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An effective risk allocation through strategic contracting in EPC projects

Network risk allocation between EPC contractor and subcontractors

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Preface

This report is the result of my graduation thesis of the MSc Construction Management and Engineering and brings an end to my studies at the Technical University of Delft. In the last few years, I have followed an interesting and unusual study path, moving from Industrial Design Engineering to the Civil Engineering faculty. A well-thought-out decision, as I was fascinated to learn more about the world of construction. Now, after half a year pre-Master and two years completing the CME Master, I can say with full conviction that this path was meant for me.

I would like to express my gratitude to all graduation committee members from the Delft University of Technology. Many thanks to the chair of my committee, Ad Straub, who helped me in the summer of 2022 to narrow down my research question, helped me focus on the relevant findings, and asked the right questions. Even with an agenda so full, you always answered my emails within a few hours with new insights and comments. Leon Hombergen, who continuously provoked interesting discussions about the practical world of Engineering, Procurement, and Construction (EPC) projects, and made valuable links with his own expertise in the infrastructure sector. You gave me refreshing new perspectives. Special thanks go to my first supervisor, Maedeh Molaei, who unbelievably always found time to help me and guide me in my research, whilst being extremely busy with conducting her own Postdoctoral research and the other trillion graduates she supervises. Our educative discussion, your thorough feedback, but also the fun conversations we had in these last months, have made my research into what it is today. Thank you for all the support!

This research was conducted in collaboration with Fluor BV. I am very thankful for all the guidance that Carolien van der Lans has given me during these months. You have made me feel very welcome in the office, and I believe our good relationship truly helped me learn a lot about work and life. I see you as a great example, and it was my pleasure to work with you.

Finally, I would like to thank my friends and family for their willingness to listen to my 'thesis-talk' and for giving me motivational talks. Not to forget, thank you to my LaTeX expert for fixing my errors.
These past months have been a roller-coaster of highs and lows, of which this is the end result!

Enjoy reading,

M.C.M. Kok
Delft, March 2023

Executive Summary

Engineering, Procurement, and Construction (EPC) projects have become an internationally popular model for construction projects, where large risks are bore by the EPC contractor and the subcontractors [Galloway, 2009; Guo et al., 2010]. Risks are inherent to all construction projects, however, the high uncertainties of the international EPC markets, and the complex EPC processes, create for abundant risks which often make it unfeasible for EPC contractors to manage the risks by relying solely on their own capabilities [Wang et al., 2016]. These projects are often of large scale, financially and technically, in a competitive environment where subcontractors have tight margins and even unrealistic budgeting [Yeo and Ning, 2002]. Furthermore, the concept of risk management is a widely discussed topic in construction literature. However, the effective allocation of these risks to certain parties down the supply chain is not a popular subject. EPC project environments are known for their adversarial relationships between stakeholders, where subcontractors have demonstrated a certain feeling of distrust within the supply chains [Dainty et al., 2001b]. The status quo of these large and complex EPC projects, is that the number of subcontractors willing and able to take on the risks of EPC projects is shrinking. There is a need for a more effective risk allocation within the supply chain.

To address this problem statement, this research focuses on analyzing how the risk allocation within the supply chain can improve, in order to improve the project performance for all parties involved. This problem statement is answered through the viewpoint of the contracting strategy used in EPC projects since the contracting strategy is a tool for allocating risks. The final output of this research is a Network Risk Allocation model and recommendations for both EPC contractors and subcontractors. This is attained by conducting exploratory research, consisting of quantitative data gathering, in order to answer the main research question:

How can risks within EPC projects effectively be allocated among the EPC contractor and subcontractors, to improve project performance through strategic contracting?

The scope of this research focuses on the supply chain of EPC projects, including EPC contractors and subcontractors.

In order to answer the main research question of this paper, the study has been separated into three phases:

Phase 1 includes the theoretical background, which entails a literature review, document review, and conducting exploratory interviews. The goal of this theoretical background was to understand the execution risks experienced in EPC projects, and the contracting strategies used to allocate risks within the supply chain. Therefore, to have a full understanding of the EPC context, the characteristics and the structure of the EPC supply chain are analyzed. It is found that the characteristics of EPC projects are the inter-dependencies of activities, the overlapping of tasks and phases, the challenging scope boundaries, and client interferences. Finally, a conceptual framework of the contracting strategy elements used for allocating risks in EPC projects is developed. This provides the theoretical foundation for the following phases. The literature review demonstrates that using clauses to transfer risks down the supply chain eventually leads to a win-lose situation for the parties involved. Moreover, it is found that the different contracting strategy elements are used to transfer risks to subcontractors in the supply chain, on a linear basis. As the supply chain of EPC projects is seen as a network, it is concluded that a network, rather than a linear, risk allocation process is needed.

Phase 2 includes a case study analysis, consisting of two projects within the 'Advanced Technologies and Life Sciences' sector. The data-gathering methodology for this case study analysis consists of both semi-structured interviews with project experts and an analysis of the project documents. For both case studies, the contracting strategy elements used are analyzed, on the basis of the conceptual framework. Furthermore, the effects of the risk allocation process on project performance are researched. The

main insights from this phase include that risks are allocated on a back-to-back basis from the prime contract, toward subcontracts. From a subcontractor's viewpoint, risks were allocated disproportionately, as subcontractors are often not capable of carrying the risks they are allocated. The contracts use penalizing contracting strategy elements, whereby liquidated damages are used, and ultimately do not enhance project performance.

Moreover, it is found that apart from contractual governance in risk allocation, soft factors, and relational governance play a large role in effective risk allocation. The results of the case study analyses concluded that a collaborative approach can aid in the risk allocation within a supply chain network, which is why a step further is taken by researching the potential of a collaborative model in EPC projects. Finally, the third phase consists of the synthesis of the results, in order to develop a model and recommendations for an effective risk allocation in EPC projects.

Phase 3 aims to develop a model which supports EPC projects towards an effective risk allocation, to improve project performance. This model is developed by synthesizing the results from phase 1 and phase 2. The model is based on a network risk allocation approach, which is needed in order to deal with the network nature of the supply chain. This includes dealing with the dynamic relationships between actors, understanding the interdependencies between certain works, and coping with complex organizational structures. A linear approach to risk allocation does not suffice in this network environment. Moreover, the research demonstrated that an effective risk allocation is not solely dependent on defining the contracting strategy elements but actually goes further than contractual obligations and arrangements. This is where relational governance comes into play, including soft factors such as trust and transparency. The human side to contracting involves not necessarily *what* is contractually obliged, but *how* the contracting parties behave around that contract. This is where a collaborative environment can aid in implementing the contracting strategy in a network approach. This demonstrates how people are key in the allocation of risks, and the importance of selecting the right subcontractor, with the right behavior and experience, as a construction partner.

Finally, this leads to a network risk allocation model, which consists of four factors, namely: network risk management, network collaboration, network-based contracting strategy elements, and a network-based partner selection. These four elements are found to affect the effectiveness of the risk allocation in EPC projects. The elements can be implemented by following the description diagram, which can be seen in Figure 1.

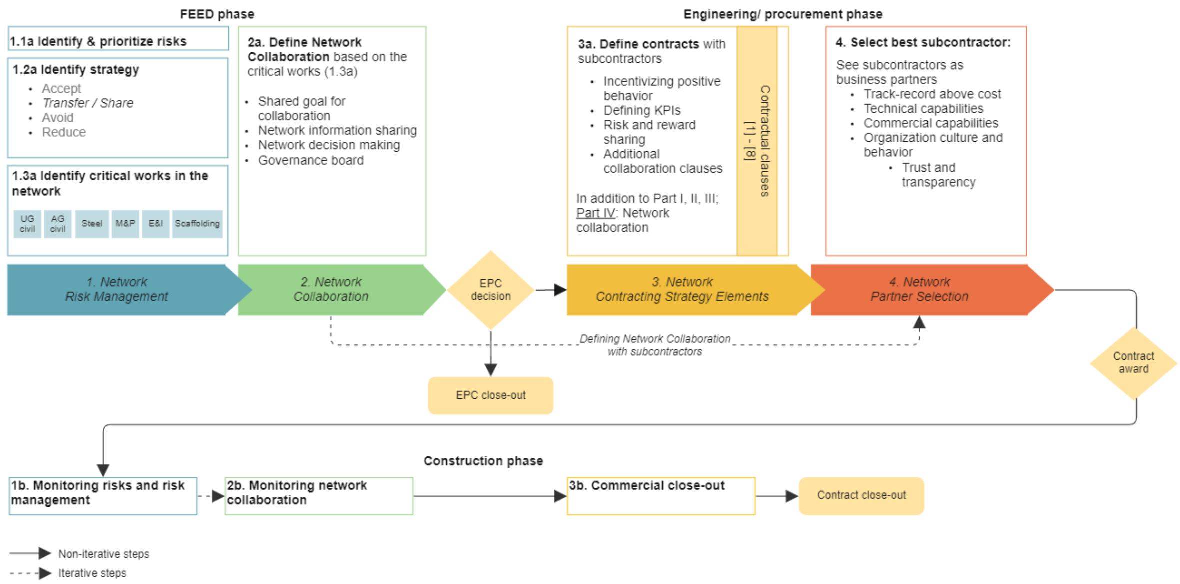

Figure 1: The description for implementing the network risk allocation model.

This model demonstrates what the different factors entail, and how these can be implemented within the different phases of EPC projects. Step 1, network risk management, and step 2, network collaboration are both to be implemented in the Front End Engineering Design (FEED) phase of the project, during the planning and design processes of the project. Step 3, defining the network contracting strategy, and step 4. the network partner selection, become relevant when moving into the engineering and procurement phase. It is important to note that after implementing steps 1 through 4, an interactive process starts between step 2 and step 4, in order to define the network collaboration with the subcontractors. Once this is complete, the contract is awarded. This then leads to another iterative process in the construction phase, of monitoring the risks and the network collaboration, a crucial step for optimizing the process. The main aim of this model is to create a collaborative environment within the supply chain, through both contractual strategy elements, such as creating commercial terms which allow for the sharing of risks and rewards, and additionally through relational governance, based on soft factors elements in the network partner selection process. It is found that in order to create such an effective risk allocation environment, both contractual and cultural changes must be adopted. Therefore, additional advice is provided on how to integrate this model into the contractual terms of the EPC contractor.

Implementing the model
For implementing this model, a few key changes in the status quo of EPC risk allocation are needed. Firstly, it is important to note that these projects are highly time-sensitive, and that time is of the essence from the moment the project is initiated. Therefore, it is important that network collaboration is implemented solely for the critical works in the network. Furthermore, the subcontractors who are participating in this network need to be incentivized to collaborate and perform. This can be done through the contractual obligations, by defining on Key Performance Indicators (KPIs) which can be linked to milestone completion dates and profit incentives. Rather than penalizing subcontractors, subcontractors need to be mobilized by the right incentives to work collaboratively and focus on productivity. The language of the contract, being either adverse or collaborative, is likely to be reflected in the behavior of the subcontractors.

Recommendations for practice and future research
For the project level, it is recommended that all the parties involved understand the importance of soft factors and invest time in the relationships and trust between the parties. Additionally, organizing meetings to discuss network collaboration in projects, and forming an integrated project schedule for all the subcontractors. Within the schedule, the various milestones within the contracts are recommended to be linked to KPIs. It is crucial to remain transparent about the risks and the KPI. Moreover, it is recommended for the EPC contractor to implement network collaboration at the *start* of the project. The EPC contractor is advised to be aware of the capabilities and scale of the subcontractors, in order to understand their position in risk management. Subcontractors should be protected, as this will benefit the project as a whole. On the other hand, the subcontractor is recommended to fully understand the contractual administration expectations and the scale of the projects, in order to mitigate their own risk.

For Fluor BV it is recommended that software is created in which the contractual administration work can be simplified for the subcontractors. Furthermore, EPC contractors are recommended to bid for programs, where multiple projects are pursued under one Client. Furthermore, the EPC contractor is advised to maintain control of engineering as much as possible, in order to reduce the risk of fragmented responsibilities. Additionally, it is needed for the Company to define the commercial terms for the 'risk and reward' model. Finally, an increase in awareness of network collaboration should be created within the Company, and soft skills are to be included as criteria in the partner selection.

Further academic research is recommended to dive into the quantitative research, where the KPIs and the risk and reward system are further developed, in order to support collaboration in practice. Defining which KPIs are relevant, and how the commercial model is defined is a challenging yet crucial part of implementing this model. Furthermore, it is relevant to conduct research into the perspective of the Client, as well as the suppliers, regarding risk allocation in EPC projects. Finally, research is to be conducted into opportunity risks in EPC projects.

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Abbreviations

BOQ	Bill of Quantities
BRMF	Business Risk Management Framework
CPAF	Cost Plus Award Fee
CPFF	Cost Plus Fixed Fee
CPIF	Cost Plus Incentive Fee
CPPC	Cost Plus Percentage of Costs
EI	Exploratory Interviews
EPC	Engineering, Procurement, and Construction
EWN	Early Warning Notice
FEED	Front End Engineering Design
FID	Final Investment Decision
GMP	Guaranteed Maximum Price
HSE	Health, Safety and Environment
KPI	Key Performance Indicator
LD	Liquidated Damage
PDM	Project Delivery Model

1 Introduction

1.1 Background

The construction industry has known many different forms of Project Delivery Models (PDMs) for completing construction projects. This report focuses on the EPC project delivery model, in which the projects contain a single-point contract that is awarded to an EPC contractor, who is, in turn, responsible for all engineering, procurement, and construction activities in the project. This approach has been implemented to overcome the difficulties found in other PDMs, such as the challenge for the owner to assign responsibility for the delay or cost overrun as a number of stakeholders are involved [Mubin and Mannan, 2013]. The advantage of EPC projects is that frictions can be reduced between design and construction, as all the phases are the responsibility of the general contractor. The contractor aims at finding suitable subcontractors based on factors such as expertise, in order to divide the work effectively. This selection and management of subcontractors is pivotal for the success of project execution, as research demonstrates that the major portion of construction projects are handled by subcontractors [Hartmann, 2010]. This causes the success of construction projects to be largely dependent on the performance of subcontractors [Mbachu, 2008] and creates that EPC contractors are highly dependent on the performance of their subcontractors.

The risks involved for contractors who operate within EPC projects are becoming extremer. Today's construction uncertainties are intensifying, as factors such as large inflation rates, scarcity in raw construction materials and workers are becoming worse, whilst the risks are in the hands of the EPC contractor [Galloway, 2009; Guo et al., 2010; Gurney et al., 2022]. One of the struggles of allocating risks effectively is the nature of the prime contracts. In the past decade, large and complex EPC projects have experienced different shifts. According to internal Company documents from Fluor BV, prime contracts on the market have shifted from cost reimbursable contracts, which are flexible to scope changes and therefore shift low risk to the EPC contractors, towards lump sum contracts where contractors had to take on large monetary risks of performing within budget. EPC contractors took on this risk, with the aim to execute strictly within scope, however, discussions arose that the risks were too high, and EPC contractors were struggling to make a profit. This intense risk for the EPC contractors trickled down the supply chain, towards subcontractors, creating aggressive claim cultures and unsustainable relations. Therefore, there exists a push from EPC contractors to change these risk profiles within EPC projects.

Furthermore, there exists a struggle in the operations by subcontractors. It can be seen that subcontractors have a tendency to focus on their own tasks and own priorities, causing misalignment within the entire supply chain, including the EPC contractor. Moreover, the interdependent nature of the different construction tasks creates overlapping risks and time-costly as well as financially costly frustrations between the parties [Javanmardi et al., 2018]. Effective allocation of these risks within the contracting strategy is a critical element in order to create a successful supply chain network. Baker et al. [2020] mentions that creating a fair and effective risk allocation within projects will provide the best chance of successful project delivery. Additionally, it is stated by Lane [2005] that "[a] contract which balances the risks fairly between a contractor and an employer will generally, in the absence of bad faith, lead to a reasonable price, qualitative performance and the minimization of disputes". Therefore, this research focuses on effectively allocating risks between EPC contractors and subcontractors, in order to reach the objectives of EPC projects.

1.2 Problem description

In the past years, contractors have been operating on tight margins and cost-driven agendas, which in turn drives sub-contractors to lower their bidding offers (price-cutting) [Yeo and Ning, 2002]. This competitive environment leads to unrealistic budgeting of projects and can result in project performance problems for clients, general contractors, and subcontractors. Therefore, many researchers have identified the pressing need for change in contracting strategies for the whole supply chain [Wood and Ellis, 2005]. Additionally, research by Dainty et al. [2001b] uncovered serious concerns existing amongst subcontractors, which demonstrate a ''fundamental mistrust and skepticism within existing supply chain relationships". This is concerning for the execution of projects, as the success of construction projects is highly influenced by the relationship between contractors and subcontractors. Additionally, research by Xu et al. [2018] shows that this relationship within the supply chain network is largely impacted by the effective allocation of risks between the contracting and subcontracting parties. Therefore, it is deduced, that effective contractual risk allocation between contractors and subcontractors has an influence on the success of projects, and needs serious improvement.

Regarding risk within construction projects, literature states that specifically EPC projects generate abundant risks for the general contractor [Tavakkoli-Moghaddam et al., 2011]. Traditional EPC projects include the engineering and design, the procurement of all materials and equipment, as well as the construction of the project, resulting in large-scale and complex project scopes. Apart from general risks that are seen in all construction projects, there are many risks that are seen repeatedly in specifically EPC projects because of their inherent characteristics [Sadeghi et al., 2016]. EPC projects face challenges such as the interdependence of activities, overlapping phases, work fragmentation, and complex organizational structures [Yeo and Ning, 2002].

Additionally, there are various trends developing in the construction sector, which call for change in EPC projects and risk allocation. A steady increase in the tendency of general contractors to transfer construction work to subcontractors is seen, giving subcontractors a large responsibility in the success of the execution [Tan et al., 2017]. It is even projected that investments in construction projects will increase over the coming decades, consequently resulting in increased subcontracted work, and thus, a need for stronger cooperation between contractors and subcontractors [Ishii et al., 2014; Tan et al., 2017]. It is found that most construction works within projects are actually completed by the subcontractors, which makes effective risk allocation between the general contractor and the subcontractors of significant importance and potential project value [Clough et al., 2015]. At the same time, the number of subcontractors found on the market, who are willing to take on the risks within EPC projects, is shrinking, making it difficult for EPC contractors to subcontract to the right party. Pícha et al. [2015] finds that (sub)contractors are becoming more adverse since EPC projects are more complex. The intense project complexities and decreasing subcontractors' risk appetite in the construction world create a challenging situation for EPC contractors to find suitable parties for their projects. The traditional contracting culture of squeezing risks down the supply chain, resulting in an inefficient claim culture is no longer desirable. Ellis [2022] points out that "Traditionally, construction projects have been built in an adversarial environment. Each member of the construction team is forced to compete with the others to earn a reasonable profit; delays, conflicts, and disputes are common".

Furthermore, it is found that current EPC projects are difficult environments for creating long-term supply chain relationships, due to the existing subcontracting culture, as well as the one-off nature of these projects [Bygballe et al., 2010; Gadde and Dubois, 2010; Cox and Thompson, 1997; Cox and Ireland, 2006]. Changing the status quo of the EPC procedures is needed, calling for innovation in the sectors. Therefore, a slow but steady interest is found toward more collaborative models of contracting, moving away from traditional adverse relationships in the supply chain, toward more cooperative mindsets.

This research will take an innovative look at effective risk allocation in order to enhance sustainable relations between subcontractors and EPC contractors, by looking at the currently used risk allocation process, and questioning its effectiveness. The Company, Fluor BV, is an EPC contractor currently experiencing the challenge of strategic contracting with sub-contractors, to allocate project risks effectively and attain project objectives. They have experience with different sub-contracting strategies, of

Figure 1.1: The various business groups of Fluor BV [retrieved from Internal Documents].

which several will be analyzed to provide an efficient risk allocation model for EPC projects. For EPC contractors and subcontractors to remain competitive in the market, and complete construction projects successfully, strategic collaboration and risk allocation are crucial.

1.2.1 Company case study

This research is completed in collaboration with Fluor BV, with specific collaboration in the procurement and contracting department of Fluor Amsterdam office. The EPC contractor will support this thesis by providing professional experience, data on projects, and guidance in the research.

When regarding large contractors who operate in the Dutch energy playing field, Fluor BV is one of the large players and currently operating in 60 countries around the globe with over 41,000 employees. Their expertise lies within the field of engineering, technology, supply chain, program management, and construction management, with a focus on three markets: Energy solutions, Urban solutions, and Mission solutions (Figure 1.1). Fluor BV works with clients in chemicals, advanced technologies and life sciences, infrastructure, mining, metal and fertilizers, and governmental sectors. The EPC contractor takes on projects concerning either specific parts of the engineering, procurement, or construction, or all engineering, procuring, and construction scope of works.

Fluor's global procurement and supply chain network is of much value in their projects. Their extended international procurement expertise, market knowledge, and global supply chain networks allow for the best value for capital investments. The focus lies on strategic sourcing of equipment, material management, contract management, and logistics functions. Fluor BV works with different forms of contracting strategies, including forms such as cost reimbursable and lump-sum proposals. According to Fluor BV [2017] there is an increasing preference of clients to transfer process performance, contractual and commercial liability, and risk to an EPC contractor. This makes the risk allocation strategy from EPC contractor towards subcontractors an important factor. Fluor BV has experience in different subcontracting strategies with their subcontractors, which provides valuable primary data and experiences for this research. The data collection method is elaborated on in section 2.5.

In this research, Fluor BV is used as a single case and reflects EPC contractors on project level. The research uses Fluor's expertise, knowledge, and experiences in the EPC contracting field in order to add value to future projects by EPC contractors in the field. Fluor BV is referred to as *the Company* in this research.

2 Research Design

2.1 Knowledge gap

In recent years, many studies in the construction literature have researched the relationship between subcontractors and contractors, and have revealed that the relationships between contractors and subcontractors have a significant effect on the eventual success of projects [Tan et al., 2017]. Xu et al. [2018] found that when trust exists between contracting parties, these parties "perform both contractually mandated actions and actions external to the contract more diligently", leading to an increased chance of improved project outcomes. Additionally, the research shows that effective contractual risk allocation has a significant impact on a trusting relationship between the contracting and subcontracting parties. Therefore, it is deduced, that effective contractual risk allocation between contractors and subcontractors has an impact on the success of projects. However, the topic of the EPC contractors and their supply chain network is overlooked in the literature. Literature focuses on the risk allocation between the Client and the contractor, without focusing on EPC contractors and their subcontractors specifically - downstream risk allocation. Additionally, a lack of research has been done regarding effective risk allocation between contractors and subcontracting parties. Especially analyses on how these risks can be allocated among in the supply chain of EPC construction projects, and what effect this has on project performance, are lacking. Lastly, the literature on the subcontractors' network and their performance are outdated, as most literature dates from before 2010. Therefore, the urgency exists to explore the current practice of risk allocation between EPC contractors and subcontractors, and the methods to allocate risks strategically.

2.2 Research objective

The objective of this research is three-fold, as firstly, the status quo of risk allocation in the EPC context is researched. Secondly, the objective is to create a model to improve this risk allocation process in EPC projects. Thirdly, the objective is to provide recommendations for EPC contractors and subcontractors for implementing this model and increasing the effectiveness of the risk allocation process. By attaining an effective risk allocation in the supply chain, a win-win situation for both EPC contractors, as well as subcontractors, can be created. Eventually, this can lead to an improved supply chain and project performance. This leads to the main research question:

How can risks within EPC projects effectively be allocated among the EPC contractor and subcontractors, to improve project performance through strategic contracting?

The results of this research provide practical relevance for EPC contractors as well as subcontractors, as this guidance in effective risk allocation can help improve risk management and create more sustainable relations within the supply chain. In practice, this can help deal with project risks, and create a productive supply chain. Currently, academic knowledge on EPC projects and related risk allocation strategies is scarce. Therefore, this research contributes to closing the knowledge gap regarding EPC project risks, risk allocation, and its supply chain.

2.3 Research questions

In order to answer the main research question, the following six subquestions will be addressed in this thesis:

1. **What are the common risks occurred in construction projects and how are these managed according to theory?**

   Subquestion 1 focuses on risks and risk management in construction projects, rather than EPC projects specifically. The literature studies on EPC projects are scarce, with only several articles that present findings on specifically EPC projects. Due to this lack of academic research on EPC projects and their characteristics, a broader look is taken, by zooming out and considering construction projects as a whole. It is assumed that EPC projects are a more specified form of construction projects, which means that EPC projects are construction projects, however, construction projects are not always EPC projects. Therefore, due to the lack of literature specifying in EPC projects, the literature found on construction projects is taken as a foundation for EPC projects. This subquestion provides the reader with a theoretical understanding of project risks and their management processes.

2. **What are the characteristics of EPC projects and how are risks allocated through contracting strategies according to theory?**

   The goal of this subquestion is to have an understanding of EPC projects and their characteristics. This demonstrates how EPC projects differ from other project forms, and how this can affect execution risks, and their allocation strategy. Furthermore, the different contracting strategies used to allocate risks, in theory, are identified. This subquestion is answered through a literature review.

3. **How are risks in EPC projects perceived, allocated, and managed in practice?**

   By answering this subquestion, the risks in EPC projects are identified. Additional findings on how these risks are allocated and managed in practice are provided, through Company (Fluor BV) document review and exploratory interviews. This provides a holistic view of the contracting strategies available for EPC projects.

4. **Which contracting strategies are seen in different EPC projects, and what effect do they have on project performance?**

   This subquestion dives into two case studies that operate in the 'advanced life science and technology' sector. These case studies are projects executed by the Company (Fluor BV) in order to assess the effectiveness of the risk allocation between the Company and the subcontractors. This provides an understanding of how effective risks are currently allocated in EPC projects.

5. **What can be learned from collaborative models in risk allocation in other sectors?**

   The fifth subquestion aims to explore what lessons learned can be taken from the collaboration models implemented in the construction industry. A collaborative model is seen as a possible solution for an effective risk allocation, however, seeing as this information is lacking within the EPC projects of the Company, a broader look is taken into other sectors. These lessons learned are based on semi-structured interviews, and literature review. This provides inspiration and valuable input for the development of a solution towards effective risk allocation in EPC projects.

6. **How can a network risk allocation model be developed to improve project performance?**

   The aim of the last subquestion is to develop a model to improve the risk allocation within EPC projects, by focusing on elements that capture the network nature of the supply chain. It also aims to provide solutions to improve the risk allocation process between EPC contractor and subcontractors. This subquestion combines theoretical knowledge with practical knowledge, to improve the risk allocation process within the Company, and add value to academics.

2.4 Research scope

The scope of this research will define the boundaries of the areas that will be explored. The boundaries of this research are defined as the following:

EPC contractors on project level: This research focuses on EPC contractors on a project level and is performed in collaboration with Fluor BV. The case studies used for primary research in chapter 7 are EPC projects completed by Fluor BV, thus, this report is limited to the EPC structure and will not focus on other forms of PDM's. It is assumed that all EPC projects are to a large extent identical regarding their risks and supply chain structure on a project level, which concludes that the results of this research are relevant for all EPC projects.

Downstream contracting: This report will focus on the downstream contracting strategy, between general EPC contractors and subcontractors. Thus, the upstream contract/ prime contract between the Client and the contractor is considered outside of the scope. However, the nature of the prime contract will be taken into consideration during the analyses of case studies, since this has an influence on how the contracting strategy trickles down to the subcontracts. Yet, the final conclusions of the research will be focused on the subcontracting format.

Supply chain: The supply chain in this report includes the EPC contractor and the subcontractors in the EPC projects. This means that the suppliers, who are often regarded as supply chain members, are disregarded in the risk allocation analysis. The risk allocation analysis focuses on the parties involved in the execution of the project, and thereby, experience the execution risks.

Execution risks: Furthermore, the research focuses on risks that are found within EPC projects in the *execution* phase. According to internal Company documents, EPC projects go through different phases, which each have their own risks. The supply chain, namely the EPC contractor and subcontractors, of the EPC projects, become most relevant during the execution phase of the project (see Figure 2.1). This is when materials are procured, subcontractors are contracted, and site work is commenced. Additionally, seeing as the procurement and construction phases of EPC projects tend to overlap, the execution entails both procurement and construction of the project (phase 2 and 3 in Figure 2.2).

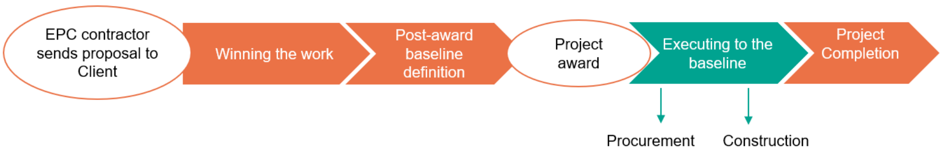


Figure 2.1: Project phases identifying scope of research [based on internal Company documents].

2.5 Research methodology

The research questions will be answered using qualitative research methods. The research is divided into three phases, each with the aim to answer the specific subquestions (see Figure 2.3).

2.5.1 Method in Phase 1

The first phase is the foundation of the research and answers the fundamental subquestions in order to provide necessary background information on the subject. This phase includes a literature review and company documents review as a method to answer subquestions 1, 2, and 3. Subquestions 1 and 2 focus on a literature review by using scientific papers to get an understanding of existing research in the fields of risk, risk management, and risk allocation in the construction sector. It aims at understanding what risks in construction are, and how these risks can be allocated through different contract strategies.

Additionally, internal company documents of the Company and exploratory interviews with Fluor em-

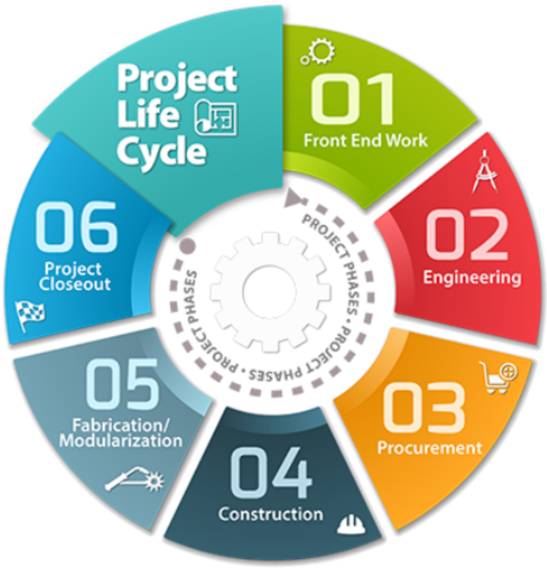


Figure 2.2: Project life cycle of EPC projects [retrieved from internal Company documents].

ployees are used to gain company-specific knowledge. This will help understand the company's experiences and internal processes, thereby answering subquestion 3. This phase provides the theoretical background for the research.

2.5.2 Method in Phase 2

In the second phase, the aim is to collect empirical data regarding the contracting strategies and risk allocation schemes in two case studies completed by the Company. These case studies both operate in the 'Advanced Technology and Life Sciences' business group of the Company. Phase two will make use of case study analyses, to see how different forms of contracting strategies may have different effects on risk allocation and project performance. Understanding how the different elements of these contracts contribute to risk allocation is an important factor. These two cases will be analyzed through internal document review and semi-structured interviews. The semi-structured interviews will take place with the project directors, managers or contracting experts of these projects, in order to get a better understanding of how these contracts were experienced. The aim of this phase is to answer subquestion 4. In addition to the case study analysis, the collaborative models in construction are analyzed, as potential inspiration for a risk allocation model. However, due to the lack of knowledge on collaborative models within EPC projects in the Company, a literature review and semi-structured interviews are conducted. These provide both academic as well as practical knowledge on how such models can be implemented for EPC projects. This thereby aims to answer subquestion 5.

2.5.3 Method in Phase 3

In the third phase, subquestion 6 is answered. The results from phases 1 and 2 are used in order to create an effective risk allocation model for EPC projects. The model is evaluated by experts in the contracting field, project directors, or managers, on the EPC contractors side (the Company). This phase will allow experts in the field to evaluate the proposed model, and discuss the applicability of the model in practice. It will demonstrate the possibilities of implementing these contractual aspects in real-life projects. Eventually, the conclusions and recommendations will be answering the main research question.

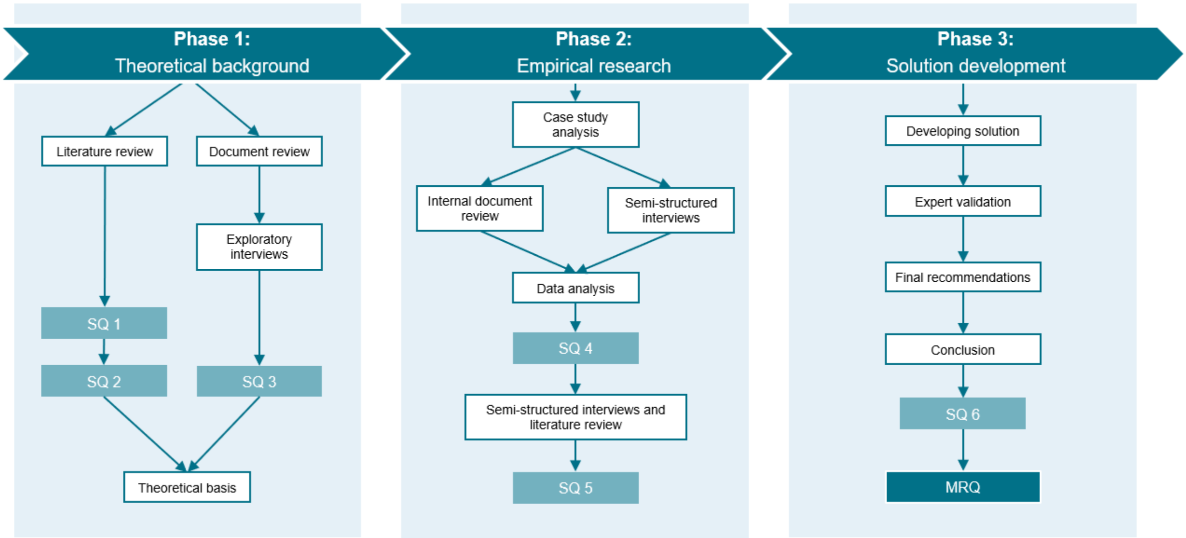


Figure 2.3: Research methodology structure [illustrated by author].

2.6 Research terminology

A summary of the organizational structure is provided to minimize confusion around terminology in this report. These include the client, the EPC contractor, the subcontractors, the prime contract, and the subcontract. In simplified terms, the structure of the organization is illustrated in Figure 2.4, where the main players for construction projects are demonstrated. The subcontracting parties are illustrated in grey scale since these parties depend on the necessary scope of work for the specific project. These subcontracting parties who are responsible for a certain set of works are referred to as commodities. This will be elaborated on in chapter 4.

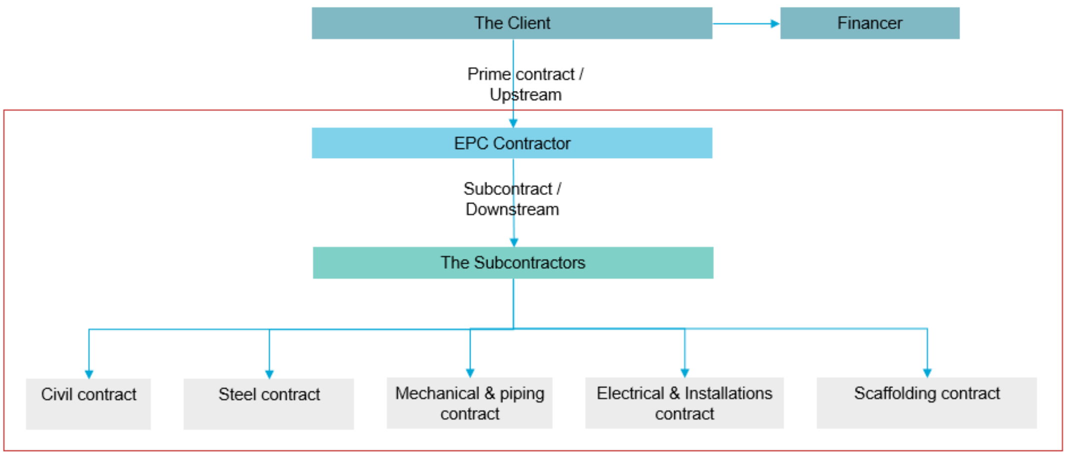


Figure 2.4: Simplified organizational structure and report terminology [illustrated by author].

The scope of this report focuses on the supply chain network in the organizational structure, demonstrated by the red box. This excludes the prime contract from the Research scope. However, the prime contract is researched briefly during the primary research phase. Furthermore, the EPC contractor is referred to as 'the Company'.

3 Risk and Risk Management in Construction Projects

This chapter demonstrates the results of the literature review. The results explain the theoretical background found regarding risks in construction projects and how these are managed in theory. This chapter thereby aims to answer:

Subquestion 1: *What are the common risks occurred in construction projects and how are these managed according to theory?*

This chapter begins by defining the key concepts for this research (section 3.1) and further elaborates on the risks found in construction projects identified by different researchers (section 3.2). In section 3.3, the concept of risk management as reviewed in the literature is explained. Finally, in section 3.4 the conclusions of the chapter are presented. An elaboration on the procedure for conducting the literature review can be found in Appendix A.

3.1 Defining key concepts

The eventual aim of allocating risks effectively is to increase the chances of project success. This research question stumbles upon specific terms such as 'risk' and 'effectively', which are open to interpretation, as well as 'success' being the aim of the research. Therefore, definitions are provided for 'risk', 'effective risk allocation', and 'project success'.

3.1.1 Risk

The concept of risk is an extensively researched concept since risks within complex construction projects are unavoidable. According to Nieto-Morote and Ruz-Vila [2011], risks can never completely be eliminated, however, the mitigation of risk can minimize the harmful consequences. Various different definitions of risk exist, due to the extensive available research on 'risks' within projects. However, each definition comes down to similar principles. Cohen and Palmer [2004] recognizes risk as "the potential for complications and problems with respect to the completion of a project task and the achievement of a project goal", whilst Husin et al. [2018] defines risk as "an occurrence of uncertainty with an absolute chance of a condition that leads to unfavorable consequences of project objectives". A more quantitative approach for risk, which is accepted by many researchers, is mentioned by Jayasudha and Vidivelli [2016], and defines risk as the "probability of an event multiplied by the consequence of the loss due to that event". Chia [2006] sums up different definitions of risk found in literature, into four main elements, namely:

1. A risk is a future event that may or may not occur.
2. A risk must also be an uncertain event or condition that, if it occurs, has an effect on, at least, one of the project objectives, such as scope, schedule, cost, or quality.
3. The probability of the future event occurring must be greater than 0% but less than 100%. Future events that have a zero or 100% chance of occurrence are not risks.
4. The impact or consequence of the future event must be unexpected or unplanned.

Based on the above definitions, and the key characteristics of risk, it can be concluded that 'risk' is best summarized by Cagno and Micheli [2011] as: "an uncertain event that may or may not happen, but which, if it does occur, has a significant impact on the project outcome".

Risk: Threat or opportunity

As it is stated that risk should have a 'significant impact on the project outcome', it is likely to see that impact as a negative impact on the project. Impacts such as cost increase, project delays occur, and incidents occurring on-site. According to Manoukian [2016], risks often carry a negative connotation for organizations as "risks can prevent a company from reaching its objectives". However, this 'impact on project outcome' can also be positive, as risk can also create an opportunity for the project outcome. Over the decades, researchers have agreed on the two-sided definition of risk, where risks can be seen as a threat or an opportunity [Krueger et al., 1993; Hillson, 2002; Frenkel et al., 2005]. Hopkin [2018] defines 'opportunity risks' as "risks that are (usually) deliberately sought or embraced by the organization" in order to create added value to the project or organization. This is an important element in risk management and risk allocation, yet within this research, there is a focus on the risks that pose a threat, rather than an opportunity, on the project. This is because risks are often seen and dealt with as 'threats' within the Company. Risks are first and fore-mostly to be mitigated, rather than enhanced for creating opportunities.

3.1.2 Effective risk allocation

The concept of 'risk' has been defined, and it is understood that risk management can help allocate project risks effectively. However, the concept of 'effective' risk allocation remains vague and open to interpretation. The Cambridge Dictionary defines the term 'effective' as "successful and thereby providing the results that you want". 'Effective *risk allocation*' can therefore be understood as allocating risks in such a manner that allows the project, and the project stakeholders to complete the project successfully. Effective risk allocation can therefore lead to project success. The assumption is therefore made, that when risks are allocated effectively, project success is reached. The term 'success' in this definition, is of course also prone to subjectivity. Success can hold different definitions for different stakeholders, depending on their perspective of the project. Therefore, the concept of 'success' in the context of projects is defined below.

3.1.3 Project success and performance

An effective risk allocation between project stakeholders is seen as a crucial element to improve project success [Shrestha et al., 2019]. Yet, measuring the success of projects is considered a debatable task, since a universally accepted definition for 'success' is lacking [Jha and Iyer, 2007]. Molaei [2021] found that even practitioners operating in the same sector do not necessarily perceive the relative importance of success factors in projects the same way. Different stakeholders have different perceptions of project success; different interests between the stakeholders result in different understandings of project success [Toor and Ogunlana, 2010]. Therefore, different project managers have different perceptions of measuring project success in a project [Koops et al., 2017]. An interesting example of this is as follows: "'An architect may consider success in terms of aesthetic appearance, an engineer in terms of technical competence, an accountant in terms of dollars spent under budget, a human resources manager in terms of employee satisfaction" [Freeman, 1992]. However, a widely accepted concept of project management and practice was defined by Atkinson [1999] as the Iron Triangle, which stipulates three factors influencing project success [Pollack et al., 2018]. This traditional model uses time, cost, and quality compliance as the main success criteria (see Figure 3.1).

These three criteria for project success are also referred to as the triple constraint items. Additionally to the findings of Atkinson [1999], researchers have identified different complementary success criteria in the construction industry. Sadeh et al. [2000] distinguishes four elements that define project success, which is quite different from the 'Iron Triangle' elements. These are; 1) meeting design goals, 2) the benefits to the end user, 3) the benefits to the developing organization, and 4) the benefit to the technological infrastructure. Whilst Koelmans [2004] complements the elements of the 'Iron Triangle' and identifies client satisfaction as an important element for project success. This is a relevant addition because client satisfaction can create further business opportunities for the contractor, and create the potential for sustainable relationships in the long term. Davis [2016] elaborates on client satisfaction and labels

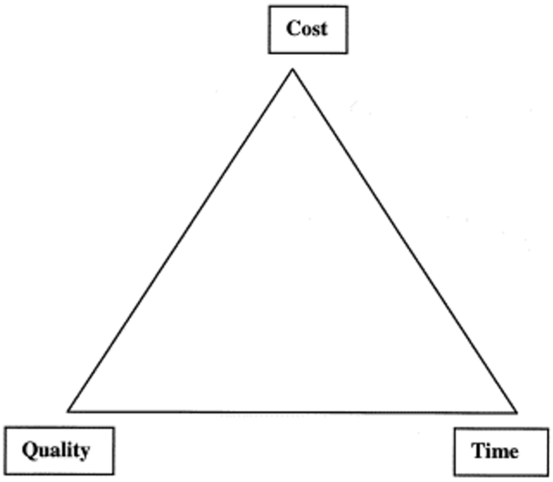


Figure 3.1: The Iron Triangle [Atkinson, 1999].

stakeholder satisfaction as a success criterion in projects, which defines how satisfied project stakeholders are with the end result. The stakeholders which are relevant for the stakeholder satisfaction criteria are dependent on the project. For this research, stakeholder satisfaction focuses on the client and (sub)contractors, seeing as these stakeholders are involved in the allocation of the project risks.

Defining 'project success' is an important element in understanding when risks are allocated effectively. Therefore, for this research, the four elements of success are taken as a basis for measuring project performance. Project performance is, therefore, measured on the basis of time, cost, quality, and stakeholder satisfaction.

3.1.4 Strategic Contracting

As defined in the main research question, this research focuses on an analysis of risk allocation through strategic contracting. Risk allocation can be tackled through different angles, however, this research zooms in on the strategic contracting mechanism of allocating risks. Contracts are in essence the tool for legally defining the formal agreements between contracting parties, and contracts can be used as "a strategic tool in obtaining a competitive advantage" [DiMatteo, 2010]. Additionally, Petersen and Østergaard [2018] identifies the difference between 'conventional' and 'strategic contracting' and defines strategic contracting as a proactive contracting form, which focuses on value creation, and prevention of conflicts, as opposed to value appropriation in conventional contracting [Bowman and Ambrosini, 2000; Dyer and Singh, 1998]. Strategic contracting thus focuses on contracting elements that promote *preventing* rather than *settling* disputes. Further on in this research, as empirical studies are conducted, strategic contracting will become a more well-defined concept.

3.2 Risks in construction

This section will dive into the theoretical findings of risk categories, risk identification, and risk management within construction projects.

3.2.1 Categories in construction risks

Different authors researching risks in the construction industry categorize risks in different manners, depending on the aim of the risk classification. Risks can be categorized, in order to find specific technical risks, creating categories that are specified on the technology. However, if the aim is to identify risks on the entire project level, then the categories are broader, zooming out on the specificity level. It is important that the categories remain on the same level of abstract, in order to include all necessary risks. Jayasudha and Vidivelli [2016] analyses the risks in the construction industry in three categories, namely business risks, technical risks, and operational risks. Here he explains that business risks involve financial risks involved with taking on projects, technical risks are risks that the project is unable to satisfy the project requirements, and operational risks refer to the inability of the customer to work alongside the core team members. On the other hand, the author Zou et al. [2006] labels risks more specifically, in terms of cost, time, quality, environment, and safety, whilst Sadeghi et al. [2016] focuses on a more detailed categorization, including the following risk groups: economic, legal-political, natural-physical, third party, contract and scope, design, owner, and construction related risks. Furthermore, research by Al-Sabah et al. [2012] focuses on external risks: political, economic, legal, social, and nature related; as well as internal risks: design, financial, construction, management, and maintenance related. Duddeck [1987] takes a more technical approach in categorizing the risks, where he focuses on the functional, structural, and contractual risks. Mubin and Mannan [2013] discusses seven EPC risk categories, specifically on oil and gas projects. These include engineering, proposal, project management, procurement and contractual, Quality-Health-Safety, human resources, and finance and audit. The categorization of project risks is usually based on the aim and importance of the risk list. Various researchers distinguish risks based on more broad terms, such as short-term and long-term and internal and external risks. A summary of the different risk categories is found in Table 3.1. Apart from Sadeghi et al. [2016] and Mubin and Mannan [2013], there is little literature to be found on specific EPC risk categories.

Table 3.1: A summary of the risk categories implemented in various literature articles on construction projects.

Jayasudha 2016	**Sadeghi 2016**	**Mubin 2013**	**Al-Sabah 2012**	**Zou 2006**	**Duddeck 1987**
Business	Economic	Engineering	Political	Cost	Functional
Technical	Legal- political	Proposal	Economic	Time	Structural
Operational	Natural- physical	Project management	Legal	Quality	Contractual
	Third party	Procurement and contractual	Social	Environment	
	Contract and scope	QHS	Nature related	Safety	
	Design	Human resources	Design		
	Owner	Finance and audit	Financial		
	Construction		Construction		
			Management		
			Maintenance		
			Functional		
			Structural		
			Contractual		

3.2.2 Identifying risks in construction projects

Zou et al. [2006] found that the construction industry, as we compare it to other industries, "is subject to more risks due to the unique features of construction activities, such as long period, complicated processes, abominable environment, financial intensity, and dynamic organization structures". This counts for construction projects in general, as these projects are started in complex and dynamic environments, which causes situations of high uncertainty and high risk, together with demanding time constraints [Jayasudha and Vidivelli, 2016]. Thus, an overview of literature found on EPC risks is combined with the literature found on risks within construction projects, regardless of the form of PDM these take on. This is done in order to create an overview of potential risks involved within EPC projects, which will, later on, be verified on the basis of exploratory interviews.

Table 3.2 demonstrates the overview of the risks found in four different literature sources. The identical risks and the risks with common roots are neglected and labeled under one category. For example, Zou et al. [2006], Sadeghi et al. [2016] and Ng and Loosemore [2007] each label the risk of inflation slightly different; 'inflation of prices', 'inflation on construction materials', and 'payments eroded by inflation'. For this research, the risk is labeled as risk 1. 'inflation of prices'. The list overview can be seen in

Table 3.2. The risks are marked by an 'X' when the risk is found in the specific literature source. This shows how often each risk occurs in the literature sources.

Sadeghi et al. [2016] and Mubin and Mannan [2013] focus on EPC risks specifically. These risks are taken as a base and complemented by different literature sources. Pícha et al. [2015] also looks at EPC contracts and the difficulties that arise from them, whereas Zou et al. [2006] dives into general construction projects and their risks, and Ng and Loosemore [2007] analyses infrastructure projects. This is done in order to create a large and broad overview of potential risks and eventually narrow them down to specific EPC risks.

When analyzing the overview seen in Table 3.2, interestingly, Pícha et al. [2015] and Sadeghi et al. [2016], who both analyze EPC construction project risks, only have two mutual risks. These are the risk 6. 'force majeur', which are external natural events that cannot be controlled, and risk 11. 'vagueness of contract clauses and documents'.

Ng and Loosemore [2007] identifies the risks involved in infrastructure projects, which is interesting since almost all of these risks overlap with the risks which are found in specifically EPC projects [risks 1., 5., 6., 9., 15., 17., 20., 23., and 26.]. Only risk number 36. 'risks in site preparation', is mentioned solely by Ng and Loosemore [2007] in the infrastructure projects. Zou et al. [2006] discusses the risks found in the construction sector, which can affect the project objectives. After identifying 50 risks found in these projects, he narrows the list down to the key 20 risks. From these key 20 risks, it is found that 9 risks overlap with the risks from other literature sources.

Table 3.2: The overlapping construction risks found in literature sources.

Risk no.	**Risk**	**Sadeghi 2016**	**Picha 2015**	**Mubin 2013**	**Loosemore 2007**	**Zou 2006**
1	Inflation of prices	X		X	X	X
2	Currency exchange rate fluctuation	X		X		
3	Sudden rise in equipment and material because of economic sanction	X				
4	Modification of government policies	X				
5	Changes in laws and regulations	X		X	X	
6	Force majeur (Earthquake, fire, flood)	X	X		X	
7	Unforeseen physical conditions (geotechnical, environment, pollution)	X				
8	Bureaucratic problems	X				X
9	Poor communication between partners	X			X	X
10	Inadequate specification and detailing (contract and scope)	X				
11	Vagueness of contract clauses and documents	X	X			
12	Inadequate conceptual design	X		X		
13	Unfamiliarity with EPC contract conditions for claims and litigations	X				
14	Incomplete and unclear scope definition due to insufficient feasibility study	X				
15	Errors and omissions in contractor's design	X		X	X	
16	Contractor does not meet owners demands (design changes)	X				
17	Too many change orders in design	X			X	X
18	Financial problems	X				
19	Owner default or delay in delivering construction site requirements	X				
20	Owner delay in approvals/ change orders	X		X	X	X
21	Lack of proper construction techniques	X				
22	Insufficiency of subcontractor management skills	X				X
23	Low management competency/skills of contractor or subcontractors	X			X	
24	Default/incapability of subcontractors or suppliers	X				
25	Disturbance/shortage in availability of labor, material, equipment	X				X
26	Different site conditions	X			X	X
27	Tight project schedule			X		X
28	Inadequate program scheduling					X
29	Unsuitable construction program planning					X
30	Variations of construction programs					X
31	Variations by the client					X
32	Incomplete or inaccurate cost estimate					X
33	Unavailability of sufficient professionals and managers					X
34	General safety accident occurrence			X		X
35	Serious noise pollution					X
36	Risks in site preparation				X	
37	Occurrence of disputes with client or sub-contractor		X	X		X
38	High performance/quality expectations					X
39	Delayed vendor information for detail designing is unavailable			X		
40	Incomplete data is provided by procurement department at proposal stage			X		
41	Delays by vendors			X		
42	Non compliance and poor enforcement of HSE requirements			X		
43	Fraudulence, leakage of information at proposal stage			X		
44	Overstress burden on employees			X		
45	Timely arrangement of advance payment guarantee & performance bond			X		
46	Increase in the rate of markup on guarantees at various stages			X		
47	Delayed payment by the client			X		

3.3 Risk management

It is found that controlling project risks has a positive effect on controlling project costs, controlling the project schedule, as well as the quality of project completion. These three factors lead back to the 'Iron Triangle' of success (subsection 3.1.3), demonstrating the effect risks can have on project success. In order to allocate risks in construction projects effectively, risk management comes into play. Edwards and Bowen [1998] explains risk management as a "systematic approach to dealing with risk". Different risk management processes can be found in the literature, each framing the process slightly differently. According to Jayasudha and Vidivelli [2016], the risk management process consists of three steps, including: **identifying** the factors that may have a negative impact on the project's cost schedule or quality baselines, **quantifying** the potential impact of these risks, and finally implementing **mitigation** measures to manage these impacts. On the other hand, an important and largely used approach is found by Project Management Institute [2008] in the PMBOK Guide and identifies the risk management process as: the risk identification, the qualitative analysis, the quantitative analysis, the planning of mitigating actions, and the risk monitoring and control. Furthermore, Mubin and Mannan [2013] explains a more elaborate risk management process consisting of eight main steps, with specific reference to EPC projects in the oil and gas sector. He mentions the following steps:

1. **Risk management planning:** which includes the setting of criteria and planning method for risk identification, the setting of criteria for probability and consequences of the risks, the selection method of risks, and the reporting method of these risks. This is usually documented in the planning phase of the project.

2. **Risk classification:** is done to understand the nature of these risks. The classification of EPC risks is discussed in subsection 3.2.1, where the differences in classifications in construction projects can be seen.

3. **Risk identification:** consists of identifying and assessing which risks can occur in the project. This can be done through different methods such as brainstorming, checklist analyses, and the Delphi technique. The risk identification is completed in section 3.2.

4. **Risk probability and impact factor:** entails those criteria should be set for the probability and impact factor. An example of this is "High impact", "Medium impact" or "Low impact" on cost, time, or quality.

5. **Risk analysis and quantification:** of which there are various ways to quantify risks based on different literature. According to Mubin and Mannan [2013], the most accepted formula for this is the *likelihood of risks (frequency* x *impact (on time, cost of quality).*

6. **Risk register:** is the format in which the risks are recorded. Within this register, the risks are ranked on the basis of time, cost, or quality.

7. **Risk mitigation strategy:** is the part where the most appropriate strategy is chosen in order to avoid the risk, transfer the risk, reduce the risk, or accept the risk. This mitigation is set to regulate the negative impact of the risk in the most effective way.

8. **Risk monitoring process:** is the process of reevaluating the risks and keeping track of changes. As risks are monitored, changes are registered, and lessons learned are identified, risk management can be improved continuously. The entire process is iterative.

Figure 3.2 demonstrates the entire model for the risk management process identified by Mubin and Mannan [2013]. The steps mentioned above are included in a visual, which shows the iterative nature of the risk management cycle, and specified all essential components of the analyses. Once the risk management steps have been undertaken, the lessons learned should be captured in order to improve the process.

Furthermore, Mubin and Mannan [2013] identifies the values which are used to define the frequencies of occurrence of risks and the impact factors related to this occurrence, in order to be able to quantify the risks. These can be found in Appendix D. When quantifying the risks of a project, these values are entered into the risk register. Hereby, the risks can be ranked on the basis of importance.

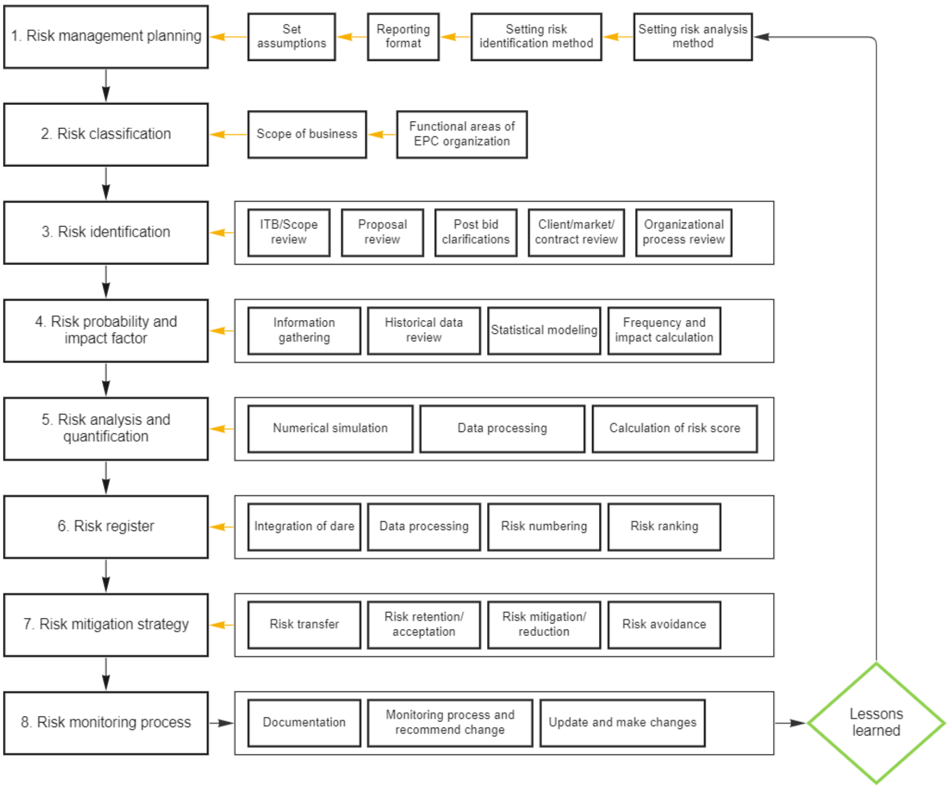


Figure 3.2: Risk management process for EPC projects [Mubin and Mannan, 2013].

Despite the wording differences found in the literature, many research findings on effective risk management can be summarized into four main steps [Nieto-Morote and Ruz-Vila, 2011]:

1. *Risk identification:* The process of determining which risks may affect the project and documenting their characteristics.
2. *Risk assessment:* The process of prioritizing risks for further analysis by assessing and combining, generally, their probability of occurrence and impact.
3. *Risk response:* The process of developing options and actions to enhance opportunities and to reduce threats to the project objectives. These include mitigation measures for the risks.
4. *Risk monitoring and reviewing:* The process of implementing a risk response plan, tracking identified risks, monitoring residual risks, identifying new risks, and evaluating the risk process effectiveness throughout the project.

Step 3. Risk response refers to mitigation measures. These mitigation measures are divided into four options, which are 1. accepting that the risk exists, 2. avoiding the risk altogether, 3. transferring the risk to another party, or 4. taking measures to reduce the probability or impact of the risk. This is chosen in response to the assessment of the risks. Thus, when referring to "allocating a risk" to a certain party, it is often related to the mitigation measure of "transferring the risk" to another party.

3.3.1 What is an 'effective risk bearer'?

Ng and Loosemore [2007] mentions that risks are too often underestimated in construction projects and that these risks are allocated to parties without the needed knowledge, resources, and capabilities to manage them effectively. This can result in serious project consequences, such as increased costs, time delays, and failure to deliver value-for-money services. Therefore, researchers focus on the idea that risk is most effectively allocated when it is allocated to the most effective bearer of the particular risk in question. The definition of this 'effective risk bearer' is however debatable. Abrahamson [1973] has established five criteria, which are known as Abrahamson's principles, where he recommends assigning the risks to the party where:

- It is in their control;
- It can be transferred as an economic transaction;
- The transfer accrues an economic benefit;
- Doing so creates greater overall efficiency; and
- Should the risk eventuate, the consequences do indeed fall on the party owning the risk.

Further research finds that the most effective risk bearer is based on three main aspects, which makes them an 'effective risk bearer'. The effective risk bearer is seen as the party which has the best ability to minimize the probability of risk occurring; minimize the degree of loss suffered, either before or after the risk event occurs; and insure against any residual risk that cannot be avoided [Posner and Rosenfield, 1977]. Therefore, this research takes into account three main aspects when analyzing the potential risk bearer, namely, on the basis of their 1. ability to control, 2. the amount of information the party has to understand the risk, and 3. the incentive for the party to manage the risk. These parameters have been summarized by Shrestha et al. [2019], and can all be influenced in order to most effectively allocate the risks within projects. The three conditions will be explained through the superior risk bearer theory of Abrahamson [1973].

1. **Control:** Risks should be the responsibility of the party who is in the most control of that risk and therefore has the most ability to minimize the probability of the risk-taking place and minimize the consequences of the risk. The degree of control is based on the methods and instruments which the risk bearer has to manage the risk.
2. **Information:** Secondly, risks are best allocated to the party who holds the most information on them regarding the risk. The more information the party has available to them regarding the risk, the more capable they are to understand and act upon the risk.
3. **Incentives:** Abrahamson [1973] believes that the incentives for a party to take on the risk should be a driving factor in the risk allocation of that risk. This comes down to incentive theory, which suggests that parties are more motivated to complete tasks and take on risks when there are external rewards available.

These guidelines by Abrahamson [1973] have found widespread support in the allocation of risk, however, the guidelines are also called into question by some researchers. C Ward et al. [1991] mentions that the guidelines proposed by Abrahamson [1973] assume an atmosphere based on trust and mutual appreciation between the contracting parties regarding the project risks. Therefore, the applicability of these guidelines depends on the nature of the relationships between the parties. According to C Ward et al. [1991], unaligned relationships can result in large debates regarding the appropriate risk bearer. Hence, C Ward et al. [1991] focuses on another element, namely the *willingness* of the party to take on the risk. This willingness to bear the risk depends on the party's:

- General attitude to risk,
- Perception of project risk,
- Ability to bear the consequences of a risk eventuating,
- Ability to manage the associated uncertainty and thereby mitigate the risk,
- Need to obtain work,
- Perception of the risk/ return trade-offs of transferring the risk to another party.

Depending on the points mentioned above, a party may be willing or unwilling to take on the risk, therefore making them an effective or ineffective risk bearer. When the willingness to take on risk is lacking, the chances that this risk will be managed effectively decreases. Therefore, it can be concluded that an 'effective risk bearer' is the party who is 1. in control of the risk, 2. holds most information about that risk, 3. has the incentive to take on the risk, and 4. is willing to take the risk.

3.4 Conclusion and next steps

This chapter presents the literature findings on key concept definitions, the risks found in construction projects, and the risk management process according to theory. This chapter thereby aims at answering subquestion 1 of this research.

The theoretical findings on construction projects identify the risks found within these projects and the risk management approaches taken in these projects. This was done by first identifying the different categorizations of risks, which vary from broader terms to more detailed terminology. The categorization demonstrates a large range of construction risk categories which is used by different researchers. Following was the identification of risks in literature articles, which are summarized in a framework and identify which risks are recognized by the different researchers. Discrepancies between different literature sources on construction risks were found, as risks in different construction projects are seen differently, from different perspectives. Additionally, in order to understand how risks can be managed, the risk management processes according to theory are demonstrated. The risk management process is a process that is usually reflected in the contracting strategy, as a way to execute the strategy. Understanding the nature of the risk management process is important, seeing as this is the foundation of allocating risks effectively. It has been found that risks are best managed by the most 'effective risk bearer', and that the risks can be mitigated through four mitigation measures, namely; 1. accepting the risk, 2. avoiding the risk, 3. transferring the risk, and 4. reducing the risk.

This theoretical background is used for the next chapter, chapter 4, which dives into the theory of EPC characteristics and risk allocation. Rather than looking at construction projects in general, the next chapter focuses on EPC projects specifically. The following chapter looks into how EPC characteristics can create and increase certain execution risks in EPC projects, which can differ from construction projects as a whole. Therefore, specifying the results for EPC projects is a crucial step in order to answer the main research question of this paper.

4 EPC Characteristics and Risk Allocation in Contract Strategies

This chapter demonstrates the results of the literature review. The results explain the theoretical background found regarding the specific characteristics of EPC projects and provide an explanation of how risks can be allocated on the basis of contracting strategies. This chapter thereby aims to answer:

Subquestion 2: *What are the characteristics of EPC projects and how are risks allocated through contracting strategies according to theory?*

In order to answer this question, section 4.1 explains the organizational structure, the phases of EPC projects, and the characteristics of EPC projects. Furthermore, section 4.2 dives into the contracting strategy elements used in contract clauses in order to allocate risks in the supply chain. Finally, section 4.3 discusses the nature of the supply chain and its effect on risk allocation.

4.1 EPC projects

Different construction projects have different forms of contracting. EPC contracts are becoming a popular form of contracting applied by the private sector, to complete large-scale construction projects [Pícha et al., 2015]. The EPC model for delivering projects has emerged over the past 20 years in order to deviate from traditional delivering methods, such as the Design-Bid-Build method [1] [Baram, 2005]. EPC projects have specific characteristics and organizational structure, which differentiates this form of contracting from other forms in the construction industry.

This section dives into the EPC organizational structure, the EPC project phases, and the EPC project characteristics, in order to gain a better understanding of what an EPC project entails. Furthermore, the contracting strategy elements applicable for risk allocation in EPC projects are explained. These are the main elements that are used in contracting strategies to allocate risks.

4.1.1 The EPC organizational structure

The EPC supply chain is structured in quite a complex one, with many different stakeholders involved, also referred to as organizational units, who are responsible for certain tasks or processes, and therefore, allow for certain information and work specifications to be shared with another process. The EPC structure is laid-out by Yeo and Ning [2002], in Figure 4.1, where he points out which organizational units and processes are involved in the process.

It is visible that according to the 'dashed lines', there are many different information flows going around the organizations. This demonstrates the various connections and dependencies in the structure. Furthermore, the 'full lines' show the responsibilities of the various organizational structures for certain processes. Referring to the three main phases of EPC projects, namely the engineering, procurement, and construction, it can be seen that the engineering phase includes the conceptual design, front-end design, and detailed design. Furthermore, the procurement phase includes the sourcing of resources, such as materials, equipment, and work-forces, the purchasing of the resources, the expediting of the resources, and the material control. Finally, the construction phase focuses on the construction of the actual product. These three phases are elaborated on below.

[1] See Appendix C for more information about the different Project Delivery Models

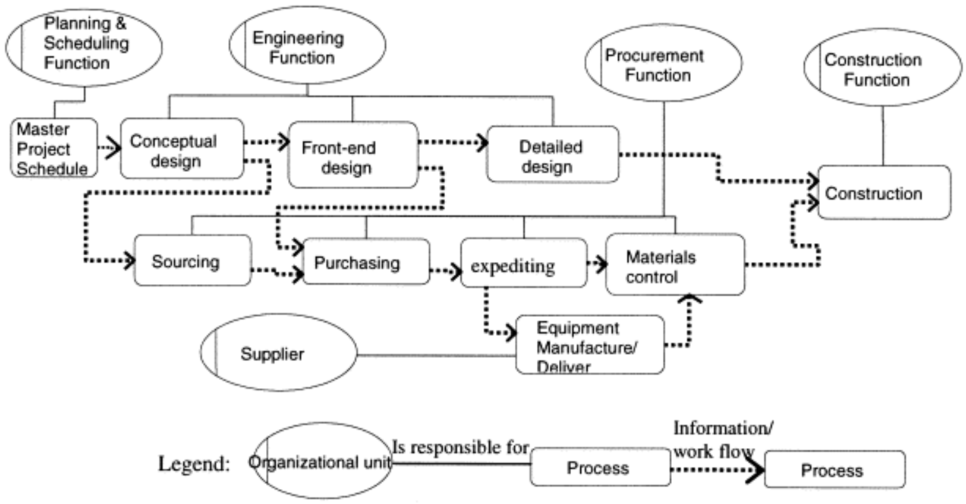


Figure 4.1: Organizational structure of EPC projects [Yeo and Ning, 2002].

4.1.2 The EPC phases

As previously mentioned, EPC projects traditionally include three distinct phases in which the EPC contractor operates. The general contractor for EPC projects holds responsibility for executing all three phases in an EPC format, namely the engineering, procurement, and construction phases. Even though the structure is split into three phases, project activities are highly interdependent. Phase overlaps in engineering/design, procurement, and construction may occur in order to reduce time, however, this comes with the potential risk of project overruns in schedule and cost, due to a lack of complete information.

The engineering (E) phase includes the identification and quantification of the needs, wishes, and desires of the client, into a list of requirements. This phase is known to have the highest level of influence on the project, due to critical decisions that need to be made. The design of this phase is usually completed through steps such as the conceptual design, preliminary design, and detailed design.

Hereafter starts the procurement (P) phase when the general contractor starts to procure the necessary equipment and construction materials based on the design drawings and other information. This phase includes sourcing, purchasing, contracting subcontractors, and on-site material management.

The final construction (C) phase is completed on the basis of work packages that are prepared during the engineering phase, whilst using the procured materials and equipment. This is then terminated by the contract closure and project handover [Yeo and Ning, 2002] [Pícha et al., 2015].

These projects experience specific risks which are present during the execution phase of the project. Within the execution of EPC projects, the focus is on the procurement and construction phases.

4.1.3 EPC characteristics

In order to understand the nature of the risks involved in EPC projects, it is important to understand the specific characteristics of these projects. The EPC project characteristics are said to be inherent, meaning that these characteristics are deep-rooted and almost of permanent presence [Sadeghi et al., 2016]. However, the question is why these EPC characteristics are so particular, and can potentially even lead to the risks involved for these projects. This is a subject that is lacking in academic literature, as not many researchers dive into the nature of EPC project characteristics. Yet, there are some relevant literature findings.

Nethery [1989] and Ballesteros-Pérez [2017] look into the fast-tracking nature of EPC projects. The phases of the EPC structure may seem to be completed successively, due to desired complete information for the sequential task. However, in practice, it is seen that, due to time constraints and so-called fast-

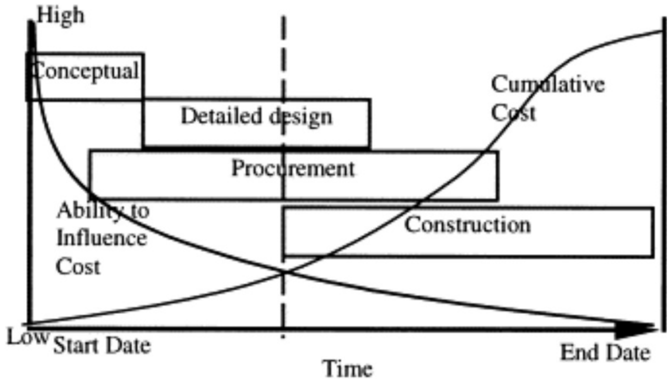


Figure 4.2: Phase overlap in EPC project [Nethery, 1989]

tracking, the phases of engineering, procurement, and construction overlap [Nethery, 1989]. Literature mentions that fast-tracking is one of the characteristics within EPC projects since these projects are mostly working on tight project schedules. Fast-tracking aims at compressing the time spend on tasks and projects as a whole, moving forward the delivery date. Ballesteros-Pérez [2017] explains that "Fast-tracking a project involves carrying out sequential activities in parallel, partially overriding their original order of precedence, to reduce the overall project duration". Fast-tracking can be attained through various ways, of which one is by overlapping work phases. By overlapping phases, there is generally less total time required for projects as they are stacked on top of each other. This is of course assuming all tasks are completed successfully. However, in practice, this creates that important decisions are made based on incomplete information at certain phases, seeing as the previous phase has not completed its work fully. In the example shown in Figure 4.2, it can be seen that the procurement phase commences whilst the project is still in its conceptual phase, creating a large overlap in phases, and opportunities for potential risks. As the procurement is started without a complete detailed design, serious change orders may occur, which can cause project delays and budget overruns. Figure 4.2 demonstrates how these phases overlap with each other, including their effects on cost.

Furthermore, Yeo and Ning [2002] identified four main EPC characteristics that can influence the risks of the project. These include, 1. the inter-dependence of activities, 2. the overlapping of phases, 3. the work fragmentation, and 4. the complex organizational structures. These are seen as inherent EPC characteristics, which are, according to his research, permanently present in EPC projects.

1. **Inter-dependence of activities:** the activities are "intricately connected and have complex process relationships", meaning that the activities have a direct or indirect influence on one-another. Due to the inter-dependency, information transfer is crucial and iterations are common.

2. **Overlapping of phases:** this is to a certain extent linked to the fast-tracking process mentioned by Nethery [1989] and Ballesteros-Pérez [2017]. The overlapping of the phases creates vagueness in the scopes of work, and difficulties in communications, due to incomplete information at different phases and changes that occur in the works.

3. **Work fragmentation:** this is created by many different organizational structures and parties involved in EPC projects. Parties need to exchange information through different lines, making communication complicated. This may even cause adversarial relations.

4. **Complex organizational structure:** this is linked to work fragmentation, where the structure of the entire organization can be seen as quite complicated.

These summarize the main characteristics found in literature on EPC projects. These inherent characteristics can create difficulties in projects and eventually may lead to the risks of these projects. Apart from the EPC project characteristics, the EPC projects have certain conditions that are followed when defining contracts. This is further elaborated on below.

4.2 Contracting strategy elements

As mentioned earlier, risks are inherent in any project and cannot be completely eliminated. However, the risks can be allocated and managed through different contracting strategies, in order to mitigate the consequences of the risk. The contract strategy frames which management decisions are made between all contracting parties [Komurlu and Er, 2020], and is therefore the foundation of the work responsibilities and agreements for the duration of the project. According to Cox and Thompson [1997], the contracting strategy encompasses the contractual relations and terms between the parties, including the agreements on the relationship, the division of responsibilities, and the reimbursement mechanism (price arrangement). These contracting strategy elements can indirectly influence how the risks are allocated between the contracted parties. Various researchers identify different elements within the contracting strategies depending on the aim of the project, however, this report focuses on the contracting elements which have an influence on the allocation of the risks within the EPC projects. These are the contractual clauses defined between the contracting parties.

4.2.1 Contractual clauses

Contractual clauses are used as contractual reinforcements in order to steer the project in the desired direction. It is found that project clients tend to transfer risks to another party, usually, the (EPC) contractor, which can be done through disclaimer clauses. According to Hartman [2000], such clauses "attempt to transfer one party's risk (which may be a legal liability) to another by contractual terms". This is done in order to limit the client's liability within the contract.

The contractual clauses are [1] the price arrangements, [2] the liquidity terms, [3] the milestone completion, [4] the construction insurances, [5] the warranty, [6] the change orders, [7] the dispute resolutions, and [8] the early warning notices clauses. Literature states that project owners, or contractors, are generally unwilling to carry the project risks, which is why most risks are transferred down the supply chain through disclaimer clauses [Zaghloul and Hartman, 2003].

[1] Price arrangements

Setting up a contract price is another element of the contracting strategy. Contract price arrangements are used as an incentive for the subcontractors to fulfill the objectives of their tasks. It specifies under which terms the reimbursement for the work is arranged, and consequently, functions as one of the instruments to allocate risks toward a certain contracting party. For this research, the focus is laid upon the risk allocation between the EPC contractor and the subcontractors, therefore, the contract price arrangement is explained in regard to the supply chain. According to various researchers, there are a few main price arrangements used within EPC projects, namely lump sum, unit price, cost reimbursable, and guaranteed maximum price structures [Moazzami et al., 2013][Komurlu and Er, 2020]. The contract price arrangements can be altered to suit certain projects and wishes, there is no one-size fits all price contract.

Lump sum The lump sum form is based on a fixed price for performing the entire scope of works [Teklemariam, 2012]. This way, the subcontractor is paid a fixed price for the completion of the agreed-upon work, regardless of the amount of money spent by the subcontractor. This makes project management easier, however, transfers the risk to the subcontractor, and may include a percentage of the cost of carrying that risk. When changes occur for the 'lump sum' price agreement, these changes are managed by change orders.

Unit price The unit price form, also known as item-based rates, is based on agreed-upon fixed prices used for specific quantities of resources, determined in the Bill of Quantities (BOQ). Basically, it is the fixed unit price for each item of work performed [Carty, 1995]. It is used when the scope of work cannot be clearly defined. In this format, the prices are set for each unit of resources, which allows a fair price to be determined by contracting parties for the completed work. This form allows the prices to be changed through change orders as the scope of the project changes.

Cost reimbursable Cost reimbursable contracts, also known as time and material contracts, simply indicate that the EPC contractor reimburses the costs made by the subcontractors on the incurred work, plus a guaranteed additional payment for overheads and profits, which are called mark-ups. The reimbursement of costs made by the subcontractors is not unlimited but limited to a cap. Regarding the additional payment, a distinction can be made between the four different cost reimbursable contracts [Landau, 2021].

Cost Plus Fixed Fee (CPFF) contract reimburses the cost incurred by the subcontractor, plus a fixed fee that is not affected by the subcontractor's performance of the project. This means that the EPC contractor bears the risk, whilst the subcontractor is protected.

Cost Plus Incentive Fee (CPIF) contract reimburses the cost incurred by the subcontractor and additionally adds on an incentive fee which is calculated based on performance targets defined in the contract. The incentive price is based upon a formula stated in the contract and therefore remains quite objective. The risk mostly lies with the EPC contractor but remains less than with CPFF.

Cost Plus Award Fee (CPAF) provides the subcontractor with an award fee when they meet certain objectives stated in the contract. However, this differs from the CPIF since the award fee is based on the subjective satisfaction level of the EPC contractor, rather than a formula.

Cost Plus Percentage of Costs (CPPC) adds on a percentage of the costs to the incurred costs of the subcontractor. This shifts the risk to the EPC contractor, as the costs may be artificially increased in order to increase the reimbursed costs. Therefore, this form is only used under very trustworthy relations. This form has additional regulations imposed on them in order to reduce the risks.

Guaranteed maximum price structures Guaranteed Maximum Price (GMP) contracts entail that the subcontractors are paid their incurred costs, with an additional agreed-upon fee. However, the subcontractor guarantees a maximum total cost that will not be exceeded. This can be seen as a hybrid form contract, between a fixed price contract and a reimbursable contract [Boukendour and Bah, 2010].

The explanations above show how the different price contracts shift the project risks towards either the EPC contractor or the subcontractors.

[2] Liquidity: Payment terms and retainage

There are two main contractual agreements that affect the liquidity of the EPC (sub)contractor, namely contract payment terms and retainage. These are to a large extent decided by the client and are trickled down the supply chain, affecting the liquidity of the (sub)contractor. By decreasing the liquidity of contracting parties, the risk of the parties not complying with contractual obligations increases, as they have less budget to spend.

Contracting strategies must include the contract payment terms and amount of retainage being withheld by the client, and can strongly restrict cash flows for the EPC contractor and subcontractors. Payment terms are the number of days in which the EPC contractor is obliged to pay the subcontractor from the date of the submitted invoice [Carty, 1995]. As for retainage, also known as retention, a percentage of the contract's price is withheld from the EPC contractor or subcontractor. The retainage percentage usually ranges from 5% to 10% of the overall contract price. The aim of retainage is to decrease the client's risk of a EPC contractor or a subcontractor not completing the project as promised [Gantner, 2021].

[3] Milestone completion incentives and penalties

Teklemariam [2012] explains that another element of contracting strategies to allocate risks is by using milestone dates, where payments are made on the basis of completed stages of the project. These milestones are defined through 1. a completion date, and 2. a completed task. Therefore, the subcontractor has a larger incentive to finish the task sooner in order to get paid earlier, whilst EPC contractor benefits from a larger chance of meeting project schedules. This can create win-win situations. The milestones can be linked to a bonus or penalty, in which the bonus reimburses a subcontractor a payment each time period work is ahead of scheduled milestone dates. However, when the agreed-upon milestones are not met, the subcontractor receives a penalty, usually a deduction from the profit [Carty, 1995].

A penalty can be defined in the form of Liquidated Damages (LDs). These are basically penalties for not meeting performance criteria, such as a scheduled date. EPC projects are unlikely to be executed under unlimited liabilities, seeing as the complexity of these large-scale projects can cause large financial implications and thus contractors are not willing to take on these commercial risks through unlimited liability. Liquidated damages are a mechanism to spread the liabilities. These are payments made by the subcontractor to the EPC contractor when a breach of contract is incurred. An example of a contract breach would be the delay in the completion date of the task by that subcontractor. Liquidated damages are implemented in order to induce subcontractors to complete their contractual agreements [Carty, 1995].

[4] Construction insurances

The construction insurance clauses allow for risks to be allocated to another party, and protect the client, the EPC contractor or subcontractor from various risks. These insurances are relevant for all parties involved in the project. It is a broad categorization of insurance that gives protection during the execution of projects. Three distinct construction insurances can be identified [Medina, 2022; Hartford, 2021]:

Builders risk insurance

This form of construction insurance protects *property* during the project; buildings, materials, supplies, and equipment. This type of property insurance helps protect the buildings which are under construction during the project execution. This property is then insured against damage caused by fire, weather, vandalism, explosions, theft, and other acts of god.

General liability insurance

General liability insurance covers a broad range of damages, which include 1. faulty workmanship, 2. job-related injuries, and 3. advertising injury.

Errors and omissions insurance

This insurance protects parties against claims from errors and mistakes made in their work. An example of an error made within construction projects can be that an engineer has made a calculation mistake, resulting in costly repairs and changes required on the work site. This can lead to lawsuits and claims from other parties. In this case, the insurance may cover the claims resulting from this mistake.

[5] Warranty

Warranties define important contractual clauses in order to mitigate risks during the execution of projects. Warranties provide a guarantee by the manufacturer or the (sub)contractors to repair or replace a defective product or workmanship. These warranties are in place to guarantee quality standards and allocate the risk of defective products or work to the party who is responsible for this work. These are important contractual clauses since defects in construction projects can show up late in the process, creating difficulties in assigning responsibility for this defect. A warranty defines what is required and expected of the (sub)contractor, in order to mitigate the risk that defective work is delivered [McIntosh, 2019].

[6] Change orders

Scope changes in construction projects are inevitable and are often a source of conflict between the client, (EPC) contractor, and subcontractors. Change orders are changes or deviations from the originally agreed-upon services specified in the contract. Change orders can generate costs and time delays, which are key elements affecting project success. These are typically issued when changes to the project create extra costs, however, are also seen when costs are reduced. Because change orders can create large project risks, the change orders clause is an important element of the contracting strategy elements. By defining the change orders in a contractual clause, the risks experienced because of changes in the project are mitigated. Change orders are particularly seen on fast-track projects, where the design and construction are overlapping [Moselhi et al., 2011].

[7] Dispute resolution

The dispute resolution clauses in a project define the levels at that the parties involved are required to be engaged in other forms of disputation, such as mediation and arbitration. This dispute resolution is an important factor within construction projects, seeing as it can limit the chances of parties going to court, which is a very timely and expensive procedure. These clauses can provide the foundation for better business relationships within the project in order to improve dispute management [Shonk, 2022].

[8] Early Warning Notice (EWN)

An Early Warning Notice (EWN) is a contractual clause that is found in construction contracts. NEC4 refers to this clause as: Clause 15- Early Warning. This clause comes down to the idea that when either the client, contractor, or subcontractor becomes aware of any issue that may delay the project or increase the cost they have a duty to inform the other party. This is done through a standard template that lists all the "issues" that need to be communicated. The issues are obliged to be communicated when a party is aware of an issue that could [Evans, 2020; Stannard, 2017; Patronus, 2015]:

- Increasing the total of the prices;
- Delay completion;
- Delay meeting a key date or;
- Impair the performance of the works in use.

The early warning specifications are to be entered into the risk register by project managers. The EWN can be used as a risk management tool, as it can reduce risks related to schedule, cost, and quality. By identifying risks as soon as possible, the consequences of these risks can be minimized. This risk management tool focuses on mutual benefit for the parties, and should not be used to transfer the risk to another party, putting them at blame. NEC 3 is based on mutual trust and cooperation, with the aim to identify the risk at the moment of identification together [NEC, 2017]. Therefore, adversarial contracting cultures should be disregarded when pursuing EWN.

4.2.2 Allocation of risks through contractual clauses

The contractual clauses summarized above allow for the risks to be transferred down the supply chain, toward another contracting party. These thereby aim to exclude a party's liability in the contract. These risks are cascaded down from the client to the EPC contractor, and finally to the subcontractors, however, not without an incentive. The incentive for the subcontractors to take on this risk is a risk premium. However, are these subcontractors the most 'effective risk bearer' to take on this risk? When the risks are cascaded down, and the subcontractor has little means and capability to control the outcome of that risk, this can create more risks [Jergeas and Hartman, 1994]. Researchers mention that this creates the potential for claims, disputes, and adversarial relationships between the contracting parties [Robert, 1997]. Figure 4.3 demonstrates research findings on what impact these contractual clauses can have when allocating risks, and what the general outcomes are of issuing these clauses.

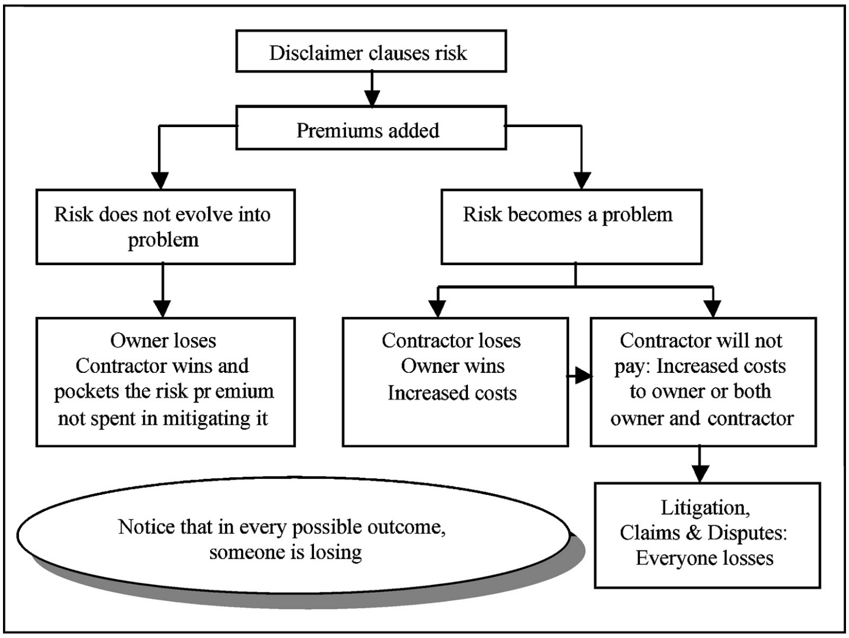


Figure 4.3: General outcomes of risk allocation through disclaimer clauses [Zaghloul and Hartman, 2003].

This visual explains that by using (disclaimer) clauses in order to allocate the risk to a party down the supply chain, the eventual outcome remains a win-lose situation. One party's win, by pushing away the risk, is another party's loss. This is a strategy, which is often seen in EPC projects, where this win-lose culture, within the traditional allocation of risks between parties, can cause risks for all stakeholders, including the subcontractors. This raises the crucial question; do these clauses allow for an effective risk allocation? In order to understand how risk allocation can be improved, a broader look is taken at the actual nature of the supply chain. By understanding how the supply chain functions, risk allocation can be adapted to the supply chain.

4.3 Supply chain network

The supply chain, regarding construction projects in general, is a widely discussed topic in literature. Research on topics such as supply chain management, performance, and integration are popular in the industry [Dainty et al., 2001a; Wibowo and Sholeh, 2015; Kumaraswamy et al., 2000]. One of the relatively new findings within literature regarding the supply chain is the idea of recognizing the supply chain as a *network*, rather than a *linear representation* of connections between parties. Cox et al. [2001] finds that supply chains are often seen as sequential dyadic relationships in literature, and often conceptualized as linear models, however, this does not accurately represent the complex nature of modern supply chains. It is seen by Choi et al. [2001] that this dyadic view of the chain does not account for the interdependencies between parties in the supply chain. Hearnshaw and Wilson [2013] mentions that "If modern supply chains are complex and adaptation to change is necessary, then there is a need to re-conceptualize supply chains away from simple linear systems towards complex adaptive systems". The supply chain is therefore often referred to as a 'supply chain network' in literature.

A network consists of the actors who play a role in the supply chain, such as the (EPC) contractor and the subcontractors. However, the network consists of more than only the relevant actors. The network becomes interesting due to the interdependencies these actors have on one another, the relationships they maintain, and the inter-organizational management needed within the network. This evolves into a complex structure. Håkansson and Snehota [1995] mentions that networks are therefore never stable, and have a dynamic nature because "actors are constantly looking for opportunities to improve their position in relation to important counterparts and are therefore looking for opportunities to create changes in the relationships". This implies that the supply chain individual actors are aiming for optimization and added value for their own tasks, whilst the inter-dependency between the actors causes dynamic relationships. Based on these findings, it can be stated that treating the supply chain actors as a network, rather than as independent actors sharing dyadic relations, gives a more accurate representation of the supply chain.

4.3.1 A collaborative network

Literature identifies various forms of networks that exist in different industries. However, the notion of a 'collaborative network' is seen as a fairly new discipline and is gaining popularity in literature [Sorenson et al., 2008; Mischen, 2015]. Research by Camarihna-Matos and Afsarmanesh [2005] explains the collaborative network "by a variety of entities (e.g., organizations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their: operating environment, culture, social capital, and goals. Nevertheless, these entities collaborate to better achieve common or compatible goals". The collaborative network stems from the idea that by collaborating between network members, it is possible to achieve goals that would have not been possible or more costly if attempted individually. It is mentioned that a collaborative network involves sharing information, resources, and responsibilities, in order to achieve a common goal and generate value for the members of the network. However, to reach this collaborative network, a feeling of mutual engagement among network members is needed, where trust, time, and dedication play a large role.

4.4 Conclusion and next steps

This chapter looked into the theoretical findings regarding three main elements, namely; the characteristics of EPC projects, the contracting strategy elements used for allocating risks, and the nature of the supply chain on a linear or network basis. This chapter thereby aims at answering subquestion 2 of this research.

This chapter finds various relevant conclusions. Firstly, in order to assess how risks can be allocated effectively within the supply chain of EPC projects, it is important to understand the characteristics of EPC projects. The main characteristics for EPC projects are 1. inter-dependence of activities, 2. overlapping of phases, 3. work fragmentation, and 4. complex organizational structure. These characteristics can increase the risks found in EPC projects and are therefore important to understand.

Furthermore, the contracting strategy elements to allocate risks within projects have been identified. The contracting strategy elements are ways to pursue the allocation of risks through contracts. The contractual clauses define how the risks are allocated through the contract. These include the price arrangements, the liquidity based on payment terms and retainage, the milestone completion incentives and penalties, the construction insurances, warranties, change orders, dispute resolution, and EWN clauses. The next section dives into the theory of a more traditional or more collaborative nature of contracts. It is seen that the traditional approach uses more linear risk allocation by transferring risk, whilst the collaborative approach focuses more on risk sharing.

Once understanding the different elements which can be used to allocate risks within the supply chain, it is important to understand the nature of these supply chains. Literature review concluded that supply chains are often regarded as networks, where dynamic relationships, inter-dependencies between actors, and complex organizational structures define these networks.

This chapter focused on the literature of EPC projects and contracting strategy elements. The following chapter, chapter 5, aims at confirming and substantiating the literature results from chapter 3 and chapter 4. This verification is completed by conducting exploratory interviews with industry experts in the Company and reviewing Company documents.

5 Risks in EPC Projects

The method of gathering information in this chapter is twofold: 1. exploratory interviews with experts from the Company, and 2. information gathered through document review from internal Company documents. The aim of this chapter is to verify the results found through literature, and to substantiate these findings for EPC projects in particular. These results demonstrate how EPC risks are perceived and dealt with in practice. Thereby, this chapter aims at contributing to the results in literature, and creating a more profound understanding of the research by answering:

Subquestion 3: *How are risks in EPC projects perceived, allocated, and managed in practice?*

Firstly in section 5.1, the definition of project success is related specifically to EPC projects, since the nature of the EPC brings other priorities in success criteria. Following is section 5.2, and looks into the organizational structure of EPC projects, and specifically points out the role of the procurement phase. Then, section 5.3 focuses on identifying the key risks which are explicitly found in EPC project, on the basis of the construction risks identified in literature. Subsequently, section 5.4 relates the contracting elements discussed in literature to the way these elements are used in practice. Finally, the EPC organizational structure verifies the organizational structure identified in literature, with regard to the structure of the EPC Company. The chosen market approach is then explained in section 5.5, and is followed up by section 5.6, which explains the nature of this supply chain. Finally, section 5.7 explains which characteristics are linked to EPC projects, making them so complex. In section 5.8, the theory and practice and compared and discussed. The chapter is concluded in section 5.9. The method of the exploratory interviews follows these steps:

1. Demonstrate literature findings to the interviewee,
2. Interviewee identifies which of the elements found in literature are applicable to the Company processes,
3. Interviewee identifies which of the elements found in literature are abundant to the Company (not relevant in EPC projects),
4. Interviewee identifies the missing elements in the literature findings.

The Exploratory Interviews (EI) were held with the four experts in EPC projects, who are summarized in Table 5.1.

Table 5.1: Summary of the exploratory interviewees.

Code	Function	Company	Years of work experience
EI 1	Contract Manager	Fluor BV	+20 years
EI 2	Contract Manager	Fluor BV	+5 years
EI 3	Project Engineer and Risk Manager	Fluor BV	+10 years
EI 4	Project Director	Fluor BV	+20 years

5.1 Project success in EPC

As mentioned in subsection 3.1.3, success is perceived differently by different researchers. It is important to understand which success criteria are relevant for EPC projects specifically, rather than construction projects as a whole. For this research, project success in EPC projects is defined by internal Company documents, which highlight the elements which are seen as important within EPC projects. The 'Iron Triangle' are universally used and standard elements for evaluating the success of projects, seeing as these elements are driving factors for (EPC) projects. According to internal Company documents, the

EPC projects specifically focus on time and costs as the main driving factors in projects. This is due to the fast-tracking nature of the projects. These criteria are monitored closely through project controls, making sure that the schedule is adhered to, and costs are kept within budget. Additionally, one of the Company's core values is assuring Health, Safety and Environment (HSE) practices throughout the project completion. The HSE Management System is a crucial part of the execution planning effort of EPC projects and is addressed on all projects during all phases. All the EPC projects completed by the Company are in line with the HSE requirements and regard this a top priority. Therefore, HSE is regarded as a crucial measurement criterion for measuring project success, thus project performance in EPC projects.

5.2 EPC organizational structure

It is important to understand the EPC structure in order to understand the nature of the risks which may be present. Yeo and Ning [2002] has formed an overview of the EPC organizational structure, which can be found in Figure 4.1. This overview is used as a basis for an elaborated and further detailed EPC structure, through knowledge from experts in the EPC project industry. The structure can be seen in Figure 5.1.

The drawn-up model demonstrates which organizational units are responsible for which tasks. Additionally, it is visible how the information streams move from one party to another through information flows. Information flows demonstrate to which parties' orders are transmitted and updates are provided on the status of delivery. The bottom five organizational units are the subcontractors who are responsible for the work of the project. These five parties have been identified by the Company as the subcontractors who are most commonly found in EPC projects. In EPC projects, these parties are referred to as the various project 'commodities'. Standard EPC projects typically include the civil contract, the steel contract, the mechanical and piping (M&P) contract, the electrical and instrumentation contract (E&I), and the scaffolding contract. Depending on the specifics of the project, these commodities may vary, however, generally, these commodities and subcontracts are applicable. Depending on the project scope, smaller commodities can be subcontracted, such as a painting contract, an elevator contract, or a fire protection contract. All these tasks, processes, commodities, and stakeholders connect to one another, creating a complex and dynamic supply chain structure.

5.2.1 The 'P' in EPC

The procurement phase can create large potential risks in EPC projects. Figure 5.1 demonstrates that the materials and supplies needed to complete the work are purchased from the suppliers/ vendors, by the procurement function of the project. Procurement is defined as the act of "purchasing material and equipment on projects, and ensuring that all material and equipment is timely available to support construction and ensure the success of a project" [internal Company document, n.d.]. This includes the process of material planning, controlling material requirements, purchasing the materials, expediting, quality surveillance, logistics, and field material management. The procurement process consists of various steps, which are demonstrated in Figure 5.2.

The P in EPC can potentially create high risks. These risks are "inherited" from the nature of items being sourced, the countries they originate from or flow through, the modes of transport and handling, the logistical hubs (or any location-specific asset), and macroeconomic influences such as wars and environmental policies. These elements cause risk identified in Table 5.2, namely: risk 4.4 Delays by vendors. Due to the overlapping phases of Procurement and Construction, this procurement risk is seen as a large execution risk. This risk can be in the hands of the client, EPC contractor, or subcontractor, depending on where the responsibility lies for 'buying' the materials.

The responsibility of procuring materials for the EPC project is dependent on the contractual arrangement between the EPC contractor and the subcontractors. Fundamentally, there are two possibilities, namely; 1. the procurement process of materials is in the hands of the EPC contractor, or 2. the procurement process of materials is contracted to the subcontractor. This can depend on whether the

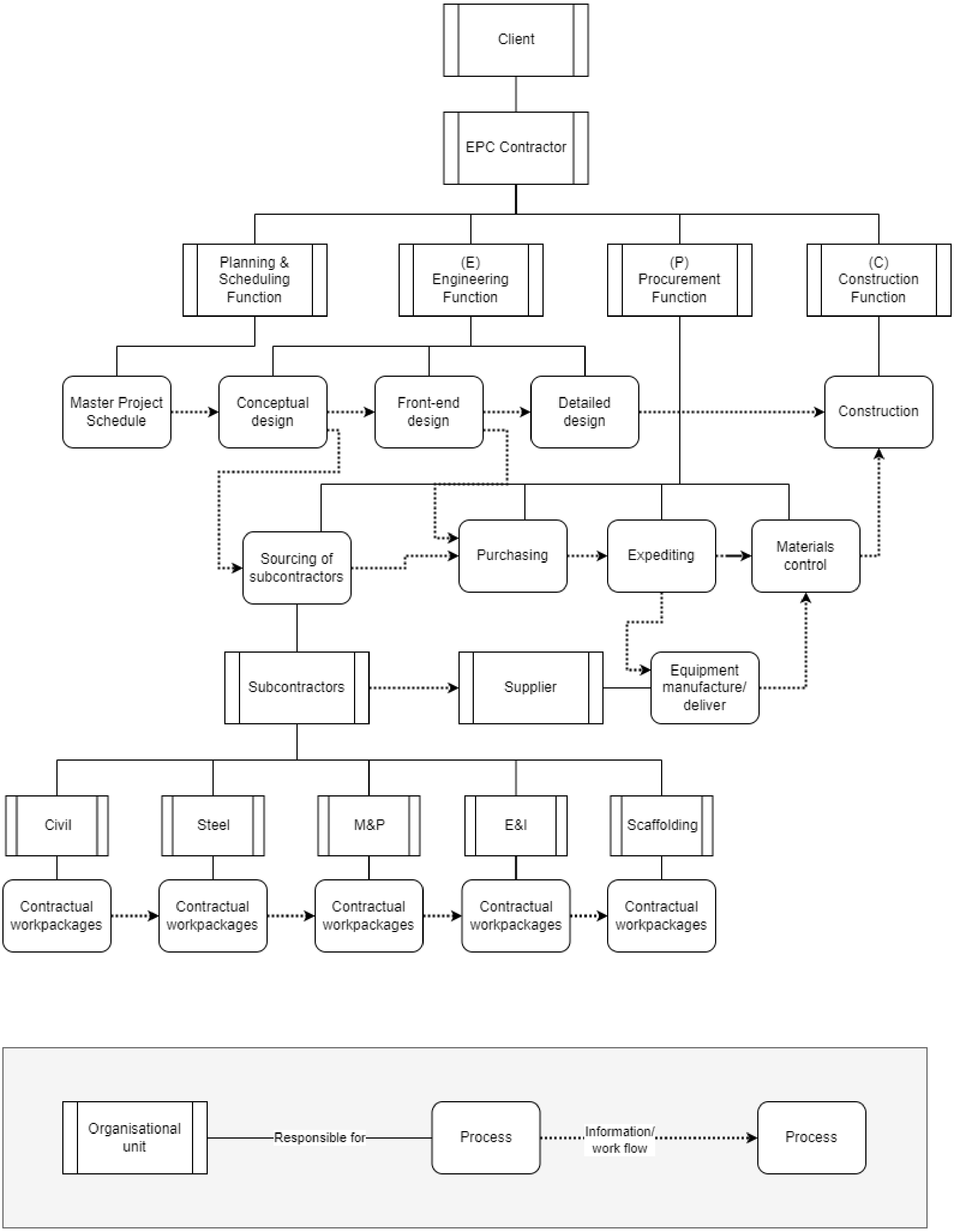


Figure 5.1: A visualization of the EPC supply chain structure.

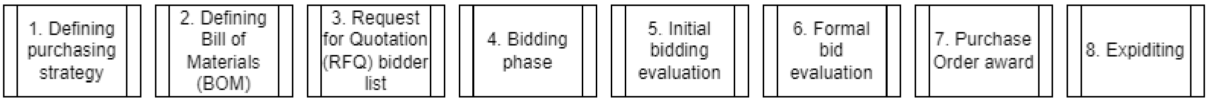


Figure 5.2: A visualization of the EPC procurement process [adapted from internal Company documents].

subcontractor has expertise in the buying process of that specific material or the negotiation position for that material. It also depends on the lead times of the materials. It is often seen that on-time purchase orders of materials are completed by the EPC contractor rather than the subcontractor, due to the EPC characteristic of overlapping phases. The long material lead times allow the EPC contractor to place purchase orders as early as possible, limiting the risk of late material delivery during construction. Therefore, the responsibility of on-time delivery and material quality is often contracted to the EPC contractor, rather than the subcontractors. The subcontractors, therefore, carry limited risks regarded to the procurement of materials and supplies. Delays in material delivery by the suppliers do however result in delays in construction and therefore, schedule delays by the works of the subcontractors. Eventually, this affects the entire project execution.

5.3 Risks in EPC projects

As mentioned earlier, project risks need to be allocated effectively in order to reach project success. However, risks are defined differently in different construction projects. Therefore, this section aims at defining risks within EPC projects. First and foremost, risks are defined as the "probability of an event occurring and the consequential significance of the occurrence" [retrieved from internal Company document, n.d.]. Furthermore, the categories of EPC risks are researched, and the risks found during the execution of EPC projects are identified. Additionally, the risk management strategy implemented by the Company is explained.

5.3.1 Categories in EPC project risks

The complex nature of EPC projects, due to their inherent characteristics, create a gigantic range of possible risks that influence the project objectives. In order to simplify these terms, a risk categorization has been made to identify the key risks found in these projects. As mentioned in chapter 3, many different ways of categorizing construction risks can be found. These categorizations are based on the aim of the risk list. Yet, there is no certain categorization for the risks found in EPC projects, except for the categorization by Sadeghi et al. [2016] and Mubin and Mannan [2013], which are not identical. However, in order to find the relevant risk categories for this research and EPC projects, the risk categories are based on the categories which are found in an internal Company document, namely the Business Risk Management Framework (BRMF). This framework is made by the Company in order to identify the risks involved in certain EPC projects. Within this framework, the categories are split up into external and internal groups. For this research, the external and internal groups are defined as:

- **External risks:** defines the risks which are usually a consequence of conditions that are 'out of control' of the project and thereby not limited to the boundaries of EPC projects.
- **Internal risks:** defines the risks which are part of the project structure, including all the organizational units defined in the EPC structure.

Due to the confidentially of the BRMF, it can not be said that these risk categories are exactly similar to the categories in the BRMF, but they come down to the same principles. These categories can be summarized into:

- **External:** 1. Geo-political, and 2. Economic-related risks.
- **Internal:** 3. Administrative, 4. Contractual and procurement, 5. Execution, and 6. Project management-related risks.

Geo-political risks include the issues that arise from national and international geographical and political situations which challenge the project. These risks can relate to war conflicts, environmental problems, governmental changes, etc. *Economic* risks involve the macroeconomic conditions which have negative consequences on the project. These issues are related to market fluctuations, in terms of all sorts of valuable resources. *Administrative* risks involve all issues which are due to administrative tasks and procedures within the project. *Contractual and procurement* risks are related to issues that involve the contractual and procurement approaches and processes within the project. This involves the contracts between all organizational units. Contractual risks include items like contract ambiguity where parties interpret clauses differently. *Execution* risks are issues that arise during the execution phase of the project, whereby the site work of the project is being executed. These risks are found during the 'Construction' phase of EPC projects. *Project management* risks are related to the risk relating to the management of tasks, processes, and stakeholders, as well as the management of project schedules and controls.

5.3.2 Identifying risks in EPC projects during execution

This section aims at translating the overall risk framework from risks within overall construction projects, towards risks that are specifically found in EPC projects during the execution phase. This is because the risks found during the execution phase have the largest impact on the subcontractors, and need to be allocated effectively within the supply chain. In Table 3.2, the risks within construction projects are summarized based on different literature sources.

The summary of literature risks within construction projects is evaluated by experts in the industry, which eventually led to a conceptualized risk framework for risks found specifically in EPC projects. This was done by identifying the risks which are:

- **Relevant** for all construction projects, including EPC projects;
- **Abundant** in EPC projects, and;
- **Missing** in the literature, yet specifically relevant for EPC projects.

A few risks were found explicitly in EPC projects completed by the Company, however not mentioned in literature. According to the interviewees, these risks play a large role in EPC projects and often cause challenges in projects. These risks include; 3.2 'failure in information flows', 4.5 'change order negotiations', 4.6 'the choosing of wrong subcontractors', 4.7 'claims from subcontractors', 4.8 'client interferences in key decisions', 4.9 'purchasing miscommunications', and 6.3 'subcontractor performance failure'. These risks have not been identified within the analyzed literature articles, and therefore are complemented in the risk framework. Additionally, some risks have been rephrased to make them more accurate for EPC projects. For example, the risk found in literature; 10. 'inadequate specification and detailing in contract and scope' has been rephrased to 4.3 'vagueness in contract and scope'. Additionally, the risk of 26. 'different site conditions' has been rephrased to 5.1 'insufficient site information', and the risk of 9. 'poor communication between partners' is labeled as 6.1 'lack of coordination and communication between contracting parties'. Finally, risk 23. 'low management competency/skills of contractor or subcontractors' has been rephrased to risk 6.2 'lack of interface management by EPC contractor or subcontractors'. Hereby, the risks relate to the EPC risks found in practice.

From the entire list of literature risks, a selection has been made to identify the top 25 internal and external risks involved in EPC projects. The lists of risks can be seen in Table 5.2, which have been verified by experts from the industry. The risks which were recognized from the literature articles are each found in at least two of the academic sources, except for risk 1.47 'delayed payment by the client' (only identified by one source [Mubin and Mannan, 2013]). This risk is reformulated in the conceptualized framework to risk 3.1 'delayed payment by the client and EPC contractor'. This is because a delay in payment by the client results in a delay in payment from the EPC contractor to the subcontractors, therefore, the risk does not merely lie with the client. On the basis of these risks, a conceptualized risk framework is created for EPC projects.

Table 5.2: Conceptualized risk framework including the top 25 risks occurring in EPC project [based on results from literature and exploratory interviews].

	Categories	no.	Risks
External	*1. Geo-political risks*	1.1	Bureaucratic problems
		1.2	Force majeur (earthquakes, etc.)
		1.3	Changes in law and regulations
	2. Economic	2.1	Inflation of prices
		2.2	Shortage in amount of available skilled labour
		2.3	Shortage in available resources
Internal	*3. Administrative*	3.1	Delayed payment by the client and the EPC contractor
		3.2	Failure in information flow (documents)
	4. Contractual and procurement	4.1	Disputes between parties
		4.2	Contract design fault
		4.3	Vagueness in contract and scope of parties
		4.4	Delays by vendors
		4.5	Change order negotiations
		4.6	Choosing of wrong subcontractors
		4.7	Claims from subcontractors
		4.8	Client interference in key decisions
		4.9	Purchasing miscommunications between subcontractors
	5. Execution	5.1	Insufficient site information
		5.2	Change orders in design
		5.3	Non compliance and poor enforcement of HSE requirements
		5.4	Lack of proper construction techniques
	6. Project management	6.1	Lack of coordination and communication between contracting parties
		6.2	Lack of interface management by EPC contractor or subcontractors
		6.3	Subcontractor performance / quality failure
		6.4	Tight project schedule

5.3.3 Explanation of the risks in EPC projects

The identified risks within EPC projects can be interpreted differently depending on the reader, therefore a short description is given.

- **1.1 Bureaucratic problems** are issues that arise from bureaucratic procedures, also known as red-tape procedures which arise from legal and organizational structures. This issue is an external factor that is seen in all sorts of construction projects. Bureaucracy can lead to delays in the approval of documents, and influence the work schedules within the supply chain.
- **1.2 Force majeur** risks are related to unforeseeable events which happen outside of the control of stakeholders and thereby prevent a party from fulfilling their contractual obligations. These include events such as wars, strikes, epidemics, floods, and earthquakes. Force majeur contractual clauses essentially free parties from liabilities and contractual obligations. Most commonly, the obligations are suspended for a later period in time. This potential risk influences all stakeholders within the project, including the client, EPC contractor, and subcontractors.
- **1.3 Changes in law and regulations** causes the risk that certain procedures in the project need to be adapted to these laws and regulations. These laws and regulations can be related to political changes, where for instance, in the Netherlands, the Nitrogen Crisis has caused changing construction regulations and benchmarks. These may force subcontractors to use different machinery and equipment, which in turn has an effect on the overall project budget. Changes in regulations can therefore negatively affect all parties within the project.
- **2.1 Inflation of prices** for construction materials, labor, and other supplies can create large budget overruns in projects. This risk is usually uncontrollable for stakeholders, however, clients and EPC contractors do have the possibility to allocate these risks strategically through contracting arrangements.
- **2.2 Shortage in the amount of available skilled labor** is a risk that is influenced by the

supply and demand of the market and thereby has a direct effect on the costs of the project. The fluctuations in the availability of skilled labor are most dependent on economic stability and are therefore uncontrollable within the project.

- **2.3 Shortage in available resources** is a risk similar to the availability of skilled labor, which is caused by the supply and demand market for resources. This is affected by external factors, such as market fluctuations, political unrest, and the energy crisis. This risk can influence the entire project on levels of quality, cost, and schedule.
- **3.1 Delayed payment by the client and EPC contractor** can cause serious liquidity risks for the contracting parties. Payments are made according to the payment terms (usually 30, 45, or 60 days after receiving invoice), however, until that time, the costs are paid by the party itself, leading to liquidity issues.
- **3.2 Failure in information flows** are risks of unsuccessfully sharing work documents or information between different parties. As visible in the Figure 5.1, there are many information flows connecting different tasks and organizational units to each other, since they are dependent on each other's information flows. When documents and relevant information are not shared successfully, this has an impact on the entire supply chain and the performance of the commodities.
- **4.1 Disputes between parties** occur in most construction projects as different stakeholders are working together on one project, where change orders are identified, causing disputes over liabilities and responsibilities of work. These disputes can have negative consequences for the objectives of an EPC project, and create adversarial relationships between parties.
- **4.2 Contract design faults** are errors that have been made in the agreed-upon contracts. This can cause time delays and disputes between the contracting parties. The client and the EPC contractor set up the contractual agreements, and carry the most risk regarding contractual faults.
- **4.3 Vagueness in contract and scope of parties** is a definite risk in EPC projects, where it is unclear which work tasks are under whose responsibility. Due to the overlapping of tasks in EPC projects, unclear scopes of work may occur. For example, the EPC contractor may be responsible for the procurement of pipes that are larger than 1 inch in diameter, and subcontractor X will be responsible for pipes that have a diameter below 1 inch. If not specified clearly in the contract and scope requirements, the work will be delayed and liability discussions will take place.
- **4.4 Delays by vendors** is a large risk, seeing as this has an influence on the performance of the entire supply chain. Especially when the vendors who supply the principal product lines in a project can cause large delays in work. The delay of supplies for one type of work, for example, the concrete for the civil works, can cause delays in sequential works in the planning, such as the works on steel.
- **4.5 Change order negotiations** occur when change orders are recorded by the subcontractors. The EPC contractor negotiates these change orders with the subcontractors, in order to decide who is responsible and accountable for the change. These negotiations can be time lengthy, and can therefore result in project delays. Furthermore, these negotiations can create strong disputes, and therefore, adversarial relationships.
- **4.6 Choosing of wrong subcontractors** is a risk that has an effect on the final project quality. Depending on the prime contract, this has a large effect on the client and the EPC contractor. Choosing the wrong subcontractors can be due to a lack of knowledge of the subcontractors, lack of available suitable subcontractors on the market, or budget constraints, resulting in awarding the cheapest subcontractors.
- **4.7 Claims from subcontractors** is a large risk for EPC contractors, as these can create large budget overruns, difficult disputes, and unsustainable contracting relationships. Changes in work (change orders) are the most common claims arising from subcontractors and result in difficult and

time lengthy negotiations. These claims create a 'win or lose' and adversarial relationship between the subcontractor and the EPC contractor.

- **4.8 Client interferences in key decisions** is a risk that may take place depending on the prime contract between the client and the EPC contractor. Depending on the nature of the contract, key decisions are made based on the preferences of the client. Key decisions, such as the selection of subcontractors, may be contracted on the client's paper, however, the risks of such large decisions trickle down the supply chain, and thereby towards the EPC contractor. Therefore, client interferences can create risks for the supply chain, and most specifically the EPC contractor.
- **4.9 Purchasing miscommunications** are part of the procurement phase of the EPC project. The EPC contractor in consultation with the subcontractors purchases the necessary materials and machinery for the project. Miscommunications on purchasing occur as many parties are involved in the process, and change orders are introduced. This involves procurement management and affects both EPC contractor as well as a subcontractor.
- **5.1 Insufficient site information** is a risk affecting the execution phase of the project, whereby the relevant information on the site is not available or not shared. This creates difficulties for the commodities who are responsible for the work on-site and therefore causes risks for the EPC contractor.
- **5.2 Change orders in design** can create large project risks within EPC projects. Change orders, which are a modification in the design of the project, have a large impact on the budget and time frame of the project, as one change can create a domino effect on other elements of the project. These change orders are even more enhanced due to the fast-tracking element of EPC projects, which means that during the design phase, procurement and construction may already be starting. This means that one design change can result in wasted procurement and construction work.
- **5.3 Non-compliance and poor enforcement of HSE requirements** is a large risk for EPC projects, as HSE requirements usually have high priority in these projects. Non-compliance with these requirements can lead to serious safety risks for workers, and harm the project as a whole. HSE and safety are core values for the Company.
- **5.4 Lack of proper construction techniques** is a large risk that can occur during the construction phase of the project. This can be due to inexperienced subcontracting parties or due to inadequate construction machinery. Furthermore, with the trends and innovations towards sustainable construction, a lack of sustainable construction techniques can create the risk of not meeting project objectives. This risk is mostly found at the bottom of the supply chain, in the works of the commodities.
- **6.1 Lack of coordination and communication between contracting parties** is a relational risk that can have negative consequences on the project as a whole. Effective coordination and communication are key between project partners in order to reach project success. A lack of these factors can create disputes, due to miscommunication, as Wu et al. [2017] explains that effective communication between contracting parties and project success go hand in hand. Due to the complexity of the EPC structure, communications flows can become hampered, and the different subcontractors (commodities) lack communication and coordination.
- **6.2 Lack of interface management by EPC contractor or subcontractors** is related to the overlapping of tasks and phases within EPC projects, as explained in section 5.7. Due to the overlapping of tasks, there are many interfaces between the tasks and commodities of the subcontracted works. These interfaces are critical within the project, and a lack of proper management between these interfaces can create huge risks.
- **6.3 Subcontractor performance failure** is the risk involved for the EPC contractor, as this may lead to increased costs and schedule overruns. Due to a lack of available skilled labor, the quality of the tasks may decrease.

- **6.4 Tight project schedule** is a risk that links back to the costs of a project since time and cost are so closely connected in large construction projects. This means that as projects are scheduled too tightly, due to for instance fast-tracking of projects, the schedule delays can have large effects on the project cost benefit. Depending on contract clauses, the responsibilities for these schedule delays lay with a certain party. This remains a risk for the client, the EPC contractor, and the subcontractors.

The identified risks within EPC projects give an overall idea of which risks are most prominent according to literature research and experts operating in EPC projects. However, it should be mentioned that this risk analysis and eventual management is an ongoing process within the projects. For example, the BRMF by the Company is reevaluated continuously as the project progresses, because risks are dynamic and vary in degrees of probability and consequences as time passes. This research focuses solely on the above-mentioned risks.

5.3.4 Risk management

The risk management process for EPC projects is based on internal Company documents. The risks management process is outlined within the BRMF, and defines risk management as "the art and science of identifying, assessing, and responding to project risk throughout the life of the project and in the best interest of its objectives".

The Business Risk Management Framework (BRMF), which is implemented by the Company as a framework to assess, manage and monitor the risks within an EPC project, involves a similar process to the risk management process explained in section 3.3. The steps taken by the Company are defined in the BRMF, and summarized in Figure 5.3. This process includes a risk register, in which categories of risks are identified, specific project risks are identified and the risks are ranked on priority. A risk priority is determined based on a combination of the ratings of risk severity and the likelihood of occurrence. An applicable risk strategy is chosen for these risks, where the most important risks based on the prioritization of the risks, are mitigated first. The mitigation measures include 1. accepting the risk, 2. avoiding the risk, 3. transferring the risk, and 4. reducing the risk. Furthermore, action plans are developed in order to define how the mitigation measures are put into action. The risks are monitored closely, to analyze the effects of the mitigation measures and allow for continuous improvement of the risk management process.

Within the Company, risks in EPC projects are managed according to six different steps, outlined in Figure 5.3.

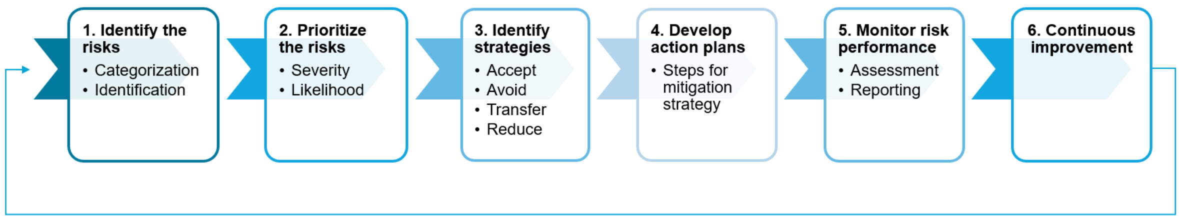


Figure 5.3: The steps for risk management based on internal Company documents.

According to the interviews, the risks within EPC projects are, where applicable, transferred from the client to the EPC contractor, down toward the subcontractors (downstream). This demonstrates the preference for mitigating the risk by *transference*, in order to reduce the liability of the client as well as the EPC contractor. This is an important finding, seeing the subcontracting parties may not be the most 'effective risk bearer' in the project. This demonstrates a gap between literature and practice.

5.4 Contracting strategy elements

The risk management and allocation within projects are pursued through the contracting strategy elements. In order to understand the practical implementation of the literature results on contracting strategies, exploratory interviews are conducted. The interviews with experts in contract management indicate two important points regarding the setup of the contracting strategy. Firstly, the contracting strategy chosen by the Company to pursue in the subcontracts (downstream contracting) is directly related to the contract pursued in the prime contract (upstream contracting). Therefore, there is a client influence on the risk allocation of the supply chain. Secondly, it is highlighted that the mitigation strategies of the most prominent risks in a project are reflected in the contracting strategy for that project, in order to allocate the risks effectively.

The exploratory interviews highlighted the cascading effects of the prime contracting strategy down to the subcontracting strategy. As mentioned before, the prime contract cannot be seen in isolation from the subcontracts. In practice, it is seen that the important risk clauses from the prime contract are flown down to the EPC contractor, which is then mirrored in the subcontracts. This is referred to as a 'back-to-back' transference of contractual risk clauses. This leads to the subcontractors having to manage large portions of the project risk. Thus, the relevant question for this research remains; how are the contracting elements seen in practice and eventually felt by the subcontractors?

5.4.1 Contractual clauses

[1] Contract price arrangements

The contract price arrangement is an important element for contracting subcontractors, as it allocates large financial risks. This element also trickles down from the prime contract, seeing as the financial risk bore by the EPC contractor due to their price contract with the client, is most likely to be reflected in the price contract between EPC contractor and subcontractor. For example, a lump sum prime contract between the client and the EPC contractor will most probably lead to various lump sum subcontracts in order to transfer the risk to the supply chain. However, the chosen contract price arrangement is dependent on the amount of engineering completed at that point in time. The price agreement is crucial for securing cash flow for the EPC contractor to continue its work and fulfill its obligations to its subcontractors. The three main contracting price arrangements used by the Company are lump sum, unit price, and cost reimbursable contracts.

Most of the prime contracts seen within the EPC projects have been contracted under lump sum in the past, however, currently tend towards more cost reimbursable contracts. The subcontracts, however, mainly use unit price contracts.

Lump sum A prime lump sum contract contains high risks for the EPC contractor, which stimulates the EPC contractor to flow this contract down to the subcontractor. In this case, the lump sum allows lower risk for the EPC contractor, yet allocates the quantity and productivity risk at the subcontractor. Therefore, a very mature scope definition is required, which comes at a cost. From the perspective of the EPC contractor, lump sum price arrangements with the subcontractors are favorable when at least 70% of the detailed engineering scope is completed by the EPC contractor. This puts the risk of exceeding the fixed price in the hands of the subcontractor. However, when the detailed engineering scope is around 30%, the contractor is aware that this will cause loads of change orders and claims in the future. Neither the subcontractor nor the EPC contractor benefits from change orders, therefore, pursuing a lump sum contract at low levels of detailed engineering is prevented. It can be said that lump sum contracts only contain lower risk for the EPC contractor when the subcontractor is able to mitigate the risks. If the subcontractor is not able to mitigate the risks which are flown down in a lump sum contract, the subcontractor will fail to meet their obligations, which in turn increases the risk for the EPC contractor. Therefore, the ability and the capacity of the subcontractor are very important elements to take into account when issuing lump sum contracts.

Unit price On the other hand, unit price is quite a popular contracting agreement with the subcontractors, because there is more freedom for modifications in work, as the quantities of resources can be altered in the process. The quantity risk remains in the hands of the EPC contractor, however, the productivity risk is for the subcontractor. Unit price agreements use a BOQ at the start of the works, which is determined in consultation with the subcontracting party. In practice, it can be seen that when the detailed engineering is at 30%, and both parties are aware that the BOQ will change as the project progresses, the unit prices are set at 'draft values'. It is then agreed that these values can be modified until a certain percentage certainty of the work is reached. Therefore, full-scope quantification is not required at the award stage. This way, fewer claims are registered, because modifications are made in consolation with both parties.

Cost reimbursable Regarding the cost reimbursable form, the quantity and productivity risk are for the EPC contractor, making this preferable for the subcontractors. This is to be used when no or very limited scope definition is available. In practice, this is a very time costly effort for the EPC contractor, because the EPC contractor is responsible for monitoring the issued time sheets closely. With large subcontract scopes, the time sheets, containing the amounts of resources (people, machines, materials, etc.) are complex, which makes it easy to lose control over the monitoring. Therefore, this form is not used for large subcontracted works where monitoring all the costs is highly time-consuming, but rather for small contracts, small quantities, with local companies, since this is more overseeable for the EPC contractor.

[2] Liquidity: Contract payment terms and retainage The contract payment terms are an important risk allocation factor regarding the financial liquidity of the EPC contractor and the subcontractors. The contract payment terms for the subcontractors are usually based on the prime contract. The EPC contractor has a 30, 45, or 60 days payment term with the client. This means that in practice, the EPC contractor tends to set the payment terms for the subcontractor equal or longer, in order to transfer the risk to the subcontractors. Each party tends to strive for longer payment terms. However, reimbursable payments are usually back-to-back payments between the client and subcontractor. These payment terms are a way to allocate financial risks since all parties want to maintain their liquidity.

Retainage of payment is seen as a way of minimizing the risk to the client, as they withhold a percentage of the project budget in case of errors in estimations or other unforeseen defects. In practice, a 10% to 20% freeze of the project budget at the start of the project can be seen, resulting in less liquidity for the EPC contractor, and thereby less liquidity for subcontractors. The more capital which is withheld from the subcontractors, the more subcontractors are forced to invest with their own budget, which creates large potential risks for negative cash flows and bankruptcy.

However, in practice, there remains the option to negotiate with the client and agree upon a monthly deduction of the loans, rather than a total percentage at the start of the project. For example, a monthly deduction of 10% of the work, until the end of the project. This allows the EPC contractor and subcontractors to maintain more cash flow for the execution of the work. Also, negotiations for advanced payment guarantees can be made, in order to increase the liquidity of the parties. An advanced payment acts as collateral for reimbursing a payment in order to complete the work. As subcontractors are paid earlier, the chance increases that these parties comply with their work obligations, and meet their schedules.

[3] Milestone completion incentives and penalties Milestone incentives and penalties are a mechanism to mitigate further negative impacts on the project. The project milestones are defined through a milestone date and a milestone task. Usually, the milestone dates which are set within the prime contract are reflected for the appropriate subcontractor. The critical milestones will usually be linked to the appropriate penalty or Liquidated Damage (LD). The milestone may also be linked to an incentive, whereby the subcontractor is rewarded for reaching the milestone dates. In practice, the incentives from the prime contract are not always flown down to the subcontracts, whilst the penalties or LDs are.

The completion incentives or penalties can actually be summarized into a 'bonus-malus' format. Rather than only issuing penalties on incomplete work, the bonus-malus format is a more collaborative model for incentivizing the subcontractors to complete work on schedule, by giving both a positive and negative incentive to complete work. This is basically an umbrella term for a completion incentive and penalty. Incentives are usually based on predetermined KPIs for the project.

These findings demonstrate how certain contracting strategy elements are seen in practice, and therefore, complement the finding from the theoretical background study. A summary of the contracting strategy elements is demonstrated in a conceptual framework, which combines the findings from the literature review, the exploratory interviews, and implementations in practice. This framework can be seen in Table 5.3, and additionally defines between which actors the contracting strategy elements are seen (Client, EPC contractor, and subcontractor). Furthermore, it is demonstrated which risk the contractual clauses can influence. It should be noted that the results for the contracting strategy elements focus on the downstream contract, between the EPC contractor and the subcontractor. For example, the [1.1] lump sum price arrangement provides lower risk for the EPC contractors, when the subcontractor is contracted under a lump sum price (downstream). This should not be confused with the price arrangement for the prime contract (upstream).

Table 5.3: Framework of contracting strategy elements used for risk allocation [based on results from the literature, exploratory interviews, and document review].

Contracting strategy elements		Theory and exploratory interview results	In practice	Contractual relations	Influence on risk
[1] Price arrangements	**[1.1] Lump sum**	• Lower risk for EPC contractor, as long as subcontractor is able to take on this risk • Subcontractor carries quantity and productivity risk • Requires very mature scope definition and comes at a cost • Less control by EPC contractor during execution • Important element is the ability and capacity of the subcontractor to take on this contract	Often seen in prime contracts, low risk for Client (upstream) and often seen for subcontracted indirect works (downstream)	C - EPC - S	All
	[1.2] Unit price	• EPC contractor carries quantity risk • Subcontractor carries productivity risk • Quantities vary (within limits), so full scope quantification is not required at award stage • More control by EPC contractor during execution	Often seen in subcontracts (downstream)		All
	[1.3] Cost reimbursable	• EPC contractor carries quantity and productivity risk • No or very limited scope definition is available or work is very unpredictable • Low risk for subcontractor as costs are reimbursed	Seen in both prime contracts (upstream) and subcontracts (downstream)		All
	[1.4] Guaranteed maximum price	• Incurred costs are payed, with an additional fee • (Sub)contractor guarantees maximum total costs which will not be exceeded (lump sum)	Mostly seen in prime contracts		All
[2] Liquidity terms	**[2.1] Payment terms**	• The longer the payment terms, the more risk for the subcontractor • Allows the Client to transfer risk to (sub)contractor • Limits cash-flow in the supply chain, creating financial risks	Low liquidity for subcontractors creates performance risk	C - EPC - S	3.1
	[2.2] Retainage	• High retainage minimizes risk for Client • Typically freezes 10%-20% project budget • Decreases liquidity of EPC contractor and subcontractors	Low liquidity for subcontractors creates performance risk		3.1
[3] Milestone completion	**[3.1] Incentives**	• Rewards subcontractors to reach milestone dates, by bonuses (win-win) • Incentives are used to stimulate performance of (sub)contractors	When implementing both incentives and penalties, this is also referred to as 'bonus malus' and 'risk and reward'	C - EPC - S	6.4
	[3.2] Penalties	• Penalises subcontractors for not meeting milestone dates, by the formulation of liguidated damages (LD)			6.4
[4] Construction insurance	**[4.1] Builder's risk insruance**	• Insuring property in the project: materials, supplies and equipment from damage • Damage can be caused by fire, weather, vandalism, etc.	Typically, the Client pursues construction insurances for all contracted parties	C - EPC - S	1.2
	[4.2] General liability insurance	• Insuring the party from 1) faulty workmanship, 2) job-related injury, 3) advertising injury / defamation			5.3
	[4.3] Errors & ommisions insurance	• Insuring parties against claims arising from error or mistakes in their work			4.2, 5.2, 5.4, 6.3
[5] Warranty		• Guarantee by the manufacturer or (sub)contractor to repair or replace a defective product/ workmanship	Often seen that the EPC contractor's warranty covers subcontractors work	C - EPC - S	5.4
[6] Change orders		• Allows for modifications to an existing construction contract • Defines how changes to project scope should be processed	Often seen that disputes arise from change orders, due to disagreement on 'change'	C - EPC - S	1.3, 5.2, 4.2, 4.5, 5.2
[7] Dispute resolution		• Defines how parties wish to resolve their disputes • Aim to reduce chances of going to court, but rather intends to settle disputes more amicably	In practice, it is seen that this remains a costly and timely practice	C - EPC - S	4.1, 4.7
[8] Early warning notice (EWN)		• Entails that early warning should be given when changes occur on the project • This reduces the risk for the entire supply chain since early action can be taken to mitigate risk • Consequences of risk are minimized	Based on co-operation and trust. In practice, it is seen that this is not always adhered to.	C - EPC - S	4.7, 5.1

5.5 The 'market approach'

According to interviews conducted, there are two main contracting strategies that can be pursued in the context of EPC projects, both of which fall under the umbrella of the "market approach." These two strategies are labeled as traditional and collaborative. While both are aimed at achieving successful project delivery, there are some significant differences between them.

The traditional approach, also known as the competitive approach, is the most commonly used contracting strategy in EPC projects. This approach involves allocating risk linearly, with the EPC contractor transferring risks downstream to subcontractors. The subcontractors, in turn, often mirror the clauses in the prime contract, which can create a win-lose situation. This is because one party is allocated to manage the risk, while the other parties are protected from it. This approach can also lead to disputes and ongoing claim negotiations, which can create an aggressive claim culture. In addition, large and complex EPC projects often subcontract smaller subcontracting firms, which may not have the resources or capabilities to take on the risks allocated to them. This can lead to disproportional risk allocation and create further complications.

On the other hand, the collaborative approach is a relatively new and innovative contracting strategy that emphasizes collaboration among stakeholders. This approach is aimed at creating a win-win situation for all parties involved. The collaborative approach is a broadly used term and is not concretely defined in contractual terms. Instead, it is a mindset that focuses on availing benefits for all parties involved. Terms like "collaboration model" and "partnership model" are often used interchangeably when discussing the collaborative approach. Despite the interest in the collaborative approach, implementation remains low in EPC projects. The interviews revealed that the collaborative approach is mainly seen in publicly initiated infrastructure projects.

Overall, the market approach defines how rewards and risks are shared among stakeholders in EPC projects, which indicates that the market approach plays a crucial role in determining the risk allocation. Table 5.4 summarizes the differences between the traditional and collaborative approaches.

Table 5.4: Overview of the non-contractual clause: Market Approaches [based on results from literature and exploratory interviews].

	Non-contractual clause	Theory and exploratory interview results	In practice
Market approach	Traditional	**Characteristics** 1. Opportunistic behaviour 2. Top down decision making 3. Linear risk allocation **Culture** • Aggressive, distrustful • Claim orientated • Win-lose	Often seen in EPC projects initiated by private clients
	Collaborative	**Characterisitics** 1. Information sharing 2. Joint decision making 3. Risk and reward sharing **Culture** • Cooperative • Innovative • Win-win	Not seen in EPC projects, however it is more often seen in other sectors such as infrastructure projects (public client)

5.6 The supply chain network

As mentioned in section 4.3, the nature of the supply chain can be understood through linear dyadic relations or rather as a network of relations. According to interviews, practice, and literature agree on the network perspective of the supply chain. In practice, it is found that the supply chain of EPC projects is to some extent regarded as a network. This is due to the dynamic nature and interconnections between actors, which creates constant influences and changes on the network. All parties have influencing power, and each position in the network has a certain effect on allocating the risks between them. No elements are isolated in the structure. The tasks and responsibilities of one actor have an effect on the remaining parties in the network and are not limited to a dyadic relation with the EPC contractor.

However, a linear nature of risk allocation can be seen in the contracting strategy. Internal documents within the Company state that the "risk should be allocated to the party who is in the best position to manage or estimate the risk and deal with it". The internal documents refer to supply chain risk management, however, this management does not specify the network relations found in the supply chain. This proposes a single party being able to take on the risk, resulting in a supply chain where risks are either for the client, the EPC contractor, or transferred to one of the subcontractors. A linear approach to finding the most appropriate risk bearer in the project. When transferring the risk to a subcontractor, the EPC contractor is to a certain extent 'saved' from the occurrence of this risk. However, in practice, this is not the case. When looking at the supply chain as a network, transferring the risk towards another party does not isolate other parties from this risk, as all parties are interdependent. Therefore, it can be said that a network risk allocation is lacking, where parties are part of the consequences of this transference.

5.7 EPC characteristics

Understanding the specific characteristics of EPC projects is crucial because they can result in various risks. These characteristics are inherent to EPC projects and have been identified in subsection 4.1.3 by Sadeghi et al. [2016]. However, these characteristics have not been validated by other literature sources, making it important to verify them through expert verification. In discussions with experts from the Company, it was discovered that a key characteristic of EPC projects was missing from existing literature.

5.7.1 Re-phrasing EPC characteristics

The findings from literature were to a large extent recognized by the interviewees. The 1) inter-dependence of activities, and 2) overlapping of tasks/ phases are both recognized as inherent EPC characteristics. However, when regarding the 3) work fragmentation and the 4) complex organizational structure, the discussion led to the conclusion that these can best be labeled as 'challenging scope boundaries'.

- **Inter-dependencies of activities:** these exist due to the dependencies of different 'commodities' on other tasks. The interviews found that the inter-dependency is highly affected by the dynamics of EPC projects, and makes the dependencies quite complex.
- **Overlapping of tasks/ phases:** it can be seen that phase overlapping plays a large role in these projects, as tasks are being fast-tracked and commodities working simultaneously.
- **Challenging scope boundaries:** the challenging scope boundaries within EPC contracts create complex settings, where a patchwork of different contracts is set up, creating a difficult organizational structure. This can create unclear responsibilities of work for different parties.

Additionally, the interviews detected 'client interferences' as an important EPC characteristic, which can be a large cause for project risk.

- **Client interferences:** When looking at the bigger picture of the supply chain structure, as shown in Figure 5.1, the question remains; how do the risks trickle down from EPC contractor to a subcontractor? It all starts with the client. According to an interview with a risk expert from within the Company, the risks within EPC are inherently taken on by the client of the project, and eventually flow down the supply chain, in which certain parties accept certain parts of these risks. Depending on the terms and conditions between the client and EPC contractor, the client may interfere in the subcontractor selection process, leading to potential overruling decisions by the client, and even the cheapest selection of subcontractors by the client. This depends on the selection process being on 'contractor paper' or 'client paper', which defines who can be involved in the selection process. Therefore, if the selection process is on 'client paper', the client has an influence on the decision-making, which causes risks that are actually felt by the EPC contractor. The EPC contractor is still liable for a certain portion of the risks that occurred by the client's interference in decision-making. This is relevant for all key decision-making, such as the approval of documents and claims which need to be assessed. The interference of the client is also relevant in the payments made by the client to the contractor and subcontractors. The entire project execution is dependent on financial input from the client since money is needed to execute the project. Even though, this research focuses on risk allocation between EPC contractor and subcontractors, the relation between EPC contractor and EPC subcontractors cannot be seen in isolation, and link to the relation to the client.

These EPC characteristics stem from the dynamic nature of EPC projects, with a constant movement in overlaps, inter-dependencies, scope boundaries, and client interferences, which in turn creates complex and challenging projects.

5.8 Discussion: comparing theory to practice

In this section, the theoretical findings (chapter 3 and chapter 4) and the practical findings through exploratory interviews and document review (chapter 5) are compared and discussed.

5.8.1 Linking EPC risks and EPC characteristics

The EPC risks are summarized in Table 5.2, which demonstrates the final 25 key risks found in EPC projects. These 25 risks within the execution phase of EPC projects are concluded from a literature study, in combination with exploratory interviews. Additionally, literature and exploratory interviews concluded that there are four main characteristics of EPC project identified; 1. inter-dependencies of activities, 2. overlapping of tasks/ phases, 3. challenging scope boundaries, and 4. client interferences. These EPC characteristics enhance the risks found in EPC projects. Therefore, the link between the risks and characteristics in EPC projects is made, by identifying which characteristics have an influence on which risks. In Table 5.5, it can be seen which risks are caused by either, 'I', the inter-dependencies of activities, 'O', the overlapping of tasks/ phases, 'S', the challenging scope boundaries of the project, or 'C', the interferences of clients in the project.

The characteristics can be seen as enhancing factors for the risk which play a role in EPC projects. For example, risk 4.6 'choosing of wrong subcontractors', can be increased by the interference of the client (characteristic C), seeing as they have the choosing power to choose the cheapest rather than the most experienced subcontractor. However, there may be other factors that cause the wrong subcontractors to be chosen, such as 'little information available on the subcontractor's performance', or 'scarcity of subcontractors with the needed expertise'. Since the external risks are risks that are not limited by the boundaries of EPC projects, the external risks are not related to the EPC characteristics, but rather to the characteristics of projects in general. These risks are not related to the engineering, procurement, or construction of the project, but are caused by factors outside of the EPC scope. Yet, the internal risks are increased by the characteristics of EPC projects, which enlarges these risks compared to these risks eventuating in construction projects in general. A complete explanation of the links between the risks and the characteristics can be found in Appendix D.

It can be concluded that the characteristics of EPC projects play a large role in the risks seen in these projects. All the internal risks found within EPC projects can be related back to one or more of the characteristics of the EPC projects. This is relevant because by understanding what characteristics increase the risks in EPC projects, the risks can be dealt with more effectively.

This concludes that the main characteristics of EPC projects can increase the majority of the risks found within EPC projects.

Table 5.5: Risks in EPC project linked to the characteristics of EPC projects [illustrated by the author]

	Categories	**no.**	**Risks**	**Characteristics**			
				I	O	S	C
External	*1. Geo-political risks*	1.1	Bureaucratic problems				
		1.2	Force majeur (earthquakes, etc.)				
		1.3	Changes in law and regulations				
	2. Economic	2.1	Inflation of prices				
		2.2	Shortage in amount of available skilled labour				
		2.3	Shortage in available resources				
Internal	*3. Administrative*	3.1	Delayed payment by the client and the EPC contractor				X
		3.2	Failure in information flow (documents)		X	X	
	4. Contractual and procurement	4.1	Disputes between parties	X			X
		4.2	Contract design fault		X	X	
		4.3	Vagueness in contract and scope of parties			X	
		4.4	Delays by vendors			X	
		4.5	Change order negotiations			X	
		4.6	Choosing of wrong subcontractors				X
		4.7	Claims from subcontractors			X	
		4.8	Client interference in key decisions				X
		4.9	Purchasing miscommunications between subcontractors	X	X	X	
	5. Execution	5.1	Insufficient site information		X		
		5.2	Change orders in design		X		
		5.3	Non compliance and poor enforcement of HSE requirements		X		
		5.4	Lack of proper construction techniques				X
	6. Project management	6.1	Lack of coordination and communication between contracting parties		X		
		6.2	Lack of interface management by EPC contractor or subcontractors		X		
		6.3	Subcontractor performance / quality failure	X			
		6.4	Tight project schedule		X		

5.8.2 Linking EPC characteristics to the network supply chain

EPC characteristics were identified through literature and interviews, resulting in four main characteristics that can enhance the risks in EPC projects (see subsection 5.8.1). Moreover, EPC supply chains can be viewed as "networks", which are represented by elements such as dynamic relationships, inter-dependencies between actors, and complex organizational structures. Dynamic relationships refer to the ever-changing interactions and connections between actors in the supply chain, inter-dependencies involve actors relying on each other for resources and information, and complex organizational structures involve many actors operating in the network, who are all related to one another.

There is an overlap between the EPC characteristics and a 'network'. Figure 5.4 demonstrates that the large inter-dependencies of activities within EPC projects are also seen in networks, as there are dynamic relationships and high inter-dependencies between actors in a network. Additionally, the overlapping of tasks and phases, referring back to the fast-tracking of projects, creates dynamic relations between the different tasks and people involved, which are represented in a network structure. This additionally creates complex organizational structures. The challenging scope boundaries of EPC projects create dynamic relationships and complex organizational structures within the project, which can be represented in a network. Finally, client interferences can cause dynamic relationships between actors, inter-dependencies between actors, and a complex organizational structure. Client interferences can cause the relationships between actors to change over time, depending on the client's needs and wishes. Furthermore, the interferences of clients in an EPC project cause a certain inter-dependency between the client, the EPC contractor, and the subcontractors. Finally, client interferences create a complex organizational structure since these interferences can create complexity in information sharing and decision-making within projects.

These links made between the EPC characteristics and a network representation demonstrate that EPC projects and their supply chain are best treated as a network, rather than a linear process. Therefore, it is concluded that a network approach can provide a more accurate representation than a linear approach in the risk allocation process within the EPC projects.

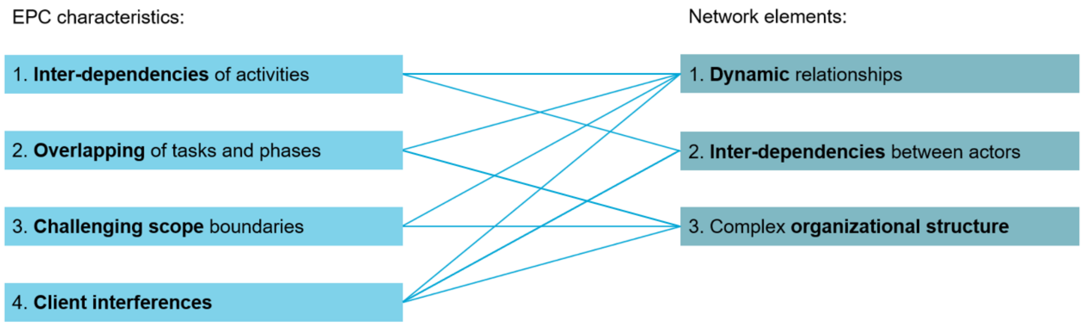


Figure 5.4: Linking the characteristics of EPC projects to a network [illustrated by author].

5.8.3 Knowledge gap in '*network* risk allocation'

Even though many researchers agree on considering the supply chain as a network, little research is available on the allocation of risks within a supply chain network. Risk allocation is seen as a linear process, where the risks are divided between (EPC) contractor and subcontractors, creating dyadic divisions between two parties. Baker et al. [2020] mentions that a construction contract, including the allocation of the risks involved, involves three main elements, namely "the asset that is to be constructed by the contractor, the time at which the asset must be completed by the contractor, and the amount the employer is obliged to pay the contractor". This insinuates a linear risk allocation between the stakeholders, seeing as the contractual agreements are made by one party with another party. Referring back to the risk management process seen in Figure 3.2, Mubin and Mannan [2013] states step 7 as "deciding on the risk mitigation strategy". The mitigation strategy to transfer the risk to another party involves a dyadic relation, where the risk is moved towards another party in the supply chain. Transferring the risk from EPC contractor X to subcontractor Y means that the risk is now in the hands of subcontractor Y, implying that other parties within the supply chain are somewhat 'saved' from that risk. However, if the supply chain is seen as a network, this risk transference would consequently affect the rest of the supply chain, seeing as the inter-dependence of the subcontractors is a key characteristic of EPC projects. This idea of a *network* risk allocation within a supply chain, rather than linear relations, is seen as a knowledge gap.

This concludes that in literature, supply chains are regarded as a network, whilst this network philosophy is not reflected back in the risk allocation processes within the supply chain.

5.9 Conclusion and next steps

This chapter focuses on the findings of exploratory interviews with four experts from within the industry, and internal Company documents review. These results aim to validate the literature findings for specifically EPC projects.

The findings from the exploratory interviews and document review have substantially complemented the results from the literature research. New insights have been added to the literature results, creating a more conceptualized understanding of EPC projects. An important conclusion of this chapter is the contracting strategy elements seen within the EPC projects. The contracting strategy elements typically cascade down from the prime contract (upstream contract) to the subcontracts (downstream contract) in EPC projects, because this allows risks to be transferred. For the next phase of this project, the contractual clauses found in literature and through interviews are bundled, creating a total of 8 contractual clause categories. These are summarized in Table 5.3. These contractual clauses are implemented in order to allocate a risk towards a certain party, a linear transferring strategy used in most EPC projects. By defining these contractual clauses, the contract can either lean towards a traditional or collaborative approach. In EPC context, this is referred to as the chosen 'market approach'.

Finally, a discussion on the findings from chapter 3 and chapter 4, with the findings from chapter 5 is provided. This section links the EPC characteristics to the risks found in the EPC projects, in order to understand what effect these characteristics of EPC projects have on risk. Additionally, it is found that to deal with the characteristics of EPC projects, the project and supply chain can most accurately be regarded as a network. This brings the conclusion that a *network* risk allocation is therefore most suitable for the risks within EPC projects, however, this *network* view of risk allocation is lacking within literature and practice. Therefore, the following chapters will test if the network risk allocation is seen in practice, by studying the risk allocation of two distinct case studies. Furthermore, it is researched how a network approach can be implemented in order to contribute to a more effective risk allocation in this supply chain network.

These main findings of phase 1 will function as the foundation for the following chapters. The following chapter, chapter 6 explains the methodology for the qualitative research design. This qualitative research design provides research guidance for the Case Study analyses in chapter 7.

6 Qualitative Research Method

This chapter explains the qualitative approach to gathering and analyzing the empirical data for this study. The qualitative research entails the analysis of two case studies. The data gathering method of these case studies is two-fold, through document analysis and semi-structured interviews. This chapter is structured by first explaining the set-up of the case study research (section 6.1), and continues by explaining the data collection of the research (section 6.2). Thereafter, the final section summarizes the scope of the two case studies (section 6.3).

6.1 Set-up of the case study research

This research uses case study methodology in order to gather qualitative data, and have an in-depth understanding of the subject in question. Case study analyses are a popularly used research methodology in qualitative and quantitative research. It is a research method that is described by Heale and Twycross [2018] as an "intensive, systematic investigation of a single individual, group, community or some other unit in which the researcher examines in-depth data relating to several variables". Researchers describe how case studies look into the complex phenomena of cases, and allow for a further in-depth understanding of these cases [Yin, 2003; Hamel et al., 1993]. The case study methodology is chosen as it "serves to provide a framework for evaluation and analysis of complex issues" [Heale and Twycross, 2018], which is valuable in understanding the contracting strategies of the case studies.

For this research, the case study methodology is used to gain qualitative data on two projects, also referred to as cases. These projects are both completed by the Company and are chosen on the basis of specific case study criteria. These two case studies are used to research the risk allocation strategy within EPC projects. The analysis is divided into two data-gathering methods, namely document analysis and semi-structured interviews (see section 6.2).

6.1.1 Objective of case studies

In this research, the aim is to identify the effectiveness of risk allocation in EPC projects. On one hand, the case studies are meant to gain insight into the nature of risk allocation within EPC projects. These risk allocation strategies can have a more linear approach or a more network approach. On the other hand, the case studies can provide insight into what effects this risk allocation has on the project performance, in order to identify where improvements can be made in risk allocation.

6.1.2 Selection of case studies

The selection of the case studies which are analyzed is based on a few criteria. Firstly, the case studies must be EPC projects, whereby (partial) engineering, procurement, and construction are completed by the EPC contractor. This criterion is important since many risks within projects stem from the responsibilities that lay with the parties involved. Once the responsibilities change, the risk perspectives within the supply chain change. This research scope is within EPC projects and their risks. Secondly, the two case studies are selected based on the phase in which they are currently operating. This research is focused on the allocation of risks within the execution phase, therefore, the two case studies must be in the execution phase, or have reached construction completion. Thirdly, the case studies are chosen on the bases of their business group within Fluor BV. Selecting two projects which operate in similar business groups (or industries) gives a more accurate understanding of the risk allocation used within this industry. The case studies are selected from the Life Sciences and Technology business group. Lastly, the two case studies were chosen on the level of knowledge and data availability, in order to attain a thorough case study analysis. Enough data and knowledge have to be available for the research to be in-depth and valuable.

The selected case studies will be analyzed through document analysis and semi-structured interviews. This selection procedure has led to the selection of the following cases:

Table 6.1: Selection of case studies.

Code	Industry	Project phase	Project description
CS1	Advanced Technologies and Life Sciences	Project completion	Data centre
CS2	Advanced Technologies and Life Sciences	Project execution	Pharmaceutical manufactory

6.1.3 Analysis of case studies

The analysis of the case studies aims at answering subquestion 4, and therefore the analysis identifies both the contracting strategies used and the effect of these contracting strategies on allocating risks within the supply chain. The analysis is separated into a within-case study and a case study comparison.

In the within-case study, both case study results are described separately, to demonstrate an in-depth exploration of every single case. This demonstrates the data collection per case, in order to gain a profound understanding of the project's prime contract, supply chain structure, project risks, and contract strategy elements. These projects are of complex nature and come with high amounts of data. This data has been analyzed for a thorough understanding of the projects, however, due to the confidential nature of the projects, certain information is anonymized in this research paper.

The case study comparison demonstrates the differences and similarities in the contracting strategy elements of the two cases, to understand how the different project structures lead to different project outcomes. The case study comparison presents the contract strategy elements for each case, and an overall understanding of how the contract strategy is pursued in EPC projects.

6.2 Data collection

6.2.1 Document analysis

This section explains the first method for collecting data on the case studies, namely document analysis. Bowen [2009] defines document analyses as "a systematic procedure for reviewing or evaluating documents— both printed and electronic material". Other researchers explain that document analysis involves examining and interpreting the data, in order to create meaning, develop understanding, and gain empirical knowledge on a topic [Corbin and Strauss, 2008; Rapley, 2007].

Objective of document analysis

The objective of the document analysis is to provide a profound background understanding of the chosen projects. The background understanding includes understanding the scope of the projects, namely, the description of activities, the location of the project, the project phase, and the initial project schedule. Furthermore, the objective is to understand the specific contractual clauses used in the projects, in order to allocate risks within the supply chain. The contractual clauses serve as a statement that can then later be discussed within the interviews. Therefore, the documents which are analyzed can function as a basis for the specified questions during the semi-structured interviews.

Selection of documents

The selection of documents used for the document analysis is dependent on the availability of documents per case study. These documents are internal Company documents. The documents which are analyzed include, but are not limited to; the project scope description, the organizational charts, the prime contract between the client and the Company, the general subcontract between the Company and the subcontractors, and documents containing contract strategy information. A complete list of the used internal documents can be found in Appendix B.

Document data analysis

The document analysis entails skimming, reading (thorough examination), and interpretation of the selected relevant documents which are available on the project. As Bowen [2009] explains, document analysis is an iterative process, whereby elements of content analysis and thematic analysis are combined. The content analysis includes organizing and structuring information into categories that help answer the research question. The thematic analysis aims at recognizing a pattern in the data that has been collected and linking the data to certain emerging themes [Fereday and Muir-Cochrane, 2006]. This thematic analysis involves a more in-depth reading and review of the collected documents, to identify the themes which are recurring in the documents. This allows for codes to be linked to the collected data and to uncover the themes which are recognized in the documents. Since this document analysis is supplementary to the semi-structured interview research method, the same themes are defined in both research methods.

The themes and codes were based on a combined technique of inductive and deductive analysis. The deductive approach involves the theory that is applied to the data and is often referred to as a “top-down” approach to data analysis [Bingham, 2022]. Therefore, predetermined codes based on the theoretical background findings are applied to the data. On the other hand, inductive analysis ”is a more emergent strategy, where the researcher reads through the data and allows codes to emerge/names concepts as they emerge” [Bingham, 2022]. This is referred to as a “bottom-up” analytic strategy.

The deductive analysis lead to certain themes and codes which emerged from the theoretical background findings, such as the theoretical framework of contracting strategy elements (see Table 5.3). The themes which emerged from the theoretical data were the following:

1. Execution risks
2. Contracting strategy elements
3. Linear and network risk allocation
4. Traditional market approach
5. Collaborative market approach

These themes relate back to the finding in chapter 3, chapter 4, chapter 5. From these themes, the document analysis predominantly provided findings for ’Theme 2. Contractual clauses’. The information gathered from the document analysis is structured based on the themes mentioned above. Information regarding ’Theme 2. Contractual clauses’ was mainly found in contractual documents, such as prime contracts and subcontracts. Within these documents, the information was structured by codes. These codes were assigned on a ”top-down” approach, namely by the results of the contracting strategy elements presented in Table 5.3. Codes are assigned to the different contracting strategy elements, such as [1] Price arrangement, [2] Liquidity terms, [3] Milestone completion, [3.1] Incentives, [3.2] Penalties, and so forth. The case study contracting strategy elements were structured using Microsoft Excel, in order to create an overview of the certain texts found in specific contracts, and assigned to a certain code. The bottom-up approach was also used, as different contracting strategy elements were found in the document analysis. This includes the code ’schedule planning’. Appendix B demonstrates which documents were reviewed per theme.

The themes and codes are applied for both the document data analysis and the semi-structured interview data analysis. The other codes which are used in the analysis are further elaborated in subsection 6.2.3.

6.2.2 Semi-structured interviews

The semi-structured interview method is supplementary to the case study analysis. Three types of interviews can be applicable for conducting interviews, namely structured, semi-structured, and unstructured

[Bolderston, 2012]. In contrast to structured interviews, which focus on pre-determined, close-ended questions, semi-structured interview questions additionally include open-ended questions. This allows for the questions to provide a light structure, however, they leave the possibility for rephrasing, or reformulating the questions in response to the answers by the interviewees [Onencan, 2013]. Semi-structured interviews are a popularly used method for qualitative data collection and are used in this research since the method allows more openness for new insights during the interviews [Onencan, 2013]. Depending on the answers by the participants, certain additional questions can be asked to have a more in-depth understanding of the theme.

Objective of semi-structured interviews

The objective of the semi-structured interviews is to get a thorough understanding of the contracting strategy used in EPC projects, with regard to risk allocation. The document analysis provides a profound understanding of the documents in place to define the contracting strategy, however, the semi-structured interviews will address questions such as 'why' certain decisions are made and 'what' effect this has on the performance of the projects. The interviews also aim to understand the opinion of both the EPC contractor as well as the subcontractors' side regarding the risk allocation in EPC projects. The interviews substantiate and complement the findings from the document analysis.

Selection of interviewees

The interview selection is based on the two chosen case studies, which are identified in Table 6.1. All participating interviewees have either been involved in CS1 or in CS2, in order to ensure their knowledge of the projects. The involved stakeholders within these projects are the client, the EPC contractor, and the subcontractors. It has been chosen not to involve the client in the interviews, for two main reasons. Firstly, the scope of this research focuses on the downstream risk allocation between EPC contractor and subcontractors. Additionally, the chosen projects remain in a sensitive project phase, which makes talking to the client about risk allocation a sensitive topic. Thus, the selection of interviewees does not include the client but is limited to professionals from the EPC contractor side, as well as the subcontractor side. Due to the sensitivity and confidentiality of the case studies, only one subcontractor could be interviewed.

The EPC contractor side involves professionals within three departments, in order to attain a holistic understanding of the case studies and different perspectives on the topics discussed. These departments include Contract Management, to have an understanding of the contracting strategies and the contractual clauses involved, Project Control and Change professionals, to provide insights on the project performance, and what effects the risks within the project have on the performance of the projects, such as schedule and cost. Thirdly, the Project Management department can provide an overall view of the project, with regard to most disciplines and other stakeholders. Additionally, these high-level departments are occasionally in contact with the client, and can therefore provide certain insights into client perspectives. When a certain position within the project cannot be interviewed, the next best alternative is chosen based on the availability and expertise of the expert. The list of interviewees can be seen in Table 6.2.

Table 6.2: List of interviewees for the semi-structured interviews.

Code	Function	Company	Work experience	Case study	Duration
I 1	Change Manager	Fluor BV	+15 years	Case study 1	1h10
I 2	Project Director Supply Chain	Fluor BV	+30 years	Case study 1	1h15
I 3	Prime Contract Manager	Fluor BV	+30 years	Case study 1	1h20
I 4	Project Director	Fluor BV	+20 years	Case study 1	1h05
I 5	Project Controls	Fluor BV	+8 years	Case study 2	1h00
I 6	Director Supply Chain	Fluor BV	+30 years	Case study 2	1h10
I 7	Project Controls Manager	Fluor BV	+30 years	Case study 2	0h45
I 8	HSE Manager	Fluor BV	+20 years	Case study 2	1h00
I 9	Process Manager	Subcontractor	+20 years	Case study 2	1h10

Interview protocol

The interview protocol guides the process of conducting the interviews. This includes three main steps, namely pre-interview, at the start of the interview, and post-interview.

The pre-interview protocol includes the steps taken prior to the actual interview date. In this step, the interviewees are provided with the informed consent form, to ensure that the data collection method is clearly explained and approved by the interviewee. Additionally, a summary of the research objective and problem description is provided, to introduce the interviewee to the research topic. The interviewee is provided with the interview themes, in order to have an idea about the interview discussions that will take place. Furthermore, the interviewees are asked to fill in a pre-interview document before the start of the interview. This document asks them to share their years of experience within the industry, and their role within the project. Furthermore, this document asks the interviewee to rate the performance of the project on the basis of the five project performance criteria. A five-point Likert scale was used, allowing the interviewee to score the performance criteria ranging from (1) "strongly disagree" to (5) "strongly agree". This document can be found in Appendix E.

Furthermore, at the start of the interview, a recap is given regarding the objective of the interview, and the interview themes. Additionally, the confidentially of the interview results is shortly discussed, and verbal permission to record the interview (audio) is asked. If the interviewee does not approve audio recording, the interview is captured by taking notes as accurately as possible. This was followed by asking the interviewee for a short elaboration on their role within the project. After understanding the role of the interviewee, the interview questions were asked, based on five main interview themes. The interview themes are identical to the five themes used in the document analyses (see subsubsection 6.2.1). The interview questions and their corresponding themes can be found in Appendix E. The interview questions are phrased accordingly to case study 1 or case study 2, seeing as the questions are based on the document review findings per case study. For example, case study 2 Q5 discussed the incentive-based clause in the prime contract, however, case study 1 does not have an incentive-based clause, and therefore, the question is changed for case study 1. Furthermore, some questions differ for the EPC contractor side, versus the subcontractor side. For the subcontractor interview questions, various questions are phrased more specifically toward the effects of that specific subcontracting company. For example, Q12 for the subcontracting party asks "How did clause 12 regarding delays affect your project performance as a subcontractor?". In total, this comes down to four different sets of interview questions, based on the same five interview themes.

The interviews are closed off by thanking the interviewee for their participation, and explaining that the results will be transcribed and shared digitally. The interviews were planned to have a duration of about 60 to 80 minutes.

6.2.3 Data analysis

The data analysis of the semi-structured interviews takes on a similar approach as for the document analysis explained in subsubsection 6.2.1. The data analysis is used to bring order to all the data which is collected, create a structured overview, and find meaning in the data which is collected. This process for the semi-structured interviews is supported by ATLAS.ti, which is a qualitative analysis software tool used to structure the data collection. The system allows codes to be assigned to the interview themes in the documents. The documents which are uploaded in the software are the interview transcripts. As explained in subsubsection 6.2.1, both deductive and inductive analysis is used.

Firstly, the data from the nine semi-structured interviews were prepared, which entailed transcribing the interviews, familiarizing them with the collected data, and uploading the interviews into the Atlas.ti software. The second step was reading through the interviews, and assigning codes to the quotations which seem relevant to the research. The themes for the codes are identical to the document analysis and are based on the themes used in the interview questions. Within these themes, certain codes were assigned.

The codes were assigned to the different contracting strategy elements listed in Table 5.3, the characteristics of EPC projects, other elements brought in by the interviewees which influence risk allocation, boundary conditions for effective risk allocation, suggestions by the interviewees on improving the risk allocation, and so on. For example, interviewee I1 mentioned "So it's all about managing characters as well", and interviewee I3 stated "I think the terms are OK, but you need to work in a trust environment". These statements both explain the importance of relationships, based on characters and trust, so they are given the code "Relationships". Interviewee I4 mentions "But this is a method that was chosen and carefully pushed downwards to the subcontractors. So there was a clause that the 'contractor for a change will get paid if the Company gets paid'. An if paid when paid clause", which was then labeled by the code "Back-to-back risks". Furthermore, findings that were specific to a certain case study, such as contracting price arrangements, were specifically labeled to that case study. An example is the code "Case study 1: Price arrangement", which included the quotations that specifically referred to the price arrangement of case study 1. Therefore, the code for price arrangement counts twice; one time for case study 1, and one time for case study 2. This was done so that the results per case study were easily traceable. The steps taken for the data analysis are demonstrated in Figure 6.1.

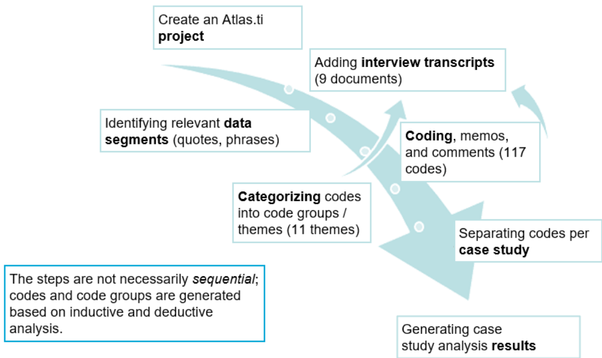
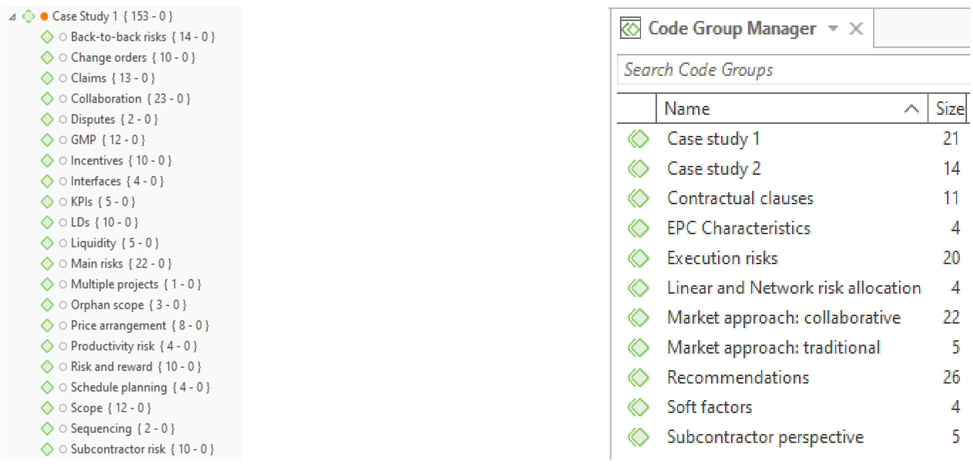


Figure 6.1: A visual describing the steps for analyzing the case study data in software Atlas.ti [illustrated by author].

A total of 117 main codes were generated from the analysis, which were categorized into 11 code groups based on the interview themes (inductive and deductive reasoning) (see Figure 6.2). A summary of all the codes created for the 9 interview documents can be found in Appendix F.



(a) A screenshot of the codes (CS1) created in Atlas.ti. (b) A screenshot of the 11 code groups created in Atlas.ti.

Figure 6.2: Two figures demonstrating the codes and the code groups created for the data analysis in Atlas.ti.

6.3 Scope of case studies

The scope of the case studies is explained in this section. Both case studies are part of the Life Sciences and Technology business group, whereby case study 1 is a data center, and case study 2 is a pharmaceutical manufactory. It is important to note that the case studies are confidential projects, which means that the cases are anonymized.

6.3.1 Case study 1

The project was initiated by a private Client, who is operating in the data center sector. The project has been completely executed and is currently in operation. The project includes the building of a data center in Europe, and is part of a larger program of projects initiated by the Client. This means that when the project is completed *successfully*, EPC contractor and subcontractors have a chance of continuing on to the next data centre project.

The purpose of these data centers is to store and process data. The building of data centers was a first-of-a-kind project for the Company. This is important to note because the Company was new to this market of data centers, which created risks in itself. The data center market is a hot market, creating the fast-track nature of this project. With the Corona epidemic, everyone went to work remotely, and the infrastructure demand for data centers changed overnight. In those conditions, it is a seller's market, where time is money from the client's perspective, as data centers start producing money once they operate. This creates a large demand for on-time delivery in these projects. The project did not define KPIs between the Client and EPC contractor, nor the subcontractors. The project first intended a form of collaboration model with the subcontractors, however, this was not pursued.

The Company was responsible for all pre-construction and other services, labor, materials, supplies, appliances, tools, equipment, and supervision and is expected to complete the Work as defined in the contracts. The works were subcontracted to various subcontractors to complete the indirect and direct works.

Essentially, these data centers are large warehouses, which are supplied with high levels of power, large cooling systems, and many computers. Within the Company business groups (see Figure 1.1), the project falls under the 'Advanced technologies and life sciences' group.

The project is a multi-million dollar investment and has incurred various challenges in the construction and management of the project. The data center is a two-story steel and concrete building and includes data halls on both levels, various offices, and electrical rooms. Furthermore, one of the main components of a data center facility is the cooling system. The project can be divided into three main elements, namely the data center, the central utility building (CUB), and the cooling towers.

The large scope of this project has led to a large number of subcontractors being issued for the construction works. These subcontracts are issued on 'Company paper', meaning that the subcontracts are drawn by the EPC contractor. On a technical basis, this project is not seen as technically complex, however, due to many different factors, the execution turned out to be quite complex.

6.3.2 Case study 2

Case study 2 is a pharmaceutical manufactory project initiated by a private Client in the pharmaceutical industry. The project is currently at 70% through construction and is being built in Europe. Much like case study 1, this project is also part of a larger program of pharmaceutical projects initiated by the Client. Once this project meets the objectives and desires of the Client, the supply chain members will have the chance to continue on to the next project in the program.

The project includes the construction of a pharmaceutical facility, to produce and operate different types of drugs. Essentially, the pharmaceutical facility is a box, and the complexity of installations and construction is found within the box. This facility can be used by blue-chip pharmaceutical clients, who produce different sorts of medicines. First of all, it's important to realize the specialist nature of the biotechnology industry. This automatically creates a limited pool of qualified contractors, fabricators, suppliers, and vendors that can actually support the delivery of these facilities. Additionally, the pharmaceutical construction is extremely time sensitive, for the reason of beating the pharmaceutical competitors to the market with the product. It is an extremely condensed market, where the pressure for on-time delivery is high. This creates a so-called hyper-track project, which is even more time-sensitive than fast-track projects. Therefore, the construction of the pharmaceutical manufactory is almost parallel to the design of the manufactory, creating a very high-risk position. This demonstrates the importance of time as a performance indicator.

This pharmaceutical manufactory is constructed in a flexible nature, to be able to produce different medicines over the years. The design of the manufactory is made such that it can be cloned and therefore replicated at different locations with the same design. This allows the Client to be able to adapt to altering future needs in the pharmaceutical industry. This is a very unique industry, where the data of such projects can quite easily be distilled back to a cost per square meter of the floor area. This is a crucial element for construction management to be able to calculate the works of the direct subcontracting parties. Essentially, the building of a manufactory entails that all these manufactories over the world are almost identical, which makes the data on these buildings very repeatable. This means that with limited engineering complete at the start of construction, it is still possible to construct, seeing as the work is measurable back to one square meter of floor area. This project falls under the 'Advanced technologies and life sciences' group of the Company business groups (see Figure 1.1).

Within this project, 5 KPIs were set between Client and Company, namely cost, schedule, HSE, client satisfaction, and non-interruption. These KPIs were linked to an incentive model for the Company, however, subcontractors were excluded from this model. Furthermore, the project intended a collaborative model with the subcontractors, but this was eventually not pursued.

6.3.3 Similarities between the case studies

- The business line for both cases is "Life Sciences and Technology", whereby case study 1 entails the construction of a data center, and case study 2 entails a pharmaceutical manufactory.
- Both case studies entail construction designs that are in essence cloneable in design. The construction of the facilities for both data centers and pharmaceutical facilities is repeatable.
- The technical complexity of the projects is inside a "box" since the installations inside the facilities contain the most critical construction elements. This entails the Mechanical and Piping and the Electrical and Instrumentation commodities in the direct subcontracted works.
- Both projects are highly time-sensitive. They are referred to as fast track projects, and even as hyper track projects, for the reason of competing competitors to the market. This originates from a commercial standpoint from the Client. The Client's top priority is starting 'production/operations' of the facility.
- Both cases intended to implement a collaboration model (Integrated Project Delivery), however, this was not pursued.
- The level of engineering at the time of construction is low, where the contracting of subcontractors starts at 20% to 30% of engineering.
- The EPC Company, Fluor, is for both projects responsible for the contract management of the project. This entails interface management and coordination.
- Certain elements of the engineering and design in these projects are completed by a third party. This means that engineering is not fully in the control of the EPC contractor, creating fragmented responsibilities.
- Both projects are part of a larger program. Once these projects have been completed *successfully*, the EPC contractor and subcontractors are likely to continue on in the following project(s) which is/are part of the Client's program.

7 Case Study Results

This chapter explains the results from the data collection of both case study 1 and case study 2. Thereby, this chapter aims at answering the following question:

Subquestion 4: *Which contracting strategies are seen in different EPC projects, and what effect do they have on project performance?*

For both case studies, the results are presented in the following structure: firstly, the results for case study 1 are presented in section 7.1, whereby the results from the document review are presented. This is followed by the results from the semi-structured interviews. The same structure is used for case study 2 in section 7.2. After explaining the results of both case studies, section 7.3 elaborates on the additional subjects related to collaboration. A summary of the contracting strategy element implications within the projects is given in section 7.4. Furthermore, section 7.5 summarizes the recommendations for an effective risk allocation which were found through the semi-structured interviews. Lastly, the conclusions from the case studies are presented in section 7.6.

7.1 Case study 1

The purpose of this section is to present the findings of case study 1. These findings attempt to create an accurate understanding of the project, however, the findings are not limited to the following aspects of the project. Due to the confidentiality of the project, certain information is anonymous. Therefore, the names of the Client, subcontractors, and other stakeholders are not mentioned specifically. Fluor BV, being the EPC contractor in this project, is referred to as the Company.

7.1.1 Results: Document review

Hereby, the results of the internal document reviews are presented. The document review elaborates on the prime contract agreement, between the Company and the Client. This is followed by an explanation of the supply chain structure in the project, regarding the subcontracted works. Lastly, the findings of the contracting strategy elements are summarized.

Prime contract

Within the prime contract, the Client and the Company agree that the work is to be performed for an amount not to exceed the GMP, and in accordance with the construction schedule. This demonstrates the importance of two specific project performance indicators: cost and schedule. As mentioned in the scope of the case study, the project is keen to be delivered within schedule, seeing as there is a huge commercial benefit for the Client to operate the facility as soon as possible. These types of projects, data center projects, work on the basis of beating competitors to the market and starting operations, seeing as large private Clients financially gain once the project is up and running.

Regarding the price arrangement, the GMP is not a usual price arrangement which the Company works with, however, this was decided upon by the Client. The GMP price arrangement indicates that in no event, the Client is responsible for paying the Company an amount in excess of the GMP. The Client is to reimburse the Company for all materials, labor, and the fee that covers profit, up till the fixed maximum price. This creates a large risk for the Company, as the Client will not pay more than contracted. In essence, this prime contract has set the scene for many risks later on in the project. The GMP meant that only partial funding is released during the execution of the project, which means that the Company did not have control of the money from the beginning. There was a pass-through mechanism, in a "if paid, when paid" clause for the price arrangement. The Client needs to provide full approval for any money spent, when there is no approval, there is no money provided. This was, therefore, a linear and back-to-back payment mechanism. This process is visualized in Figure 7.1.

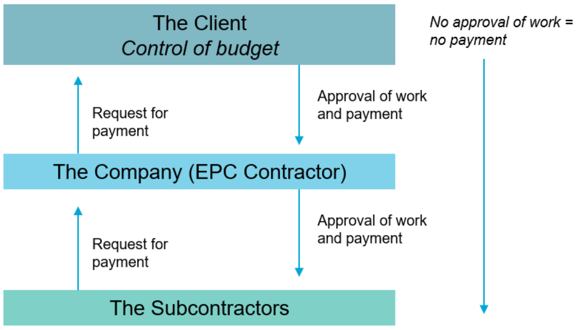


Figure 7.1: A visual describing the process for the Guaranteed Maximum Price arrangement [illustrated by author].

Supply chain structure

The responsibilities within the supply chain are slightly different than in a typical EPC project, regarding the design and procurement. The design of the data center was split under the responsibility of the Client, the Company, and the subcontractors. The Client had its own engineering outfits set, which caused them to pursue certain designs. The Company received these elements of design, progressed with this design, and finally, the subcontractors were responsible for the final detailing of the design, including for example the routing of cables and specific dimensions. The detailed design scope was within the subcontractor scope and this provides that the subcontractors had the best knowledge of design status and quantities. This structure led to fragmented design responsibilities in the execution.

Moreover, the procurement of supplies, such as materials and machines, is not fully the responsibility of the Company, but it is partially outsourced. Depending on the lead times of the materials, the materials have been procured by the Client and the Company, which were typically longer lead and proprietary equipment, or by the subcontractors, typically shorter lead equipment.

The work completed by the subcontractors can be divided into two categories: namely the direct works and the indirect works. More than 20 subcontracts have been issued, of which half are concerning direct works, and the remaining half concern indirect works. Direct works include the works which are directly related to the building of the data centers, such as the piling activities, the underground works, and the mechanical works. The indirect works are not directly related to the building of the data centers, but support the process, such as temporary work facilities, medical services, and security. It is important to note whether the works completed by the subcontractors are direct or indirect since this influences the basis of the contracting strategy element [1] price arrangements. This is explained later on in this chapter.

Figure 7.2 demonstrates the main commodities for direct works in case study 1. The two largest subcontracts, in terms of scope and value, are Mechanical and Piping (M&P) and Electrical and Instrumentation (E&I). The Civil contract is also large, however, this contract was split up into three smaller contracts, namely piling, concrete, and steel. The Civil contract was awarded to one subcontractor, who subcontracted these three works downwards. This created that the Company, being responsible for the contract management, did not have control over these three subcontracts.

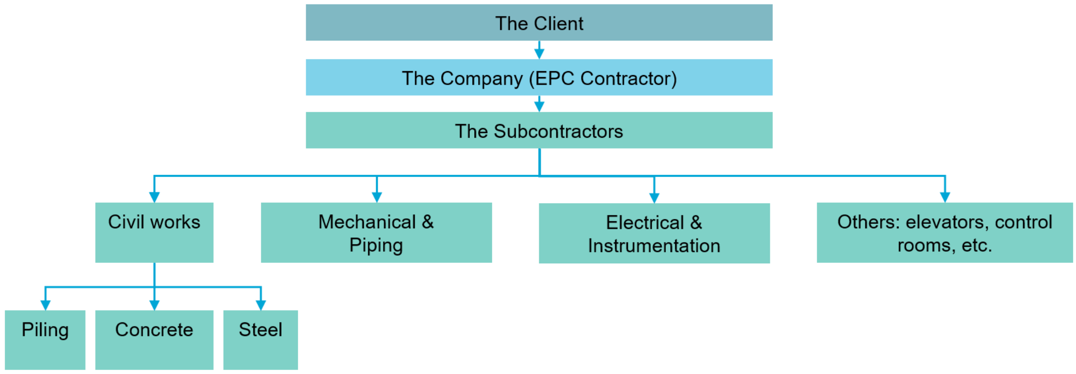


Figure 7.2: A visual describing the commodities for direct works for case study 1 [illustrated by author].

Contracting strategy elements

The contracting strategy elements are summarized in Table 5.3, and have been researched for this specific case study. These contracting strategy elements and the corresponding clauses can create risks within the project. By understanding how the contracting strategy elements have been defined in internal documents, certain risks can be better understood. In various contracting strategy elements mentioned below, reference is made to a back-to-back clause. This means that the clause has almost identically been cascaded down from the Client to the Company, towards the subcontractors. It was 'flown down', on a linear basis. The different contracting strategy elements are explained below:

[1] Price arrangements The price arrangements between the Company and the subcontractors are mainly chosen based on the direct and indirect works of the subcontractors. Overall, the indirect works were completed on a lump sum price, which included the mobilization of resources to the work site, the demobilization of resources to clear the work site of all temporary facilities, the site establishment, and the personnel.

The direct works were contracted under a unit price arrangement, where the quantity risk lies with the Company, and the productivity risk lies with the subcontractor. This is done because the risk of quantity should not be given to the subcontractor, as engineering is not yet complete once construction starts. Without full engineering scope, the quantities of material needed cannot yet fully be defined.

[2] Liquidity terms The liquidity terms for the subcontractor are influenced by the payment terms and the retainage. In case study 1, the payment terms are based on the prime contract, namely the Guaranteed Maximum Price arrangement. The payment terms between the Company and the subcontractors (X) are longer than the payment terms between the Company and the Client (Y), to reduce the risk to the Company. Furthermore, the amount of retention is on a back-to-back basis, and is identical between Client and Company, as for the Company and subcontractors.

The liquidity terms of the contract are influenced by the clause that states that the subcontractor will get paid for a change when the Company gets paid. An 'if paid, when paid' clause. The time for payments to be issued can reach up to X + Y amount of days since it has to be approved by the Company and then by the Client. However, contractually, the subcontractors are obliged to proceed with the works with or without compensation.

[3] Milestone completion The milestone completion dates are contractually linked to LDs in this contract, which has been set back-to-back from the Client to the Company, down towards the subcontractors. These milestone completion dates imply that for not timely achieving the milestone dates, the subcontractor pays an amount for each day of late completion (with a limit to the contract value). The LDs are an estimated price of the actual damages caused by the delay.

Neither the prime nor the subcontracts use incentive schemes for their milestone completion dates.

[4] Insurances Insurances are organized by the Client and set back-to-back for the subcontractors (Owner Controlled Insurance Program).

[5] Warranty The Company provides all warranties to the Client, based on the warranties from the subcontractors. The Company withholds a certain percentage of retention value through the warranty period to ensure that all defects shall, at no cost to the Company, be corrected by the subcontractors. This includes 24 months after the date of substantial project completion.

[6] Change orders and [8] Early Warning Notices (EWN) The EWN process is issued when there is a change, therefore, interchangeably used with change orders.

The EWN process is set up in such a way that contractually any change, which affects either the schedule or the cost of the project, has to be notified as a change order by the subcontractor within X amount of days to the Company. If this notice is not given on time, there is no compensation given to the subcontracting party. This clause is set back-to-back.

Change orders have been a crucial element of this contract. The prime contract has been defined in such a way that change orders are necessary due to the limited defined scope at the start of the project, creating an extremely high number of change orders to be issued. All changes due to further defined work packages and designs further on in the project were contractually put through as change orders. There existed a pass-through mechanism (back-to-back), where the Company, being in between the subcontractors and the Client, issued every change that the subcontractor raised towards the Client. If the Client approved the change order, the Company approved the change order, and the change was executed. If the Client did not approve the change order, the Company did not approve the change order, and the subcontractor would not get paid. This results in a change order becoming a claim; a potential claim culture.

[7] Dispute resolution Any dispute controversy or claim arising out of or relating to the contract is finally settled by arbitration. This was a back-to-back clause in the contracts. Disputes arose out of change orders which were not accepted and therefore became a claim.

7.1.2 Results: Semi-structured interviews

Hereby, the results of the semi-structured interviews are presented. These results are split under the project performance results, the main execution risks within the project, the effects of the contracting strategy elements, the results on interface management, and the nature of the risk allocation.

Project performance

As mentioned in subsubsection 6.2.2, the interviewees were asked to score the project based on the five project performance criteria. The average of the scores was calculated and is presented in Table 7.1. Based on the average results, it is 'disagreed' by the interviewees that the project performed within schedule. This demonstrates that case study 1 scores the lowest on performing within schedule, and highest on quality and HSE requirements. To see the details of the scores, see Appendix E.

Table 7.1: Case study 1 average 'Likert Scores' on project performance by the interviewees.

Performance criteria	(1) Strongly disagree	(2) Disagree	(3) Neutral	(4) Agree	(5) Strongly agree
Within schedule		X			
Within budget			X		
Quality specifications				X	
HSE requirements				X	
Client satisfaction			X		

These results demonstrate that there is a need for an effective risk allocation in order to increase schedule performance.

Main execution risks occurred in the project

According to several interviewees from case study 1, the largest execution risks within the project affected the duration of the project, causing issues with delay and rescheduling of tasks. The main risks which were experienced in the project are summarized in Table 7.2, and the table shows that all these main risks negatively affected the schedule of the project. These risks have been identified by interviewees I1, I2, I3, and I4 as the largest risks on the project.

Table 7.2: The main execution risks occurred within case study 1 [based on semi-structured interview results].

no.	Occurred execution risk	Explanation	Consequence	Risk bearer
1.2/ 1.3	Force Majeur/ Changes in regulations	COVID caused huge disruptions in the progress. Health measures and changes in COVID regulations caused that work was temporarily stopped.	Schedule delay	All parties
2.2	Availability of qualified direct labor	Due to COVID and Ukraine war, there was a lack of direct labor available.	Schedule delay	All parties
3.1	Delayed payments	Subcontractor only works when funding is available, but with partial funding release (GMP) the subcontractors can't be secured.	Schedule delay	Subcontractors
4.9	Faults in supply of materials	There was a defect in one of the materials, which was the risk of the subcontractor. It caused huge disruption in the piling phase, which delayed subsequent works.	Schedule delay	Subcontractors
5.2	Change order in design	Many change orders occurred in design, because the contract was awarded at a low level of engineering. The process for change orders was time intensive.	Schedule delay	The Company (Fluor), and Subcontractors
6.1	Coordination of work	Lack in coordination during the execution phase. This is tied in with the interface management risk.	Schedule delay	The Company (Fluor), and Subcontractors
6.2	Interface management	Due to lack of interface management, partial work had to be resequenced. Since the schedules between subcontractors do not tie in perfectly, it results in the risk of orphan scopes.	Schedule delay	The Company (Fluor)

7.1.3 Effects of contracting strategy on project performance

The results from the interviews explained the effects that the contracting strategy elements had on managing the risks and thus the final project performance. Several contracting strategy elements, in the form of contractual clauses, had a large impact on the performance of the project. The contractual clauses which had the most influence on the allocation of risks are mentioned below:

[1] Price arrangement and [2] Liquidity

The prime contract, being a GMP is in essence a lump sum basis, however, all changes which occur in the project are managed and paid through allowances. This lump sum nature is highly risky for the Company, as a maximum price is fixed for the entire project. Interviewee I2 mentioned that "the nature of lump sum work is in nature claim heavy". This is because the level of engineering remains low when execution starts, resulting in many changes in the design execution during the project. All these changes are managed through change orders. If change orders are not accepted by the Client, they result in claims, thus resulting in a claim-heavy process.

The GMP has caused large risks down in the supply chain. Interviewee I4 explained that the 'if paid when paid clause' was quite a hard condition of the contract, which lead to a lot of negativity, and hurt the subcontractors financially. This clause led to "a lot of burden for the subcontractors".

The direct subcontractors were mainly contracted on a unit rate basis, which leaves the productivity risk at the subcontractors, but the quantity risks at the Company and Client. Interviewee I3 mentioned that "the productivity risk should always be for the subcontractor, flown downwards". This is because the subcontractors are the ones constructing the project, meaning they are best capable of influencing their own productivity and thereby managing the risk. Furthermore, the quantity risk should not be with the subcontractor, due to the incomplete engineering at the time of construction in these kinds of projects.

The indirect subcontractors were mainly contracted on a lump sum bases, in order to place the quantity and productivity risk for indirect works at the subcontractor. However, Interviewee I3 mentioned that often more people are needed than initially calculated, such as personnel responsible for administrative work. With a set lump sum price, subcontractors often demand an 'extension of time' in order to complete the work, seeing as they have reached the maximum price. This creates the potential risk of delays for EPC contractor and Client.

Regarding liquidity in the project, there is a large commercial risk caused by the limitation of liquidity on the subcontractors' side. "Within the construction contract, the Client needs to provide full approval for any money spent. When there is no approval, there is no money provided" (Interviewee I3), creating difficulties in enabling works, and a large financial risk for the subcontractors who are obliged to complete their works as stated in the contract.

[3] Milestone completion

All subcontractors have LDs linked to their Milestone Completion dates, which have been flown down, back-to-back, from the prime contract. No incentives were linked to their Milestone Completion dates.

- **Incentives**
  No incentive-based clauses were contractually put forth for the subcontractors. The interviewees were asked their opinion regarding more of a pain and gain mechanism, in order to improve the project performance. The opinions were to some extent contrasting. Interviewee I4 mentioned that "there were about six larger subcontractors working at site simultaneously. They all need the same space at a certain moment. Who gets the space first? So if you incentivize that, you will enhance your schedule security". It was also mentioned that "It's always better to have positive measures against a negative", rather than solely a penalty (LDs).

  On the other hand, interviewee I1 said, "I do not think the incentive is big enough to make a drastic change in the project". Also, interviewee I3 stated, "I am not convinced that an incentive scheme would have improved the process for this project".

- **Liquidated damages** (LDs)
  All the subcontracted works have LDs linked to their milestone completion dates, which are done on a back-to-back basis with the prime contract. The contractual LDs mean that if a subcontractor issues an 'extension of time' since they need more time to complete their work, the party is obliged to substantiate this delay; demonstrate why the work cannot be completed within schedule, and what the impact is of the delay. If this is not accepted, the subcontractor is liable to pay LDs. Interviewee I1 explained that usually, in business, these LDs are not likely to be enforced, but they are in place if it is necessary. The interviewee mentions that they should not be used too quickly, because you need subcontractors for future work, "So from a relationships standpoint, LDs are not the best tool to enforce all the time. It is used in tight circumstances". Interviewee I2 mentions that "I think liquidated damages are rarely effective, we rarely call down on them".

  Interviewee I2 additionally discusses the downsides of using LDs for the subcontractors. It was mentioned that actually implementing LDs can often result in claim discussions, which in itself can create further delays in the project. Therefore, goes against the aim of mitigating the risk of delays. Furthermore, it was found that LDs can create more costs for the project as a whole.

> When subcontractors read the contractual terms, where Milestone Completion dates are linked to LDs, the subcontractors will evaluate the potential financial impact of these LDs, and will price their contract accordingly. This can lead to higher contract costs. Even though LDs are seen as an aggressive penalty, they are in place to increase the performance of the subcontractors.

[6] Change orders/ claims / disputes

Regarding the change order clause, it states that if the subcontractor does not give the notice to change and a rough order of magnitude, within X number of days, the subcontractor waives their right to any compensation or change in schedule. This clause is on a back-to-back basis with the prime contract. If there is no compensation given, because the change order is not accepted, the subcontractor is obliged to keep on performing. Interviewee I4 mentioned that "they have an obligation to do that, otherwise, it is a breach of contract. So yes, the contract is quite in favor of the Client".

In this change order process, the change is issued by the subcontractor and verified by the Company. Subsequently, the change is negotiated between the Company and the Client, regarding the compensation for the change. Once this negotiation is completed, the compensation for change is then negotiated between the Company and the subcontractors. This resulted in high amounts of negotiation time and interaction between the parties. This again had an influence on the progress of the project. It was stated by Interviewee I4 that "the contract with the Client was not helpful for the Company to deal with changes of subcontractors".

Furthermore, interviewee I3 states that in practice, the contractual clause which states that X amount of days is provided to the subcontractor to give notice is, in practice, handled in a more fair and reasonable way. Contractually, no compensation for change is to be given if the notice of the change is not given on time. In practice, this is not pursued as strictly. However, it is mentioned that the subcontractors do need to comply with the administrative side of the contract. If there is a delay and the notice is given by the subcontractor, but, the subcontractor does not provide documentation and proof of the delay, it becomes fairly difficult to negotiate the delay with the Client. Interviewee I3 states that "Often it is seen that subcontractors are able to give the notice, but the quantification of the delay does not come within the time-frame, and they don't give a follow up". This puts the Company and the Client in a difficult position to decide whether the delay is accepted, and therefore the contractor is blocking the Company and the Client from making decisions on their delay. Thus blocking the mitigation process of the risk. This can delay the project even further.

The high number of issued change orders stems to a large extent from the low definition of engineering at the time of construction, and the fragmented responsibility of the design. The interviewee mentioned that ideally, you want to be in full control of the design, such that whenever there is an issue with the contract, it is clear where the issue stems from. This can reduce the number of change orders, and create a better understanding of the responsibilities.

7.1.4 Interface management

Through the interviews, it was found that a large extent of the risk can be brought back to the interface management of the project. The sequencing of work within the construction was a crucial element, which lead to execution risks. The EPC contractor carries the risk of coordination. The Company is responsible for structuring the scope of the works by the subcontractors. If all subcontractors have completed their work, which is contractually defined in their scope, and there is an element missing, which was not clearly defined in the scope of a subcontractor, there is a so-called 'orphan scope'. This becomes a large risk for the Company; who is managing the works of the subcontractors? These orphan scopes will not be executed until they are assigned to a certain party. The sequencing of work, and managing those interfaces of the direct work, is therefore a large risk that is carried by the Company. Interviewee I1 states that "If you have six different subcontractors, and they each have their own critical path that they are working towards, and it does not speak to the overall program, then there will be gaps", so-called orphan scopes. It is essential that all the work schedules tie into the final milestone completion date with the Client. If these do not tie into each other correctly, the managing Company is at risk. Orphan scopes due to a lack of interface management is a large challenge. Once orphan scopes are detected, there is a large chance that certain works need to be rebuilt, and resequenced, giving in on both time and costs. Furthermore, a lack of communication also affected interface management. Interviewee I4 stated that "there was a lot of correspondence but not enough communication between the parties". This creates difficulties in managing the interfaces of these types of projects. A large risk which lays with the EPC contractor, and is not necessarily mitigated through the contracting strategy elements in place.

7.1.5 The nature of risk allocation

In order to understand the nature of the risk allocation for case study 1, certain quotes from the interviews have been depicted which demonstrate a more traditional, and linear approach to risk allocation within the project. As mentioned in chapter 5, risk allocation is seen as a linear process within the literature, where risks are divided on a dyadic basis. For this case study, certain interview quotes support this idea. The first proof quote is, "We tried to be back-to-back with the prime contract terms" (Interviewee I2), explaining that most ideally, all the risks were transferred from the Client, towards the Company, down to a subcontracting party. This entails transferring the risk linearly. Moreover, Interviewee I1 states that "Generally, the real risk on the subcontractors stems from the Client, because it's back-to-back. If the Client doesn't pay, the subcontractors don't get paid", referring to the GMP price arrangement. This demonstrates that there is a linear process in allocating the risk of liquidity down toward subcontractors. Furthermore, Interviewee I3 stated that many times, communications and negotiations regarding change orders were done in two straight lines - top to bottom - from subcontractor to the EPC contractor, to the Client. This is a linear process of communicating and negotiating between the parties. As explained previously in this section, many of the contractual clauses have been pushed through on a back-to-back basis, from the prime contract to the subcontracts. This demonstrates the more traditional linear nature of risk allocation in case study 1, where most clauses allow for risks to be flown down directly on a linear basis.

7.2 Case study 2

The purpose of this section is to present the findings of case study 2. These findings attempt to create an accurate understanding of the project, however, the findings are not limited to the following aspects of the project. Due to the confidentiality of the project, certain information is anonymous, and thus the names of the Client, Subcontractors, and other stakeholders are not mentioned specifically. Fluor BV, being the EPC contractor in this project, is referred to as the Company.

7.2.1 Results: Document review

Hereby, the results of the internal document reviews are presented. The results explain the price arrangement of the prime contract, being the leading contract in the project, the supply chain structure, and the contracting strategy elements.

Prime contract

Within the prime contract, the Client and the Company agree that the work is performed under a cost reimbursable contract. The cost reimbursable contract has a cap on liability, which indicates that the reimbursements of costs cannot exceed a certain cap. Furthermore, the prime contract works with an incentive system, whereby the incentive system includes both a gain and a loss mechanism. These are based on predetermined KPIs. This means that the Company is able to increase its profit on the project once they meet the predetermined KPIs. The five KPIs which the Company aims to meet are concerning cost, schedule, HSE requirements, client satisfaction, and non-interruption of existing operations. This prime contract does not pursue LDs, seeing as delays are part of the incentive scheme (bonus-malus). Figure 7.3 demonstrates this as a visual.

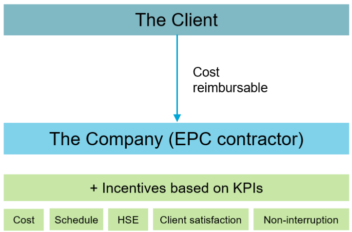


Figure 7.3: A visual describing the prime contract for case study 2 [illustrated by author].

Supply chain structure

The supply chain structure for this case study involves the EPC contractor (the Company), and the subcontractors for both direct and indirect works. The responsibilities within the supply chain are based on the EPC model, such that engineering, procurement, and construction are performed by the EPC contractor, however, it also includes the interface management of the activities. Additionally, it is important to note that some of the engineering elements were under the responsibility of the Client since the Client had a certain view on the repeatability of the design. This creates that the engineering and design responsibilities are to a certain extent fragmented.

This EPC project works with various different subcontractors for both direct and indirect works. The direct works are works that are directly related to the construction of the pharmaceutical facility, such as the Civil works, and the Mechanical and Piping works. The indirect works are not directly related to the construction of the pharmaceutical facility, but support the process, such as temporary work facilities, and medical services. Over 20 subcontracts were pursued. The subcontracts were pursued in single contracts, with the preference of not subcontracting further down by the subcontractors. Figure 7.4 shows the main subcontracts for the direct works on the project.

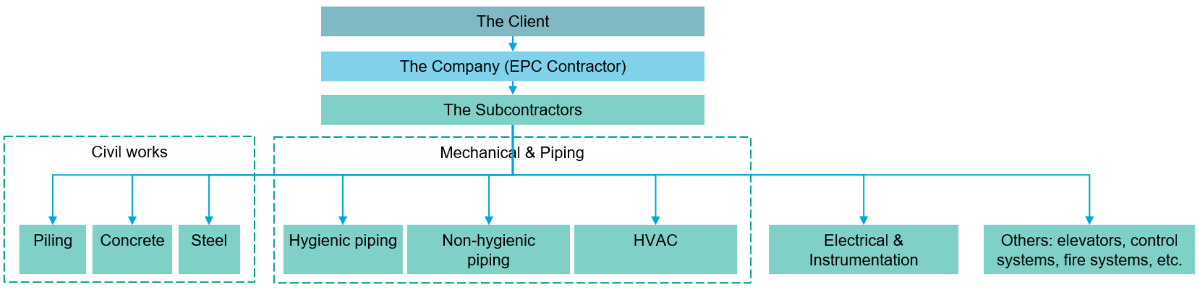


Figure 7.4: A visual describing the commodities for direct works for case study 2 [illustrated by author].

Contracting strategy elements

The contracting strategy elements are summarized in Table 5.3, and have been identified for case study 2. This is done in order to gain an understanding of the effects these contracting strategy elements have on the risk allocation within this EPC project. The contracting strategy elements which had a relevant influence on the risk allocation are discussed below.

[1] **Price arrangements** The indirect works are completed on a lump sum price arrangement basis. This means that all the temporary work facilities, site establishment, etc. are subcontracted for a fixed price. This lump sum price is estimated on data from previous projects, the estimated duration of the project, and the estimated productivity of the subcontractor. This lump sum contract means that as the project delays, the indirect work needs to be prolonged, seeing as more administrate work needs to be done, the temporary facilities need to remain for a longer time span, and so forth. This creates claims for 'extension of time', which is a risk for both the EPC contractor and the Client.

On the other hand, the price arrangements between the Company and the subcontractors are predominantly cost reimbursable for direct works. This is done on a back-to-back basis with the prime contract. Due to the very little amount of scope definition at the start of the project, where contracts were pursued at only 30% of engineering completed, this little scope definition asks for flexibility in quantity and scope changes. These cost reimbursable contracts allow the subcontractors to change defined quantities of the work and keep the productivity and quantity risk for the EPC contractor. Several subcontracts were performed under unit price work, whereby the quantities are also remeasurable, however, the productivity risk remains with the subcontractor.

[2] Liquidity terms The liquidity terms are formed on a back-to-back basis, where the payment terms from the Client to the Company are slightly longer than the payment terms from the Company to the subcontractors. This is done in order to provide a low-risk position for the Company. Due to the cost reimbursable payment mechanism, the liquidity terms for the direct subcontractors have minimized risk, since in principle, all their expenses, regarding time and material, will be reimbursed. This is quite in favor of the subcontractors.

[3] Milestone completion The milestone completion dates were linked to LDs within the subcontracted work. Once milestone completion dates were not met, the subcontractors were liable to pay the predetermined LDs. The prime contract entails an incentive model, however, this incentive model was not flown down to the subcontractors. Nor were the set KPIs. Therefore, this clause was not set back-to-back.

[4] Insurances The insurances within this project were issued differently per subcontractor. This clause is not set back-to-back. Depending on the scale of the subcontractor, a certain insurance policy was pursued.

[5] Warranty The Company provides the warranty for the end product to the Client, which is set back-to-back with the subcontractors. This entails that at the end of the day, the subcontractor warrants for their own scope, within a time span of X months after the date of substantial project completion. The Company withholds a certain retention value through the warranty period to ensure that all defects shall, at no cost to the Company, be corrected by the subcontractors. This leaves the risk for defects of the end-product at the subcontractor.

[6] Change orders and [8] Early Warning Notices (EWN) The change order clause and EWN process are used combinedly, seeing as an EWN is given when there is a change occurring in the scope. The change order clause mentions that if the evidence of a change is not provided within the time span allowed in the contract, the contractor will have waived any right to additional compensation for this change. Therefore, the administrative risk lies with the subcontractor, seeing as the provision of evidence is often seen as an administrative burden for the subcontractor.

[7] Dispute resolution The dispute resolution clause is pursued on a back-to-back basis with the prime contract, meaning that the dispute resolution procedure is identical for all parties involved. This involves the referral of the dispute to executives, optional mediation, and arbitration of the dispute.

7.2.2 Results: Semi-structured interviews

Hereby, the results of the semi-structured interviews are presented. The results of the semi-structured interviews explain the project performance results, the main execution risks within the project, the effects of the contracting strategy elements, the nature of the risk allocation, and the proportionality of the risks for subcontractors.

Project performance

Similar to the pre-interview protocol for case study 1, the interviewees were asked to score the project based on the five project performance criteria. The averages of the scores were calculated and are presented in Table 7.3. This demonstrates that the project scores lowest on performing within schedule. Based on the average results, it is 'disagreed' by the interviewees that the project performed within schedule. Performing within schedule seems to be the largest challenge of this project. To see the details of the scores, see Appendix E.

Table 7.3: Case study 1 average 'Likert Scores' on project performance by the interviewees.

Performance criteria	(1) Strongly disagree	(2) Disagree	(3) Neutral	(4) Agree	(5) Strongly agree
Within schedule		X			
Within budget				X	
Quality specifications				X	
HSE requirements				X	
Client satisfaction				X	

Main execution risks occurred in the project

The largest execution risks within case study 2 were identified through the interviews. The identified risks in Table 7.4 are the risks that had the most impact on the project performance of the project. It is seen that these risks had the most impact on the schedule of the project, causing delays in the project. These risks have been identified by interviewees I5, I6, I7, and I8 as the largest risks on the project.

Table 7.4: The main execution risks occurred within case study 2 [based on semi-structured interview results].

No.	Occurred execution risk	Explanation	Consequence	Risk bearer
1.2	Force Majeur	COVID is often used as a reason for subcontractors to be delayed in their works, late delivery of supplies, etc. However, it is difficult to prove if this is true or if it is due to performance issues. A lot of claims are issued for reasons of COVID and the Ukraine war. Comes down to a trust issue.	Schedule delay	All parties
2.2	Availability of qualified direct labor	There is a limited pool of qualified contractors, that can support the delivery of these facilities.	Schedule delay	All parties
4.5	Change order negotiations	The delay in completion of engineering caused many change order negotiations to take place. Seeing as construction and engineering happened quite in parallel (overlap), this created significant schedule delays.	Schedule delay	The Company, and Subcontractors
6.4	Tight project schedule	Extremely time-sensitive market, for the reason of beating competitors. This can create difficulties in the sequencing of work, and management of interfaces.	Schedule delay	The Company, and Subcontractors

7.2.3 Effects of contracting strategy on project performance

The interviews with the experts from case study 2 gave insight into the effects of the contracting strategy elements. The contracting strategy elements are implemented in order to mitigate risks within the project, however, the actual effects of these contracting strategy elements are discussed with the interviewees. The contracting strategy elements which had the most influence on the allocation of risks are mentioned below:

[1] Price arrangement and [2] Liquidity

The indirect work which is contracted on a lump sum basis is quite dependent on the schedule of the project. Once projects delay, which was the case in this project, the indirect works need to be prolonged.

Interviewee I5 explains that this lump sum basis causes claims for an 'extension of time'. As the direct work is delayed, the indirect works need to support the work for a longer time period, and therefore subcontractors tend to demand more budget. This is a risk for the EPC contractor and the Client.

The price arrangement for the direct works, being predominantly cost reimbursable, allowed for the subcontractors to limit their risk, whilst working with little scope definition in terms of engineering. Interviewee I7 mentions that "In these types of projects, you have to give the subcontractors the ability to remeasure" since the engineering is not yet well defined. If this is not done, the risk becomes too high for the subcontractors. Especially in the case of COVID, in which labor and materials were difficult to attain, and prices fluctuated greatly, the interviewee mentions that "because it was cost reimbursable, it hasn't hurt the subcontractors as much as if it was a lump sum project". Even though there were price increases due to COVID, the risk was limited since costs are reimbursed. It is stated that "this price mechanism has alleviated some of the pain" (Interviewee I6). Additionally, interviewee I6 mentions that for the unit price contracts, these subcontractors hold the productivity risk, whilst the Company holds the quantity risk. A preferable contract form for the EPC contractor, as the productivity is with the party who actually executes the work.

[3] Milestone completion

All subcontractors have LDs linked to their milestone completion dates. This, however, is not on a back-to-back basis with the prime contract, seeing as the prime contract makes use of an incentive model. The subcontracts did not include incentives nor KPIs.

- **Incentives**
  The subcontracts within case study 2 did not include an incentive scheme nor KPIs, whilst the prime contract did. Interviewee I9 mentions that in these kinds of projects, "it is usually a stick and no carrot...". Additionally, he states "I believe that from the subcontractor's perspective, an incentive model would be preferred". Interviewee I7 agrees with this notion and mentions that "Incentives are typically not flown down to the subcontractors", even though they are presented in the prime contract. Regarding an incentive model, as opposed to only LDs on the subcontracts, I6 mentions that in the modern day, subcontractors want to see pain and gain. They want more openness, and they want more transparency, which opens the door for more collaborative construction.

  The incentives which are seen in the prime contract are linked to the set of KPIs. However, there are not KPIs set for the subcontracting parties. Most of the interviewees explained that they have hardly ever seen incentives and KPIs flown down to the subcontractors. This is mainly due to the time-intensive nature of setting these incentives and defining the KPIs per subcontractor. Since this project is schedule driven, there is often no time to sit down with each other and define these specifications. This demonstrates a fragmentation of incentives and KPIs between the Client and the subcontractors.

  The incentives and KPIs set within the prime contract did have a positive influence on collaboration between the Client and the EPC contractor. It is mentioned by interviewee I7 that the relationship between the Company and the Client was very strong. The setting of KPIs resulted in the fact that their project goals were aligned, and that incentives create a positive work environment.

- **Liquidated damages (LDs)**
  The use of liquidated damages on the subcontracts in order to reach high project performance can be debated. Interviewee I6 states "Nobody intentionally runs late. We're all in this together. So, therefore, LDs would not really be applicable. In a collaborative model, you don't get your gain if you run late. So, I think that just motivates all the right behaviors, instead of a traditional model". Additionally, he states that once you keep all the subcontractors focused, and keep all the workers motivated for the final end goal of the project, the LDs will not be enforced in the project. This indicates that the LDs are only present for a worst-case scenario.

[6] Change orders

It was found through the interviews that the change order clause, which states that the subcontracting party is obliged to give notice of a change within x number of days in order to receive compensation, is not that strictly adhered to in practice (Interviewee I8 and Interviewee I9). In practice, it is seen that there is more flexibility for change orders, thus reducing the risk of subcontractors waiving their right to compensation. However, in this project, many change orders were caused by the impact of Force Majeur (COVID), and it is seen that this is a subject of discussion. Interviewee I6 explains how COVID made it difficult to truly see to what extent the subcontractors are impacted by specifically COVID events, or actually by their own performance - "This makes it a trust issue" (interviewee I6). This created many claims regarding 'extension of time' by the subcontractors, which is a risk for the EPC contractor and the Client.

7.2.4 The perspective of the subcontractor

Interviewee I9, being one of the subcontracting parties of this case study, elaborates on the proportionality of the risks that the subcontractors carry. Interviewee I9 mentions that the risks that the subcontractors carry are not always proportional to their capabilities. He explains that especially for the smaller subcontracting parties, it is difficult to adhere to the obligations stated in the contracts. "These parties often do not have the legal expertise in-house", while the contracts contain high legal complexity. He states that "most contracts are unfair by design because they ask the subcontractors to carry an amount of risk which they are not comfortable with. This is the moment when subcontractors need strong negotiation skills. But if you do not have the right people in-house for this negotiation, you end up getting into a contract which is not feasible for the subcontractor". Interviewee I9 states that the smaller the subcontractor, the less proportionate the risks are. Without the legal expertise in-house, these parties skim through the contracts and sign them. Smaller subcontractors hope for the best, and at the end of the day, they find that they are being asked to provide things that they cannot deliver. Eventually, they are faced with LDs which they cannot handle. This demonstrates a large factor in the risk allocation of EPC contractors. It is important to understand the scale of the subcontractors, in order to effectively allocate risks within the supply chain. Furthermore, it was mentioned that "Sharing risks in a more collaborative environment, can help deal with these struggles for the subcontractors" (Interviewee I9).

7.2.5 The nature of risk allocation

To understand the nature of the risk allocation for case study 2, certain quotes from the interviews have been depicted that demonstrate the linear approach to risk allocation. Several interviewees explained the traditional nature of this project, where LDs are primarily used to push subcontractors toward their milestone completion dates. It is mentioned that most clauses were flown down from the prime contract towards the subcontractors, however, Interviewee I7 mentions that "it's not been particularly unfair in this way". Seeing as the cost reimbursable contract was flown down towards the subcontractors, the subcontractors carried relatively low quantity and productivity risk in the project.

The nature of the risk allocation does remain linear, due to the various contracting strategy elements that are transferred directly from Client to subcontractor, and the linear communication streams between the parties. Moreover, the traditional contracting strategy used, in which subcontracts are contracted separately, creates linear communication streams.

7.3 Additional findings: relational governance

The semi-structured interviews touched upon various themes which are relevant to the subject of risk allocation in EPC projects. The five themes extracted from the literature review and exploratory interviews are execution risks, contractual clauses, market approach, linear and network risk allocation, and collaboration (see subsubsection 6.2.1). Moreover, a prominent subject emerged from the semi-structured interview results. This subject was referred to as an essential aspect of an effective risk allocation in EPC projects, and is linked to the theme of "collaboration". Within the data analyses, two subjects appeared, namely "People and relationships", and "Understanding the human side of contractual obligations". These two subjects were later combined under the label "Soft factors to contractual obligations". This finding actually demonstrates the importance of relational governance, where relationships play a large role rather than solely the importance of contractual governance.

7.3.1 Soft factors to contractual obligations

All 9 interviewees agree on the fact that at the end of the day, it is the people who affect the performance of the project, not solely the contract. Interviewee I3 states, "The failure lies in that people focus on the contract, but do not focus on investing time in relationships and trust, and how you work *vis-a-vis* with each other. The trust should be between subcontractors, the Company, and the Client, in a triangle format. However, many times it is executed in two straight lines – top to bottom. The collaboration is more in forming those relationships and trust''. Furthermore, it was mentioned that "We need more focus on the teams that are put together, put more investment in the relationship''. Examples are given about different project teams which the experts have worked with. It was mentioned that they have worked previously with the same subcontracting company, the same contractual terms, but different teams, different people, and thus different project performance outcomes. ''This demonstrates the importance of collaboration. People are key to a success of a project". Interviewee I1 adds to this and explains that the performance of a subcontracting party is not necessarily linked to the company name. ''It also has to do with the type of people. The team". Interestingly, the contract in itself is not highlighted as thoroughly as the people performing the contract. Interviewee I4 proves this by saying ''It's all people, it's all people work", and interviewee I7 agrees, and says ''The effectiveness of risk allocation also depends on the willingness of the subcontractors, the relationship with the subcontractor".

Moreover, Interviewee I3 mentions that the contract terms are the ultimate rules for when everything fails. "I think the terms are OK, but you need to work in a trust environment, the terms should only be there in a worst-case scenario. Because if people work in trust, rather than working by the contract, people operate well''. Various interviewees mentioned that the contract is the final resource, for when things ultimately go wrong in the project. The contract operates as guidelines to fall back to when necessary, but should not be the source of discussion. "It is in the way *how* the contractual terms are operated'', rather than in the contractual terms themselves (Interviewee I3). Furthermore, interviewee I1 mentions that within a project, it can be quite difficult to pinpoint the cause of a delay. Therefore, it can be easier to refer to what is stated in the contract. "Sometimes what is stated on paper is an unfair representation", which causes a certain subcontractor to be punished hard due to contractual obligations. However, "you do not want to get too aggressive with your subcontractors, because you can hurt them... You want to protect them as much as you can". At the end of the day, these are the subcontractors that are available, this is the market in Europe. This demonstrates the importance of soft factors to contractual obligations set in the contracts. Furthermore, Interviewee I6 states that ''The ability to pick up the phone to the CEO, or the owner of these companies and say, we have a problem, we need your help. That is worth its weight in gold these days, a lot more than any contractual document or leverage. The ability to sue somebody that's secondary in this industry - yes, you can do it, of course. And if you have to do it, you will do it. But it's all about collaboration, transparency, cooperation". This demonstrates the importance of the soft factors in an effective risk allocation within EPC projects.

7.4 Comparison of contracting strategy elements

A comparison of the contracting strategy elements used in the case studies is provided in Table 7.5. The table explains the conclusions and implications of the contracting strategy elements in the two different case studies. These conclusions and implications are based on the document review and semi-structured interview results.

Table 7.5: An overview of the contracting strategy elements used in the two case studies and their implications on the case studies [summarized by the author].

Contracting strategy elements		Theory and exploratory interview results	In practice	Case study conclusions and implications
[1] Price arrangements	[1.1] Lump sum	• Lower risk for EPC contractor, as long as subcontractor is able to take on this risk • Subcontractor carries quantity and productivity risk • Requires very mature scope definition and comes at a cost • Less control by EPC contractor during execution • Important element is the ability and capacity of the subcontractor to take on this contract	Often seen in prime contracts, low risk for Client (upstream) and often seen for subcontracted indirect works (downstream)	• Indirect works contracted on lump sum basis create that as project delays, more indirect staff is needed, eventually leading to 'extension of time' claims • This can create risks for delaying the project and increasing costs • Lump sum is not always effective for indirect work
	[1.2] Unit price	• EPC contractor carries quantity risk • Subcontractor carries productivity risk • Quantities vary (within limits), so full scope quantification is not required at award stage • More control by EPC contractor during execution	Often seen in subcontracts (downstream)	• Direct works contracted on unit price basis is effective for managing risks, as productivity should be the risk of the subcontractor who is in control of the productivity • Allowing the quantities to be remeasured creates for lower risks in the project (low engineering)
	[1.3] Cost reimbursable	• EPC contractor carries quantity and productivity risk • No or very limited scope definition is available or work is very unpredictable • Low risk for subcontractor as costs are reimbursed	Seen in both prime contracts (upstream) and subcontracts (downstream)	• Cost reimbursable contracts for the direct work are effective for reducing risks for subcontractors, seeing as all costs are reimbursed (until cap) • Successful and fair risk allocation when litte scope is defined
	[1.4] Guaranteed maximum price	• Incurred costs are payed, with an additional fee • (Sub)contractor guarantees maximum total costs which will not be exceeded (lump sum)	Mostly seen in prime contracts	• GMP used as prime contract creates large risk the supply chain • "If paid, when paid" clause causes difficulties with liquidity • Causes financial burden for EPC contractor and subcontractors
[2] Liquidity terms	[2.1] Payment terms	• The longer the payment terms, the more risk for the subcontractor • Allows the Client to transfer risk to (sub)contractor • Limits cash-flow in the supply chain, creating financial risks	Low liquidity for subcontractors creates performance risk	• Payment terms are typically back-to-back from prime contract to subcontracts, to limit risk for Client and EPC contractor • Often approval is needed by the Client for payments to subcontractors, this creates large risks and adversial relations
	[2.2] Retainage	• High retainage minimizes risk for Client • Typically freezes 10%-20% project budget • Decreases liquidity of EPC contractor and subcontractors	Low liquidity for subcontractors creates performance risk	• Retainage is typically back-to-back from prime contract to subcontractors, to limit risk for EPC contractor • Negotiating for low retainage is beneficial for the entire supply chain
[3] Milestone completion	[3.1] Incentives	• Rewards subcontractors to reach milestone dates, by bonuses (win-win) • Incentives are used to stimulate performance of (sub)contractors	When implementing both incentives and penalties, this is also referred to as 'bonus malus' and 'risk and reward'	• Incentives are typically not seen in downstream contracts (typically not back-to-back) • However, incentivising the subcontractors can enhance schedule security • Incentivising positive behavior can be beneficial for the project performance
	[3.2] Penalties	• Penalises subcontractors for not meeting milestone dates, by the formulation of liguidated damages (LD)		• Penalties are defined as LD's, and are often on back-to-back basis from prime contract to subcontracts to minimize the risk of the EPC contractor • Not likely to be enforced in projects as it creates disputes • Pursuing LD's can create claim dicussions, project delays, and increased costs • Not a tool that should be pursued easily as it can impact performance of project and relations with subcontractors
[4] Construction insurance	[4.1] Builder's risk insurance	• Insuring property in the project: materials, supplies and equipment from damage • Damage can be caused by fire, weather, vandalism, etc.	Typically, the Client pursues construction insurances for all contracted parties	No additional implications found within the case studies.
	[4.2] General liability insurance	• Insuring the party from 1) faulty workmanship, 2) job-related injury, 3) advertising injury / defamation		
	[4.3] Errors & ommisions insurance	• Insuring parties against claims arising from error or mistakes in their work		
[5] Warranty		• Guarantee by the manufacturer or (sub)contractor to repair or replace a defective product/ workmanship	Often seen that the EPC contractor's warranty covers subcontractors work	No additional implications found within the case studies.
[6] Change orders		• Allows for modifications to an existing construction contract • Defines how changes to project scope should be processed	Often seen that disputes arise from change orders, due to disagreement on 'change'	• The change order process is typically a linear process, whereby the change is notified by the subcontractor to the EPC contractor, who then notifies the Client • This process is time consuming, however, in schedule driven projects time is limited
[7] Dispute resolution		• Defines how parties wish to resolve their disputes • Aim to reduce chances of going to court, but rather intends to settle disputes more amicably	In practice, it is seen that this remains a costly and timely practice	No additional implications found within the case studies.
[8] Early warning notice (EWN)		• Entails that early warning should be given when changes occur on the project • This reduces the risk for the entire supply chain since early action can be taken to mitigate risk • Consequences of risk are minimized	Based on co-operation and trust. In practice, it is seen that this is not always adhered to.	• The EWN clause typically allows the subcontractor several days for notifying a change to the EPC contractor (back-to-back clause) • Subcontractors often do not comply with the quantification requirements of delays (documentation), which blocks the mitigation process of the risk

7.5 Recommendations given by the interviewees

This section elaborates on the recommendations for an effective risk allocation within EPC projects. These findings were found through semi-structured interviews with experts. In total, 26 codes were found for the recommendations from the experts. These recommendations are listed below, including the number of interviewees who have mentioned these recommendations (no.).

Table 7.6: A summary of the recommendations found through the semi-structured interviews.

Group	Code	no.
Recommendations	Focus on the people and relationships	9
	Human side to contractual obligations	7
	Focus on the selection of subcontractors	6
	Invest in subcontractors	5
	Integrated schedule/ critical path	5
	Maintain control of engineering	5
	Financial clarity for subcontractors	5
	Collaboration agreements between subcontractors	5
	Allocating risks proportionally	4
	Work in trust	4
	Understand capacity and scale of subcontractor	3
	Protecting subcontractors	3
	Involving subcontractors	3
	Focus on programs versus one-off projects	3
	Partial collaboration model	3
	Steering to productive work force	2
	Subcontractors want more transparency	2
	See contract as final source	2
	Setting KPI's at project start	2
	Work towards triangle approach	1
	Understanding the risk	1
	Quality risk at subcontractor	1
	Not grouping subcontractors	1
	Productivity risk at subcontractor	1
	Invest during design and engineering	1
	Direct work at unit rate	1

These recommendations give valuable input in improving the risk allocation for EPC projects. The recommendations which were mentioned by five or more interviewees are listed and explained below:

1. **Selection of subcontractors**: The selection of fit-for-purpose subcontractors is seen as an important element for mitigating the risks within EPC projects. Various interviewees mentioned the importance of selecting the right subcontractors. Interviewee I3 mentions, "We need more focus on the teams that are put together, put more investment in the relationship". Moreover, the interviewee states that "more emphasis should be on the capability of the subcontractor employees, not solely the organization (subcontractor), but particularly the person - who is the manager, who is the scheduler, etc.". This recommendation is combined with the recommendation code "Invest in subcontractors" seeing as these two recommendations are aligned. The selection of the subcontractors goes hand in hand with investing in the subcontractors. It is not about finding the cheapest labor who is able to fulfill the work; it is about investing more in subcontracting parties, to find the fit-for-purpose subcontractors for the job. The selection criteria used by the Company for their EPC projects can be seen in Appendix H.

2. **Understanding the soft factors to manage risks**: This recommendation combines the recommendation code of 'Focus on the people and relationships' and 'Human side to contractual

obligations', as these are both concerning the soft factors to managing risks. While many risks can be mitigated through careful planning and the implementation of appropriate controls, there are also a number of "soft" factors that can have a significant impact on a project's risk profile. It was mentioned by all the interviewees that the soft factors to managing risks are a key element that is often forgotten in EPC projects. "The failure lays in that people focus on the contract, but do not focus on investing time in relationships and trust, and how you work vis a vis with each other" was stated by interviewee I3, which relates to relational governance in projects. Interviewee I6 adds that "The ability to pick up the phone to the CEO, or the owner of these companies and say, we have a problem, we need your help. That is worth its weight in gold these days, a lot more than any contractual document or leverage". It is recommended that more time is invested in the soft factors, such as relationships, communication, and collaboration in these project teams. This is elaborated on in recommendation six.

3. **Integrated schedules**: Rather than having a schedule for each subcontract, it is advised that an integrated schedule is shared and used by all subcontracting parties. Interviewee I3 states, "Make the subcontractors agree with the schedule", by creating an integrated schedule for all subcontractors to work towards. This can decrease the risk of rescheduling works, and orphan scopes, thereby dealing with the characteristics of EPC projects.

4. **Control of engineering**: It is advised to maintain the control of engineering as an EPC contractor. This is obviously depending on the prime contract, however, to help allocate risks, it is most effective to have the engineering in the hands of one party, namely the EPC contractor. Interviewee I2 says that "Having control of the engineering is a fundamental thing to allocate the risks more effectively. If we can control the engineering and we are responsible for the changes, it puts us in a better understanding of where the risk lays".

5. **Financial clarity**: Moreover, financial clarity for all parties is a crucial element in allocating risks effectively. Interviewee I4 mentioned that financial clarity down the supply chain, for subcontractors specifically is important. Subcontractors should have a clear understanding of payment expectations from the Client and the EPC contractor, in order to support their work. The Client and the EPC contractor should therefore be proactive in handling the change notices and giving on-time responses regarding payments.

6. **Collaboration**: This recommendation is linked to the second recommendation, and identifies collaboration as an important element that is often lacking in EPC projects. All the interviewees agreed on the importance of collaboration within the supply chain in order to allocate risks effectively. It was mentioned that "the risk lies in the coordination of the work done by the subcontractors. In essence, the Company should be in the middle to do that coordination. You need to get that flexibility, to be getting more integrated with the subcontractors". Additionally, it was found that "The trust should be between subcontractors, the Company, and the Client, in a triangle format. However, many times it is executed in two straight lines – top to bottom. The collaboration is more in forming those relationships and trust". Moreover, interviewee I6 states that "instead of the old fashioned way of LDs per day that you slipped on the delay, a more collaborative nature of risk and reward can be applicable. Nobody intentionally runs late, especially in the collaborative environment, everybody is trying to help". This can incentivize the entire supply chain towards good performance, on a project level, rather than on a task level. Keeping the end goal in mind. Interviewee I6 adds that ''Managing the risks collectively, can give you a better chance of meeting project objectives"

7.6 Conclusion

The two case studies operate in a unique industry, where the demand for on-time project delivery is extremely high. These types of projects are referred to as fast-track, or even hyper-track projects, where the Client's main objective is to start operating the facility, whether it is in the technical or pharmaceutical industry. This creates a large overlap between the different project phases, in engineering and construction. Construction is done almost in parallel to the engineering of these kinds of projects, creating high risks in the execution of the projects. It is seen that the main risks which occurred in the case studies ultimately had the most effect on the project schedule.

Regarding the contracting strategy elements used for the allocation of risks in these case studies, it is seen that both cases use a linear, more traditional form of risk allocation. The risks are allocated on a back-to-back nature, and subcontractors are responsible for completing their independent scopes, rather than sharing responsibilities amongst the supply chain. It is concluded that certain contracting strategy elements have a larger influence on the risk allocation than others, and thereby, have more effect on the performance of the project (see Table 7.5). Firstly, it can be concluded that the [1] price arrangement between EPC contractor and subcontractors, which is often influenced by the price arrangement in the prime contract, has a large effect on the amount of risks carried and allocated to a certain party. It was seen that in case study 1, where GMP prime contract trickled down to the subcontractors, create large commercial risks for the EPC contractor as well as subcontractors, and is therefore not a price arrangement which lends itself for an effective risk allocation. On the other hand, the cost reimbursable price arrangement minimizes risk for the subcontractors, as their costs are reimbursed as scopes change over time. The commercial risks for subcontractors originate from the agreed-upon price arrangements, thus, it is an important tool for risk allocation. Furthermore, the [3] milestone completion contracting strategy element is a key tool in risk allocation, as incentives versus penalties (LDs) can affect the behavior of certain parties. It is found that typically in EPC projects, incentives may be included in the prime contract, but are not flown down in the subcontracts. Penalties (LDs) are linked to milestone completion dates, however, these are not likely to be enforced, as they can create large disputes and an adverse relationship. They are in place for when things ultimately go wrong. Thirdly, it is discovered that the [6] change order processes also have an important impact on effective risk allocation, as a lot of time is lost on change order negotiation processes between subcontractors, EPC contractors, and the Client. These three contracting strategy elements are considered to have had the most impact on the performance of the case studies.

Interestingly, most of the risks found in these projects lie in the management and coordination of the tasks within the supply chain, which is mainly the responsibility of the EPC contractor, as the general contractor. The management and coordination of the works in the construction phase are where difficulties arise, with interface management, and change order negotiations. The lack of interface management and coordination, leading to change order negotiations, which escalate into claims and disputes, create that time is lost on discussions, rather than focusing on work productivity. The interviews with experts highlighted the importance of coordination and soft aspects in handling risks. Rather than solely focusing on contractual obligations, it is crucial to understand the importance of the people and relationships in the supply chain, also referred to as relational governance. Within these projects, there is too much focus on the contracts instead of on the performance of the projects and the people involved. This focus on the contracts takes away the attention from the performance and productivity of the subcontractors, which is time-consuming on projects where time is essential. Focusing on contractual terms, change order negotiations, and disputes means that attention is taken away from the execution and delivery of the project, which is crucial in these hyper-track projects.

Several interviews have concluded that working more collaboratively can reduce the risks that are linked to management and coordination of work. Creating a collaborative model within the supply chain can help bring back the focus on productivity and performance, rather than contractual terms and adversarial relationships. Furthermore, it is the collaborative model that can bring the risk allocation to a network approach, rather than working with a dyadic relationship. However, there is little experience found on collaborative models within the Company and their EPC projects. Thus, the next chapter looks at potential lessons learned from collaborative models in other sectors.

8 Collaboration in other sectors

This chapter aims to gain a comprehensive understanding of the collaborative model used in construction projects, which can serve as a source of inspiration for risk allocation within EPC projects. The findings from chapter 7 suggest that integrating a collaborative model within the supply chain could lead to a more efficient risk allocation process. Despite the lack of experience with collaborative models within EPC projects at the Company, other sectors can provide valuable insight into the implementation of collaborative elements within projects. Therefore, this chapter aims at answering the following question:

Subquestion 5: *What can be learned from collaborative models in risk allocation in other sectors?*

This chapter first explains the chosen research method for answering this research question (section 8.1), which includes a literature review and semi-structured interviews. The chapter continues by discussing the results from the literature review (section 8.2), and the results from the semi-structured interviews (section 8.3). Finally, the conclusions of the chapter are summarized in section 8.4.

8.1 Research Method

The qualitative research method for answering this subquestion is twofold and exists out of a literature review and semi-structured interviews. The research method is similar to the research method explained in chapter 6.

8.1.1 Literature review

The objective of the literature review is to gain theoretical knowledge on collaborative models used in construction projects. This theory can be translated to EPC projects, in order to provide recommendations for implementing a collaborative model. The literature consists of academic articles and articles published by organizations (such as publications by Rijkswaterstaat [2022]). An elaboration on the procedure for conducting the literature review can be found in Appendix A.

8.1.2 Semi-structured interviews

The objective of the semi-structured interviews is to gain practical knowledge on the implementation of collaboration models. As explained in chapter 6, the semi-structured interviews include open-ended questions, to allow for a light structure, and leave the possibility for rephrasing or adding on questions where deemed necessary. The flexibility of this interview method encourages conversation, with the aim to attain a greater depth of information [Onencan, 2013].

Selection of interviewees

The methodology employed for selecting interviewees in this study adheres to specific criteria to ensure the relevance and validity of the collected data. The first criterion for selection is that all participating interviewees must have practical experience in the implementation of a collaborative model. Additionally, the roles of the interviewees must be related to Project Management, Contract Management, or Risk Management. These functions are believed to provide the best understanding of implementing a collaborative model within construction projects. In addition to these criteria, the availability and expertise of the expert are also taken into account. The list of interviewees is demonstrated in Table 8.1.

Interview protocol

The interview protocol for the semi-structured interviews follows the same steps as explained in chapter 6. Naturally, for these interviews, asking the interviewee to rate the performance of the project in the pre-

Table 8.1: List of interviewees for the semi-structured interviews in the infrastructure sector.

Code	Function	Company	Work experience	Business line	Duration
I 10	Business Manager Infrastructure	Fluor BV	+30 years	Infrastructure	1h00
I 11	Commercial Manager	Fluor BV	+10 years	Infrastructure	0h45
I 12	Risk and Contract Manager	Fluor BV	+30 years	Infrastructure	1h05

interview protocol is not included in this part.

Interview analysis

The analysis for the semi-structured interviews took on the same approach as explained in chapter 6. This includes transcribing the interviews and assigning codes to the quotations which seemed relevant. This data analysis was done on a deductive and inductive basis. The codes and themes assigned to the interview transcripts for this part of the research differ from the codes and themes within the case study research. In total, 24 codes were established, which were assigned to 9 different groups. These 9 groups were established by grouping the codes into these categories, and these are based on inductive and deductive analysis. The 9 groups can be seen in Figure 8.1, and the 24 codes can be found in Appendix F.

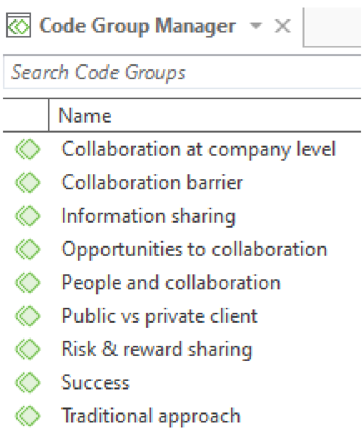


Figure 8.1: A screenshot of the 9 code groups created in Atlas.ti.

8.2 Results from the literature review

This section provides the results from the literature review regarding collaboration in EPC projects. Firstly, the shift away from traditional contracting towards collaborative contracting in the construction industry is explained. Secondly, a popular model for collaboration, named Supply Chain Collaboration, is analyzed.

8.2.1 Traditional versus collaborative contracts

Kapoor [2021] explains that collaborative contracting differentiates itself from traditional, adversarial contracting practices, by the level of risk and reward the parties jointly share. "In a traditional contract, one party's failure to deliver its promise means the other party has a legal claim against it. However, in a collaborative contract, points of failure and risk are anticipated. Thus, collaborative actions are agreed upon such that no one party bears all of the risks in an unforeseen event".

In recent years, the competitive, traditional, and to a large extent, adversarial relationships between contracting parties have been criticized by many academics and practitioners [Meng, 2013]. This type of approach can lead to distrustful relations in the supply chain, where parties fear opportunistic behavior [Beach et al., 2005]. According to various researchers, this leads to risk-sharing avoidance, and significant costs related to defining responsibilities and minimizing individual risk, rather than minimizing project risk as a whole. Based on the literature, the traditional approach is defined by three characteristics that affect risk allocation, namely 1. opportunistic behavior of parties, 2. top-down decision-making within the project, and 3. allocating risk to the party which can most 'effectively' bear the risk (linear). These aspects of the traditional approach can create adversarial relations between stakeholders since risk allocation is based on a win-lose situation.

Collaboration has therefore become a more popular term in the construction industry, as the competitive approach seems unsustainable in a tighter market. It is even stated by Shaikh et al. [2020] that "Supply chain of construction is deficient due to lack of collaboration and integration". 'Collaboration' is a broad term, which is often used interchangeably with terms such as alliances, and partnerships, since these are all forms of working together [Hughes et al., 2012]. However, the terms are defined differently. Yeung et al. [2007] defines alliancing as to "establish inter-organizational relations and to engage in collaborative behavior for a specific purpose", whilst partnerships or partnering is defined by the Construction Industry Institute [1991] as "a long-term co-operation between two or more organizations committed to achieving specific business objectives by maximizing the effectiveness of each participant's resources", and are popularly seen in forms such as Public-Private-Partnerships [Tang et al., 2010].

Garcia and Murguia [2021] defines collaboration as "a process of inter-organizational interaction that involves the effective and transparent transfer of information and knowledge so that working together will increase value for each independent unit". Increasing the value for each independent unit refers to a win-win situation within the supply chain. When implementing this definition for collaborative forms, it is obvious that there are many different forms that collaboration contracts can take on. The strategic decision for collaborative contracting has not universally been accepted in the construction industry, particularly so, within the supply chain of projects [Beach et al., 2005]. This also raises the question, of whether the supply chain within EPC projects, characterized by their large risks, is able to embrace this concept of mutual trust and cooperative attitude.

8.2.2 Supply Chain Collaboration

Despite the lack of universal acceptance of collaborative models as a means to enhance supply chain performance, the literature suggests that more collaborative models can improve project performance when implemented correctly ([Manley and Chen, 2015]). A popularly used term for implementing collaboration in the supply chain of projects is referred to as 'supply chain collaboration'. Shaikh et al. [2020] mentions three explicit characteristics of effective supply chain collaboration, which are 1. information sharing, 2. joint decision making, and 3. risk and reward sharing (see Figure 8.2).

1. **Information sharing:** refers to "capturing and disseminating timely and relevant information for decision-makers to plan and control supply chain operations" [Simatupang and Sridharan, 2005].
2. **Joint decision-making:** focuses on planning and operational contexts, where decisions about project planning, measuring criteria, and key operational decisions are decided jointly by the supply chain. The implementation of a joint decision-making process is intended to foster a long-term relationship with the stakeholders, decrease the incidence of client complaints, and enhance client satisfaction. Such an approach can also enable an organization to be more responsive to changing client needs.
3. **Risk and reward sharing:** refers to the degree to which supply chain members share, instead of divide, the costs, the risks, and the benefits within a project. This is related to the commercial terms of the contracts.

Wiengarten et al. [2010] adds on to point 1; "Companies need to realize that unless the exchanged information is of high quality they cannot expect a high return from their collaborative initiatives in terms of improved operational performance. Making joint decisions and sharing risks and benefits throughout the supply chain does not improve a company's operational performance if the exchanged information is of poor quality". This specifies that the information should be of high quality, and therefore timely, accurate, and relevant.

A collaborative model is contradictory to the traditional approach of supply chain management, where in the traditional approach, the allocation of risks is born by one party, who is most effective for bearing that risk. Stanek [2004] mentions that strategically, contractors and subcontractors may pursue collaborative or partnership approaches, in order to further innovate, access new markets, and share the risks of the project.

Figure 8.2: Supply Chain Collaboration elements [illustration adapted from Shaikh et al. [2020]].

This concludes that the decision for taking a more traditional or rather a more collaborative approach for a project has a large influence on the allocation of risks within an EPC project.

8.3 Results from the semi-structured interview

The semi-structured interviews provided relevant input regarding the view on collaborative models in construction projects. The semi-structured interviews are aimed to understand what hampers EPC projects from attaining collaboration in projects. Secondly, the semi-structured interviews try to highlight the elements that are key for implementing such a collaboration model.

8.3.1 Barriers to implementing collaboration

The interviewees agree that collaboration is seen as a huge opportunity within all construction projects. However, pursuing collaboration in projects can be challenging. What makes it challenging are the barriers to implementing a collaboration model in EPC projects. The barriers stated by the interviewees are listed in Appendix G. However, despite these barriers being present, there is huge potential found in pursuing more collaborative approaches. It is mentioned by Interviewee I10 that "Project success lies in personal relationships and breaking conventions - dare to think, but also move outside the box". Understanding the barriers is an important step in implementing such an innovative model since it allows the people involved to anticipate and plan for these potential challenges.

8.3.2 Key elements for integrating collaboration in EPC projects

The semi-structured interviews have led to a few key elements of collaboration, which could be applicable for EPC projects. These elements are found in different construction sectors and implemented to work towards a collaborative working environment in construction projects. These elements are the following:

1. **Identification of critical works:** Interviewee I11 mentions that clearly identifying the highly critical from the less critical direct works can be beneficial. This is an element that stems from an infrastructure project whereby the critical works are contracted separately from the less critical works. An example of this is a project initiated by the Client 'Rijkswaterstaat', whereby a project is separated into two phases [Rijkswaterstaat, 2022]. This approach is not directly applicable for EPC projects, however, the main idea can be translated to the works of subcontractors. By identifying

the highly critical from the less critical direct works, a specific strategy per level of criticality can be chosen.

2. **Early contractor involvement:** It is mentioned by all interviewees that within these collaborative models, early (sub)contractor involvement is an important element. By involving the (sub)contractors early on in the process, within the engineering and design phase, the (sub)contractor's expertise and experience can be used as valuable input, to optimize the project's design, cost, and schedule.

3. **Focus on productivity:** It is mentioned by Interviewee I11 and interviewee I12 that providing a culture where the focus of the supply chain is shed upon the productivity of the workforce, rather than on the contractual obligations, can help create more trustworthy relationships. Having that shared goal of successfully attaining the end project with all the subcontractors is crucial, rather than each subcontractor looking at their individual work scopes and obligations.

4. **Defining KPIs:** According to interviewee I12, setting KPIs can help align the project goals, and the goals of the subcontractors, with the overall strategic objectives of the project. This creates a mutual understanding of targets and goals. This is a somewhat controversial element, seeing as it is also quite time-consuming to set these performance indicators with the subcontractors.

5. **Contractual implications:** Contractually defining the collaborative model is an important step towards collaboration (Interviewee I10). Even though it remains difficult to enforce cooperation and collaboration clauses, setting agreements within the contracts helps set a tone for a project, from the start of a project. Rijkswaterstaat [2022] has developed key points for setting contractual agreements to support collaboration in projects. These key points are demonstrated in Figure 8.3.

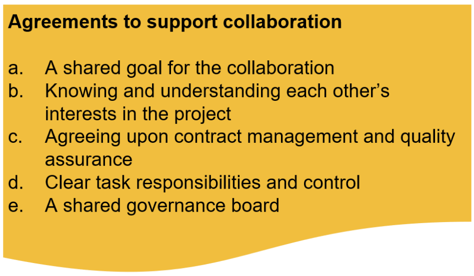


Figure 8.3: Contractual agreements to support collaboration [illustration adapted from Rijkswaterstaat [2022]].

Overall, the collaborative model can be implemented in any project, given certain boundary conditions. It is mentioned that collaboration is based on trust and transparency, trust between parties, on a personal level more so than on an organizational level. Interviewee I10 mentions that "collaboration does not, or hardly, exist on a company level", highlighting the importance of the people rather than the company name. Additionally, the interviewee states that "trust is hard to gain but easy to lose". Collaboration is based on goodwill between parties, according to interviewee I11. This can be enhanced by working together on projects regularly as opposed to one-off projects. Portfolios of projects with a group of subcontractors can help maintain relationships over a longer period. One-off EPC projects commonly associated with EPC projects make it less attractive to maintain relationships, seeing as parties will not be depending on each other in the future. Shifting towards portfolio projects can stimulate collaborative attitudes.

8.4 Conclusion and next steps

In chapter 7, the recommendations given by the interviewees included 2. understanding the soft factors of risk management and 6. increasing the level of collaboration within the supply chain. It was mentioned that to improve the risk allocation in these projects, there should be more focus on the relational governance within contracts, which is why in this chapter, the collaborative model is researched. This chapter explains how the collaborative model is seen and used in other sectors within the construction industry, by completing both a literature review and conducting semi-structured interviews. The results demonstrate what can be learned from the collaborative model in other sectors, and function as inspiration for implementing the collaborative model in EPC projects. This chapter thereby answers subquestion 5.

Firstly, the research method for this research question is explained. The qualitative research method is two-fold, existing out of a literature review and semi-structured interviews with three experts. Secondly, the results from the literature review are presented. The literature review found that in recent years, the traditional form of contracting is criticized by many academics [Meng, 2013], demonstrating the potential of a more collaborative model in construction projects. Collaborative models can take on many shapes, however, a popularly used collaborative model is explained by Shaikh et al. [2020] and involves 1. information sharing, 2. joint decision-making, and 3. risk and reward sharing.

Moreover, various barriers to implementing collaboration in EPC projects are found, as well as key elements for integrating collaboration in EPC projects. In order to integrate a collaborative model in EPC projects, it is stated that [1] the critical works need to be identified, so that the collaboration can be defined according to these criticalities. It is stated that [2] subcontractors need to be involved earlier on in the process, in order to align mindsets before construction. Thirdly, there is a need to [3] focus on productivity, rather than contractual obligations. Productivity can also be enhanced by [4] defining KPIs and using this as a tool to work towards project objectives. Finally, it is stated that the collaboration needs to be [5] contractually defined, in order to assure collaborative procedures. These five elements are quite in line with the six recommendations from the case study analysis (see section 7.5). The recommendations from the case study analysis include providing [5] financial clarity, which is can be achieved by clearly [4] defining KPIs. Furthermore, the element of [3] focusing on productivity is very much related to [3] integrating schedules, and [6] collaborating within the supply chain. It can be said that the opinions of experts in both sectors complement and strengthen each other.

In conclusion, it is seen that collaborative models contain a lot of potential for increasing the performance of construction projects, including EPC projects. Despite the barriers to implementing such a model, it can enhance a network approach to risk allocation, seeing as risks are taken on collaboratively. The results from this chapter function as input for developing a solution in the following chapter (chapter 9).

9 Developing the Solution and Evaluation

This chapter analyzes the results from the previous chapters, in order to provide recommendations for the EPC company on how to improve the risk allocation in their contracting practices. The results from the literature review, document review, and case studies will provide a foundation for the development of a model. This will thus answer subquestion 6.

Subquestion 6: *How can a network risk allocation model be developed to improve project performance?*

This chapter starts by explaining the key inputs for developing the model (section 9.1). The following section introduces the model, which consists of three figures (section 9.2). Following is the evaluation of the model, by discussing the model with three experts in the field (section 9.3), which then leads to the development of the final model (section 9.4). In section 9.5, an explanation is given on how to implement network collaboration in contracts. Finally, a conclusion to this chapter is provided (section 9.6).

9.1 Key inputs for the development of the model

This section explains which input from this research is used for developing the model.

9.1.1 Literature and document review findings

The chapter 3, chapter 4 and chapter 5 provide the background knowledge for the development of a model. Firstly, the risk management approach explained in Figure 3.2 and in Figure 5.3 demonstrate key steps for risk management, namely: identifying the risks, prioritizing risks, identifying the risk mitigation strategy (accept, transfer, avoid or reduce), and risk monitoring. When referring to the 'allocation' of risks, we typically think of the risk mitigation strategy 'transfer'. This means allocating the risk from one party to another. However, the entire risk management process is crucial in the risk allocation process, as effective risk management increases the chance of successful risk allocation [Hopkin, 2018].

9.1.2 Knowledge gap in 'network risk allocation'

The section 2.1 explains how a network form of risk allocation is missing in the literature. Additionally, the case study research demonstrated how a linear risk allocation is not always appropriate in EPC projects, and a network approach can help for a more effective risk allocation. Therefore, the network approach is an important element in the development of the model. A network approach takes into account the network elements (Figure 5.4) and their effect on the allocation of risks. A network approach, therefore, understands the dynamic relationships within the supply chain, the interdependencies between actors (and their works), and the complex organizational structure within the supply chain.

9.1.3 The case study results

The case study results are explained in chapter 7 and have provided crucial findings to be integrated into the model. Firstly, the contracting strategy elements provide useful findings on how certain contracting elements affect the performance of the project. Therefore, a complete overview is provided on the contracting strategy elements, including the recommendations on how to implement these elements in future EPC projects. This overview is presented in Table 9.2. This overview takes into account how certain clauses can negatively influence the project performance, as explained in Figure 4.3, yet also how certain clauses can be used in a different manner, in order to increase their effectiveness. An example of this is the milestone completion element. It is recommended to provide incentives for subcontractors on the basis of a bonus-malus system, where LDs are defined against an incentive, in order to positively incentivize the workers, rather than solely punishing them.

Additionally, the recommendations by the case study interviewees are used as key input for the model. These recommendations can be found in section 7.5. These recommendations include 1. the selection of subcontractors, 2. understanding the soft factors, 3. integrated schedules, 4. maintaining control of engineering, 5. providing financial clarity, and 6. integrating collaboration. However, solely recommendations 1, 3, 5, and 6 will be implemented in the model, as these can be defined as concrete steps in the process toward a network risk allocation process. Recommendations 2, and 4 will be referred to in section 11.3 as recommendations on project or organizational level.

9.1.4 Collaboration in other sectors

Additionally, chapter 8 explains the lessons learned of collaboration from other sectors, which can positively influence the risk allocation within EPC projects. Therefore, the key elements for integrating collaboration in EPC projects are important inputs for the model. However, before implementing the supply chain collaboration model, it should first be translated to the context of EPC projects.

Supply Chain Collaboration for EPC projects

As explained in subsection 8.2.2, the supply chain collaboration model exists out of three elements, namely: 1. information sharing, 2. joint decision-making, and 3. risk and reward sharing. For these theoretical elements to be applicable to EPC projects, they need to be contextualized. This is done on the basis of the case study, and the interview results. An overview of how the elements are defined for EPC project specifically can be seen in Table 9.1. The last column in the table explains on which chapter the translation to EPC context has been based, which were the recommendations in chapter 7 and in chapter 8.

Table 9.1: Applying the collaboration model to EPC projects.

Theory **Supply Chain Collaboration**		Theory applied to EPC projects **Network Collaboration**		Based on results:
1. Information sharing	Capturing and disseminating timely and relevant information for decision-makers to plan and control supply chain operations. - [Simatupang, 2005]	**1. Network information sharing**	• Availability of information for network • Integrated project schedule for supply chain • Providing KPI transparency	• Ch. 7 and Ch. 8 • Ch. 7 • Ch. 7 and Ch. 8
2. Joint decision-making	Focuses on planning and operational contexts, where decisions about project planning, measuring criteria, and key operational decisions are decided jointly by the supply chain. - [Shaikh et al, 2020]	**2. Network decision-making**	Triangle approach to key decision making: • Execution planning decisions • Change order decisions	• Ch. 7
3. Risk and reward sharing	Degree to which supply chain members share, instead of divide, the costs, the risks and the benefits within a project. - [Shaikh et al, 2020]	**3. Risk and reward sharing**	• Linking both incentives and LDs (bonus malus) to milestones • Sharing contingency and sharing incentive pool	• Ch. 7 and Ch. 8 • Ch. 7

The Supply Chain Collaboration model is rephrased to 'Network Collaboration', to demonstrate that the supply chain is referred to as a network, rather than individual, independent parties. Moreover, the three elements of Network Collaboration are explained below:

1. **Network information sharing** refers to sharing information with the network in order for the parties within the network to improve their performance. An essential element is an integrated schedule for the subcontracting parties. This resulted from the case study analysis (Table 7.6). Having an integrated schedule for all the subcontractors promotes a collaborative atmosphere, where all parties understand the milestones of other subcontracting parties, and thus, they can collaborate towards that integrated schedule. Therefore, moving away from fragmented work scopes, towards united scopes, where there is less risk of orphan scopes. Additionally, providing transparency on KPIs to the supply chain is an important element in network information sharing. Subcontractors seek financial clarity, regarding what they can earn and lose, in order to perform according to their obligations. The addition of the 'network' to 'information sharing' demonstrates that information is not only shared with various parties but it is understood that if one party receives information, this affects other parties. The inter-dependency is a key element here.
2. **Network decision-making** refers to not necessarily making decisions 'jointly', seeing as this is not seen as a feasible measure in privately initiated EPC projects, however, it refers to *discussing* key decisions with the network, rather than on a linear basis. This was a strong learning point from case study 1, where decision-making was done linearly, causing time to be lost on a lengthy decision-making process and disputes. Instead, network decision-making focuses on a triangle approach to key decisions: discussing change orders with the Client, EPC contractor, and the appropriate subcontractor(s), at the table. This allows for all the necessary change order information to be exchanged by the parties who have the best knowledge of that change order. Furthermore, it entails decision-making and discussion regarding execution planning. This reduces the risks of misunderstandings on site since planning has been agreed upon by all parties. This can lead to schedule optimization and improved risk management.
3. **Risk and reward sharing** mainly focuses on linking both incentives and LDs to milestone completion dates. These are linked to the commercial terms of the project. The case study analysis and interview with the subcontractor found that by only penalizing the subcontractors, little incentive is given for the subcontractors to perform at their best. Additionally, by creating a shared contingency and shared incentive pot for the subcontracting parties, barriers to collaboration and innovation are removed, while aligning incentives for the project team. A shared contingency and incentive pot forces parties to work together, including the EPC contractor.

Additionally to these three elements, it is found through the lessons learned in Figure 8.3 that two other elements are crucial for implementing collaboration in construction projects. These are having a shared goal for collaboration between all participating parties, and identifying a governance board that is responsible for governing the collaboration during the execution of the project. This will be elaborated on in Figure 9.5.

Table 9.2: Framework of contracting strategy elements used for risk allocation and recommendations on their implementation for a network-based contracting strategy (based on results from literature review and case study analysis).

Contracting strategy elements		Theory and exploratory interview results	In practice	Case study conclusions and implications	Recommendations
[1] Price arrangements	**[1.1] Lump sum**	• Lower risk for EPC contractor, as long as subcontractor is able to take on this risk • Subcontractor carries quantity and productivity risk • Requires very mature scope definition and comes at a cost • Less control by EPC contractor during execution • Important element is the ability and capacity of the subcontractor to take on this contract	Often seen in prime contracts, low risk for Client (upstream) and often seen for subcontracted indirect works (downstream)	• Indirect works contracted on lump sum basis create that as project delays, more indirect staff is needed, eventually leading to 'extension of time' claims • This can create risks for delaying the project and increasing costs • Lump sum is not always effective for indirect work	Pursuing lump sum contracts for indirect works in projects can create a risk for claims ('extension of time'), thus increasing project delays. Therefore, unit price or cost reimbursable contracts may be more effective for the risk allocation of indirect works.
	[1.2] Unit price	• EPC contractor carries quantity risk • Subcontractor carries productivity risk • Quantities vary (within limits), so full scope quantification is not required at award stage • More control by EPC contractor during execution	Often seen in subcontracts (downstream)	• Direct works contracted on unit price basis is effective for managing risks, as productivity should be the risk of the subcontractor who is in control of the productivity • Allowing the quantities to be remeasured creates for lower risks in the project (low engineering)	The productivity risk should lay with the subcontractor, as they have most control of this risk, and therefore, they are the most effective risk bearer.
	[1.3] Cost reimbursable	• EPC contractor carries quantity and productivity risk • No or very limited scope definition is available or work is very unpredictable • Low risk for subcontractor as costs are reimbursed	Seen in both prime contracts (upstream) and subcontracts (downstream)	• Cost reimbursable contracts for the direct work are effective for reducing risks for subcontractors, seeing as all costs are reimbursed (until cap) • Successful and fair risk allocation when little scope is defined	Cost reimbursable contracts allow for a fair risk allocation when the scope of the project is limited, therefore, an effective tool for risk allocation. This can be pursued on a back-to-back basis with the prime contract. This price arrangement best supports a collaborative environment with subcontractors.
	[1.4] Guaranteed maximum price	• Incurred costs are paid, with an additional fee • (Sub)contractor guarantees maximum total costs which will not be exceeded (lump sum)	Mostly seen in prime contracts	• GMP used as prime contract creates large risk the supply chain • "If paid, when paid" clause causes difficulties with liquidity • Causes financial burden for EPC contractor and subcontractors	Not a contract form that allows for effective risk allocation. Not recommended to take on projects with a GMP, seeing as it can hurt both EPC contractor and subcontractors.
[2] Liquidity terms	**[2.1] Payment terms**	• The longer the payment terms, the more risk for the subcontractor • Allows the Client to transfer risk to (sub)contractor • Limits cash-flow in the supply chain, creating financial risks	Low liquidity for subcontractors creates performance risk	• Payment terms are typically back-to-back from prime contract to subcontracts, to limit risk for Client and EPC contractor • Often approval is needed by the Client for payments to subcontractors, this creates large risks and adversarial relations	Negotiate with the Client for good liquidity terms, to reduce the risk of the subcontractors. Subcontractors should be stimulated to perform, which can only be done with financial support.
	[2.2] Retainage	• High retainage minimizes risk for Client • Typically freezes 10%-20% project budget • Decreases liquidity of EPC contractor and subcontractors	Low liquidity for subcontractors creates performance risk	• Retainage is typically back-to-back from prime contract to subcontractors, to limit risk for EPC contractor • Negotiating for low retainage is beneficial for the entire supply chain	
[3] Milestone completion	**[3.1] Incentives**	• Rewards subcontractors to reach milestone dates, by bonuses (win-win) • Incentives are used to stimulate performance of (sub)contractors	When implementing both incentives and penalties, this is also referred to as 'bonus malus' and 'risk and reward'	• Incentives are typically not seen in downstream contracts (typically not back-to-back) • However, incentivizing the subcontractors can enhance schedule security • Incentivizing positive behavior can be beneficial for the project performance	Recommended to implement incentives for subcontractors to incentivize good performance and productivity. This can be done in combination with setting KPI's, which are linked to the incentives.
	[3.2] Penalties	• Penalizes subcontractors for not meeting milestone dates, by the formulation of liquidated damages (LD)		• Penalties are defined as LD's, and are often on back-to-back basis from prime contract to subcontracts to minimize the risk of the EPC contractor • Not likely to be enforced in projects as it creates disputes • Pursuing LD's can create claim discussions, project delays, and increased costs • Not a tool that should be pursued easily as it can impact performance of project and relations with subcontractors	Focus on protecting subcontractors, rather than penalizing subcontractors. Pursuing LD's can financially hurt subcontractors, which results in project delays. LD's should be in place for ultimate situations.
[4] Construction insurance	**[4.1] Builder's risk insurance**	• Insuring property in the project: materials, supplies and equipment from damage • Damage can be caused by fire, weather, vandalism, etc.	Typically, the Client pursues construction insurances for all contracted parties	No additional implications found within the case studies.	Understand the insurance capabilities of smaller subcontractors. These parties often have less financial capability for securing their works.
	[4.2] General liability insurance	• Insuring the party from 1) faulty workmanship, 2) job-related injury, 3) advertising injury / defamation			
	[4.3] Errors & omissions insurance	• Insuring parties against claims arising from error or mistakes in their work			
[5] Warranty		• Guarantee by the manufacturer or (sub)contractor to repair or replace a defective product/ workmanship	Often seen that the EPC contractor's warranty covers subcontractors work	No additional implications found within the case studies.	The warranty of the works should be the responsibility of the party who executed the work (most effective risk bearer).
[6] Change orders		• Allows for modifications to an existing construction contract • Defines how changes to project scope should be processed	Often seen that disputes arise from change orders, due to disagreement on 'change'	• The change order process is typically a linear process, whereby the change is notified by the subcontractor to the EPC contractor, who then notifies the Client • This process is time consuming, however, in schedule driven projects time is limited	The discussions around change orders should include all parties, in order to increase the effectiveness of the process. By discussing key change orders in a triangle format (Client - EPC contractor - subcontractor), no time is lost to inefficient communication. It is recommended to discuss change orders collaboratively.
[7] Dispute resolution		• Defines how parties wish to resolve their disputes • Aim to reduce chances of going to court, but rather intends to settle disputes more amicably	In practice, it is seen that this remains a costly and timely practice	No additional implications found within the case studies.	
[8] Early warning notice (EWN)		• Entails that early warning should be given when changes occur on the project • This reduces the risk for the entire supply chain since early action can be taken to mitigate risk • Consequences of risk are minimized	Based on co-operation and trust. In practice, it is seen that this is not always adhered to.	• The EWN clause typically allows the subcontractor several days for notifying a change to the EPC contractor (back-to-back clause) • Subcontractors often do not comply with the quantification requirements of delays (documentation), which blocks the mitigation process of the risk	It is recommended to discuss the importance of quantifying the EWN change orders with the subcontractors, so that risk mitigation can be done most effectively. What is expected from subcontractors? Subcontractors need to be fully aware of this process, in order to reduce their chance of waiving the right to compensation.

9.2 Introducing the model

A solution model is developed based on the key inputs explained in the previous section. A 4-factor model for effective risk allocation is created, by focusing on a *network* risk allocation strategy, since it is believed that this is most effective for the nature of the EPC supply chain. The model is complemented by two other figures, namely the description diagram, and the diagram elaborating on integrating network collaboration in contracts. Essentially, the three diagrams each increase in the level of detail (LOD) to the previous one (see Figure 9.1).

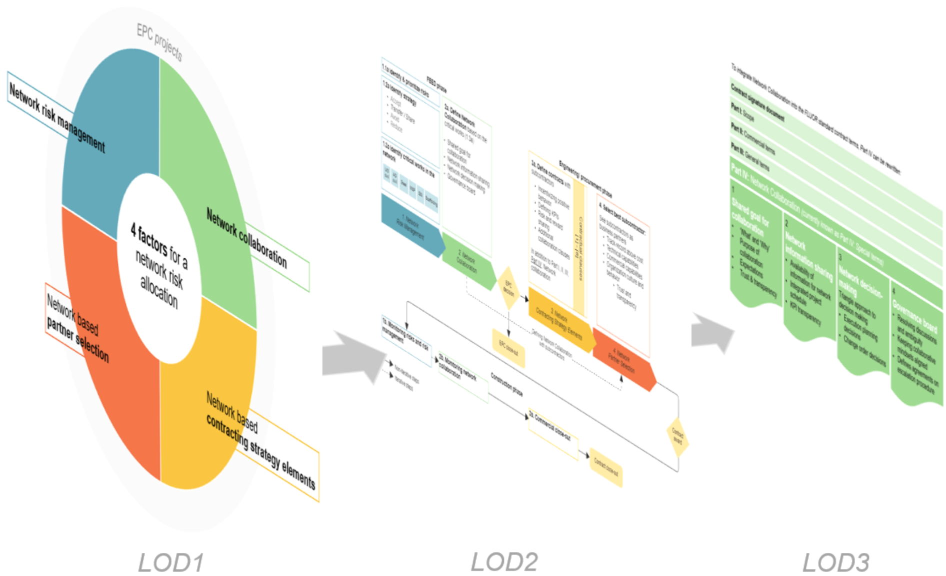


Figure 9.1: A visual of how the three diagrams of the model interrelate in the level of detail (LOD).

9.2.1 The 4-factor model

Firstly, the model, shown in Figure 9.2, demonstrates the four factors which help attain a network risk allocation within EPC projects, to improve project performance (LOD1). This is the basis of network risk allocation.

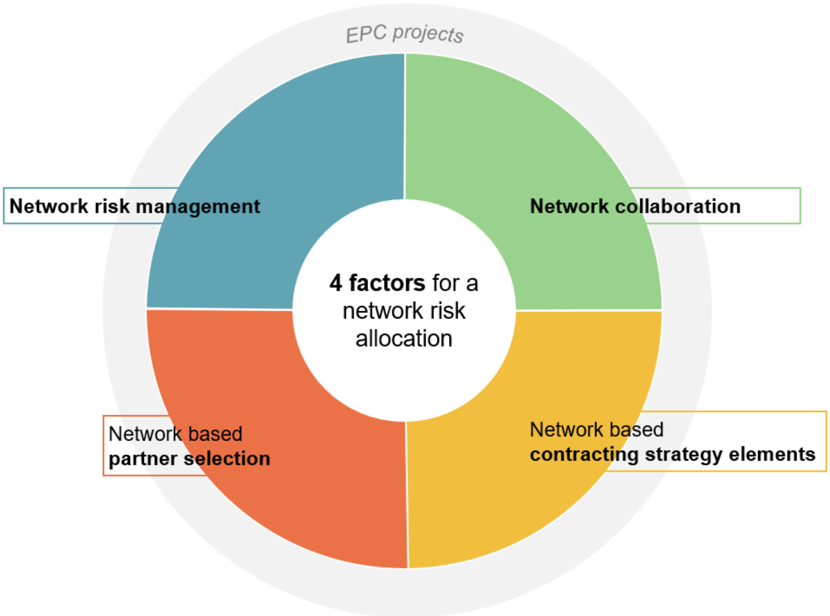


Figure 9.2: The model developed for a network risk allocation.

The four factors for a network risk allocation are:

1. **Network risk management:** This refers to the risk management process currently applied by the Company (Figure 5.3), however, this risk management process is translated to a *network* format. Network risk management differs from the original form of risk management, by not predominantly transferring risks towards the most effective risk bearer, a linear risk transfer process seen in the case study research, however transferring or sharing risks where appropriate. Rather than 'transferring' risks down to subcontractors where possible through contracting, also the option of 'sharing' the risk between subcontractors becomes a strategy. For example, EPC projects often see friction in where the scaffolding is placed for construction. This creates the risk for subcontractors that the scaffolding is not placed effectively, thus creating a coordination risk for the EPC contractor. For instance, when three subcontractors need scaffolding for their on-site work, it is recommended that this risk is *shared* rather than transferred to a single party. By letting the subcontractors share this risk, it creates that they collaboratively decide on the scaffolding position, creating a win-win situation. Furthermore, *network* risk management also includes the process of identifying critical works in the network, understanding the interrelations and inter-dependencies between these works, and pinpointing where the high-risk tasks are. It focuses on seeing relationships between risks, and relationships between the supply chain and these risks.

2. **Network collaboration:** Network collaboration is a factor that influences the risk allocation in projects, as the case study results demonstrated that collaboration between network parties can reduce the burden per subcontractor. The elements of network collaboration are explained in section 9.5, where supply chain collaboration is translated to the specifics of EPC projects. This includes 1. shared goal for collaboration, 2. network information sharing, 3. network decision-making, and 4. governance board.

3. **Network-based contracting:** Within a network risk allocation, it is important that the contracting strategy aligns with the network approach. This network-based contracting refers to the way in which contracts are issued between EPC contractors and subcontractors, through the contractual clauses and recommendations explained in Table 9.2. These clauses can be used to define contracts on a more collaborative approach, rather than a traditional approach.

4. **Network-based partner selection:** For an effective network risk allocation between EPC contractor and subcontractors, it is crucial that the partner selection is aligned with the network approach. Partner selection on a traditional basis focuses on the expertise of the subcontractor in past projects (track record) and selecting based on the lowest tender bid [Doloi, 2012]. However, this *network* based partner selection focuses on a more thorough selection process, since one bad apple in the subcontractor group, can spoil the whole bunch (network inter-dependencies). Having an underperforming subcontractor in the network can cause certain works to be delayed, and due to the characteristics of EPC projects, this affects all the supply chain players. Therefore, this method does not suffice. All the subcontracting parties rely on each other to deliver the expected results of the agreements. Therefore, a network-based partner selection is advised, which entails a more detailed and relational approach to selecting subcontractors. This attempts to increase the value of a project through its partner selection.

9.2.2 The description diagram

It is important to understand that the factors of this model do not stand alone. These four factors impact each other and can enhance the effectiveness of risk allocation with the EPC project. To clarify the factors and their influence, a description in the form of a flowchart is provided in Figure 9.3. This description diagram gives guidance for implementing the network risk allocation model. However, this model will be evaluated, improved, and explained in section 9.4.

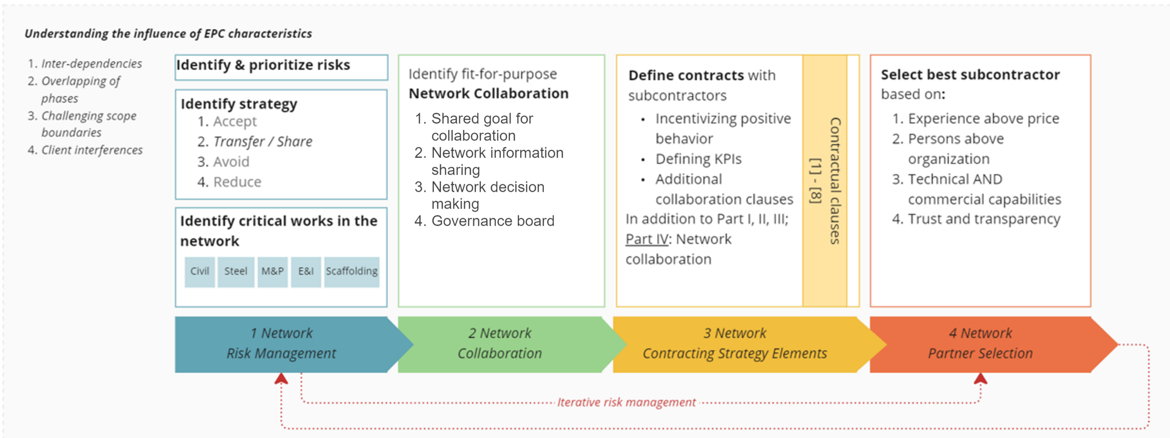


Figure 9.3: The description for implementing the network risk allocation model (original version).

9.2.3 Step 2: Network Collaboration

Along with the model and the description for implementing the model, a closer look is taken at how network collaboration can be defined in the contract. This has led to the following four elements, which are important for defining network collaboration. These key points are based on the contractual agreements to support collaboration by Rijkswaterstaat [2022] (see Figure 8.3), and the Network Collaboration elements (network information sharing and network decision-making) presented in subsubsection 9.1.4. The original version of this visual can be seen in Appendix I and describes four key elements for integrating Network Collaboration into the standard contract terms of the Company. In summary, these four elements are:

1. Shared goal for collaboration
2. Network information sharing
3. Network decision-making

4. Governance board

During the expert evaluation, the content of the elements was discussed, and the final version with an explanation can be found in Figure 9.5.

9.3 Expert evaluation

The goal of expert evaluation is to discuss the main recommendations and solutions to see to what extent the model is applicable in practice.

9.3.1 Evaluation approach

The expert evaluation is organized through a physical focus group discussion setting. This is a commonly used qualitative approach, to share feedback, and suggestions, and discuss the proposed recommendations and solutions. Hennink [2014] describes a focus group as "an interactive discussion between pre-selected participants, focusing on a specific set of issues. The aim of the focus group is to gain a broad range of views on the research topic". The experts involved in the focus group are employees from within the Company. The experts were selected on the basis of their knowledge of the topic. The four experts are mentioned in Table 9.3.

Table 9.3: List of experts participating in the evaluation focus group discussion.

Code	Function	Work experience
E1	Director Contract Management	+15 years
E2	Executive Project Director	+15 years
E3	Prime Contract Manager	+30 years
E4	Global Director Contract Management	+10 years

The main goal of this discussion was to evaluate the applicability and comprehensibility of the model in practice. Therefore, the discussion was led by the following three questions:

1. To what extent do you agree or disagree with the proposed factors for effectively allocating risks in EPC projects?
2. To what extent do you think the steps for an effective risk allocation in EPC projects are applicable in practice? Do you have suggestions for making the model more practical?
3. To what extent do you think the four elements of Network Collaboration can be integrated into contracts to enhance collaboration?

Firstly, a short presentation was given to the experts, to provide some background knowledge on the research. A PowerPoint presentation was used to support the discussion and allow for visual interaction, and the experts were all provided with a printed version of the model.

9.3.2 Outcome of the focus group discussion

[1] Viability of the proposed factors for influencing effective risk allocation
Experts were initially asked to give feedback on the model by answering question 1. All the experts agreed on the 4 factors and the wording of the model.

[2] Applicability of steps to describe the implementation of the model
The participants were asked about the applicability of the steps, thereby answering question 2. Overall, the applicability of the steps is agreed upon by all the experts. It is clear how the description links to the model, and the steps are well-defined. A few suggestions have been made for improving the model:

- Step 1: Expert E2 discussed the step 'Identify critical works in the network' and explained that to his knowledge, the civil commodity is never considered critical work. He states that it is best to separate the civil works into underground and above-ground civil works since these two works have different levels of criticality. The complexity starts with the above-ground works. Civil underground works are low in criticality, seeing as they do not depend on other commodities yet, being the first works on site. Little added value would come from integrating them into the collaboration model. Civil underground works can be incentivized through completion bonuses.

- Step 2: Expert E3 states that it remains unclear what is meant by the 'fit-for-purpose' network collaboration step. He suggests different phrasing for this step. It should be clear that in step 2 'Network collaboration', a traditional or a collaborative approach is chosen based on the criticality of the works (fit-for-purpose). It is decided that step 2 is best rephrased to "Define network collaboration for the critical works".
- Step 3: This step was clear.
- Step 4: Expert E3 states that the enumeration of points for subcontractor selection causes the reader to believe these points are in terms of ranking (Most (1) to least important (5) criteria). To avoid this, it is recommended to use bullet points, so that each criterion weighs the same.
- Step 4: Expert E2 suggests changing the vocabulary used for '3. persons above organization' to '3. organization culture'. This keeps the criterion broader since the persons within a company tend to act according to the culture of the organization. However, when solely selecting a specific person, rather than an organization, you have the risk that this person leaves the company or moves to a different project. Expert E3 adds to this, that he does not see it as feasible for the Company to select based on persons if the organization behind that person is not suitable. However, it is important to also look at the capabilities of the person.
- Step 4: It is recommended by expert E2 to change the vocabulary of '2. Experience above price' to '2. Track-record above costs'.

Additionally, the iterative nature of the steps is discussed. It is said that steps 1 and 2 become iterative during the construction phase of the project. Steps 3 and 4 have been terminated by this time since the contract and the selection of partners are set in stone. An iterative loop between step 1 and step 2 within the construction phase needs to be added to the model to increase its applicability. Moreover, expert E1 suggests it should be clearer in which EPC phases this process takes place (see Figure 2.2). Lastly, a remark is given about "Understanding the influence of EPC characteristics. These are important for the implementation of this model, however, they are too confusing within the visual. Therefore, it is recommended to elaborate on this within the research, not within the visual.

[3] Applicability of network collaboration into contracts
Lastly, the participants were asked about the integration of the four elements of network collaboration into the contracts of the Company (see Appendix I). This thereby answered question 3. Overall, all the experts were convinced of the applicability of the network collaboration integration into contracts. Several recommendations on the elements:

- Element 2: It is stated by all experts that the financial transparency fits within the commercial terms of the contract, rather than the network collaboration terms. This can be reworded towards KPIs transparency, seeing as this entails the part of the contract that subcontractors are putting at risk with each other. This is part of the collaboration.
- Element 3: It is stated by expert E1 that it should be clear 'who' is included within the 'triangle approach' for decisions regarding execution planning and change orders. The experts agree that most preferably, the triangle approach includes the Client, as well as the supply chain (EPC contractor and subcontractors).
- Element 3: It is noted that within the bullet 'planning decisions', it should be clear what planning decisions this entails. Seeing as the main planning is on a higher level (Client), these planning decisions refer to execution planning, on-site planning, and day-to-day planning with the collaboration network.

- Element 4: Expert E3 states that it should be clear 'who' the board includes, 'when' the board comes together, and 'how often' they come together. According to the experts, the board members should be senior executives with decision-making power. Additionally, a clear description of escalation/dispute handling should be described.

These recommendations and suggestions by the experts are used to improve the model. The next section demonstrates the final model.

9.4 Final model

Firstly, the 4-factor model is not altered from the original version (Figure 9.2), seeing as the experts agreed on the presentation of these 4 factors. However, the description model did receive various suggestions for improvement, leading to the final description model in Figure 9.4.

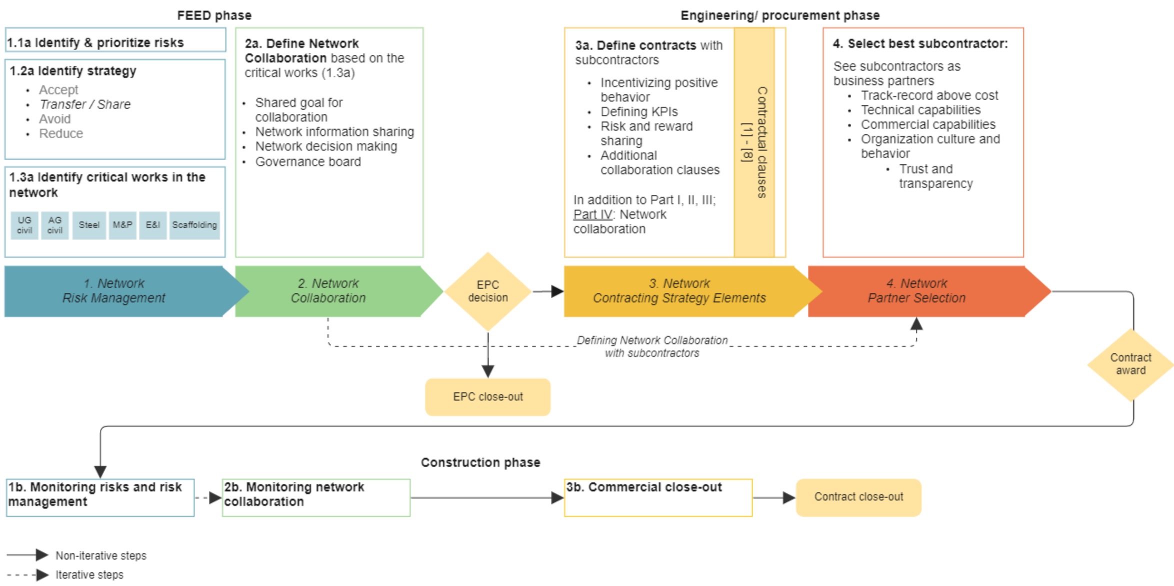


Figure 9.4: The description for implementing the network risk allocation model (final version).

The description model explains how the four factors can be used as steps toward a network risk allocation approach. By following this model throughout the project life cycle phases, guidance is given to create a network risk allocation between EPC contractors and subcontractors in EPC projects. The first two steps, namely 1. 'Network Risk Management' and 2. 'Network Collaboration' apply during the FEED phase of the project, which is after the construction feasibility study, and before the Final Investment Decision (FID) has not yet been made. Step 1.1a commences by identifying and prioritizing the risks within the project, both internal and external risks. Mubin and Mannan [2013] describes how to prioritize these risks based on severity and likelihood. Step 1.2a is identifying the strategy for these risks, for which the risk *allocation* focuses on transferring the risk or sharing the risk. Once this strategy has been chosen, step 1.3a suggests identifying the critical from the less critical works in the network. These works include underground civil works, above-ground civil works, steel works, mechanical and piping works, electrical and instrumentation works, and scaffolding works. Regarding these works, it is found that in most EPC projects, the critical works start with the 'above-ground' works. Civil 'underground work' is seldom to never seen as critical work. In EPC projects, the civil underground subcontractor is the first subcontractor on-site, which creates that there is little complexity and interdependence for this work. This also creates little to no added value for this party to be thoroughly involved in a collaboration model. It is advised that for such a non-critical commodity, the work is incentivized by applying milestone completion bonuses to reach the out-of-ground setting as quickly as possible.

The identified critical works are input for step 2a. the network collaboration. This is a crucial step, seeing as one of the downsides to collaboration models is the time-intensive nature of setting up such a model with the right parties (barrier 1 in Table G.1). Therefore, it is advised to keep the network collaboration model for when it is truly necessary. Interviewee I6 mentioned that "You would very rarely do the civil, the foundations, and the painting in a collaborative model", due to the low level of complexity of these tasks, and the high levels of time sensitivity in these EPC projects. In order to increase the feasibility of implementing a network collaboration, it is recommended to define the network collaboration based on the identified critical works. With the critical commodities, the network collaboration is then formed based on the four elements: shared goal for collaboration, network information sharing, network decision-making, and a governance board. These elements are elaborated on in section 9.5.

After the FEED phase, a decision is made whether the project continues into engineering and procurement, or whether the project is not realized, and the EPC project is closed-out. This is called the FID, where the Client decides to (not) make the major financial commitments. If the project is pursued, the project moves into the engineering and procurement phase of its project life cycle and continues to step 3a. Step 3a focuses on defining the contracts with the subcontractors. The contracts are defined on the basis of the contracting strategy elements defined in Table 9.2. The main recommendation for this step is to define the contracts on a network basis, where the elements incentivize positive behavior, by setting both incentives as well as LDs. Furthermore, it is recommended to link the incentives with KPIs, seeing as this aligns the parties in attaining the project objectives. Moreover, the risk and reward sharing mechanism is to be contractually defined, which explains to which extent subcontractors share certain risks and those financial burdens (further explained in subsection 9.5.1). The additional part IV in the contract is elaborated in Figure 9.5.

Step 4 includes the network partner selection, and focuses on the subcontractor's capability, and to which extent these subcontractors are structured to meet the project's obligations. It is recommended that the subcontractors are seen as business partners by the EPC contractor, to immediately set the collaborative attitude at the start of the project. For the partner selection criteria, a look is taken at the currently used criteria by the Company (see Appendix H), which is focused on mostly quantitative criteria. This network partner selection recommends that these partners are based on their track record and previous experiences on projects, more so than their tender bidding price. Technical capabilities are important to consider, as well as the commercial (financial) capabilities of the subcontractor. In order to increase the proportionality of the risks carried by the subcontractors, their commercial stability should be proportional to that risk. This is often neglected and can create huge risks for the subcontracting party as well as the other parties in the network. Finally, the network partner selection focuses on the culture of the partnering organization (soft skills). According to the interviewees, certain subcontracting parties are known for their claim aggressive culture, which immediately promotes the wrong behavior in a collaborative environment. Understanding the culture of the organization is the first step in understanding the person for the job. Once the culture of the organization is in line with the intent of the project, the EPC contractor is recommended to thoroughly interview the onsite management team, based on not only hard skills, but also soft skills. These are the people that are ultimately relied on for delivering the project execution. Within this process, subcontractors are recommended to explain their 'behavior' on previous projects. Questions can be asked such as "How did you collaborate in these circumstances?", "How would you behave when ... happens?". This can provide a good understanding of how culture and behavior of the subcontracting company. A certain sense of trust and transparency needs to be created as a foundation of the collaboration model.

Once the best subcontractors have been selected, an iterative process is created between step 4 and step 2a, as the network collaboration needs to be defined in consultation with the subcontractors. All the points within network collaboration need to be discussed, and the governance board members need to be selected from the subcontracting party. This means that only in step 4, the governance board becomes operational. Once this iteration has led to a defined network collaboration in the contract, the contract is awarded, which thus leads to the construction phase. This is when steps 1b and 2b become relevant. This is an iterative process for monitoring the risks and the collaboration performance during the execution of the project. A crucial part of the network risk allocation process. Step 1b involves reevaluating the risks, keeping track of changes, and identifying potential new risks. As risks are monitored, changes are registered, lessons learned are identified, and risk management can be improved continuously. The same holds for the network collaboration process. Once construction starts, the collaboration starts. This needs monitoring and makes room for continuous improvements. Finally, as the construction phase comes to project completion, there is step 3b. commercial (financial) close-out, and finally, contract close-out. This is the termination of the EPC project.

9.4.1 Non-critical works

As explained by the description diagram, network collaboration is defined based on the critical works in the project. This is because it can be too time sensitive to integrate all the parties in the supply chain, whilst not all these parties actually attain added value by collaborating so intensively. Therefore, the non-critical works can be contracted on a more traditional basis. For example, the civil underground works are seen as a non-critical commodity, and thus, this party will have little to no gain in a risk and reward-sharing mechanism. The underground civil works carry little risk, due to a low level of inter-dependency, and few technical interfaces, which makes it less attractive for such a party to share risks with more critical works. However, once a more traditional approach is chosen, this does not mean that collaboration cannot be defined in the contract. It may still be useful to define certain collaborative terms in a less time-intensive manner. Additionally, trust and transparency may not be a priority in the subcontractor selection criteria, seeing as this party has a straightforward job, where commercial terms are more prioritized. This format, therefore, depends on the criticality of the work.

9.5 Implementing a network collaboration contract

Implementing collaboration into contracts is an important step for the contractual governance of collaboration. Nikulina et al. [2022] explains that to attain collaboration, both contractual governance and relational governance are important. This implies that the contracts need to support the collaboration which is desired. Two important elements within contracting are defining the commercial (financial) collaborative terms and defining the network collaboration in the contract.

9.5.1 Commercial terms for collaboration

This element ties in with the 'risk and reward' sharing in step 3 defining contracts. At the end of the day, collaboration can be fostered by commercially incentivizing the participants in the model. Realistically, it comes down to financial feasibility. Without financial gains, what is there to win? The commercial model should be a model that supports collaboration, with a clearly defined and achievable set of KPIs that are aligned with the project goals. The commercial model refers to the [1] price arrangement in the contracting strategy clauses (Table 9.2), which is seen as a crucial element for the success of a network risk allocation. Through the empirical study in chapter 7, it is found that the cost reimbursable model best supports a collaborative environment. It is advised that the contracts take on a cost-reimbursable price arrangement, where all actual costs and overheads are refunded so that there is no commercial risk for the subcontractors, only the risk of losing profit. Furthermore, the gained profit can be based on performance. Profits can be seen as reward buckets, which are created to hold the profit for the subcontractors. These buckets are at risk in instances of poor performance in accordance with the contract. Reward buckets can be shared between certain commodities and interfaces, so that the risk of management and coordination decreases, and incentive is given to the subcontractors to manage their work interfaces. This provides an example of how the commercial model can support network collaboration.

9.5.2 Defining network collaboration

Additionally, the next level of detail (LOD3) is explained, which focuses on how the network collaboration (step 2) is to be defined in the contract.

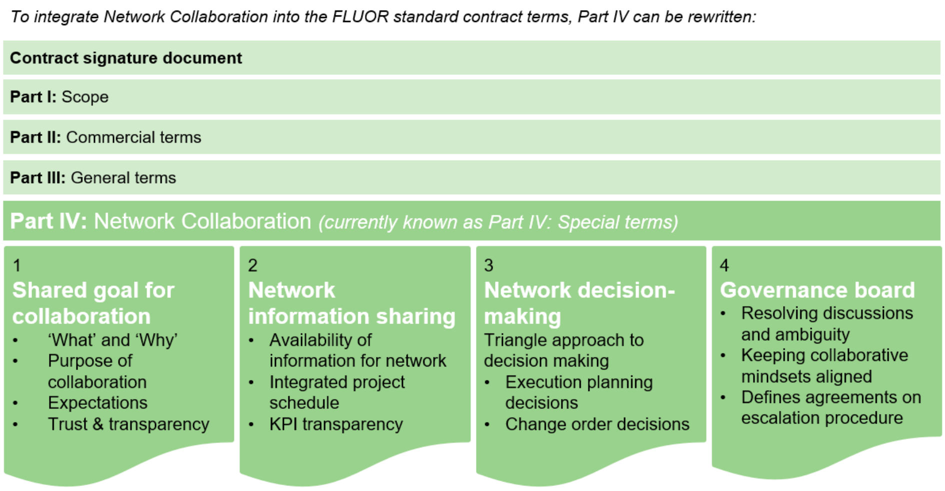


Figure 9.5: The four key elements for implementing collaboration in contracts (final version).

Figure 9.5 elaborates on the four elements which are necessary for integrating Network Collaboration into contract terms. These elements refer back to subsubsection 9.1.4, and elaborate on what needs to be defined for contractual governance. The Company (Fluor BV) works with a predefined subcontractor contract (including parts I, II, and III). It is advised that the contract adds an additional part IV, which focuses on the main elements of network collaboration. Defining the network collaboration terms in the contract with the subcontractors immediately sets a collaborative tone for the project, demonstrating the importance of this collaboration. This mobilizes the subcontractors with the right mindset - from the beginning of the project, until the end of the project. It is recommended that when introducing this additional contract, it is written based on 4 main elements, namely:

1. **Shared goal of collaboration:** focuses on aligning the perspectives and expectations of the parties involved. This includes the 'what' and 'why', the purpose and expectations of the collaboration, and the shared understanding of 'trust and transparency'.
2. **Network information sharing:** defines what information is important to share within the network, and where transparency is crucial. It is recommended to share project schedules amongst the supply chain so that all subcontractors work towards the integrated project schedule. Furthermore, KPIs and measurement criteria should be defined in this element.
3. **Network decision-making:** explains which decisions and discussions are made in a triangle approach with the subcontractors, EPC contractor, and preferably the Client. These are discussions about the execution planning and change orders so that misunderstandings and discussion time about planning and change orders can be reduced.
4. **Governance board:** focuses on monitoring the execution of the collaboration goals and agreements. This governance board is recommended to include 1 to 2 persons per organization (most preferably also the Client), and ideally in the position of 'managing director' or above. Moreover, the governance board is responsible for resolving discussions and ambiguity regarding the network collaboration in the project, and keeping the collaborative mindsets of the parties on and off-site aligned. Furthermore, clear agreements should be made regarding the escalation procedures.

It should be noted that the element of 'risk and reward sharing', explained in Table 9.1, is not included in this Part IV of the contract, seeing as this is included in the Part II Commercial Terms of the contract (explained in subsection 9.5.1).

9.6 Conclusion

The purpose of this chapter is to develop a network risk allocation model, which can be implemented in projects in order to improve the performance of EPC projects. It was found that the network risk allocation model is based upon four main factors, which are 1. network risk management, 2. network collaboration, 3. network based contracting strategy elements, and 4. network based partner selection. A key element here is that the network approach focuses on understanding the relations between the different subcontractors and their work. These factors all influence the effectiveness of the risk allocation in EPC projects.

Firstly, the network risk management is based upon the original risk management process, however, it integrates the possibility of *sharing* risks within the network, as well as identifying the *critical* works within the project. The network collaboration is based on the theory of 'Supply Chain Collaboration' by Shaikh et al. [2020], however, the elements for collaboration have been translated for EPC projects specifically. Thirdly, the network-based contracting strategy is focused on defining the contracting strategy elements in such a manner, that the network as a whole can benefit from these clauses. Furthermore, it focuses on positively incentivizing the network, in order to keep motivating the right behaviors. Finally, the network-based partner selection aims at understanding which partners are best chosen, whilst looking broader than the traditional form of partner selection. It focuses on soft skills, as well as hard skills.

Moreover, the description diagram demonstrates how this model can be used in practice, by following the steps mentioned in Figure 9.4. Additionally, four key elements have been identified for defining collaboration into contracts (see Figure 9.5). These elements are key elements in order for collaboration to not only be a verbal agreement, but also to define its importance in the contracts, and set the project off to a collaborative start.

Conclusively, it all comes down to the goal of completing projects within time, within budget, and within HSE requirements, whilst protecting the subcontracting parties in that journey. By integrating a network model, where parties focus on collaborating, understanding the critical works and interfaces, and being incentivized to solve the execution issues together, fewer change orders will take place, which can cause fewer negotiations, claims, and disputes to arise. The number of change orders will most likely decrease because as one subcontractor creates a change for another subcontractor, rather than issuing a change order to the EPC contractor, the subcontractors will come together and discuss the consequences collaboratively. There is a profit at stake for each party to perform well (risk and reward), which makes subcontractors feel a sense of shared responsibility.

The following chapter discusses the implications of the results as well as the limitations of this research.

10 Discussion

This chapter includes the implications of the research results (section 10.1) and the limitations of the research (section 10.2).

10.1 Implications of the results

The Engineering, Procurement, and Construction (EPC) projects have become an internationally popular model for construction projects, where large risks are bore by the EPC contractor and the subcontractors [Galloway, 2009; Guo et al., 2010]. However, EPC projects in the construction supply chain are seen as an under-developed research area [Ke et al., 2015], especially in the downstream risk allocation of these projects. Therefore, exploratory research has been conducted, with the aim to develop a model and an action plan, on how to improve the risk allocation between the EPC contractor and the subcontractors, through strategic contracting. This is completed by developing a model which identifies the key factors towards a *network* risk allocation approach. A network approach is identified as an approach that can help deal with the characteristics of EPC projects, by sharing the risks and reducing the dis-proportionality of the risks carried by the subcontractor.

The concept of risk management is a widely discussed topic in construction literature, seeing as risks are inherent in construction projects. Wang et al. [2016] found that the high uncertainties of the international markets, in which EPC project operate, and the complex EPC processes make it unfeasible for EPC contractors to manage the risks by relying solely on their own capabilities. The subcontracting party (Interviewee I9) agrees with this, as it was stated that risks are often disproportional for smaller subcontracting parties to carry. It is seen that risk management is a popular topic within the industry, however, risk allocation theories are rarely found. Risk allocation is a crucial element within risk management, as this "allocation" simply transfers the risks to other parties down the supply chain, by using contracting strategies. Peckiene et al. [2013] explains that there are many studies that emphasize 'equitable risk allocation', however, it is often seen that the 'responsibility' of the proper allocation of risks lies with the Client. Research hereby focuses on the upstream risk allocation process, between the Client and the general contractor, however, little attention is given to the smaller subcontracting parties, who carry risks that may not be proportionate or equitable. Therefore, the research into effective risk allocation with contractual parties in the supply chain is a very important topic with both scientific and practical relevance. The lack of research on this topic demonstrates the need for understanding how risk allocation can be applied more effectively, to attain project goals and good project performance. As clients typically accept as little risk as possible [Peckiene et al., 2013], the risks are transferred to the contractor, who in turn prices this risk, due to the possibility that the risk escalates and becomes their responsibility. In other words, this creates higher project costs, and raises the question, is the subcontractor capable to carry that risk? Therefore, this research does not only bring valuable knowledge to the subcontractor's side, but also to the project as a whole since an effective risk allocation can create a win-win situation for all parties.

The literature review in chapter 4 identified the contracting strategy elements available for allocating risks within construction projects. These contracting strategy elements are tools for allocating or transferring risks to certain parties down the supply chain. The contracting strategy elements are not limited to these elements, as effective risk allocation goes beyond contractual governance. Allocating risks does not merely rely on contractual obligations and arrangements, yet it is also influenced by relational governance. Relational governance stresses the importance of relationships between actors in the supply chain [Lu et al., 2015], within a trusting and transparent environment. Only when applying both in the process of allocating risks, will risks actually be managed effectively. This idea of a network risk allocation focuses on the holistic view of risk allocation, including more than contractual obligations. The network risk allocation includes the implementation of a network collaboration contract. It is studied that when aiming for a collaborative network in EPC projects, both the contractual (formal) as well as relational (behavioral) governance must interplay. Nikulina et al. [2022] explains this quite well, as the contractual mechanisms provide an arena for the relational governance to be realized, and for collaboration between partners to be practiced and pursued. This is why defining collaboration into contracts and having commercial terms which support collaboration are crucial for attaining collaboration in EPC projects. As collaboration needs all participating parties to rely on each other's trust and transparency, this raises the question if this sector is capable of doing so. This potentially needs a culture change, from a traditional adversarial environment, focused on claims and disputes, towards a collaborative network, where parties share both the risks and the rewards, whilst focusing on performance, rather than claims. Attaining a fully collaborative environment, in a sector known for its traditional approaches, will be complex in practice. Brooke and Litwin [1997] states that this may demand radical organizational change when coming from traditional practices, as it not only demands different organizational structures but also behaviors. Especially as EPC projects are often large international projects, working globally with subcontracting parties, the aspect of culture can become a challenge. Already within the Company (Fluor BV), it can be seen that a different perspective on risk allocation is seen in America versus Europe. The approach to risk allocation and subcontractor relations tends to be more formal and traditional in America as opposed to the Netherlands. Cultures can greatly influence the feasibility of this model.

It is also believed that the EPC context influences the extent to which this model can be implemented in a programmatic way. In an ideal world, the network collaboration is set-up with a number of subcontractors; a process which requires dedication and effort from all participants. Once this model has been set-up and successfully implemented, it would be valuable to *maintain* this supply chain group and put their knowledge of the collaborative model to use in further projects - a programmatic approach. However, it can be debated to what extent this model can be implemented in a programmatic way. As EPC projects are mostly seen as one-off projects, where the subcontracting parties are selected based on geographical factors, it is difficult to create a programmatic process with this model. These EPC projects are international projects, which creates a larger pool of subcontractors that can be selected than solely in the Netherlands. So in the practical world, it will hardly be seen that two stand alone projects, located in different regions, will continue with the same supply chain group. This makes it difficult to create a programmatic model. This *can* however be created in programs, where several projects are under the umbrella of one Client. As subcontractors are desiring longer working agreements, where they can rely on sustainable relations between the EPC contractor and themselves [Lee et al., 2018], it can be valuable for an EPC contractor to win programs instead of one-off projects. However, this depends on what the market is offering.

Moreover, it can be discussed whether collaborative models are suitable for EPC projects which are highly schedule driven. Collaborative models are time-consuming models, and therefore, it can be questioned if there is time available in EPC projects to set up a network collaboration. Research shows that the costs within construction projects are at their peak, during the execution of a project [Capone et al., 2014; Malekani, 2019]. This means that every day a subcontractor delays, due to the change order negotiations or disputes regarding interfaces, this is an extra day paying for the direct and indirect costs on site, such as labor waiting to do their job, and keeping the facilities up and running. However, by spending more time in the initiation/ FEED phase of the project, where costs remain low, on creating the right team, with incentives to perform and collaborate well, the risk of delays during execution is mitigated. Therefore, spending time on a network collaboration model at the start will eventually maximize the potential for success during the EPC execution. This raises the question if this model is solely applicable for EPC projects, or if it has value to construction projects in general. Risk allocation affects the success of all construction projects. Therefore, the model for a network risk allocation is applicable to construction projects in general terms. However, the identification of critical works, and specifically framing a collaborative model around the critical works, is not suitable for all construction projects. It must be noted that collaboration is best attained when all stakeholders are involved and aligned. Therefore, it can be said that this model is applicable to projects which are schedule driven, contain critical interfaces, and therefore, require a time-efficient approach to an effective risk allocation.

Finally, it is important to discuss the positive side of risk, namely, opportunity risk. As mentioned in chapter 3, risks can be interpreted as threats or as opportunities. In this research it is found that in practice (referring to the case study analysis), risks automatically carry a negative connotation amongst practitioners and create a behavior which demonstrates the need to "get rid" of the risk. There is an aversion towards risks in EPC projects, and therefore, risk management resolves around the idea of removing risks where possible. Risks as *threats* are recognized far more in practice, than risks as *opportunities*. Conclusively, it is found that within EPC projects, a lack of attention is given to the opportunities that can arise from risks, which is a loss of potential added value to a project.

10.2 Limitation of the research

The limitations of this research are the following:

- The research is limited to the perspective of one EPC Company, and one subcontracting party. This obviously creates quite a narrow idea of how risk allocation is perceived by these parties, as different parties may have different perspectives on the topic. A smaller subcontracting party can have a significantly different perspective on how equitable the risk allocation is compared to larger subcontracting parties. Also, the Client is not included in this research, however, the Client has a significant influence on the risk allocation process. It would have provided a more thorough understanding if more perspectives were included.
- The framework was validated by experts from within the Company, which means that the viewpoints regarding this topic can be quite similar among the experts. A more in-depth analysis could have taken place if the opinions of experts from outside of the Company would have been included.
- The framework has been discussed and optimized through a validation process with experts. However, the framework has not been validated in practice, but solely in a conceptual environment. Therefore, it must be noted that it remains challenging to foresee the practical implications of the framework.
- The primary research includes an analysis of just two case studies, that have been completed by the Company as an EPC contractor. Analyzing more case studies from within the Company could provide a more complete understanding of the risk allocation process within EPC projects.
- The research includes two case studies from within the same Business Group, namely Life Sciences, and Technology. A more holistic stand could be gained when expanding this group, and diving into projects from different sectors.
- Many risks within EPC projects are created by the dependency of the supplier. This factor has not been researched in this paper, however, it can have a significant impact. Therefore, including the supplier within the supply chain could have provided a more thorough risk allocation analysis.

11 Conclusions and Recommendations

This chapter elaborates on the conclusions of this research. This chapter will first answer the subquestions of this research (section 11.1), in order to finally answer the main research question (section 11.2). Finally, recommendations for both practice and further research are presented (section 11.3).

11.1 Answering the subquestions

1. **What are the common risks occurred in construction projects and how are these managed according to theory?**
   The first subquestion dives into the theoretical background of risks and risk management within construction projects. Since the subject of risks within EPC projects is lacking in literature sources, the theory was used for a more general viewpoint on execution risks within construction projects as a whole. The identification of risk within construction projects is a popular topic within academic literature. Therefore, a literature comparison of the identified risks by four different researchers was completed, in order to identify the overlapping and recurring risks in theory. This led to a total of 47 overlapping construction risks found in literature, whereby the most common risks (occurrence in at least 3 out of 5 literature articles) were: the inflation of prices, changes in laws and regulations, force majeur, poor communication between parties, errors and omissions in contractor's design, change orders in design, owner delay in approvals of change orders, different site conditions, and occurrence of disputes. The same holds for risk management, which is a topic that is widely discussed between researchers and practitioners. An overall understanding of the risk management process was found, which includes the 1. identification of risks, 2. assessment of the risks, 3. risk response strategy, and 4. risk monitoring process. The risk response strategies are widely accepted in literature and include accepting, avoiding, transferring, and reducing the risk.

2. **What are the characteristics of EPC projects and how are risks allocated through contracting strategies according to theory?**
   In order to understand the nature of the risks within EPC projects, both the structure as well as the characteristics of EPC projects have been researched. The organizational structure demonstrates the three main phases of EPC projects, namely Engineering, Procurement, and Construction. The theory presented that EPC projects are characterized by their inter-dependence of activities, the overlapping of project phases, work fragmentation, and a complex organizational structure. It is found that these inherent characteristics, can eventually create prominent risks within EPC projects. These projects are often referred to as fast-track projects, as the phases of engineering, procurement, and construction overlap drastically, in order to compress time. Moreover, the contracting strategies available for allocating risks within construction projects are researched, since these contracting strategies are a tool for transferring risk from one party to another. Various contracting clauses have been identified, however, the theory also demonstrates that by transferring risks to another party through contractual clauses, there is always a losing party (Figure 4.3). This demonstrates the win-lose situation caused by transferring risks down the supply chain. Furthermore, research finds that supply chains are complex systems, and often referred to as 'networks' in literature. This demonstrates that if the supply chain is a network, transferring risk to one party in the network automatically has an effect on the rest of the network. Parties cannot be seen in isolation from each other.

3. **How are risks in EPC projects perceived, allocated, and managed in practice?**
   A better understanding of risks in EPC projects is attained by conducting exploratory interviews with four experts. This complements the literature research found on construction risks, by focusing more on the practical findings on EPC specific risks. It was found, that in addition to the theoretical

EPC structure, EPC projects are carried out by a set of five standard commodities. These are civil, steel, mechanical and piping, electrical and instrumentation, and scaffolding. These commodities interface with each other during the execution of the project. Furthermore, a total of 25 main execution risks in EPC projects have been identified by the experts. These risks are managed in a similar manner as stated by theory and are allocated or transferred to other parties by the use of contracting strategy elements. A framework with the contracting strategy elements used in practice, to contractually allocate risk to a certain party. It came to the attention that as the Company takes on risks from the Client, its main objective is to flow down that risk to one of the subcontractors as a strategy to minimize their own risk. This somewhat contradicts the theory of the 'most effective risk bearer' ([C Ward et al., 1991]), as the risk is not necessarily flown down to the party who is willing and capable to take on this risk. This is where theory and practice fail to align, and where a network form of risk allocation becomes relevant. As supply chains are seen as networks, in both theory and practice, it is seen that a knowledge gap exists in a network approach to risk allocation.

4. **Which contracting strategies are seen in different EPC projects, and what effect do they have on project performance?**
In order to answer this subquestion, the conceptual framework developed in chapter 5 is used to analyze the risk allocation process in two case studies. These case studies are two EPC projects, both in the 'Advanced Technologies and Life Sciences' business group, which were analyzed on the basis of document analyses and semi-structured interviews. This led to the findings of how certain contracting strategy elements affected the project performance, and why certain contracting strategies were implemented in the way they were. In both cases, the contracting clauses were mostly of back-to-back nature, a linear risk transfer. Both the projects scored lowest on the 'within schedule' criteria. This means that the projects were not delivered within time, yet time is a crucial element in these fast-track projects. Overall, it can be said that the contracting strategy elements all have different effects on project performance. However, by only penalizing subcontractors and flowing down risks through clauses, productivity is hampered. Furthermore, the interviews concluded that the effectiveness of risk allocation goes beyond contractual clauses and obligations. It was found that the soft factors of contracting have a large influence on the risk allocation within projects. This includes the relationships between people, and their willingness to collaborate. Relational governance, not solely contractual governance, where trust plays a large role. The subcontracting party states that the risks are often not proportionate to what the subcontracting party can carry, however, a more collaborative environment can aid in carrying those risks.

5. **What can be learned from collaborative models in other sectors?**
This subquestion emerged due to the results from the case study analyses, which concluded that a collaborative model can help improve the risk allocation and management process in EPC projects. Since the collaborative model is not seen within the EPC projects within the Company, a broader look is taken at other sectors within construction. This subquestion aims as a source of inspiration, to identify how collaboration can be integrated into EPC projects. Three main elements for supply chain collaboration have been analyzed, which include 1. information sharing, 2. joint-decision making, and 3. risk and reward sharing. Along with these main elements for collaboration, certain elements are recommended by the interviewees for integrating collaboration into EPC projects, which include the importance of contractually defining collaboration (contractual governance). This is an important element in the development of a solution model.

6. **How can a network risk allocation model be developed to enhance project performance?**
Finally, the last subquestion focuses on the development of a solution, which can aid EPC projects towards a more effective risk allocation. It was concluded from the case study analyses that a linear risk allocation approach does not necessarily support project performance. Therefore, the solution for a more effective risk allocation is based upon a network approach, where the importance lies in understanding the inter-dependencies of actors and activities, and how certain risks influence

the rest of the network. A network risk allocation model is developed, based on four factors that, when correctly implemented, create a more effective risk allocation in EPC projects. This concluded in four factors, namely, 1. network risk management, 2. network collaboration, 3. network based contracting strategy elements, and 4. network based partner selection. These four factors all have a crucial influence on the effectiveness of risk allocation and provide guidance for EPC projects to hold stronger relations between the different actors in the network. The factors are to be implemented on the basis of the EPC phases, namely the FEED phase, the engineering and procurement phase, and the construction phase. The first two steps, 1. network risk management, and 2. network collaboration, take place in the FEED phase of a project when the project is focused on planning and design. Consequently, step 3 of implementing the network based contracting strategy elements starts at the beginning of the engineering and procurement phase of the project. This is followed by step 4, which entails the network based partner selection. When the partner selection has been completed, the network collaboration can become operational. This then leads to the contract award and is followed by the iterative procedure of monitoring both the risks as well as the collaboration during the construction phase. Once the construction phase is complete, the commercial close-out and finally the contract close-out are attained. By implementing the model based on the model description, a network risk allocation can allow for enhanced project performance.

11.2 Answering the main research question

How can risks within EPC projects effectively be allocated among the EPC contractor and subcontractors, to improve project performance through strategic contracting?

The subquestions in this research have been answered in order to finally answer the main research question. The main goal was to identify how risk allocation in EPC projects can be done more effectively, through the use of strategic contracting, for both EPC contractor and subcontracting parties. It was observed that there is a gap between theory and practice regarding risk allocation. In theory, as well as in practice, supply chains are regarded as a network, whilst this network philosophy is not reflected back in the risk allocation process within the supply chain. It is seen that project delays are the largest consequence of the risks in EPC projects and that the risks are found mainly in the coordination and management of the tasks. This causes time lost on change orders, disputes, and ongoing negotiations. However, it is found that a network risk allocation approach can help deal with the EPC characteristics, and thereby, better manage the risks which are inherent in these projects. The developed network risk allocation model is recommended for EPC projects, for various reasons. By explicitly identifying the supply chain as a network, the subcontractors can gain a certain feeling of inclusiveness, where they are part of the network, namely as a business partner. This automatically sets a certain behavior. This model focuses on understanding the relations between the different tasks and parties, in order to understand where risks lie and how they are best allocated. It focuses on incentivizing parties for collaborating and keeping in mind the end goal, rather than working adversely, and focusing on separate project scopes. The focus is on incentivizing positive behavior through contracts, rather than the status quo of adversarial behavior.

It should be kept in mind that these EPC projects have a time-sensitive nature. From the moment the Client awards the project to an EPC contractor, the project is high-paced. Therefore, the model demonstrates how strategic contracting steps can be taken to allocate risks effectively, whilst maintaining the high-paced environment. By effectively implementing the network approach in the critical parts of the project, risks can be shared between actors. Collaboration between the actors involves sharing best practices, continuously learning from others, and reducing the high risk within the management and coordination of tasks.

To conclude, it can be said that the contract is the language of a project. The language of the project should not be undermined in its power to affect the performance of a project. The contracting parties will behave depending on the language of the contract. It is all about mobilizing the right parties, with the right incentives and behaviors, at the *start* of the project. This mobilization is done through the four-factor model, where the focus should be shed on the network philosophy, moving away from the traditional approach. These factors all play a role within the contracting strategy of EPC projects and can guide risk allocation towards improved project performance. Network risk allocation is therefore seen as a part of strategic contracting, where the strategy goes beyond contractual obligations, and combines the use of relational and contractual governance to obtain project objectives. Strategic contracting is therefore based on defining contractual clauses *in balance* with the desired relationship between contracted parties. By applying this 4-factor model, the risks can be allocated in a network manner and enhance strategic contracting. This model thereby helps to avoid a claim culture, whilst aiming for a claim avoidance culture, by focusing on collaborating toward the main end goal: successful project completion for all parties.

11.3 Recommendations

These research results can conclude with some final recommendations to the EPC contractor parties and subcontracting parties. Recommendations for the project level and for the organizational level are distinguished, to clarify that different management levels need to take action. Furthermore, recommendations for further scientific research are identified.

11.3.1 Recommendations on project level

For both EPC contractor and subcontractors

- **Understanding the soft factors of contracting**, also referred to as relational governance, is an important recommendation for all the parties, as there is more to contracts than only written obligations. As was mentioned by interviewee I3, the failure lies in that people focus on the contract, but do not focus on investing time in relationships and trust. This is a change of mindset needed for a collaborative environment.
- **Organizing meetings to discuss the network collaboration** with the parties involved. Keeping an open discussion about how the model is perceived by the parties is a crucial part of making it a success. These meetings are recommended to be organized in order to keep all the parties aligned with the expectations of the network collaboration approach.
- **Forming integrated project schedules** and milestone dates with all the commodities in the supply chain, so that all work schedules tie into the final milestone completion date. This can help subcontractors to focus on the end goal, and understand how their work ties into the other works. By understanding the schedules of the other 'partners', collaboration can be enhanced, as subcontractors are aware of how their work can obstruct or advance certain works of others. Specifically for the EPC contractor, this may require a specific software or program to be developed, in order to synchronize these schedules.
- **Defining KPIs within the supply chain** is recommended in order to align the goals of the project. KPIs can be defined in line with the KPIs set by the prime contract with the Client. Having all the parties measure the performance of the project by the same performance criteria will help keep subcontractors aligned with the project goals.
- **Being transparent in the network about risks** that one faces. Trust can only be attained by being transparent in the challenges and opportunities that arise for each party, and as commercial risks and rewards are shared, it is crucial to be transparent in these risks and rewards.

For the EPC contractor

- **Implementing collaboration at the start of the project** is a key recommendation for the EPC contractor. If collaboration is desired within the supply chain, it is crucial that the implementation starts at the beginning of the project. At the beginning of the project is when subcontractors can be mobilized with the right behaviors and collaborative attitudes. Case study 2 is an example where the collaborative model was implemented late, during the execution of the project, however, by that time all the parties have already decided how they interact with each other and do not feel the urge for changing their attitudes. Therefore, if collaboration is desired, this should be a clear strategy from the beginning.

- **Understanding the capabilities and scale of the subcontractors** is crucial for an effective risk allocation in the supply chain. As subcontracting parties come in many different shapes and sizes, it is important to understand their capabilities. Parties need to be equipped sufficiently to support the work. The E&I subcontractor can be an expert in installing the power supplies and transformers, however, they may have little expertise in the legal obligations (documentation of change orders). Understanding the capabilities and scale of the subcontractors is a crucial step in understanding if this party is an efficient risk bearer.
- **Protecting the subcontracting parties** is a recommendation that stems from the fact that reaching project success is only attainable if all parties perform successfully. If one subcontracting party fails to meet contractual obligations because the contract has been set up too aggressively, it finally leads to a delay in that work, which in turn leads to delays in all other works, change orders, and claim negotiations. At the end of the day, there is a limited pool of subcontractors available, these are the parties that are equipped to do the job. Therefore, it is important to protect subcontractors from risks that they cannot handle. This is in everybody's interest.

For the subcontractor

- **Understanding the contractual administration requirements** in these large EPC projects. This is a huge recommendation for the subcontracting parties that take on EPC work, seeing as often subcontractors focus on executing the work, whilst correct documentation of change orders and other works is forgotten. Disputes between subcontracting parties and the EPC contractor can be avoided by understanding what is required from the EPC contractor regarding contractual administration.
- **Understanding the scale of projects** and the scale of the risks involved in these projects. It is seen that when risks are transferred to subcontractors, these risks are priced for by the subcontractor. However, pricing a risk does not necessarily increase the capability of a subcontracting party to actually mitigate the risk. Therefore, the scale of the projects and the risks involved should be well understood. Also when risks are shared among several parties.

11.3.2 Recommendations on organizational level

The recommendations on the organizational level are directed towards the EPC contractor, specifically Fluor BV, on a higher management level.

- **Support subcontractors with administrative requirements.** Both case studies demonstrated that a large risk carried by the subcontracting parties is their inexperience and incompetence with the contractual administration requirements. This was mostly seen regarding the administration of change orders in projects. Therefore, it is recommended to create a system that the subcontractors can work with, to thus, mitigate the risk that subcontractors fail to comply with the paperwork requirements because they do not understand or prioritize the procedures.
- **Win programs** rather than solely one-off projects, as stated in the recommendations by the interviewees (Table 7.6). Nikulina et al. [2022] explains that "because of the temporality of projects, there is often a lack of time to develop trust between the parties" which can hamper the network collaboration in projects. Therefore, it is recommended to aim and win a program as an EPC contractor, rather than solely one-off projects. Both the case studies were part of a larger program, which created the possibility for the supply chain to automatically continue on to the next project if the previous project was delivered successfully. This creates incentive for good performance, and possible strong long-term relations over several projects with a certain group of subcontractors. These programs allow more time for the true development of trust and collaborative atmospheres.

- **Maintain control of engineering in EPC projects.** It is advised for the Company to focus its bids on projects where it can maintain control of engineering within the project. As interviewee I2 has mentioned, this is seen as a fundamental element in allocating risks more effectively. By staying in control of the engineering, without fragmenting the responsibilities across subcontractors and the Client, the Company stays responsible for potential changes, and therefore, puts the Company in a better understanding of where the risks are.
- **Defining the commercial terms for 'risk and reward' models.** This is a crucial condition for implementing the solutions of this research. Defining the risk and reward model is a challenging task, as it needs to be both commercially viable and proportional for the EPC contractor as well the subcontractors. To engage subcontracting parties in a network collaboration model, all the potential wins and losses should be clearly defined. This is best first researched and developed on an organizational level, and later on, specified per project. A basic recommendation of how this can be defined as mentioned in section 9.5. Regarding the Company, Fluor BV, the commercial terms under 'Contract Terms - Part II' are recommended to be altered according to the risk and reward scheme.
- **Increasing awareness of network collaboration** by organizing workshops and discussion sessions. Network Collaboration requires trust and transparency from the parties within the supply chain network. However, it is recommended to first align the ideas of trust and transparency within the EPC company itself. What does collaboration mean to different people in the organization? It is important that this becomes a point of discussion on the organizational level.
- **Introducing soft factors and behavioral aspects** in the partner selection process. It is recommended that the Company, Fluor BV, improves its selection procedure for subcontractors (see Appendix H), by adding on certain selection criteria based on soft factors and behavioral aspects. This is one of the key results from the case study analysis and is found to be a large influencing factor in effective risk allocation. Soft factors are evidently quite a subjective selection criteria, and it is therefore recommended to discuss this on an organizational level rather than on a project level.

11.3.3 Recommendations for further research

The following points are recommendations for further academic research:

- **Moving from qualitative to quantitative research** by conducting research into KPIs and risk and rewards systems. KPIs need to be developed and an appropriate measurement system for these KPIs needs to be in place in order to effectively align the goals of EPC projects. Which KPIs are relevant for which EPC projects is a topic which needs further research. Furthermore, a risk and rewards system needs to be defined. This is crucial for the implementation of the network risk allocation model, as the commercial model is a large factor in incentivizing subcontractors to collaborate. What do these parties have to lose, and what do they have to win when participating in this model?
- **Researching the perspective and the role of the Client** in risk allocation and collaboration. As explained in this research, the Client plays a large role in the allocation of risks, as the Client flows risks down the supply chain. Additionally, it is preferred that when pursuing a collaborative contract, the Client is aligned with this ambition. This raises the question, how does the Client of EPC projects perceive risk allocation and collaboration in these projects? Ultimately, it is recommended to align all the stakeholders involved in the project, which makes it valuable to understand the perspective of the Client regarding this topic. Furthermore, their role in the selection of subcontractors can evidently have a large effect on the network based partner selection process. Therefore, understanding the Client's role and perspective on this topic is key.
- **Further research into the role of the suppliers within EPC project risks**. As procurement is a large part of EPC projects, and the supplies of materials and equipment are what enable the execution of these projects, it can be said that the performance of the projects is highly reliant on

the suppliers within the supply chain. The suppliers are outside of this research scope, however, it is very valuable to understand their position within this risk allocation model.

- **Further research into opportunity risks**. As explained in subsection 3.1.1, risks are often seen as threats, yet there are often possibilities for seizing opportunities through risks. Maximizing the likelihood of an opportunity risk can have positive consequences for the supply chain in EPC projects. Furthermore, focusing on opportunity risk can enhance a positive work atmosphere, and move away from adversarial relationships.

Bibliography

Abrahamson, M. (1973). Contractual risks in tunnelling: how they should be shared. *Tunnels and Tunnelling*.

Al-Sabah, R., Menassa, C., and Hanna, A. (2012). Evaluating significant risks in the Middle East North Africa (MENA) construction projects from perspective of multinational firms. *University of Wisconsin*, 78:1–10.

Alves, T. D. C. and Shah, N. (2018). Analysis of Construction Contracts: Searching for Collaboration. *Construction Research Congress 2018: Construction Project Management - Selected Papers from the Construction Research Congress 2018*, 2018-April:148–157.

Atkinson, R. (1999). Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International Journal of Project Management*, 17(6):337–342.

Baker, E., Hill, R., and Hakim, I. (2020). Allocation of Risk in Construction Contracts.

Ballesteros-Pérez, P. (2017). Modelling the boundaries of project fast-tracking. *Automation in Construction*, 84:231–241.

Baram, G. (2005). Project Execution Risks in EPC/Turnkeys Contracts and the Project Manager's Roles and Responsibilities.

Beach, R., Webster, M., and Campbell, K. M. (2005). An evaluation of partnership development in the construction industry. *International Journal of Project Management*, 23(8):611–621.

Bingham, A. (2022). Deductive and inductive approaches to qualitative data analysis.

Bolderston, A. (2012). Conducting a Research Interview. *Journal of Medical Imaging and Radiation Sciences*, 43(1):66–76.

Boukendour, S. and Bah, R. (2010). The guaranteed maximum price contract as call option. *http://dx.doi.org/10.1080/01446190110049848*, 19(6):563–567.

Bowen, G. (2009). Document Analysis as a Qualitative Research Method. *Qualitative Research Journal*.

Bowman, C. and Ambrosini, V. (2000). Value Creation Versus Value Capture: Towards a Coherent Definition of Value in Strategy. *British Journal of Management*, 11(1):1–15.

Brooke, K. L. and Litwin, G. H. (1997). Mobilizing the Partnering Process. *Journal of Management in Engineering*, 13(4):42–48.

Bygballe, L. E., Jahre, M., and Swärd, A. (2010). Partnering relationships in construction: A literature review. *Journal of Purchasing and Supply Management*, 16(4):239–253.

C Ward, S., B Chapman, C., and Curtis, B. (1991). On the allocation of risk in construction projects. *International Journal of Project Management*, 9(3):140–147.

Cagno, E. and Micheli, G. J. (2011). Enhancing EPC supply chain competitiveness through procurement risk management. *Risk Management*, 13(3):147–180.

Camarihna-Matos, L. M. and Afsarmanesh, H. (2005). Collaborative networks: a new scientific discipline. *Journal of Intelligent Manufacturing*, 16:439–452.

Capone, P., Getuli, V., and Giusti, T. (2014). Constructability and safety performance based design: A design and assessment tool for the building process.

Carty, G. J. (1995). Construction. *Journal of Construction Engineering and Management*, 121(3):319–328.

Chia, E. S. (2006). Risk assessment framework for project management. *IEEE International Engineering Management Conference*, pages 376–379.

Choi, T. Y., Dooley, K. J., and Rungtusanatham, M. (2001). Supply networks and complex adaptive systems: control versus emergence. *Journal of Operations Management*, 19(3):351–366.

Clough, R., Sears, G., Sears, S., Segner, R., and Rounds, J. (2015). Construction Contracting: A Practical Guide to Company Management.

Cohen, M. and Palmer, G. (2004). Project Risk Identification and Management.

Construction Industry Institute (1991). In search of partnering excellence. .

Corbin, J. and Strauss, A. (2008). Strategies for qualitative data analysis. *Basics of Qualitative Research.*

Cox, A. and Ireland, P. (2006). Relationship management theories and tools in project procurement. In *The Management of Complex Projects: A Relationship Approach*, page 251.

Cox, A., Sanderson, J., and Watson, G. (2001). Supply chains and power regimes: Toward an analytic framework for managing extended networks of buyer and supplier relationships.

Cox, A. and Thompson, I. (1997). 'Fit for purpose' contractual relations: determining a theoretical framework for construction projects. *European Journal of Purchasing & Supply Management*, 3(3):127–135.

Dainty, A. R., Briscoe, G. H., and Millett, S. J. (2001a). New perspectives on construction supply chain integration. *Supply Chain Management*, 6(4):163–173.

Dainty, A. R., Briscoe, G. H., and Millett, S. J. (2001b). Subcontractor perspectives on supply chain alliances. *https://doi.org/10.1080/01446190110089727*, 19(8):841–848.

Davis, K. (2016). A method to measure success dimensions relating to individual stakeholder groups. *International Journal of Project Management*, 34(3):480–493.

DiMatteo, L. A. (2010). Strategic Contracting: Contract Law as a Source of Competitive Advantage. *American Business Law Journal*, 47(4):727–794.

Doloi, H. (2012). Empirical Analysis of Traditional Contracting and Relationship Agreements for Procuring Partners in Construction Projects. *Journal of Management in Engineering*, 29(3):224–235.

Duddeck, H. (1987). Risk assessment and risk sharing in tunnelling. *Tunnelling and Underground Space Technology*, 2(3):315–317.

Dyer, J. H. and Singh, H. (1998). The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage. *Academy of Management*, 23(4):660–679.

Edwards, P. J. and Bowen, P. A. (1998). Risk and risk management in construction: a review and future directions for research. *Engineering Construction and Architectural Management*, 5(4):339–349.

El-Sayegh, S. and Monir El-Sayegh, S. (2008). Evaluating the effectiveness of project delivery methods.

Ellis, G. (2022). Guide to Building Collaboration in Construction.

Evans, S. (2020). NEC3 ECC – Early Warning.

Fereday, J. and Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods.*

Fink, A. (2019). *Conducting Research Literature Reviews: From the Internet to Paper.*

Fluor BV (2017). Engineering bulletin: Lumpsum porposal workflow procedure.

Freeman, M. (1992). Measuring project success. *Project Management Institute.*

Frenkel, M., Hommel, U., and Rudolf, M. (2005). Risk Management: Challenge and Opportunity - Google Books.

Gadde, L. E. and Dubois, A. (2010). Partnering in the construction industry—Problems and opportunities. *Journal of Purchasing and Supply Management*, 16(4):254–263.

Galloway, P. (2009). Design-Build/EPC Contractor's Heightened Risk—Changes in a Changing World. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 1(1).

Gantner, S. (2021). Retainage of Payment, What's the Purpose?

Garcia, A. and Murguia, D. (2021). A Scenario-based Model for the Study of Collaboration in Construction.

Guo, Q., Xu, Z. P., Zhang, G. F., and Tu, T. T. (2010). Comparative analysis between the EPC contract mode and the traditional mode based on the transaction cost theory. *Proceedings - 2010 IEEE 17th International Conference on Industrial Engineering and Engineering Management, IE and EM2010*, pages 191–195.

Gurney, R., Outram, K., and Kapoor, G. (2022). How Inflation Is Impacting Construction Projects.

Håkansson, H. and Snehota, I. (1995). *Developing Relationships in Business Networks.* London: Routledge.

Hale, D. R. (2005). *AN EMPIRICAL COMPARISON OF DESIGN/BUILD AND DESIGN/BID/BUILD PROJECT DELIVERY METHODS.* PhD thesis, University of Texas.

Hamel, J., Dufour, S., and Fortin, D. (1993). Case Study Methods. *Sage.*

Hartford (2021). Builder's Risk Insurance.

Hartman, F. (2000). Don't park your brain outside: A practical guide to improving shareholder value with SMART management. *Project Management Institution.*

Hartmann, A. (2010). Subcontractor procurement in construction: the interplay of price and trust. *Supply Chain Management: An International Journal*, pages 354–362.

Heale, R. and Twycross, A. (2018). What is a case study? *Evidence-Based Nursing*, 21(1):7–8.

Hearnshaw, E. J. and Wilson, M. M. (2013). A complex network approach to supply chain network theory. *International Journal of Operations and Production Management*, 33(4):442–469.

Hennink, M. (2014). *Focus Group Discussions.* Oxford University Press.

Hermans, M. and Wamelink, H. (2021). Lecture Procurement of Complex Projects - Project Delivery Models.

Hillson, D. (2002). Extending the risk process to manage opportunities. *International Journal of Project Management*, 20(3):235–240.

Hopkin, P. (2018). Fundamentals of Risk Management: Understanding, Evaluating and Implementing effective risk management.

Hughes, D., Williams, T., and Ren, Z. (2012). Differing perspectives on collaboration in construction. *Construction Innovation*, 12(3):355–368.

Husin, S., Abdullah, A., Riza, M., and Afifuddin, M. (2018). Risk assessment of resources factor in affecting project time. *Advances in Civil Engineering*, 2018.

Ishii, M., Kanai, S., and Ohuchi, H. (2014). Study on the Established Measures for Urbanization and Industrialization on the Changwon General Mechanical Industrial Complex in South Korea. *International Journal of Engineering and Technology*, 6(5).

Javanmardi, A., Abbasian-Hosseini, A., Liu, M., Hsiang, S. M., Alireza Abbasian-Hosseini, . S., and Asce, A. M. (2018). Benefit of Cooperation among Subcontractors in Performing High-Reliable Planning. *Article in Journal of Management in Engineering*.

Jayasudha, K. and Vidivelli, B. (2016). ANALYSIS OF MAJOR RISKS IN CONSTRUCTION PROJECTS. 11(11).

Jergeas, G. and Hartman, F. (1994). Contractors' protection against construction claims.

Jha, K. N. and Iyer, K. C. (2007). Commitment, coordination, competence and the iron triangle. *International Journal of Project Management*, 25(5):527–540.

Kapoor, A. (2021). What is Collaborative Contracting? *Contract Solutions*.

Ke, H., Cui, Z., Govindan, K., and Zavadskas, E. K. (2015). The Impact of Contractual Governance and Trust on EPC projects in Construction Supply Chain Performance. *Engineering Economics*, 26(4):349–363.

Koelmans, R. (2004). PROJECT SUCCESS AND PERFORMACE EVALUATION. *The South African Institute of Mining and Metallurgy*.

Komurlu, R. and Er, A. (2020). Evaluation of an OBCE Conversion Contract in a Large-scale Oil and Gas Project.

Koops, L., Van Loenhout, C., Bosch-Rekveldt, M., Hertogh, M., and Bakker, H. (2017). Different perspectives of public project managers on project success. *Engineering, Construction and Architectural Management*, 24(6):1294–1318.

Krueger, N. F., And, J. R., and Dickson, P. R. (1993). PERCEIVED SELF-EFFICACY AND PERCEPTIONS O F OPPORTUNITY AND THREAT "*. *Psychological Reports*, 72:1235–1240.

Kumaraswamy, M., Palaneeswaran, E., and Humphreys, P. (2000). Selection matters - In construction supply chain optimisation. *International Journal of Physical Distribution and Logistics Management*, 30(7):661–680.

Landau, P. (2021). Cost Reimbursement Contract.

Lane, P. (2005). The Apportionment of Risk in Construction Contracts. *International Conference on Arbitration and ADR in the Construction Industry*.

Lee, J. K., Han, S. H., Jang, W., and Jung, W. (2018). "Win-Win Strategy" for Sustainable Relationship between General Contractors and Subcontractors in International Construction Projects. *KSCE Journal of Civil Engineering*, 22(2):428–439.

Lu, P., Guo, S., Qian, L., He, P., and Xu, X. (2015). The effectiveness of contractual and relational governances in construction projects in China. *International Journal of Project Management*, 33(1):212–222.

Malekani, J. (2019). Benefits of good FEL (Front-End Loading).

Manley, K. and Chen, L. (2015). Collaborative learning model of infrastructure construction: a capability perspective. *Construction Innovation*.

Manoukian, J.-G. (2016). How Risks Can Turn Into Opportunities.

Mbachu, J. (2008). Conceptual framework for the assessment of subcontractors' eligibility and performance in the construction industry. *http://dx.doi.org/10.1080/01446190801918730*, 26(5):471–484.

McIntosh, M. (2019). Warranty in Construction.

Medina, B. (2022). Types of Construction Insurance.

Meng, X. (2013). CHANGE IN UK CONSTRUCTION: MOVING TOWARD SUPPLY CHAIN COLLABORATION. *Vilnius Gediminas Technical University*, 19(3):422–432.

Mischen, P. A. (2015). Collaborative Network Capacity. *http://dx.doi.org/10.1080/14719037.2013.822527*, 17(3):380–403.

Moazzami, M., Ruwanpura, J., and Jergeas, G. (2013). Conversion Method for Applying Convertible Contracts in Oil and Gas Projects Relational Contracting Strategies View project Building Information Modeling (BIM) View project Conversion Method for Applying Convertible Contracts in Oil and Gas Projects.

Molaei, M. (2021). In Pursuit of Success: Evaluating the Management of Engineering Projects, Cross-Sectoral Analysis of Project Management Efforts. *Delft University of Technology*.

Moselhi, O., Leonard, C., and Fazio, P. (2011). Impact of change orders on construction productivity. *Canadian Science Publishing*, 18(3):484–492.

Mubin, S. and Mannan, A. (2013). Innovative Approach to Risk Analysis and Management of Oil and Gas Sector EPC Contracts from a Contractor's Perspective Project Evaluation View project Innovative Approach to Risk Analysis and Management of Oil and Gas Sector EPC Contracts from a Contractor's Perspective. *Journal of Business & Economics*, 5(2):149–170.

NEC (2017). NEC early warning notices: a unique risk management tool of mutual benefit.

Nethery, S. (1989). Model Planning and Controlling System for Engineering, Procurement and Construction of Industrial Projects. Technical report, Civil Engineering Database.

Ng, A. and Loosemore, M. (2007). Risk allocation in the private provision of public infrastructure. *International Journal of Project Management*, 25(1):66–76.

Nieto-Morote, A. and Ruz-Vila, F. (2011). A fuzzy approach to construction project risk assessment. *International Journal of Project Management*, 29(2):220–231.

Nikulina, A., Volker, L., and Bosch-Rekveldt, M. (2022). The interplay of formal integrative mechanisms and relational norms in project collaboration. *International Journal of Project Management*, 40(7):798–812.

Onencan, A. (2013). Interviewing Techniques. *TPM, TU Delft*, page 8.

Patronus (2015). Early Warning Notices – NEC Contracts.

Peckiene, A., Komarovska, A., and Ustinovicius, L. (2013). Overview of Risk Allocation between Construction Parties. *Procedia Engineering*, 57:889–894.

Petersen, B. and Østergaard, K. (2018). Reconciling contracts and relational governance through strategic contracting. *Journal of Business and Industrial Marketing*, 33(3):265–276.

Pícha, J., Tomek, A., and Löwitt, H. (2015). Application of EPC Contracts in International Power Projects. *Procedia Engineering*, 123:397–404.

Pollack, J., Helm, J., and Adler, D. (2018). What is the Iron Triangle, and how has it changed? *International Journal of Managing Projects in Business*, 11(2):527–547.

Posner, R. A. and Rosenfield, A. M. (1977). Impossibility and Related Doctrines in Contract Law: An Economic Analysis. *The Journal of Legal Studies*, 6(1):83–118.

Project Management Institute (2008). A GUIDE TO THE PROJECT MANAGEMENT BODY OF KNOWLEDG.

Rahola, T. B. S. and Straub, A. (2013). Project delivery methods in European social housing energy renovations. *Emerald group*, 31.

Rapley, T. (2007). Doing conversation, discourse and document analysis. . *Sage*.

Rijkswaterstaat (2022). Handreiking toepassing 2-fasen aanpak bij Rijkswaterstaat projecten. *Rijkswaterstaat: Ministerie van Infrastructuur en Waterstaat*.

Robert, C. (1997). Managing change orders and claims. *Journal of Management in Engineering*.

RVO (2020). Design Build Finance Maintain and Operate (DBFMO) .

Sadeghi, B., Kashani, H., Mohammad, ., Mortaheb, M., and Student, M. S. (2016). Defining Mitigation Strategies for Recurring EPC Contract Risks.

Sadeh, A., Dvir, D., and Shenhar, A. (2000). The Role of Contract Type in the Success of R&D Defense Projects under Increasing Uncertainty. *https://doi.org/10.1177/875697280003100303*, 31(3):14–22.

Shaikh, F. A., Saeed Shahbaz, M., Ud Din, S., and Odhano, N. (2020). Civil Engineering Journal The Role of Collaboration and Integration in the Supply Chain of Construction Industry. 6(7).

Shonk, K. (2022). What is Conflict Resolution, and How Does It Work?

Shrestha, A., Tamošaitiene, J., Martek, I., Hosseini, M. R., and Edwards, D. J. (2019). A Principal-Agent Theory Perspective on PPP Risk Allocation. *Sustainability 2019, Vol. 11, Page 6455*, 11(22):6455.

Simatupang, T. M. and Sridharan, R. (2005). The collaboration index: A measure for supply chain collaboration. *International Journal of Physical Distribution and Logistics Management*, 35(1):44–62.

Sorenson, R. L., Folker, C. A., and Brigham, K. H. (2008). The collaborative network orientation: Achieving business success through collaborative relationships. *Entrepreneurship: Theory and Practice*, 32(4):615–634.

Stanek, B. (2004). Measuring alliance value and risk: A model approach to prioritizing alliance projects. *Management Decision*, 42(2):182–204.

Stannard, K. (2017). NEC: AN EARLY WARNING OF NEC4'S CHANGES TO THE EARLY WARNING CLAUSE. *MDA Law*.

Tan, Y., Asce, A. M., Bin Xue, ., and Cheung, Y. T. (2017). Relationships between Main Contractors and Subcontractors and Their Impacts on Main Contractor Competitiveness: An Empirical Study in Hong Kong. *Journal of Construction Engineering and Management*.

Tang, L. Y., Shen, Q., and Cheng, E. W. (2010). A review of studies on Public–Private Partnership projects in the construction industry. *International Journal of Project Management*, 28(7):683–694.

Tavakkoli-Moghaddam, R., Mousavi, S., and Hashemi, H. (2011). A Fuzzy Comprehensive Approach for Risk Identification and Prioritization Simulataneously in EPC Projects. In *Risk Management in Environment, Production and Economy*.

Teklemariam, H. (2012). CONTRACT STRATEGY FOR CONSTRUCTION PROJECTS. *Academia*.

Toor, S. u. R. and Ogunlana, S. O. (2010). Beyond the 'iron triangle': Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects. *International Journal of Project Management*, 28(3):228–236.

Wang, T., Tang, W., Du, L., Duffield, C. F., and Wei, Y. (2016). Relationships among Risk Management, Partnering, and Contractor Capability in International EPC Project Delivery. *Journal of Management in Engineering*, 32(6):04016017.

Wibowo, M. A. and Sholeh, M. N. (2015). The Analysis of Supply Chain Performance Measurement at Construction Project. *Procedia Engineering*, 125:25–31.

Wiengarten, F., Humphreys, P., Cao, G., Fynes, B., and McKittrick, A. (2010). Collaborative supply chain practices and performance: exploring the key role of information quality. *Supply Chain Management*.

Wood, G. D. and Ellis, R. C. (2005). Main contractor experiences of partnering relationships on UK construction projects. *https://doi.org/10.1080/0144619042000287714*, 23(3):317–325.

Wu, G., Liu, C., Zhao, X., and Zuo, J. (2017). Investigating the relationship between communication-conflict interaction and project success among construction project teams. *International Journal of Project Management*, 35(8):1466–1482.

Xu, Z., Yin, Y., Li, D., and Browne, G. J. (2018). Owner's Risk Allocation and Contractor's Role Behavior in a Project: A Parallel-mediation Model. *https://doi.org/10.1080/10429247.2017.1408388*, 30(1):14–23.

Yeo, K. T. and Ning, J. H. (2002). Integrating supply chain and critical chain concepts in engineer-procure-construct (EPC) projects. *International Journal of Project Management*, 20(4):253–262.

Yeung, J. F., Chan, A. P., and Chan, D. W. (2007). The definition of alliancing in construction as a Wittgenstein family-resemblance concept. *International Journal of Project Management*, 25(3):219–231.

Yin, R. (2003). Case study research: Design and methods. *Sage*.

Zaghloul, R. and Hartman, F. (2003). Construction contracts: the cost of mistrust. *International Journal of Project Management*, 21(6):419–424.

Zou, P. X. W., Zhang, G., and Wang, J.-Y. (2006). Identifying Key Risks in Construction Projects: Life Cycle and Stakeholder Perspectives.

A Literature Review

The following section explains how the literature review for chapter 3 and chapter 4 have been executed. Fink [2019] describes the literature review as a "systematic, explicit, and reproducible method for identifying, evaluating, and synthesizing the existing... work produced by researchers, scholars, and practitioners". The following steps were taken for a systematic and holistic literature review:

1. Identification of article databases and keywords
The literature sources used for this research include, but not limited to, journals, websites, books and thesis publications. These were retrieved from article databases such as Google Scholar, Scopus, Elsevier, ScienceDirect, and the TU Delft repository. The literature sources were found by searching for specific keywords, which are relevant for the research subquestions (subquestion 1 and subquestion 2). Keywords include: construction risks, execution risks, risk management, strategic risk allocation, EPC project characteristics, contracting strategies, downstream contracting, subcontractors, EPC supply chain, and process industry. Often, finding a relevant article led to more relevant articles through the article citations.

2. Screening the articles
To ensure that only the relevant literature is used, the articles are screened based on several criteria. Firstly, the articles with priority were publications in English. Additionally, the criteria was based on the phase of the project (execution phase), and focused on construction projects, specifically EPC projects. Moreover, focus was shed on downstream contracting, therefore, priority was given to articles which focused on the supply chain (general contractor and subcontractors).

3. Scientific quality assurance
This step includes checking the articles for quality assurance. This was done on the basis of the publication year and number of citations. Articles published between 2010 and 2022 were given priority. Moreover, articles cited 3 times or less were additionally checked, by searching for other articles that supported the findings.

4. Synthesizing the results
Finally, this steps involves comprehending the information gathered from the articles, and examining and combining it to thoroughly address the two subquestions (results can be found in chapter 3 and chapter 4).

B Document Review

This section presents how the document review was conducted. The document review includes all the internal Company (Fluor) documents that have been examined, and are related to contracting and risk allocation. The document review provides relevant information for the research questions, specifically subquestion 3 and subquestion 5. The document review takes the same approach as explained for the literature review, based on research by Fink [2019] (see Appendix A). This section explains the document review method, a list of the internal documents used in chapter 5, and a list of the internal documents used for the Case Studies in chapter 7.

B.1 Document review method

1. Identification of article databases and keywords
The aim of the document review is to answer subquestion 3, and therefore looks into how the risks within EPC projects have been perceived, allocated and managed in practice. Therefore, documents are found on Fluor's database, known as "Knowlegde Online". Moreover, the "Fluor University" database is used for additional training documents.

2. Screening the articles
All the internal documents from within the Company are regarded as accurate and of quality (most recent revisions used).

3. Scientific quality assurance
The documents chosen from the Company portfolio are documents that have been written at the corporate level, meaning that the documents are recognized by the Fluor company.

4. Synthesizing the results
Synthesizing the results includes comprehending the information from the documents, analysing these results to eventually provide answers to subquestion 3. The results from the document review are demonstrated in chapter 5.

B.2 Internal documents for Chapter 5 and Chapter 7

Both chapter 5 and chapter 7 analyze internal Company documents. The first analyzes internal documents for the background study, while the latter analyzes internal documents for the case study analyses (case study 1 and case study 2). Regarding the case study analyzes, these documents are used to find information per theme. The internal documents analyzed can be found in the table below (Table B.1).

Table B.1: A list of the internal documents used for the document review.

Document review

Internal documents for background study

Doc #	Document name	Explanation of document
FBV1	BUSINESS RISK MANAGEMENT FRAMEWORK (BRMF):)	This document is a formalized and systematic process for assessing, managing and monitoring business risks (both project and non-project related risks). This process is an integral part of the work process and the way they manage the business and control the projects.
FBV2	Contract patchwork	This document shows examples of how contract patchworks are framed, and on what factors this patchwork depends. This is valuable for understanding the contracting strategies.
FBV3.1	Contract part I Scope of work	This document is the first document in the contract with subcontractors. It demonstrates how the 'scope of work' is defined in these contracts with the subcontractors. This includes articles and clauses.
FBV3.2	Contract part II Commercial terms	This document is the second document in the contract with subcontractors. It elaborates on the commercial terms agreed between the parties. This includes mainly the price arrangements.
FBV3.3	Contract part III General terms	This document is the third document in the contract with subcontractors. This contract part uses articles and clauses to define the obligations set with subcontractors.
FBV4	Contractor Pre-qualification	The purpose of this practice is to address requirements for the screening, pre-qualification, and evaluation of contractors in the development of a Project Bidders List and contract-specific proposed bidders lists.
FBV5	Procurement process flows	This document explains what the process of procurement within the Company looks like. This a useful document for understanding how procurement works, which parties are involved, and the influence of procurement on other phases of the project.
FBV6	Supply Chain Risk Mitigation Strategy	This document explains the internal strategy for mitigation risks within EPC projects. It explains how risk mitigation strategies need to be translated into contracts.
FBV7	Prime contract management	This document dives into the elements of the Company's prime contracts. It explains the different articles written for prime contracts, and how these allocate risks in a certain way. The document helps understand how these prime contracts influence the subcontracts (upstream and downstream contracting).
FBV8	Performance-based contracting	This document explains the different contracting strategies that the Company operates. It dives into the importance of performance within contracting. This document is very useful for understanding the implementation of different contracting strategies.
FBV9	Proposal presentation for confidential projects	These documents entail projects which the Company has written a proposal for, including the contracting strategy for these projects. These projects were not necessarily pursued, however, the presentations were presented to the Client. These presentations look at the different market approaches and the project management plan of these projects.
FBV10	Partnership model	This document explains a partnership model which the Company has written out for a proposal to the Client. This document is used in order to understand which elements are important for a partnership model in EPC projects.

Document review

Internal documents for case study analysis

CS	Doc #	Theme	Document name	Explanation of document
1	CS1.1	NA	Project scope description	The document describes the scope of the project.
1	CS1.2	NA	Organisational chart	This document describes the organisational structure of the project. This includes the parties involved, and the roles on the project.
1	CS1.3	2, 3, and 4	Prime contract	This document describes the obligations set between the Client and the Company.
1	CS1.4	2, 3, and 4	General subcontract	This document describes the obligations set between the Company and the subcontractors. This involves part I, II, and III.
1	CS1.5	2	Contract analysis subcontractors	This document analysis all the subcontractor contracts, with respect to their clauses.
1	CS1.6	3	Contract strategy document	This document describes the strategy chosen for the project, including the market approach. This gives insight in how the contract is operate.
2	CS2.1	NA	Project scope description	The document describes the scope of the project.
2	CS2.2	NA	Organisational chart	This document describes the organisational structure of the project. This includes the parties involved, and the roles on the project.
2	CS2.3	2, 3, and 4	Prime contract	This document describes the obligations set between the Client and the Company.
2	CS2.4	2, 3, and 4	General subcontract	This document describes the obligations set between the Company and the subcontractors. This involves part I, II, and III.
2	CS2.5	3	Contract strategy document	This document describes the strategy chosen for the project, including the market approach. This gives insight in how the contract is operate.
2	CS2.6	2	Scope of services	This document lays out the scopes with regard to services delivered by the subcontractors.
2	CS2.7	2	Scope of Facilities	This documents lays out the scopes with regard to the facilities provided by the subcontractors. This includes interface management.
2	CS2.8	5	Incentive & Rework	This document explains the incentive scheme which was pursued in the prime contract.
2	CS2.9	5	Assessment of Cost Incentive Model	This document explains how the incentive model is assessed within the prime contract.

Themes
1. Execution risk
2. Contractual clauses
3. Market approach
4. Linear and network risk allocation
5. Collaboration

C Project Delivery Model

This report focuses on the EPC format, which is a specific form of a PDM. A PDM is an umbrella term which is a relevant concept to understand properly in order to understand what makes EPC projects unique.

A PDM refers to the chosen approach in organizing the project team that will manage the entire design and execution of a project. Hermans and Wamelink [2021] defines a PDM as, "The way in which tasks, responsibilities, risks are distributed amongst the parties involved in a construction or maintenance related activity or project". The type of PDM adopted by projects in the construction sector have a significant role in regard to the process in which the project develops. These models have the ability to "promote and reward behaviors that support the delivery of successful projects; engage participants in the pursuit of what is best for the project and not only for individual parties; and even define how projects will be run and which tools will be used from an operational standpoint to run the design and construction processes" [Alves and Shah, 2018]. A suitable PDM is seen as a tool to optimise the chances of achieving project objectives and success [El-Sayegh and Monir El-Sayegh, 2008].

Different literature sources consider different PDM forms, which are summarized in Table C.1.

Table C.1: Summary overview of Project Delivery Models in the construction sector

[Rahola and Straub, 2013; Hale, 2005; Rahola and Straub, 2013; Komurlu and Er, 2020; RVO, 2020]

	Design-bid-build	**Design-build** or **EPC**	**DB(F)M(O)**	**Supply chain integration**
Characteristics	The owner enters a contract with architect/engineering firm, and a separate contract with construction company (two separate contracts).	The owner provides requirements for the specified project and awards a contract to one company who will both design and build the project (responsible for design/engineering, procurement, and construction).	The consortium is responsible for design, building, (financing), maintenance, and (operations) of the construction. No separate contracting between banks, subcontractors, etc.	Supply chain (subcontractors/ suppliers) are encouraged to be involved early in the design phase, forming a mutual understanding in the contract.
Advantages	1. May result in a lower cost project due to the competitive nature of the bidding process 2. Separating the design team from the construction team can potentially reduce conflicts of interest	1. Shorter lead times 2. Involvement of the construction companies in the design decisions 3. Higher price certainty 4. Better communication between the actors involved 5. Reduced construction time	1. The integrated contract reduces costs 2. Insights into costs enables better decision making	1. Early involvement of key participants creates improved communication 2. Less chances of frictions due to earlier alignment 3. Spreading of risk and responsibility
Disadvantages	1. Typically, long project duration 2. The owner may be vulnerable to change orders, delays, and additional costs	1. Limited owner's control 2. Requires contractors who can bear large scope risk (added liability)	1. Need for appropriate financing party 2. Risks involved over long term (30 years)	1. May be difficult to make changes as the project develops 2. Requires a high degree of planning in the very early stages of a project

D Theory on Risk

D.1 Risk management

As explained in chapter 4, risk management consist of various steps, including the identification and quantification of the risks. In order to quantify the risks, the frequency and impact of these risks needs to be defined. Mubin and Mannan [2013] has developed standard values for these aspects, which simplifies the process of quantifying these elements. A summary of these values can be found in Table D.1 and Table D.2.

Table D.1: Standard values of frequency of occurrences and impact factors.

Frequency of Occurrence	Frequency (F)	Type and Level of Risk Impact	Impact Factor (I)
Very high chance	90 %	When maximum impact on scope, time and cost	0.9
High chance	75%	High impact on scope, medium impact on time and lesser impact on cost	0.6
Greater chance	60%		
Possible	45%	High impact on time, medium impact on scope and lesser impact on cost	0.3
Likely	30%		
Unlikely	15%	When high impact on cost of the project, medium impact on time and lesser impact on scope	0.1

Table D.2: Frequency of occurrence of risks in EPC projects.

Sr. No	Chances of Occurrence	Frequency
1	Almost sure that risk will occur in next project	91% - 99%
2	Extremely high chances of occurrence	81% - 90%
3	High chances of risk occurrence	71% - 80%-
4	Fair chances of risk occurrence	61% - 70%
5	May occur with some chances of occurrence	51%-60%
6	50 - 50 (May or may not occur)	50%
7	May not occur but some chances are still there	41%-49%
8	Poor chances of occurrence	31% - 40%
9	Extremely poor chances of occurrence	21% - 30%
10	No chances of occurrence but still it is a risk	11% - 20%
11	Almost sure that risk will not occur in the next	1% - 10%

Table 3
Impact Factor for Risk Quantification

Sr. No	Type and level of risk Impact	Impact Factor (I)

D.2 Risks related to EPC characteristics

In subsection 5.8.1, the EPC risks are linked to the characteristics of EPC projects. To clarify the reason for this relation between the risk and the characteristic, an explanation is provided below. The characteristics are labeled as: I= inter-dependencies of activities, O= overlapping of tasks/ phases, S= challenging scope boundaries, C= client interferences.

Risk 3.1 (C) = As the Client holds the project budget, this can cause delayed payments to the supply chain. The Client decides the money flow.
Risk 3.2 (O/S) = The overlapping of tasks and vague scope boundaries can create difficulties in sharing information between the right parties, seeing as the work is not defined well. It causes difficulties in understanding who needs what information.

Risk 4.1 (I/C) = The interdependence between activities causes that when one party fails, another party is effected by this. This can cause disputes. Furthermore, the client interferences can cause frustrations down the supply chain.
Risk 4.2 (O/S) = As tasks of different works overlap, the contracts need to make sure that there is no scope missing from the contracts. This can create errors in the design. Also, as scopes of work are unclear, there is a risk that the contracts contain faults.
Risk 4.3 (S) = Since the scope boundaries can be challenging, this creates the risk of misunderstandings which works are whose responsibilities. Also a risk of orphan scopes.
Risk 4.4 (S) = The scope boundaries can be challenging, and the materials are being purchased by different parties (long lead / short lead items). As delays are caused by vendors, it can be challenging to point out who is responsible for the orders.
Risk 4.5 (S) = As scopes boundaries are unclear, it is difficult to pinpoint what is a change and what is not.
Risk 4.6 (C) = The client may have a say in the selection of the subcontractors, which creates the risk of choosing the wrong subcontractors.
Risk 4.7 (S) = The unclarity in scope definition can cause many claims from the subcontractors side. This can cause a claim oriented project.
Risk 4.8 (C) = The interferences by clients can cause difficulties in making decisions.
Risk 4.9 (I/O/S) = The interdependence between activities can also cause interdependence of each others materials. However, as scopes are unclear, this can cause miscommunications regarding who purchases which materials. Additionally, the overlapping of phases results in subcontractors needing the same materials at the same time, which can also create miscommunications.

Risk 5.1 (O) = The overlapping of activities creates that site information is constantly changing.
Risk 5.2 (O) = Since construction is starting whilst engineering and procurement is still being completed, changes in design can occur.
Risk 5.3 (O) = The overlapping of the activities can create chaos on the work site, which leads to less control over HSE requirements.
Risk 5.4 (C) = The client has influence on the chosen subcontractors and their work, which can cause that the cheapest subcontractor is chosen, who cannot provide the best construction techniques.

Risk 6.1 (O) = The overlapping of the phases creates difficulties in communication between the works.
Risk 6.2 (O) = Since the phases overlap, interface management is a key aspect. There are a lot of interfaces between the works, creating difficulties in the management of these parties.
Risk 6.3 (I) = The inter-dependencies between the activities makes that one party's failure, is the other party's failure.
Risk 6.4 (O) = The overlapping of the phases, also referred to as fast-tracking, creates high time sensitivity.

E Semi-structured interview protocol

The interview protocol is followed to help as guidance before the interviews and during the interviews. It consists of the pre-interview protocol, which is completed before the start of the interview, the introduction given at the start of the interview, the questions which are asked during the interview, and the concluding remarks. The protocol is described as follows:

E.1 Pre-interview protocol

The pre-interview protocol entails the steps taken before the date of the interview. This involves sending out an invitation to the participant via Teams, in order to set the time and date for the interview. Furthermore, an introduction of the research is shared in an A4 format, for the participant to understand the objective of the interview and for them to have a broad understanding of the subject. Additionally, a pre-interview protocol document is shared with the participants, and they are kindly asked to fill in this document. This document is presented below:

Pre-interview protocol - to be filled in

This document is meant to be filled in by the interviewee before conducting the interview. If there are any questions, please contact the researcher.

Date: ....
Project name: ....
Name of the interviewee: ....
Role of the interviewee in the project: ....
Years of work experience: ....

To understand the overall performance of the project, the interviewee is asked to score the project based on five performance indicators. Please score the project by marking an '' X '' in the table below. This is based on the ''Likert Scale'' defined as:

(1) ''Strongly disagree'', (2) ''Disagree'', (3) ''Neutral'' (4) ''Agree'', (5) ''Strongly agree''.

Performance criteria questions:

1. ''Do you agree that project X has performed within agreed upon schedule?''
2. ''Do you agree that project X has performed within agreed upon budget?''
3. ''Do you agree that project X has met the agreed upon quality specifications?''
4. ''Do you agree that project X has met HSE requirements?''
5. ''Do you agree that project X has reached client satisfaction?''

Table E.1: Pre-interview scoring table for case study analysis, based on the 'Likert Scores'.

Performance criteria	(1) Strongly disagree	(2) Disagree	(3) Neutral	(4) Agree	(5) Strongly agree
Within schedule					
Within budget					
Quality specifications					
HSE requirements					
Client satisfaction					

Thank you for your participation.

E.1.1 Results: Project performance scores

The averages of the project performance scores in presented in chapter 7. The individual scores provided by the interviewees in demonstrated in Table E.2.

Project performance scores					
Case 1	I1	I2	I3	I4	**Average**
Schedule	2	1	4		**2**
Budget	3	2	3		**3**
Quality	4	4	4		**4**
HSE	4	4	4		**4**
Client satisfaction	4	2	3		**3**
Case 2	I5	I6	I7	I8	**Average**
Schedule		2	2	3	**2**
Budget		4	4	4	**4**
Quality		4	4	4	**4**
HSE		4	4	4	**4**
Client satisfaction		3	4	4	**4**

Table E.2: Project performance scores by the interviewees.

E.2 Interview introduction

The interview starts with thanking the participant for taking part in the research and showing their interest in the subject. A brief summary is given about the consent form, which discusses the Human Research Ethics aspects of the primary data. This includes an explanation of the use of the data gathered and the anonymity of the data in the research. Moreover, the objective of the interview is briefly summarized. Subsequently, the interviewees are asked to give an introduction of themselves, explaining their role and responsibilities within the project (case study 1 or case study 2). This is followed by the first interview question. The interview questions are divided into 5 themes.

Interview themes

1. Identifying the largest execution risks in the project
   (a) Goal is to understand where the largest 'weak spots' lie within the execution of the project; where the challenges were faced. This is important to see which strategy has been used to manage these risks.
2. Expert opinion on the contracting strategy elements
   (a) Goal is to understand the practical implications of certain contractual clauses, and what consequences this had on the risk allocation within the supply chain.
3. Perception on the nature of the supply chain risk allocation: Linear or network risk allocation
   (a) Goal is to understand the interviewees perception of risk allocation in the supply chain.

4. Expert opinion on the traditional market approach within EPC projects
    (a) Goal is to understand what affects the chosen market approach has on the allocation of risks, and to understand the positive and negative factors of this market approach.
5. Integrating the collaborative market approach into the supply chain 'network' as a risk allocation strategy
    (a) Goal is to hear the opinions regarding collaboration in EPC projects, and if the interviewees believe this can be applicable.

E.3 Interview questions

In total, 4 sets of interview questions have been set up. The interview questions for participants of case study 1 and case study 2 differ slightly. This is due to the different document review results, which lead to different questions on the project. Additionally, the interview question for the subcontractors are also reworded to suit the party in question.

E.3.1 Case study 1: EPC Contractor

Theme 1: Execution risks

1. Could you please provide an example of the most important risks in the project, and how these were allocated between EPC contractor and subcontractors (supply chain)?

2. What consequences did this allocation strategy have for the subcontracting parties in the supply chain?

Theme 2: Contracting strategy elements

3. This question focuses on Exhibit 1 art. 2 (LDs): The clause on LD set for late completion states that damages suffered by Company for each day of late completion are compensated by the contractor. To your belief, to what extent do these LDs promote good project performance in practice?

4. This question focuses on Exhibit 1 art. 2 (Incentives): Within the general subcontract, the milestone completions are linked to certain LD, however, there is no incentive connected to the work (bonus malus). To what extent can incentives-based clauses improve the performance of project X? How have you experienced this in other project?

5. This question focuses on Clause 12 on delays: it reads that the ''company's sole liability for delay shall be only extension of time, no damages recovery". How does this clause effect the performance of the project?

6. Clause 15 discusses change orders and early warning notices. It states that 'if notice is not given on time (2 to 5 days), no compensation is provided. What effects does this clause have in practice?

Part III art 3.0 Conditions and risk of work defines that the contractor assumes the risk of conditions and will regardless of complications complete the work within the time and budget as promised.

7. What affect did the risk allocation within project X between Fluor and subcontractors have on creating a claim culture in the supply chain?

8. To what extent do you think that the subcontractors carry the effective amount of risk in this EPC project? To what degree is the amount of risk (dis)proportionate?

Theme 3: Linear and network risk allocation

9. EPC networks are characterized by the inter-dependencies of their activities in the execution phase. As one subcontractor is delayed, a domino effect arises, creating the delay of other works. How can this be dealt with within the risk allocation?

Theme 4: Traditional market approach

According to documents and exploratory interviews, project X uses more of a traditional contracting strategy approach, where risks are allocated back-to-back from prime to subcontracts through clauses. This entails that those risks are transferred down to subcontractors.

10. What have been the positive and what have been the negative consequences of this back-to-back risk allocation?

11. Have you experienced that transferring a risk down to the subcontractor resulted in eventually greater risks for the project as a whole? Can you explain?

Theme 5: Collaborative market approach

12. The prime contract initially stated that the development of an integrated project delivery (IPD) with subcontractors would be discussed. Can you explain why this not pursued?

13. An alternative approach to a traditional market approach is the 'Supply chain collaboration', which includes a risk and reward sharing mechanism. How did this project make use of risk and reward sharing, so that risks can be managed more collaboratively?

14. What is your opinion on forming collaborative agreements within the supply chain, to allocate risks more effectively?

15. What are the barriers of implementing collaborative agreements within project X?

16. If you have any experience with such an agreement, how do you think it can be applied?

Do you have any other recommendations for improving the risk allocation in EPC projects?

E.3.2 Case study 2: EPC Contractor

Theme 1: Execution risks

1. Could you please provide an example of the most important risks in the project, and how these were allocated between EPC contractor and subcontractors (supply chain)?

2. What consequences did this allocation strategy have for the subcontracting parties in the supply chain?

Theme 2: Contracting strategy elements

3. This question focuses on Exhibit 1 art. 2 (LDs): How are LD's defined between the Company and the contractors and to your belief, to what extent do these LDs promote good project performance in practice?

4. This question focuses on Exhibit 1 art.2 (Incentives): The prime contract includes incentive-based clauses however, these are not flown down to the subcontracts. Why is this the case, and to what extent could incentives-based clauses improve the performance of project X? How have you experienced this within other projects?

5. This question focuses on Clause 12 on delays: it reads that the ''company's sole liability for delay shall be only extension of time, no damages recovery". How does this clause effect the performance of the project?

6. Clause 15 discusses change orders and warning notices. It states that 'if notice is not given on time, no compensation is provided. What effects does this clause have when it is used in practice?

Part III art 3.0 Conditions and risk of work defines that the contractor assumes the risk of conditions and will regardless of complications complete the work within the time and budget as promised.

7. What affect did the risk allocation within project X between Fluor and subcontractors have on creating a claim culture in the supply chain?

8. To what extent do you think that the subcontractors carry the effective amount of risk in this EPC project? Is the amount (dis)proportionate?

Theme 3: Linear and network risk allocation

9. EPC networks are characterized by the inter-dependencies of their activities in the execution phase. As one subcontractor is delayed, a domino effect arises, creating the delay of other works. How can this be dealt with within the risk allocation?

Theme 4: Traditional market approach

According to documents and exploratory interviews, project X uses more of a traditional contracting strategy approach, where risks are allocated back-to-back from prime to subcontracts through clauses. This entails that those risks are transferred down to subcontractors.

10. What have been the positive and what have been the negative consequences of this back-to-back risk allocation?

11. Have you experienced that transferring a risk down to the subcontractor resulted in eventually greater risks for the project as a whole? Can you explain?

Theme 5: Collaborative market approach

12. The prime contract initially stated that the development of an integrated project delivery (IPD) with subcontractors would be discussed. Can you explain why this not pursued?

13. An alternative approach is the 'Supply chain collaboration', which includes a risk and reward sharing mechanism. How did this project make use of risk and reward sharing, so that risks can be managed more collaboratively?

14. What is your opinion on forming collaborative agreements within the supply chain, to allocate risks more effectively?

15. What do you think are the barriers of implementing collaborative agreements within project X?

16. If you have any experience with such an agreement, how do you think it can be applied?

Do you have any other recommendations for improving the risk allocation in EPC projects?

E.3.3 Case study 2: Subcontractor

Theme 1: Execution risks

1. Could you please provide an example of the most important risks in the project, and how these were allocated between EPC contractor and your subcontracting party (supply chain)?

2. What consequences did this allocation strategy have on your subcontracting company?

Theme 2: Contracting strategy elements

3. There is no usage of incentive-based clauses for the subcontractors. How do you think incentives-based clauses could improve your performance in project X? How have you experienced this in other projects?

4. The clause 12 regarding delays states that the ''company's sole liability for delay shall be only extension of time, no damages recovery". How has this clause effected your performance in the project?

5. Clause 15 discusses change orders and warning notices. It states that 'if notice is not given on time, no compensation is provided. What effects does this clause have in practice on your work?

6. What affect did the risk allocation within project X between Fluor and your subcontracting company have on creating a claim culture in the supply chain?

7. To what extent did you feel a claim culture within project X, and what effect did this have on your performance as a subcontractor?

8. To what extent do you think that the subcontractors carry the effective amount of risk in this EPC project? Is the amount (dis)proportionate?

Theme 3: Linear and network risk allocation

9. EPC networks are characterized by the inter-dependencies of their activities in the execution phase. As one subcontractor is delayed, a domino effect arises, creating the delay of other works. How can this be dealt with within the risk allocation?

10. In a supply chain network, information sharing is crucial. How have you experienced the information sharing between you and the other subcontractors?

Theme 4: Traditional market approach

According to documents and exploratory interviews, project X uses more of a traditional contracting strategy approach, where risks are allocated back-to-back from prime to subcontracts through clauses. This entails that those risks are primarily transferred down to subcontractors.

11. To your understanding, do you think this market approach was fit for purpose for this project, with the aim of reaching good project performance?

Theme 5: Collaborative market approach

12. An alternative approach to the traditional market approach is the 'Supply chain collaboration' where risks and rewards are shared. What is your opinion on risk and reward sharing mechanisms, so that risks can be managed between the network of subcontractors?

13. What is your opinion on forming collaborative agreements within the supply chain (between subcontractors), to allocate risks more effectively?

14. What do you think are the barriers of implementing collaborative agreements within project X?

15. How can more collaborative elements be integrated in the risk allocation contract strategy to improve the performance of subcontractors?

Do you have any other recommendations for improving the risk allocation in EPC projects?

E.4 Closing the interview

The interview is concluded by asking the participants if there are any unaddressed points that they would like to discuss. These topics, remarks, or recommendations are then discussed further. The interview is closed off by thanking the interviewee for their participation, and proactively supporting this research.

F Coding Data from Atlas.ti

F.1 Coding in chapter 6

In chapter 6 an explanation is given on the process of data collection and data analysis in the software Atlas.ti. This data collection includes the coding of the data, in order to structure the relevant findings from the interviews. A total of 117 codes have emerged, based on deductive and inductive analysis. The codes are shown in Figure F.1.

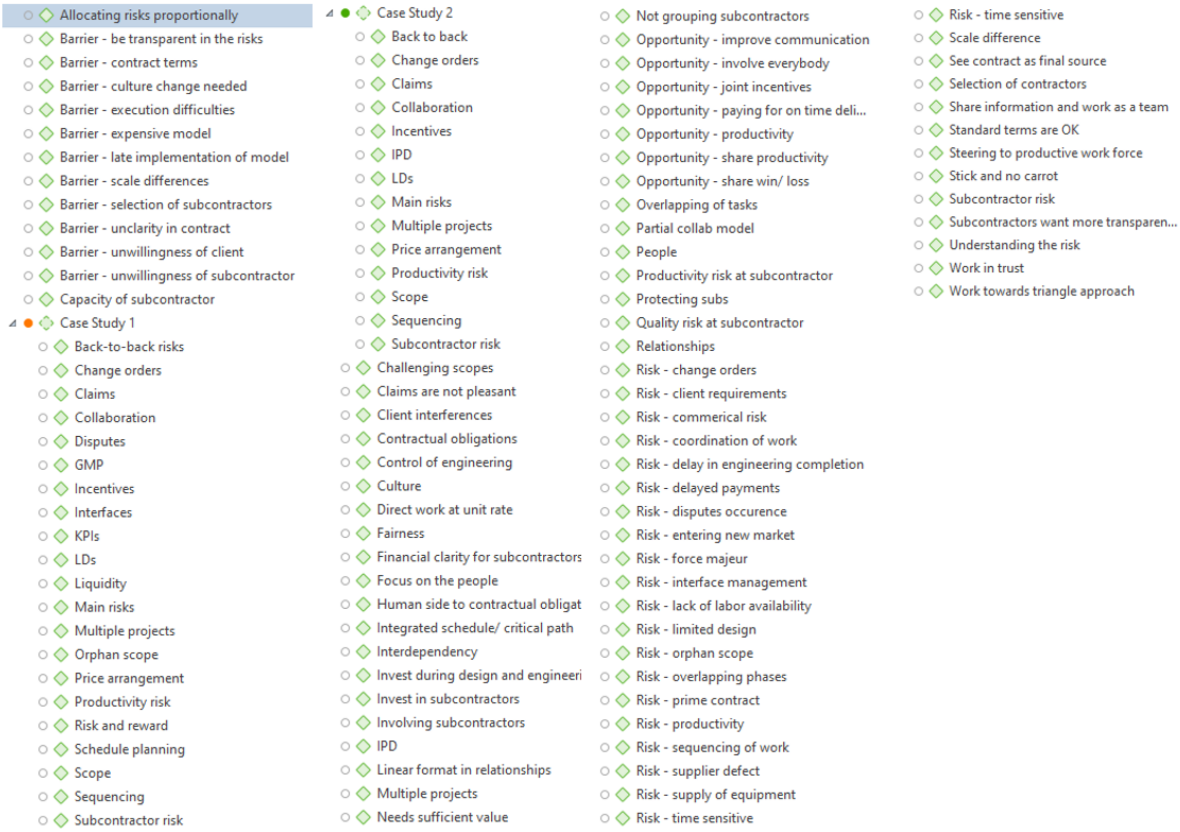


Figure F.1: A list of all the main codes created in Atlas.ti. for chapter 6.

It can be seen that there are multiple codes which include "Barrier - ". These represent the barriers for implementing a collaborative model. Therefore, "Barrier - culture change needed" means that implementing a collaborative model in EPC projects can be difficult, seeing as, according to an interviewee, a culture change is needed within the organization. Additionally, The codes which include "Opportunity - ", are codes which refer to opportunities for implementing a collaborative model. Moreover, the codes which include "Risk - " are the identification of risks found in the case studies. "Risk - change order" therefore identifies change orders as one of the main execution risks in the project.

Furthermore, it is visible that certain codes have been categorized per case study. These codes were structured per case study so that the analysis in chapter 7 could be done more easily.

F.2 Coding in chapter 8

In chapter 8 it is described how the semi-structured interviews are analysed through Atlas.ti. This is a similar process to the data analysis process explained in chapter 6. The 24 codes that emerged from this data analysis process, based on deductive and inductive analysis, are demonstrated in Figure F.2.

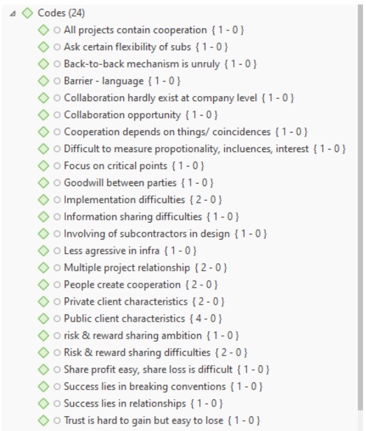


Figure F.2: A list of all the main codes created in Atlas.ti for chapter 8.

G Barriers to implementing collaboration

The barriers to implementing collaboration are found through the exploratory interviews in chapter 8. These barriers are important to understand in order to be able to overcome them. The barriers are listed in Table G.1.

Table G.1: The barriers for implementing a collaboration model in EPC projects, based on interview results.

Barrier to implementing collaboration model	**Explanation**	**Proof quote**
1. Time consuming	Collaboration models can require more time at the start of the project to implement.	''Time is key in these private projects, so the question remains, is there enough time to implement such a model?" – Interviewee I11
2. Unwillingness of subcontractors	Subcontractors do not want to take the risk of other subcontractors underperforming	''Several contractors didn't want to work in an IPD, they wanted to be able to point to Fluor for costs, instead of their 'partners"' - Interviewee I3
3. Unwillingness of client	Dependent on whether the subcontracts are on Client or EPC Contractor paper, the Client can be unwilling to implement a collaboration model. This can create a large barrier.	''The Client was also not promoting the integrated model, they were driving to individual contracts" – Interviewee I3, ''However, it is difficult to get the client on board with it, because they think they're paying too much" – Interviewee I6
4. Cultural change	Changing from a traditional towards a more collaborative approach in risk allocation requires a large cultural change from the stakeholders.	''The main reason that this was not pursued is the inability to take the cultural step change that's needed with a client organization. For the client to say, 'Yes, we buy into this, we support it fully" – Interviewee I6
5. Risk and reward sharing implementation	The 'risk and reward sharing' element of the collaboration model can be difficult to implement since parties are hesitant to take the commercial risk of others.	''It is difficult to measure, and take into account proportionality, influence, interests in the shares... Sharing profit is easy, sharing a loss is difficult" – Interviewee I10
6. Based on trust and cooperation	The collaborative model is based on trust and cooperation between stakeholders. This is difficult to attain in an environment where relationships are known to be adversarial.	''Trust is hard to gain but easy to lose!" - Interviewee I10
7. Implementation difficulties	Implementing the collaborative model requires the parties to invest time and money into research to implement and monitor the process. New models can be difficult to implement.	''Everybody wants to do collaborative approach, but it's not so easy to execute" - Interviewee I1, ''Nice marketing, but nobody helps with actually implementing it" – Interviewee I10

H Subcontractor Qualification

H.1 Qualification criteria

Internal document (Fluor BV): 000.430.F0145A Contractor Survey Questionnaire

The list below demonstrates the qualification criteria used by the Company for selecting subcontractors. This list is not complete, seeing as only the criteria which are relevant to this research are included. Within the prequalification procedure of the Company, the bidders are evaluated per commodity and on the basis of the following criteria:

1. Organization
    - Company structure (sole proprietorship, partnership, corporation, etc.)
    - Net worth
    - Banking references
    - Bonding references
    - Bonding limit
2. Bidding interest
    - Preferred job cost range (max/min)
    - Type of work
    - Types of work usually subcontracted to others
3. Labor relations
    - NA
4. Products
    - List manufacturers for which the subcontractor is a licensed distributor
5. Fabrication
    - NA
6. Work history
    - Project profiles (last three years)
    - Experience in project location and local area
7. Technical capabilities
    - NA

I Model Evaluation

In chapter 9, the model is explained and the model is discussed with experts from within the Company. One element of the final solution model is the recommendation for implementing collaboration within contracts. This involves four main elements, which are recommended to integrate into the contract, in order to align the parties on the expectations of collaboration. The original model, before evaluation with the experts, can be seen in Figure I.1.

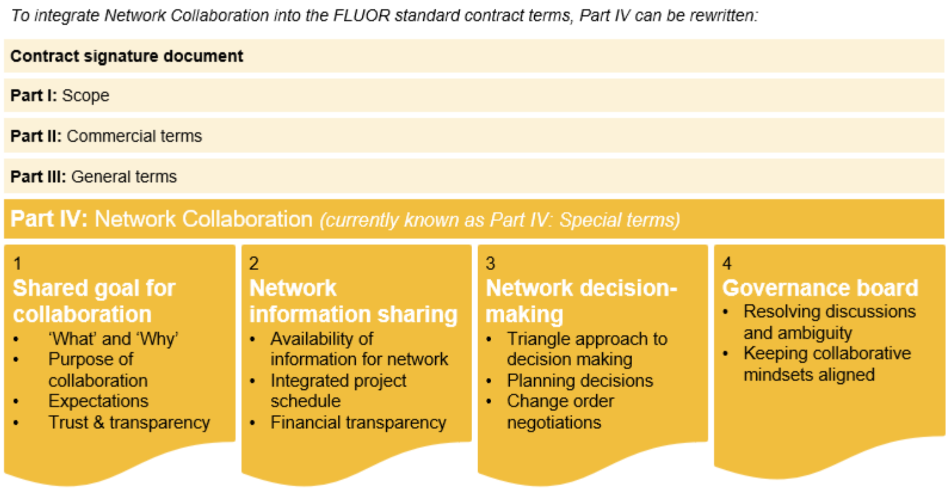


Figure I.1: The four key elements for implementing collaboration in contracts (original version).