, 16/03/2022 13:55
“...we found that not all information in the drawings, whereas they supposed to be for existing support, several existing supports were modified without proper information. Existing support were removed,”

Document: Project A Interview 5, 17/03/2022 15:18
“...brownfield. One of the, complexities or difficulties, is to have a good understanding of what you have in the existing drawings and documentation versus what you really have in the field. And unfortunately, even though the client believe that the documentation is perfect, it’s 100%, but it’s not necessarily true. So you cannot trust that. Is important, at least the most important key information to verify offshore, if the installation really match the drawings we have. Just for example, what happened in this troubleshooting according to the contract we were supposed to trust 100% in all the documentation, but at the end it didn’t match. As example, yeah, all these supports were supposed to be there according to drawings, but they were not. There should haven’t been any problem if they were there. And this is an example from piping, but I’m pretty sure that this thing for any other discipline: automation, instrument, if you trust what you have in the drawings and you do your engineering based on that and at the end it’s not the same, well it could be a total disaster.”

Document: Project B interview 03, 23/02/2022 11:02
“Yes. For example I can say, umm, I can give an example.. For example we did design for maybe 60 meters, I mean heat tracing cable. And this heat trace is going through two levels, and we didn’t realize during the design that one of the level there is this fire wall. And just passed through the firewall, but really we didn’t realize that. And also we needed to split. Because the heat tracing cannot go through the firewall, and we have one cable that we had to split because of offshore realized that, but But it’s difficult sometimes to check on their PDMS model. Even in the in isometric, piping isometric, it’s difficult because there’s no clear indication that it is passing through a fire wall, you know, and this could be a challenge.”

Document: Project B interview 03, 23/02/2022 11:02
“And there’s no clear indication on the, also, umm, the PDMS model. And it’s difficult for electro to identify, you cannot find the information right, you know right? That’s it, it’s also a challenge for Electro discipline I mean from my point of view while we’re talking. For example, um, updating drawings, for example. If you don’t have the right information, or actual from the platform, I mean. Sometimes you just. You can say that

we don't have updated drawings. And information is not like you have offshore. That is another challenge you can face."

Document: Project B interview 04, 23/02/2022 11:02
"...in the modification project you are going into an existing system, you have from the start of, normally you are depending on the existing documentation. And, to say that, normally the existing documentation is maybe not detailed enough, maybe there are something that's wrong with the update. So you often have to go offshore to verify this."

Document: Project C interview 1, 21/03/2022 12:06
"The complexity of finding the information. Sometimes you need to assume and you continue. So yeah, mainly is the lack of information for the existing facilities was the big challenge here."

Document: Project C interview 2, 22/04/2022 13:57
"So there was a design and. Installation executed for this part but. As what we know from this project, it was not perfect enough. There were many grey areas and there are many errors in the design for the onshore power part, it was never actually commissioned. It was never alive. So that in a way that is actually increasing a complexity from electrical perspective because we are dealing with existing systems which were never alive and we cannot rely so well on the documentation. The quality of it is poor. It was never brought into the asbuilt level as it should be. So that is giving us a lot of challenges."

Document: Project C interview 2, 22/04/2022 14:58
"...instead of modify and find all the different challenges because there is always a risk, continuously. How well we can rely on what we have in place today. Documentation wise also especially documentation-wise."

Document: Project C interview 2, 22/04/2022 15:00
"Yeah, you yeah. Platform C2 was built quite recently, but still we see there are many, many flaws in the documentation. So we don't have a complete trust in it."

4.1.4.2.4 Uncertainty on the scope

Coding reason: uncertainty on the project scope due to the potential "unknown" arising later in the project.

Document: Project B interview 04, 23/02/2022 11:02
"And when you have delivered the FEED report, you try to follow that one because there should not be any changes. But the that's not, that's not true. There will be.."

Document: Project B interview 04, 23/02/2022 11:02
“And also how deep down in detail we go into FEED phase, but in detail engineering there might be some, umm, You discover that something has to be changed based or upgraded based on, that umm, things you discover. Just to say that, when you have routed the a pipe layout for instance, and you’re coming in with pipe supports, you have to move, other have taken that area..”

Document: Project B interview 04, 23/02/2022 11:02
“But it’s not easy to estimate for all these things, even if you know ’cause you based your estimation on, that everything is OK. Yeah. And then it should not be because that sometimes you have to find out in the FEED then so we can discuss it with the customer up front and take extra hours. But that’s, that’s something you should have, maybe discover that then in a in a FEED if you’re lucky to do the FEED. It’s not always that you do it, yeah. There were also changes of routine and because we started. Um. when we started with detail engineering in the FEED, based on what was delivered in the engineering study by other company. We thought we had taken that into account when everything of that was discussed just before we handed over the project. Yeah, but it was a huge job even though afterward. So that took time.”

4.1.4.2.5 Understand criticality of project deliverables

Coding reason: poor understanding of the project deliverable criticality causes uncertainty.

Document: Project A Interview 4, 01/03/2022 12:50
“Ah, we had a bit of a different approach in the subsea interface because we weren’t, we were sort of directly, or the only building block that was directly affecting that first oil milestone. And that there was a huge fine of 100 million if we didn’t meet it. And are even though it wasn’t identified at first, and so nobody believed us. But it was later on identified that we were sort of the red line throughout the whole project. So we were on critical path from day one.”

Document: Project A Interview 4, 01/03/2022 13:56
“I don’t think anybody who worked on Project A, um, apart from a few 5-6 people knew what the subsea part was, and how close we were to not making it. Now everybody says Project A is a success story, and of course the success is built upon everybody doing their job, both topside, subsea commissioning, project engineers, project leaders. But if you look at what’s on most of those building blocks and stuff had been, as a total on the critical line. But our building block was built on the critical line, so you didn’t have a block that’s topped with a date. It’s topped with on the first oil and it started when the project started.”

4.1.4.2.6 Understand how a tool works

Coding reason: poor understanding on how a tool works creates uncertainty in the solution made during engineering.

Document: Project B interview 02, 29/03/2022 13:56
"So other complexity... Another complexity. I would say the technology development for example, artificial intelligence/software that are used. For example this software for detecting leakage on pipelines, how the software really works, often we engineers don't know in details. Other example a supplier supplies a complex system, but how could they like educate the engineers in the project in a way which people can understand easily and remember this.."

4.1.4.3 Unknown

The code supporting the category Unknown can be found in section 4.1.4.3.1.

4.1.4.3.1 Unidentified scope revealed during the project

Coding reason: "unknown" which is discovered later in the project.

Document: Project A Interview 5, 29/03/2022 18:51
"I don't have many changes. I have some small changes. I think it. It's fine, It's more like what they didn't consider during FEED. Yeah, but the but this project I think, the people working like a, ah, the how to say, this export pump, maybe you heard about they had problem after we do the tie in, even it is not in our scope but since we tied in to the new well so the export pump have problem, so we had to solve that."

Document: Project A Interview 6, 16/03/2022 13:53
"...after the first shut down in 2018, several things happened that we're not supposed to happen, like vibration in lines, especially vibrations,...(deleted)... basically vibration in several lines, especially in the support line. And after that we establish a plan how to solve all the issues and it was as you can imagine, tight schedule and, um yeah, because none of them was scheduled."

Document: Project A Interview 6, 16/03/2022 14:01
"...we had to modify the operation of some system, increasing the closing time of the valve, em process also, and provide new ways to the sequence on how to operate in – I think was the second or third stage separator. So there were a lot of things in. It was mainly a piping work, but of course involved Process a lot and Automation a lot also. And the main task there was to organize and synchronized at all disciplines were able to

provide the info on time, not only to have the solution from Engineering point of view, but also to have all the prefab and installation on time. And of course the client was absolutely involved on this because they were absolutely interested."

Document: Project A Interview 6, 17/03/2022 08:28
"DI: Yes. I'm interested with this information about the troubleshooting project from the literature they say there, this uncertainty is probably one of the dimension of complexity, but would you regard this situation as uncertainty, or was it something that, in theory, should be able to be predicted, or how do you see it? PDLA1: well, one of the main issues to avoid something like that could happen is to involve a specialized people. It could be a third party or specialized people hired for that to have full control of dynamic load. Because that part is not completely handled as eh, models or anything like that, for the dynamic loads. Normally one load that is used all theoretical calculations, for stress and and supports, but not handled in the way we finally did it. Actually one of the, as a lesson learned, the client include for the more recent project. So the client also had a lesson learn because they were not aware of that."

Document: Project A Interview 6, 17/03/2022 13:27
"DI: Yes, so technical, organizational, any more example? Even anything that is external to the project itself which, for some reason affect the project. Do you have any experience regarding that? PDLA1: Well, external things we can say that all the changes that are happening during the project, not necessarily are external, but other things that you don't know from the beginning. But the organization needs to be prepared to handle all the changes in a proper way."

Document: Project B interview 04, 04/05/2022 13:19
"And also how deep down in detail we go into FEED phase, but in detail engineering there might be some, you discover that something has to be changed based or upgraded based on, that umm, things you discover. Just to say that, when you have routed the a pipe layout for instance, and you're coming in with pipe supports, you have to move, other have taken that area"

Document: Project B Memo 1, 03/03/2022 21:00
"One of the purchase package had to be ordered already during the study phase. Later during detail engineering, some finding during HAZOP, HAZID, and working environment workshop lead to changes of the equipment specification (which cause delay and cost increase). During the detail engineering, there were several equipment which were not foreseen during the front end study required to be purchased."

4.2 Common Challenges in *Brownfield* Projects

From the interviews and observations (documentation, minutes of meeting), there has been identified several common topics which are appearing in all the project cases. They are unique to *brownfield* oil and gas projects and therefore considered important to be presented in this master's thesis.

4.2.1 Reliability of Existing Documentation

The finding from all the project cases is that the reliability of information contained in the existing documentation pose uncertainty to the projects. Older production facilities tend to have undergone several modifications along their lifetimes. Some field modification that had taken place have not been documented properly. Such situation caused misinformation to the subsequent modification projects. Older facilities tend to have this problem, and the older the facility is, the higher risk for multiple projects have been carried out without proper documentation update. However, this issue did also occur on newer installations.

4.2.2 Which Version of The Requirements Shall Be Followed?

Another common issue is regarding the version of requirements which shall be followed upon modification of an old facility. When the platform or facility was originally constructed, the design followed regulations and standards which were applicable at that time. With a lifetime about 20 years (and some installations got extended to beyond 30 years), the newer version of regulation and engineering standards often require a different setup/configuration, which are not possible to be achieved by older types of equipment. In order to fulfill such requirement, often the entire equipment is required to be replaced completely by a newer type, which will require significant capital investment. When encountering this situation, the project team together with the client would perform a technical evaluation and propose a justification to the selected approach. The client who is operating the facility has the responsibility to comply to the regulation and they report their equipment compliance regularly towards the authorities. Deviations against the newer requirement may be granted in some situation, given there is no compromise towards safe operation of the facility. The operator, assisted by the engineering company, files the deviation by giving detailed information, reason of the deviation, and impact analysis. In the situations where deviating from the requirement will have impact safe operation, the project shall follow the newer version of the regulation and perform the modification accordingly. Example of situations where deviation can be given: Fire and gas detection system which are designed prior to establishment of IEC 61508 and 61511 standards have a different design process as what described in those standards. However, the equipment is proven to function and documented to fulfill its required functionalities, probability of failure on demand, safeguarding actions, and therefore can be argued that the equipment do not compromise safe operation of the platform.

4.2.3 Coordination with Operations

Modification projects and operation are often performed by two different groups within the client's organization, and thus could create conflict of priority. Operation team aims to keep their production target, where interruption caused by construction work can be seen as disturbance. Since the modification is done on an operating platform, there is a limitation on access for the project team to perform installation and construction offshore. Some type of works can be done during normal operation, but some others require partial or complete shutdown of the platform. It is important for the project to coordinate their installation and construction activities in order to align with the plan from operation team. Activities which require production shutdown must be communicated to the client, and coordinated against operation team.

Chapter 5

Discussion

5.1 Comparison with TOE Framework

The TOE framework introduced by Bosch-Rekveldt et al. (2011) was formed based upon literature study in combination with case study involving 6 large engineering projects. They point out that the project complexity framework which were available prior to their research were not considering much of the softer aspects such as organizational complexity. They identified that Organizational was indeed an important theme in the context of project complexity, supported by their finding that project complexity elements are dominated by the elements related to organizational complexity (21 elements). As comparison, the other categories which are Technical and Environmental are consisting of respectively 15 and 10 elements.

The data gathered in this master's thesis show similar distribution, that the codes related to Organizational category are dominating the total population of the gathered codes (47 out of 84), supporting that Organizational is an important theme. While Technical, External, and Clarity Assurance are represented by respectively 18, 5, and 14 codes. (See Table 3.8).

Bosch-Rekveldt et al. (2011) included uncertainty in goals and uncertainty in method into the Technical category. This master's thesis also includes these two types of uncertainty, but instead of putting them under Technical category, they are being put under the new category Clarity Assurance, together with other elements containing uncertainty, unknown, and ambiguity. This is exemplified by codes such as "Ensure clear understanding of what to deliver and when" and "Ensure good understanding of the applicable engineering methods".

In its final form, the framework proposed by this master's thesis shows similarity towards the TOE framework introduced by Bosch-Rekveldt et al. (2011). Their framework reflects upon Baccarini's Technological and Organizational dimensions (Baccarini, 1996), explicating the third dimension Environmental covering among others political situation, remote location, and number of stakeholders. Bosch-Rekveldt et al. listed the sub-categories and elements in table 4 on their paper. There are similarities between the items shown on their list and the data collected in master's thesis.

The main similarity is how the categories Technical, Organizational, and Environmental are being structured. There is one to one similarity between those and the framework proposed by this master's thesis: Technical, Organizational, and External.

The main difference is that Bosch-Rekveldt et al. included 'risk' as an element which appears under the three categories. They intend to highlight the importance of managing risk, and point out that risk can occur as part of any of the three main categories they proposed. In this master's thesis, a different approach has been taken by explicating a separate core category Clarity Assurance, which emphasizes the action towards clarifying the unknown, uncertainty and ambiguity. By explicating and placing this core category as an overarching category, an emphasize is equally given towards both 'ensuring clarity' itself as an important aspect and the interrelationships of the elements requiring clarity in the project.

5.2 Comparison with PMI-view

As described by Bakhshi et al. (2016), the PMI-view puts emphasize on structural complexity (such as variety, size, and interdependence), uncertainty, and socio-political situation. This school of thought is believed to be inspired by Baccarini (1996), who introduced Technological and Organizational complexity. Williams (1999) developed this framework further and proposed a new description of project complexity which included the structural dimension, such as numbers of activities and interdependencies of elements, as well as the uncertainty of objectives and methods.

This master's thesis shares similarity with PMI-view, where the three core categories Technical, Organizational, External are mostly covering structural complexity aspects such as variety of tasks, multi-discipline team, interface, methods, and products, as well as interdependency between them. The last core category Clarity Assurance is related to uncertainty and ambiguity in goals and methods, and also in team coordination and communication.

Bakhshi et al. (2016) point out that the research by Shenhar (2001) suggested some projects, such as those in construction, have a lower degree of uncertainty, while projects requiring innovation like IT and defence have a higher degree of uncertainty. *Brownfield* projects are in general construction projects by nature, where modification towards existing facility is being performed. Often both the goals and methods are known and therefore uncertainty related to these are lower when compared to innovation projects.

Bakhshi et al. (2016) further argue that the PMI attention upon project complexity was on multiple stakeholders and ambiguity, disregarding other aspects of complexity, and similar approach was also followed by a large number of researchers belonging to this school of thought. This is also being reflected by the framework proposed by this master's thesis. The dominant elements concerning uncertainty is due to ambiguity. Multiple stakeholders did also contribute to project complexity as described by the Automation Engineer in Project A. In Project C, there are 3 different platforms being involved. As described by the Technical Safety Engineer, it was difficult to obtain information from these different organization.

5.3 Comparison with SoS view

The attempt to explicate uncertainty was first proposed by Williams (1999), proposing that other than the structural complexity, one should also consider the uncertainty about the goal and the method. These two factors add to the complexity of the project. The work by Williams (1999) has became an insight in constructing the framework proposed by this master's thesis, through explicating the core category Clarity Assurance. In its further development, however, the SoS-view shifted their focus towards system complexity.

Bakhshi et al. (2016) describes Systems of Systems as "large-scale integrated systems that are heterogeneous and independently operable on their own, but are networked together for a common goal". The SoS-view takes into consideration the largeness of the system, autonomous and independent systems/organizations involved in the project, the lack of control towards them, as well as the uncertainty in the solution. In addition to that, emphasize is also given towards the uniqueness of each system, and that each system has its original design purpose which is not the same as the project's goal, thus showing adaptability of the system to serve the project goal. This is not the general case with oil and gas engineering projects, which usually are not involving many autonomous/independent systems. Solutions are also usually rather clear in terms of product and method.

A more recent framework proposed by Kiridena and Sense (2016) combines between complexity dimensions in terms of TOE dimensions and the complexity levels of a project seen from system perspective (see Table 2.6). According to this framework, from the system perspective, a project can be a complicated, complex, or complex adaptive. Furthermore, project complexity can be categorized under TOE dimensions regardless of the complexity level. What makes each level different from one another is how the Technical, Organizational, and Environmental dimension are being interrelated against each other. Kiridena and Sense (2016) argue that in projects which have the lowest level of system complexity, the three dimensions TOE are clearly separated from each other, while in more complex projects there are intersections between those dimensions, for example there are elements which belong to Technical-Organizational, Technical-Environmental, or Organizational-Environmental dimensions. At the most complex project system, all the three TOE dimensions are interrelated altogether. The finding from this master's thesis shows that in *brownfield* projects, most of the elements of project complexity can be traced back against the three core categories Technical, Organizational, and External. When compared against Kiridena and Sense's project complexity profile, this finding suggests that *brownfield* projects are typically have a low degree of system complexity, supporting that PMI-view is more relevant to this type of projects.

5.4 Comparison with Complexity Theorist View

Bakhshi et al. (2016) found that most complexity theorists gave focus solely on a single functional aspect of the project, whereas all the features and characteristics discussed in theories are time-dependent, observer-dependent and problem-dependent, which require further exploration in order to understand how these characteristics operate in various types of projects. Some of the theories are relevant to complexity in *brownfield* projects, since they are also sharing the perspective of PMI-view, for example: organizational theory (Cicmil and Marshall, 2005) and contingency theory (Baccarini, 1996). Some other theories, on the other hand, put focus on the areas which are outside of the characteristic of *brownfield* projects: co-evolutionary theory (Benbya and McKelvey, 2006), theory of constraints (Rand, 2000), systems theory (Checkland, 1999), network theory (Pryke, 2005), and adaptive self-organization theory (Jaafari, 2003).

5.5 Support Towards PMI-view

As discussed above, the framework proposed by this master's thesis shows a large extent of similarity with the frameworks which are constructed based upon PMI-view. This is due to that *brownfield* projects are in fact engineering and construction projects. Therefore the elements and interrelationships between them strongly reflects the PMI-view, which is more widely adopted in such project types.

The second reason, is that a low degree of autonomy within the system constituting a *brownfield* project put them closer to the PMI-view. Therefore, structural complexity dominates the elements of project complexity in *brownfield* projects.

Chapter 6

Conclusion

This master's thesis explores complexity in large *brownfield* (modification of existing facility) oil and gas projects and seeks to classify complexity in such projects through implementation of a holistic multiple-case study involving three projects. The data are collected through interviewing project participants (13 interviews in total) and observation upon project documentation (4 documents). Analysis is performed using *grounded theory* methodology, utilizing the procedures developed by Corbin and Strauss (2015).

To answer the Research Question: **How complexity in *brownfield* oil and gas projects can be classified?**, this master's thesis proposes a framework which classifies complexity in *brownfield* oil and gas projects into 4 categories: Technical, Organizational, External, and Clarity Assurance.

The category Technical is concerning the product that the project is targeting to deliver and the method employed to achieve the goal of the project.

The category Organizational is related to organizing variety, interdependency, and uncertainty of the elements within the project.

External is considered as influence or impact from outside of the project, where the project team does not have ability to control directly, and thus can only respond to them. Some examples of External factors are change in regulation and extraordinary events like the pandemic.

The fourth category Clarity Assurance emphasizes on the importance of ensuring clear understanding. At the same time, this category is overarching the three other categories (Technical, Organizational, and External) as Clarity may concern one or combination of them. The elements which fall under this core category can be recognized as having a form of unknown, uncertainty, or ambiguity.

This master's thesis seeks to contribute to the community of research by improving the TOE framework introduced by Bosch-Rekveldt et al. (2011) through proposing a new category Clarity Assurance. While Bosch-Rekveldt et al. (2011) recognize Risk as a sub-category which appears under each of the TOE category, this master's thesis takes a different approach by explicating a separate core category Clarity Assurance. By explicating and placing this core category as an overarching category, an emphasize is equally given towards both 'clarification' itself as an important aspect, and the interrelationships of some Technical, Organizational, and External elements in the project.

To the community of project practitioners, this master's thesis seeks to provide insight by presenting various types of complexity being experienced by project participants in *brownfield* oil and gas projects. Furthermore, this master's thesis seeks to contribute to the practitioners in *brownfield* oil and gas projects with a framework that can be easily and correctly understood, enabling them to effectively identify the types of complexity encountered in their projects.

Appendix A

Supplementary Information

A.1 Code Structure from open coding and constant comparison based on 4 interviews in Project A and 4 interviews in Project B

Codes hierarchy	Number of references
Achieving the goal of the project	
Capacity of existing equipment or system	1
Details	1
Design verification	1
Detailed scope which is not yet known	1
Have no time to look at details	1
Different drivers for selecting a solution	1
Different modification projects follow the same company guidelines	1
Establish technical solution	1
Integration toward existing system is more complex compared to building something completely new	1
Keep the design simple	1
Preventing human error	2
Understand the project scope	2
Understanding technical requirement	1
Applicable technical requirement	1
Applicable regulation	1
Applicable standard	1
Use of technology	1
Causes of incidents	**1**

Table A.1 continued from previous page

Codes hierarchy	Number of references
Clarity	
Different supplier or product can have different terms	1
Problem caused by incomplete information in existing documentation	1
Subjectivity in interpreting the requirement	1
Uncertainty on the scope	5
Understand client requirement	3
Understand criticality of project deliverables	2
Common challenges in brownfield projects	
Definition of complexity	1
Collaborate to process information	1
Involving a lot of parameter	2
Impact to the project	
Delayed input can require re-design	1
Delayed input causes delay in progress	1
Human error	4
Knowledge	
Acquire new knowledge	1
Related to new client	1
Collaborate to acquire new knowledge	1
Curiosity supports learning	1
Knowing detailed functionality	1
Knowledge transfer	1
Learning new technology	1
Learning to use a new tool	1
Non-technical	
Communication	1
Communication with the client	1
Culture awareness in communication	3
Establishing trust	5
Maintain clear and trustworthy communication	4
Coordination	1
Change Management	3
Client availability	1
Client and contractor in same location	1
Coordinating interface	2
Interface management	1
Coordination of the project team	
Depending upon input from other disciplines	3

Table A.1 continued from previous page

Codes hierarchy	Number of references
Coordination with 3rd party	
Coordination with Drilling and Wells	
Coordination with Operation	
Coordination with supplier	1
Difficult to get input from supplier	1
Coordination with various project stakeholders	2
Make effective approach	2
Adapt the workflow	4
Planning for offshore implementation	
POB capacity	1
Scheduling for installation	1
Lack of Resources with specific competence	1
Limited time available	1
Manager's role in managing complexity	1
Leader should be clear on the technical requirement	1
Leader should manage and not get too involved in the details	1
Planning	1
Stress	1
Project size	1
Task of a Technical Safety Engineer	1
Task of an Automation Engineer	1

Table A.1: Coding result from open coding and constant comparison based on 4 interviews in Project A and 4 interviews in Project B

A.2 Code Structure from open coding and constant comparison based on data from Project A (6 interviews and 1 document) and B (4 interviews and 1 document)

Codes Hierarchy			Number of References
Causes of incidents			1
Clarity			
	Different supplier or product can have different terms		1
	Problem caused by incomplete information in existing documentation		4
	Subjectivity in interpreting the requirement		2
	Uncertainty on the scope		5
	Understand client requirement		3
	Understand criticality of project deliverables		2
Common challenges in brownfield projects			
	Clarifying which version of the standard and regulation applicable to the project		1
	People working from different locations		1
Definition of complexity			2
	Collaborate to process information		1
	Involving a lot of parameter		2
Impact to the project			
	Delayed input can require re-design		1
	Delayed input causes delay in progress		1
	Human error		4
	Mixing roles cause inefficiency		1
Organizational			
	Communication		3
		Communication with the client	3
		Culture awareness in communication	3
		Ensure clear understanding	4
		Establishing trust	5
		Maintain clear and trustworthy communication	4
	Constraints		
		Lack of Resources with specific competence	1
		Limited capacity of resources	1
		Limited time available	1

Table A.2 continued from previous page

Codes Hierarchy			Number of References
Coordination			3
	Change Management		4
	Client availability and involvement		1
		Access to Client	1
		Client and contractor in same location	2
	Coordinating interface		2
		Interface management	1
	Coordinating procurement packages		2
	Coordination of the project team		2
		A dedicated coordinator for a complicated building block	1
		Align the team	3
		Depending upon input from other disciplines	3
		To resolve ongoing issues	1
	Coordination with 3rd party		1
	Coordination with Drilling and Wells		1
	Coordination with neighbouring platform		1
	Coordination with Operation		1
		Lack of involvement of the Operators (end users)	1
	Coordination with supplier		2
		Difficult to get input from supplier	1
	Coordination with various project stakeholders		2
	Make effective approach		2
		Adapt the workflow	4
	Planning for offshore implementation		
		POB capacity	1
		Scheduling for installation	1
Learning			
	Acquire new knowledge		1
		Related to new client	1
	Acquire resource with required skills and knowledge		1
	Collaborate to acquire new knowledge		1
	Curiosity supports learning		1
	Knowing detailed functionality		1
	Knowledge transfer		1
	Learn engineering methods		3
	Learning new technology		1
	Learning to use a new tool		1

Table A.2 continued from previous page

Codes Hierarchy	Number of References
Learning to use engineering tools properly	2
Manager's role in managing complexity	1
Assign priority levels to the tasks	1
Coordinate the team	3
Ensure clear scope for each roles in the team	2
Ensure correct implementation sequence	1
Establish guidelines	1
Leader should be clear on the technical requirement	1
Leader should manage and not get too involved in the details	1
Provide training to team member	2
Motivation	1
Planning	1
Identify amount of workpackages	1
Identify requirement for platform shutdown	1
Prepare installation sequence	1
Preparing engineering tools	2
Resolve problem	
Resolve problem which arise during the project	1
Risk Management	1
Stress	1
Project size	2
Dividing the scope into smaller pieces	1
Interaction between many parts	1
Interdependence between the parts	1
Task of a Technical Safety Engineer	2
Task of an Automation Engineer	1
Technical	
Capacity of existing equipment or system	1
Details	1
Design verification	1
Detailed scope which is not yet known	1
Have no time to look at details	1
Different drivers for selecting a solution	1
Different modification projects follow the same company guidelines	1
Establish technical solution	3
Integration toward existing system is more complex compared to building something completely new	1

Table A.2 continued from previous page

Codes Hierarchy	Number of References
Keep the design simple	1
Preventing human error	2
Understand the project scope	2
Understanding technical requirement	1
Applicable technical requirement	1
Applicable regulation	1
Applicable standard	1
Use of technology	2
Unknown	
Unidentified scope revealed during the project	4

Table A.2: Coding result from open coding and constant comparison based on data from Project A (6 interviews and 1 document) and B (4 interviews and 1 document)

A.3 Code Structure from Theory Integration Stage

Code Hierarchy					Number of References
Clarity assurance					
	Ambiguity				
		Different supplier or product can have different terms			1
		Ensure clear understanding of what to deliver and when			4
		Ensure good understanding of the applicable engineering methods			3
		Establish solution which complies to various drivers in the project			1
		Subjectivity in interpreting the requirement			6
	Uncertainty				2
		Problem caused by incomplete information in existing documentation			
		Uncertainty on the scope			5
		Understand client requirement			3
		Understand criticality of project deliveriables			2
		Understand how a tool works			1
	Unknown				
		Unidentified scope revealed during the project			4
External					
	External Organization				
		Coordination with Drilling and Wells			1
	New regulation				1
Organizational					
	Communication				3
		Culture awareness in communication			3
		Ensure clear understanding of what to deliver and when			4
		Establish and maintain good communication with the client			3
			Client availability and involvement		1
				Access to Client	1
				Client and contractor in same location	2
		Establish trust			5
		Maintain clear and trustworthy communication in the team			4
	Constraints				

Table A.3 continued from previous page

Code Hierarchy	Number of References
Acquire resource with required skills and knowledge	1
Lack of Resources with specific competence	1
Limited capacity of resources	1
Limited time available	1
Coordination	3
Change Management	9
Coordination of procurement packages	2
Coordination of the project	2
A dedicated coordinator for a complicated building block	1
Adapt the method	6
Align the team	3
Depending upon input from other disciplines	3
To resolve ongoing issues	1
Coordination with 3rd party	1
Coordination with Drilling and Wells	1
Coordination with neighbouring platform	1
Coordination with Operation	1
Lack of involvement of the Operators (end users)	1
Coordination with supplier	2
Difficult to get input from supplier	1
Coordination with various project stakeholders	2
Iinterface coordination	2
Iinterface challange for getting required information	1
Iinterface Interface management	1
Planning for offshore implementation	
POB capacity	1
Scheduling for installation	1
Learning	
Acquire new knowledge	1
Collaborate to acquire new knowledge	1
Learning new technology	1
Related to new client	1
Curiousity supports learning	1
Ensure good understanding of the applicable engineering methods	3
Learning to use engineering tools properly	2
Planning	1
Identify amount of workpackages	1
Identify requirement for platform shutdown	1

Table A.3 continued from previous page

Code Hierarchy				Number of References
		Prepare installation sequence		1
		Prepare required spareparts		1
		Preparing engineering tools		2
Technical				
	Details			1
		Design verification		1
		Detailed scope which is not yet known		1
		Have no time to look at details		1
	Method			
		Different modification projects follow the same company guidelines		1
		Keep the design simple		1
		Preventing human error		2
		Use of technology		2
	Product			
		Capacity of existing equipment or system		1
		Establish technical solution		3
		Integration toward existing system is more complex compared to building something completely new		1
		Understand the project scope		2
	Understanding technical requirement			1
		Applicable technical requirement		1
			Applicable regulation	1
			Applicable standard	1

Table A.3: Coding result from the integration stage based on the data from Project A and B

A.4 Code Structure from The Saturation Phase

Code Hierarchy				Number of References
Clarity assurance				
	Ambiguity			
		Different supplier or product can have different terminologies		2
		Ensure clear understanding of what to deliver and when		5
		Ensure good understanding of the applicable engineering methods		4
		Establish solution which complies to various drivers in the project		1
		Subjectivity in interpreting the requirement		3
		Understand client requirement		4
	Uncertainty			
		Ensure achievement adequate level of details when moving the project to the next stage		4
		Ensure reliable information for supporting the basis for engineering design		2
		Problem caused by unreliable information in existing documentation		12
		Uncertainty on the scope		3
		Understand criticality of project deliverables		2
		Understand how a tool works		1
	Unknown			
		Unidentified scope revealed during the project		7
External				
	Influence from External organization			1
	Lots of people leaving the project due to high demand on the job market			2
	New regulation			5
	Performance of Suppliers			1
	The pandemic causing delays			2
Organizational				
	Communication			
		Culture awareness in communication		1
		Ensure clear understanding of what to deliver and when		6
		Establish and maintain good communication with the client		5
			Client availability and involvement	2

Table A.4 continued from previous page

Code Hierarchy	Number of References
Access to Client	1
Client and contractor in same location	3
Establish trust	4
Maintain clear and trustworthy communication in the team	6
Constraints	
Acquire resource with required skills and knowledge	1
Lack of Resources with specific competence	4
Limited capacity of resources	3
Limited time available	3
Tasks requiring competencies which the project do not have	1
Coordination	
Change Management	10
Coordination of procurement packages	3
Coordination of the project	11
A dedicated coordinator for a complicated building block	2
Adapt the method	6
Align the team	7
Depending upon input from other disciplines	4
To resolve ongoing issues	1
Coordination with 3rd party	1
Coordination with Drilling and Wells	1
Coordination with neighbouring platform	1
Coordination with Operation	1
Lack of involvement of the Operators (end users)	1
Coordination with supplier	8
Difficult to get input from supplier	1
Coordination with various project stakeholders	3
Ensure adequate equipment testing onshore to avoid a lot of troubleshootings offshore	1
Interface coordination	3
Challenge for getting required information	1
Interface management	1
Planning for offshore implementation	
POB capacity	2

Table A.4 continued from previous page

Code Hierarchy				Number of References
			Scheduling for installation	1
	Learning			
		Acquire new knowledge		2
			Collaborate to acquire new knowledge	1
			Learning new technology	2
			Related to new client	1
		Curiosity supports learning		1
		Ensure good understanding of the applicable engineering methods		4
		Learning to use engineering tools properly		3
	Planning			
		Identify amount of workpackages		1
		Identify requirement for platform shutdown		2
		Plan the resources required in the organization		1
		Prepare installation sequence		2
		Prepare required spareparts		1
		Preparing engineering tools		2
Technical				
	Method			
		Avoid disturbance to live systems which can disrupt production		1
		Design verification		3
		Different modification projects follow the same company guidelines		1
		Ensure adequate level of detail achieved before proceeding to next stage		2
		Keep the design simple		1
		Preventing human error		2
		Understanding the applicable technical requirement		5
			Applicable regulation	1
			Applicable standard	1
		Use of technology		3
		Use of workshop		2
	Product			
		Capacity of existing equipment or system		1
		Establish complicated functionalities involving various systems		2
		Establish interface between various systems		2
		Establish technical solution		3
		Establishing complicated functionalities		3

Table A.4 continued from previous page

Code Hierarchy		Number of References
	Understand the project scope	2

Table A.4: Coding result from the saturation phase based on the entire data from all project cases

A.5 Example of Interview Transcription

Excerpt from an interview with Project Delivery Lead (PDL) in Project A.
Interview date: 10 February 2022

David Ibrahim: So this, umm, large scope in the project does it involve some form complexity, how you handle, yeah, the solution? If you can take one example or two or maybe, any type of complexity?

PDLA1: Yeah, but when you mean complexity, what exactly you want to me to explain? Complexity, what point of view: technical or organization or?

David Ibrahim: Yes both yes.

PDLA1: Everything? OK, I can tell you complexity we had, something that we call troubleshooting that was maybe the most complex thing during the project, because after the first shut down in 2018, several things happened that were not supposed to happen, like vibration in lines, especially vibrations, and there was a shutdown – not because of us – shut down in the platform for operational issues, and then some existing support where broken, some supports were displaced and then we started to discover, what was the problem and how we have to solve it. And that was like a special project inside the project, because we have to involve third parties, as for example, (deleted) a company specialized in exploring those vibrations and dynamic load to kind of model all the lines, to locate where supposed that vibration, to ensure that all the supports were calculated to the proper load, because it looks like the water hammer effect are not considered in the proper way in our project. Normally is the client who provides the force and we work with that. But sometimes that value is not actually the right one. So we struggled a lot to find how to discover or to find out which were the right forces, that's why we have to to include this third party. And we also had offshore at another company (deleted) to do some measurements of vibrations. And yeah, basically vibration in several lines, especially in the support line. And after that we establish a plan how to solve all the issues and it was as you can imagine, tight schedule and, um yeah, because none of them was scheduled.

David Ibrahim: No, So – this kind of – fixing the new situation is happening in parallel to the original project plan.

PDLA1: Yeah, totally in parallel. And due to this issues some lines were needed to be replaced, several new support, and actually, we found that not all information in the drawings, whereas they supposed to be for existing support, several existing supports were modified without proper information. Existing support were removed, eh, we had to modify the operation of some system, increasing the closing time of the valve, em process also, and provide new ways to the sequence on how to operate in – I think was the second or third stage separator. So there were a lot of things in. It was mainly a piping work, but of course involved Process a lot and Automation a lot also. And the main task there was to organize and synchronized at all disciplines were able to provide the info on time, not only to have the solution from Engineering point of view, but also to have all the prefab and installation on time. And of course the client was absolutely involved on this because they were absolutely interested.

David Ibrahim: Yeah, How did the project handle this? There is the original scope of the project, but on the same time also you have to tackle you situation anyway?

PDLA1: Yes.

David Ibrahim: Uhm, same resources or how?

PDLA1: Yes, there were the same resources. The project was originally organized or split in building blocks, as I mentioned before, uh. Several building blocks belong to 1 PDL. The PDL function is like a multi discipline coordinator, to make sure that all the disciplines have the right information, they communicate and to make sure that the deliverables are according to the schedule, and prefab, and construction can have all the input need to proceed, right? So this troubleshooting started in 2020. And the project was more or less, not totally finished, but was more or less finished. So several building blocks were completed, so, uh, several resources instead of being demobilized, were kept in their project to continue with this troubleshooting task that was, in a way not a formal building block, but was handled similar, with the team members, eh, organization similar to a building block. And the key issue is of course in all these, not only for this particular task, but also for the normal building blocks and normal project is to make sure that everybody have a clear understanding of milestones, what to deliver, that's the key. Because it's easy to say "OK, we have this milestone, everybody have to comply", but not necessarily all disciplines have a clear scope for each milestone. So one of the main task is to make sure that everybody have a clear understanding of their deliverables to each one of the milestones. And a special focus on the work packages and the materials. That was actually a key factor for success of this project.

A.6 Example of Coding Performed on an Interview Transcription

Coding Summary by File
Project A
04/05/2022 15:11

Classification	Aggregate	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Document

Files\\Project A Interview 2

Code

Codes\\The framework\Organizational\Constraints\Lack of Resources with specific competence

Classification	Aggregate	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
	No	0.1474	1			
				1	DI	28/02/2022 14:35

subsea was new for Company T at that time, so there was not a lot of in build knowledge or inhouse knowledge, so there was not many people to ask at that time.

Codes\\The framework\Organizational\Coordination\Coordination with supplier

Classification	Aggregate	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
	No	0.1428	1			
				1	DI	28/02/2022 14:34

the subsea vendor was not decided, so we needed to do lots of interface with the different possible vendor and go through the different possible scenarios

Codes\\The framework\Clarity assurance\Ambiguity\establish solution which complies to various drivers in the project

Classification	Aggregate	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
	No	0.0756	1			
				1	DI	29/03/2022 10:57

And Area classification was another thing that I was doing. And that's a very subjective topic I guess as well. I mean we had lots of discussions over the use of compact flanges and versus welding, and the consequence on the area classification. Whether it's acceptable or not, and it's. Yeah, that's the that was quite challenging because you've got different drivers you're trying to from my perspective versus trying to interpret the standards the best I could, and I guess the client has a driver to have a lower cost or... Maybe they've got a different end goal as well. Maybe now that I'm trying to make things more expensive, people you got to try and understand, and what they have to accept, what they're doing as well. So you want to train to present that the best you can, and they can make an exception they want. Couple of examples there.

Codes\\The framework\Clarity assurance\Ambiguity\subjectivity in interpreting the requirement

Classification	Aggregate	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
	No	0.1024	2			
				1	DI	27/01/2022 13:14

And I guess in technical safety with a lot of evaluations, that can be very subjective to either your own personal interpretation of standards, your experience on how it's been done in the past, And uh, trying to interpret how the client has done this previously, and how they want to do it now.

Codes\\The framework\External\New regulation

	No	0.1556	1

1 DI 28/03/2022 21:23

The other complexity you've got from safety at least, but I think it goes on across other disciplines is the age of the platform that you're installing a project on. We've got two projects just now going that I'm working on ones on and then installation from 2005 startup or 2004 and the other one is from 2015. And in those not 10 year gap, There's been some, let's say, significant changes in standards and what have you. So you're trying to say, For your modification, you should be applying the new standards of course, but then you're trying to put it in a platform that designed on old standard, for example fire loads. That's a.. It's basically going up from 250 kilowatts per meter squared up to 350 kilowatts per meter squared as a jet fire fire load. So you try and install something for 350 next summer, that's 250, and then you want to connect to pipe between the two. And then you, yeah? It it adds extra conversations that needs to be needs to be hard to see. Where does the boundary go.. How much extra cost is it there... Is it gonna take to to do this... And do you actually spend that extra cost? What you gain from that extra cost? Uhm, and really, what is the requirement when PTIL come knocking on the door anyway? Is that a an old part of the platform that's regulated by the 2005 regulations, or is it something new that's gone in so it should be regulated by the 2021 regulations or 2022 regulations now so. There's a bit of complexity there.
Uhm So.
Yeah, so at age of platform is the shifting standards and the major Greenfield elements, like in a new module compared to the integration with an existing modules. Something of a complexity which is maybe more common complexities rather than something specific say to safety

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