Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Engineering
Dept. of Industrial Economics and Technology Management

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Analyzing Cost-Efficiency: A Game Theory Approach to Comparing Project Delivery Methods in Norway's Road Construction Industry

Master's thesis in Project Management
Supervisor: Bjørn Sørskot Andersen
Co-supervisor: Aristidis Kaloudis
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Abstract

Nye Veier, a road construction company in Norway, has employed two types of project delivery approaches to implement their projects (1-ECI & 2-ECI):

(*1-ECI: developing zoning plan by the client and consultant, contractor is engaged after zoning plan approval.*

2-ECI: engaging contractors from the beginning and developing zoning plans by contractor and client)

Nye Veier employs the 2-ECI project delivery approach to conduct complex projects for which the zoning plans are challenging to develop by the client and consultancy, and where execution knowledge and experience are required. In this ECI project method, the projects implemented have turned out to be expensive and challenging for the client. This MSc thesis was conducted to identify the drivers of cost increases in the 2-ECI projects and to determine which ECI project delivery approach (1-ECI or 2-ECI) is more cost-beneficial for the client.

To achieve the research objective, information from 10 interviews with three different involved parties in Nye Veier projects was used (client, contractor, and consultant), and document reviews and literature reviews were conducted. Additionally, Game Theory principles were applied to simulate the tendering process and project phases to reach a detailed understanding of parties' decision-making, interactions, preferences, and motivations.

The results show that involving the contractor after the zoning plan development phase (1-ECI) is more beneficial in terms of cost-efficiency for the client in the current market condition. However, if a project is highly complex, 2-ECI is a better approach to be employed and provides more opportunities in comparison with 1-ECI.

In the 2-ECI project delivery approach, project costs may increase due to several reasons. These reasons include high uncertainty and complexity in projects, lack of contractors' expertise, misuse of trust in the collaboration phase, lack of information and sufficient ground investigation, lack of appropriate incentives, underestimating the project budget by the client, and receiving expensive conditions on the zoning plan from authorities.

Moreover, this study highlights that the incentive of future collaboration that contractors may have with the client plays an important role in the success of ECI projects.

Sammendrag

Nye Veier, et veibyggingsselskap i Norge, har benyttet to typer prosjektleveransemetoder for å gjennomføre sine prosjekter (1-ECI og 2-ECI):

(*1-ECI: utvikling av reguleringsplan av klienten og konsulenten, entreprenøren engasjeres etter godkjenning av reguleringsplanen.*

2-ECI: engasjering av entreprenører fra begynnelsen, og utvikling av reguleringsplaner av entreprenør og klient)

Nye Veier benytter 2-ECI prosjektleveransemetoden for å gjennomføre komplekse prosjekter hvor reguleringsplanene er utfordrende å utvikle av klienten og konsulenten, og hvor gjennomføringskunnskap og erfaring er nødvendig. I denne ECI prosjektmetoden har de gjennomførte prosjektene vist seg å være dyre og utfordrende for klienten. Denne masteroppgaven ble gjennomført for å identifisere årsakene til kostnadsøkninger i 2-ECI prosjekter og for å avgjøre hvilken ECI prosjektleveransemetode (1-ECI eller 2-ECI) som er mest kostnadsoptimalisert for klienten.

For å oppnå forskningsmålet ble informasjon fra 10 intervjuer med tre forskjellige involverte parter i Nye Veier-prosjekter benyttet (klient, entreprenør og konsulent), og dokumentgjennomganger og litteraturgjennomganger ble gjennomført. I tillegg ble prinsipper fra spillteori anvendt for å simulere anbudsprosessen og prosjektfaser for å oppnå en detaljert forståelse av partenes beslutningstaking, interaksjoner, preferanser og motivasjoner.

Resultatene viser at involvering av entreprenøren etter utviklingsfasen av reguleringsplanen (1-ECI) er mer fordelaktig med hensyn til kostnadseffektivitet for klienten under dagens markedsforhold. Men hvis et prosjekt er svært komplekst, er 2-ECI en bedre tilnærming og gir flere muligheter sammenlignet med 1-ECI.

I 2-ECI prosjektleveransemetoden kan prosjektkostnadene øke av flere grunner. Disse grunnene inkluderer høy usikkerhet og kompleksitet i prosjekter, mangel på entreprenørers ekspertise, misbruk av tillit i samarbeidsfasen, mangel på informasjon og tilstrekkelig grunnundersøkelse, mangel på passende insentiver, undervurdering av prosjektbudsjettet fra klientens side, og mottak av kostbare betingelser på reguleringsplanen fra myndighetene.

Dessuten fremhever denne studien at insentivet til fremtidig samarbeid som entreprenørene kan ha med klienten spiller en viktig rolle i suksessen til ECI-prosjekter.

Table of Contents

List of Figures

List of Tables

Acronyms and Definitions

0.1 Acronyms

- **BVP:** Best Value Procurement
- **C:** Estimated Project Cost
- **Ei:** Contractors (Entreprenører) (players)
- **DB:** Design Build
- **DBB:** Design Bid Build
- **Dp:** Demand created by Nye Veier in the market
- **ECI:** Early Contractor Involvement
- **GT:** Game Theory
- **HSE:** Health, Safety, and Environment
- **M:** Minimum Rational Markup
- **NY:** Nye Veier
- **Ph:** The price strategy that provides the highest profit for contractors
- **Pi:** Price Strategies
- **PD:** Prisoner's Dilemma
- **Q:** Demand in the market
- **π1:** Payoffs of the strategies

0.2 Definitions

- **Early Phase of Projects:** Project planning phase
- **1-ECI:** When a zoning plan is developed by a consultant and Client, and the contractor is engaged in the project after zoning plan approval.
- **2-ECI:** When a zoning plan is developed by the contractor and the client, and the contractor becomes involved in the project before zoning plan development.
- **Collaboration Phase:** The phase of the 2-ECI project delivery approach in which client and contractor collaborate in developing zoning plans.

Preface

This project is the result of one year of studying project features in the road construction industry in Norway, including the ECI project approach, and the BVP method, in addition to Game Theory analysis methods and their applications in project management. The initial phase of this project was dedicated to the Specialization project, which I presented in Fall 2023. In the initial phase, ECI project delivery approaches were studied as well as ECI project delivery approaches implemented by Nye Veier to reach points where game theory analysis can be used to simulate the projects and assist Nye Veier (the client) in decision-making.

In the second phase, as an MSc thesis, all the phases of the two types of ECI project delivery approaches employed by Nye Veier were simulated using GT principles. This method provides an in-depth understanding of the ECI project delivery approaches, complementing the theoretical analysis and empirical study conducted in this research to address the research questions.

The contribution of this study lies in analyzing ECI by employing GT and providing suggestions and models that can help the client make informed decisions regarding choosing cost-beneficial project delivery approaches.

1 Introduction

This project includes two subprojects: Specialization and Master Thesis. In the Specialization project, I undertook research on a specific Early Contractor Involvement (ECI) project approach utilized by Nye Veier, which involves engaging contractors at the earliest project phase. To gain a comprehensive understanding, I conducted three interviews with contract and market managers, as well as project managers at Nye Veier. The findings from that study revealed potential areas within that specific ECI project delivery approach where the application of Game Theory (GT) could help in delivering a comprehensive assessment for Nye Veier.

Within this MSc thesis project, I am engaged in a comparative study of two distinct ECI project approaches. Utilizing GT simulations as a methodological framework, I aim to provide a comprehensive analysis of these approaches. Specifically, I examine two project delivery methods: one where contractors become involved after zoning plan development, and another where contractor engagement precedes zoning plan development. Through a comparison of the analytical outcomes derived from these methods, I present recommendations and a comparative evaluation of their cost-efficiency.

This project is closely linked to my Specialization project, and since this thesis builds upon that work, I've integrated relevant sections from the theoretical framework and data obtained in the empirical study of the Specialization project.

In this introduction section, a background of the project delivery methods and GT is presented. Then, the problem statement and research questions are formulated. Afterward, the limitations of this study and the structure of the thesis report are outlined.

Note: 'In the entire report, the two project delivery approaches under study are referred to as the 1-ECI and 2-ECI, with explanations as follows:

1-ECI: zoning plans are developed by the client and consultant, and the contractor becomes engaged in the project after zoning plan approval from authorities.

2-ECI: the contractor becomes engaged in the project from the earliest phase, before zoning plan development. In this approach, the development of zoning plans is carried out by the client and contractor.'

1.1 Background

Project requirements are different, project delivery methods should be selected according to project requirements. Each project's delivery method should be specified based on its unique features, including the project timeline, level of innovation, size, and complexity. Considering all necessary factors when selecting the delivery approach, such as at which stage of the project the contractor comes on board and how early they should become involved, is important. This factor significantly affects the project delivery approach and its potential for success (Kantola and Saari, 2016).

The traditional method of delivering projects, which includes Design-Bid-Build (DBB) contract structure, has been used in both public and private projects requiring detailed design and cost estimation before tendering processes begin and contractors become engaged for implementation. This method involves three parties: the client, who defines the project requirements; the designer, responsible for the design aspect; and the main contractor, responsible for project implementation. (Mahdi and Alreshaid, 2005). However, this approach has encountered challenges when it comes to complex projects, particularly in the relationship between parties, because the information sharing is not sufficient, and a foundation of collaboration and trust isn't built appropriately between parties (Snippert et al., 2015). Despite having the design ready before the main contractor's involvement, it often leads to redesigning, resulting in changes to the project's cost (Mahdi and Alreshaid, 2005).

To address the challenges often encountered in Design-Bid-Build (DBB) projects, a design-build (DB) contract structure is employed, where one party handles both the design and implementation phases. This integration helps to minimize conflicts between involved parties (Al Khalil, 2002).

In traditional delivery methods, whether employing Design-Bid-Build (DBB) or Design-Build (DB), collaboration between parties typically begins late, and there's often a lack of implementation perspective during the planning and design phases. By involving the main contractor in the planning phase and using their execution knowledge and experience in design, more constructible designs can be provided, in addition to a stronger foundation for collaboration. This innovative project delivery approach is known as Early Contractor Involvement (ECI). Under this method, the contractor joins the project during the planning phase and they are selected for the project based on their qualifications and experiences, allowing for the utilization of their construction expertise in planning, leading to lower uncertainty in project design, planning, and cost estimation (Molenaar et al., 2007).

Besides all the advantages, the ECI project approach seems to be challenging to implement as a new project delivery method (Song et al., 2009). The challenges are for example risk allocation (Scheepbouwer and Humphries, 2011), and difficulties in managing stakeholders (Farrell and Sunindijo, 2022).

Game Theory (GT) as a strong analysis tool can be used to analyze complex and challenging situations for making informed decisions and selecting better strategies in situations where parties face conflicts of interest. This theory was originally developed as an economic theory, but its applications have expanded to other fields, including project management. The application of GT in project management is becoming more and more popular due to its ability to provide strong analysis of different types of complex situations (Barough et al., 2012, Piraveenan, 2019). On the other hand, since projects are mostly complicated and challenging, GT can be used as a decision-making tool in strategic decision-making processes and can help in managing risks in projects, maximize profitability, help to improve bidding systems, and consequently increase project success (Narbaev et al., 2022, Ho, 2006)).

Despite the popularity of applying GT in project management and related research areas, few articles have applied GT analysis to study integrated project delivery approaches (DB). There remains a gap in analyzing the tendering process and using GT to develop bidding strategies for complex projects. Additionally, there is a research gap in studying financial problems in projects through GT analysis methods. Furthermore, there is a need to connect GT with its application in real projects by conducting empirical studies and analyzing real-life data using GT simulations (Narbaev et al., 2022).

This study aims to address the mentioned research gaps in employing GT in project management by using GT in analyzing two different project delivery approaches used in the road construction industry. Hence, I used GT to analyze the tendering process of two ECI delivery approaches that include DB contract structures. Additionally, this study investigates the factors contributing to cost increases in the zoning plan development phase of

2-ECI, and GT analysis provides a deeper understanding of the incentives and drivers affecting cost increases. All this analysis is done using real-life data of road construction projects in Norway that have been implemented by Nye Veier.

1.2 Problem Statement

Nye Veier is a road construction company in Norway that utilizes different project delivery approaches to implement their projects. In one approach (1-ECI), the contractor is engaged in projects after the client (Nye Veier) and a consultant company develop the zoning plan. In the other approach (2-ECI), the zoning plan is developed by the contractor and client, so the contractor is involved from the earliest possible phase of the project.

In the 2-ECI approach, the contractor and client collaborate during the collaboration phase to develop the zoning plan, which is then submitted for approval from the authorities. The same contractor continues with the project implementation phase. The 2-ECI approach is employed when the project scope is too complex to be developed by consultancy and the client (Nye Veier), and execution experience and knowledge are required in zoning plan development (OECD, 2021). The objective of employing the 2-ECI approach is to reach cost and time-optimized zoning plans, more feasible and constructible zoning plans, reduce the risks of implementation, and create better relationships between parties (Lenferink et al., 2012).

Despite the goal of optimizing project costs, the cost of projects implemented by employing the 2-ECI approach by Nye Veier had been always higher than the client's expectations. Therefore, Nye Veier stopped employing the 2-ECI approach.

This study aims to provide a detailed analysis of the two ECI project delivery approaches employed by Nye Veier. This analysis is crucial for making informed decisions about selecting the most appropriate project delivery approach by the client (Nye Veier). By thoroughly analyzing these approaches, Nye Veier can determine which type is more beneficial based on their goals and conditions, thereby preventing potential challenges and losses. To achieve this objective, the following research questions will be addressed in this study:

1. What are the drivers of the cost increase in the 2-ECI project delivery approach?
2. Which project delivery approach (1-ECI or 2-ECI) is more beneficial for Nye Veier in terms of cost efficiency?

1.3 Limitations

This study is limited to studying two types (1-ECI & 2-ECI) of project delivery approaches that have been used for implementing projects by Nye Veier.

In this study of ECI, the 'Equitable Payment Plan' was not examined as a success factor due to several reasons. The research focused on key factors that directly impact project delivery, like collaboration dynamics, decision-making strategies, and risk management, which are essential for ECI projects. Additionally, evaluating payment plans involves complex financial details that would have broadened the study's scope and weakened its main focus.

Since the studied projects are in the road construction sector, the GT simulation models developed in this study are tailored to road construction projects. While these models may have relevance to projects in other industries, they are developed based on information specific to road construction projects in Norway.

The GT simulations are treated as isolated games, which may not accurately reflect real-world scenarios. It's important to note that these models are influenced by and also influence other games in which the players are involved (Brandenburger and Nalebuff, 1997), a factor that has not been considered in this study.

Furthermore, this study did not examine or incorporate environmental effects such as governmental decision-making on infrastructure project prioritization (Odeck, 2010), or regulatory changes, in the development of simulations or the analysis of complex situations.

1.4 Structure of the Project

This report includes six main chapters, in addition to the abstract, preface, list of abbreviations, conclusion, and appendices.

The first chapter is the introduction. In the introduction chapter, background information on the research area, the problem statement, the research questions, the project's objectives, limitations, and the report's structure are provided and explained.

The second chapter presents the theoretical framework necessary for understanding and analyzing the data gathered from empirical study.

The third chapter is dedicated to methodology. In the methodology chapter, information about data collection methods, data analysis, data validity, data reliability, generalizability of the results, ethical considerations, and methodological limitations are presented.

In the fourth chapter, 'Empirical Work,' an introduction to Nye Veier is provided, along with information about the two types of ECI project delivery methods studied in this project. This is followed by the analysis and the results of conducted interviews with the three parties involved in the implemented ECI projects by Nye Veier.

In the fifth chapter, the GT simulations are presented. By using the empirical study results, the two ECI project approaches are simulated, analyzed, and presented in the fifth chapter.

Finally, in the sixth chapter, titled 'Discussion,' the research questions are addressed. The results of the empirical study, theoretical analysis, and simulations are discussed and the findings of this work are compared with previous works.

2 Theory

In this chapter, theories pertinent to ECI project delivery approaches, DB contract structures, BVP selection criteria, GT simulation principles, the application of GT in project management, and various market structures are presented. Theoretical models are subsequently developed based on these theories and are further utilized to analyze the empirical study results.

2.1 Design-Build (DB) contract Structure

Design-Build (DB) is a contract structure that has become popular in construction projects recently. In this method, one entity manages both design part and construction aspect of a project. Unlike traditional methods where these tasks are handled separately by different entities, in DB, they are integrated (Perera et al., 2022).

In this structure, a contract is signed between the client and the contractor. After signing the contract, all the tasks of the project, including the engineering, implementation, and relevant tasks for execution and design, are carried out by the main selected contractor (Riksheim et al., 2020).

The time of involving the contractor in a project that uses DB contract structure is varied. Sometimes, contractors join in the earliest phase of projects, helping out with important early tasks. Other times, contractors might join later, for example during the detailed engineering part. If the contractor joins later, the owner of the project or the client hires a separate design consultant to work on the initial project planning and come up with the basic design concept before engaging the project contractor. This is because a basic estimation can be provided for the tendering process and assessing the bidders (Shang and Migliaccio, 2020, Alleman and D., 2020). Even though in the second-mentioned method the contractor engages later, their experience still helps with designing and building the project to meet the project goals. The DB contract structure offers flexibility, allowing it to adapt to various situations and thereby enhancing the efficiency and success of construction projects (Wondimu, 2019, Wondimu et al., 2017).

Engaging contractors can be facilitated through various procurement approaches, such as Best Value Procurement (BVP) (Wondimu et al., 2018) which is explained further in the following.

2.1.1 Best Value Procurement (BVP)

BVP is a procurement approach that provides an efficient contractor selection in tendering processes. This method has been used in construction and infrastructure projects (Narmo et al., 2018). BVP includes selecting vendors based on their qualifications, their expertise in risk assessment, and their added value to the project. This method is usually employed when there is a long-term collaboration between the client and the contractor (Högnason et al., 2019).

In this selection method, instead of relying on detailed specifications from the client, BVP emphasizes that expert vendors should evaluate project outcomes, pricing, and execution (Wondimu, 2019). BVP serves as a solution to address issues in infrastructure projects, such as financial and scheduling problems and conflicts, by selecting a well-qualified contractor with expertise in managing risks, planning projects, and managing projects (Wondimu, 2019). Different contractors have different experiences and solutions in managing risk (Perrenoud et al., 2017). This diversity presents an opportunity for the client to select the contractor with the most experience in the specific project type and provides better risk management (Wondimu, 2019).

2.2 ECI

Traditional project approaches involve a procedure that usually starts with the client employing consultants to create a thorough project design, including engineers and architects. Following completion and approval of the design, the client chooses and employs a contractor to handle the construction work in accordance with the consultants' design. This sequential approach involves separate contracts for the design and construction phases, with the design being finalized before the construction phase begins (Turner, 2014).

When a project is complex, it is required to employ contractors' knowledge and experience in design (Song et al., 2009). Traditional methods, in which the contractor becomes involved after the design phase, do not contribute to addressing today's construction challenges (Luo et al., 2017).

ECI is a project delivery method that involves bringing in the contractor's expertise early in a project, even before the design is fully developed. This approach aims to enhance the design's feasibility for construction and optimize costs during the pre-construction phase (Scheepbouwer and Humphries, 2011).

By applying ECI, the contractor can be engaged in both the front-end phase and the execution phase. By using contractors' knowledge and experience during the early stages of complex projects, possible risks in the implementation phase can be prevented (Wondimu, 2019).

Under the ECI method, the contractor joins the project during the planning phase and they are selected for the project based on their qualifications and experiences, allowing for the utilization of their construction expertise in planning, leading to lower uncertainty in cost estimation. After the completion of the planning phase, now with more information available for the details of the project, a target price contract can be signed. If the project is completed at a lower cost than the target price, the contractor receives a portion of the savings, it acts as an incentive for the contractor to develop optimized plans and deliver the project at the lowest possible cost (Molenaar et al., 2007).

Different project owners have come up with their own versions of ECI to fit their specific needs. Some have opted for a relationship-based model that covers the entire project from start to finish. Others have decided to go for a hybrid method, in which the contract begins with an early collaborative method and then shifts to a more traditional method during the execution phase (Wondimu, 2019). For example, ECI with a two-stage tendering approach is widely employed in the UK. In the first stage, contractors are brought on board to contribute insights and expertise during the design phase. The second stage involves implementation based on the design developed in the first stage (Rahmani et al., 2013). This approach is similar to a Design-Build (DB) contract, where the contractor has responsibility for both the design and construction aspects of the project, ensuring seamless integration and efficient project delivery (Wondimu et al., 2018).

ECI can be employed in several project phases, such as the development, design, and implementation phases. Additionally, projects can be conducted by applying the ECI method while the contract structures can be different. The contract structure can be the traditional type DBB (Design-Bid-Build), can be the more open contract structure such as DB (Design-Build), or it can be any other type of contract structure (Walker and Lloyd-Walker, 2012, Wondimu et al., 2018, Wondimu et al., 2020).

ECI is a flexible approach in its integration within the project lifecycle, with options to implement it only during the phase of defining the project and developing the design, or extending it into the execution phase. The timing of involving the contractor in which project phases depends on many factors such as the project owner's decision, project needs, and objectives (Rahman and Alhassan, 2012). There are some owners who prefer a more hybrid approach of ECI. In this case, the contract initially adopts a collaborative approach during the project's early phases and the project method transitions to a conventional contract type in the implementation phase of projects (Scheepbouwer and Humphries, 2011). In the case of engaging contractors after the project definition and design, defining the project scope and developing the design is done by the project owner with assistance from an external entity like a consultant (Walker and Lloyd-Walker, 2012, Wondimu et al., 2020, Pheng et al., 2015).

A conceptual model is developed in this study and presented in Figure 1, for demonstrating the three different ECI project delivery approaches based on the reviewed articles. In this model, the timing of involving the contractors in projects, contract structures, and contractor selection criteria are specified (Wondimu et al., 2020, Scheepbouwer and Humphries, 2011).

1. ECI is engaging the contractor in the design and implementation phase only. The planning phase can be done by the client or the client and a consultant.
2. ECI is engaging contractors from the earliest possible phase of the project.
3. ECI is a hybrid model that includes using contractors' knowledge and experience in the design and planning phase, and using the conventional method in the implementation phase.

The contract structure used in the 1&2-ECI methods is more open, like DB, while in 3-ECI is less open like DBB. BVP is the selection criteria that has been usually employed in ECI project delivery approaches which is selecting contractors based on the qualifications and price (Wondimu et al., 2020).

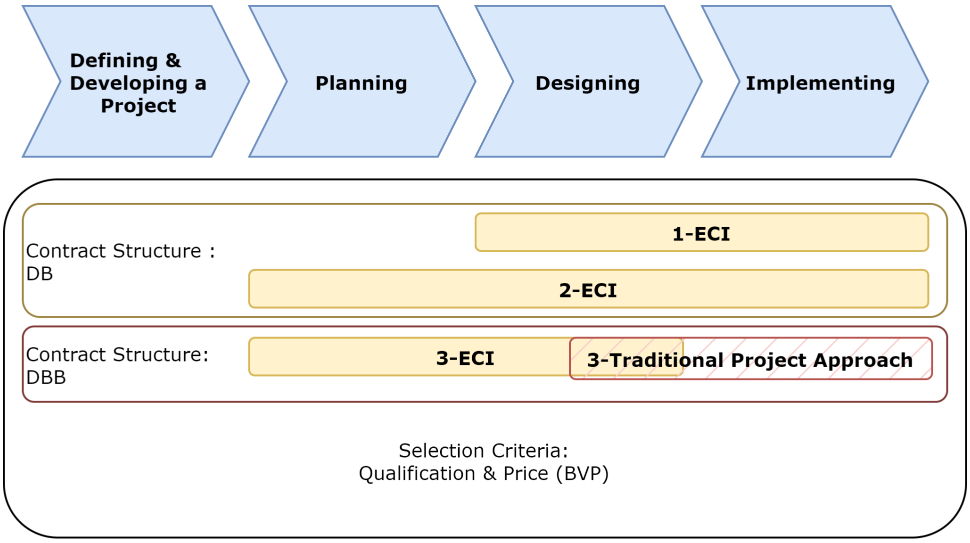

Figure 1: **ECI Approaches**

2.2.1 ECI Opportunities, Challenges & Success Factors

ECI brings many advantages to projects by involving the main contractor early. These benefits include using construction expertise in the design phase to create more constructible and feasible designs, identifying and mitigating risks with execution knowledge, and reducing uncertainties in the early phases of projects (Nibbelink et al., 2017). By engaging contractors early on projects, more efficient and productive communication between parties can be created. Effective communication allows parties to share the required information and knowledge (Song et al., 2009). Furthermore, it provides an opportunity to cultivate stronger relationships between parties (Rahman and Alhassan, 2012, Rahmani, 2021). In this approach, clients and contractors collaborate at a high level, working together to deliver project outcomes. This collaboration can result in goal alignment between the two parties (Marius et al., 2022).

Collaboration between parties in the project planning phase often results in the generation of more innovative solutions by contractors (Lenferink et al., 2012). Moreover, the early engagement of contractors has been found to yield cost savings, as they are capable of providing cost-efficient solutions. This is attributed to contractors' wealth of execution knowledge and experience, equipping them with the capacity to propose innovative and cost-effective solutions for projects (Eadie and Graham, 2014).

On the other hand, choosing the right type of ECI procurement approach poses challenges. According to the literature, it is challenging to determine the right time of contractor involvement and decide on how much early contractors should be engaged in projects (Wondimu et al., 2016). The timing of contractor engagement and choosing the type of ECI project delivery approach depends on many factors, and project owners decide based on the project's needs as well as environmental factors such as market competitiveness and contractors' availability (Thanh Luu et al., 2003). The number of available contractors, the number of highly qualified and competent contractors in the market, the number of available projects in the market, and other market factors can affect the selection of the right project delivery method (Thanh Luu et al., 2003, Ying et al., 2022, OECD, 2021). Furthermore, selecting the appropriate ECI approach, particularly concerning the optimal timing for contractor engagement, is crucial. Improper timing in contractor involvement can result in cost or time overruns and, in the most severe cases, project failure (Wondimu et al., 2016).

Risk allocation represents a significant challenge in ECI projects, as contractors often bear a relatively high level of risk. Financial incentives, such as sharing cost savings from the target price, may not adequately compensate for these risks (Rahmani, 2021, Scheepbouwer and Humphries, 2011). Moreover, despite the ECI approach's goal of enhancing collaboration among parties, establishing a trust-based relationship during the collaboration phase remains difficult. Achieving this requires complete transparency and honesty throughout the collaboration process (Farrell and Sunindijo, 2022).

In construction projects implemented through an integrated project approach, contractual incentives can motivate selected contractors to fulfill their responsibilities effectively (Fu et al., 2015). There is a direct relationship between the designed incentive systems in a project and the outcomes of that project. Therefore, project incentive systems should be tailored to the specific requirements of each project (Bresnen and Marshall, 2000). Appropriate incentives in an ECI project can help foster relationships between parties during the collaboration phase and compensate for the risks that contractors assume (Rahmani, 2021).

Companies have different goals, priorities, and perceptions of benefits. By considering companies' expectations of rewards and benefits, proper incentive systems can be designed to foster effective collaboration within a project. Otherwise, an improperly designed incentive system can negatively impact collaboration (Bresnen and Marshall, 2000). It is challenging to realize what is companies' definition of benefit in a project and design a suitable incentive system to ensure project success.

The incentive system is effective in creating win-win cooperation between parties as well as goal alignment in projects, leading to project success. While incentives are usually considered monetary incentives, it is not always the case. Even though monetary incentives can be effective, parties have different goals of being involved in a project. Therefore the incentives should be specified based on the parties' goals and expectations of participating in projects. These incentives are not always of monetary value and can be non-monetary (Wang et al., 2023, Atkinson et al., 2023). The monetary incentives in ECI projects include sharing cost savings achieved through target price contracts, and any rewards involving monetary value such as bonuses for various purposes. Non-monetary incentives on the other hand are based on the non-monetary goals and motivations of each party involved. By considering the motivations of companies participating in a project, effective goal alignment and collaboration can be facilitated (Wang et al., 2023, Atkinson et al., 2023).

Despite these challenges, various factors mentioned in the articles can contribute to the success of a project using the ECI approach. These factors include the appropriate timing of engaging the contractor, which is different depending on the project's requirements and conditions (Wondimu et al., 2016, Song et al., 2009). The second factor is trust and transparency. Establishing a trust-based relationship between parties in the project, both during the collaboration and implementation phases, is very important. The third factor is the required qualifications. The selected contractor for the project should equipped with the necessary qualifications. The project owner should also be proficient, as it can impact the project process. The last factor is risk allocation, risks should be shared fairly between the client and contractor, which is not currently the case. The amount of risk assigned to contractors is relatively higher than that assigned to clients (Wondimu et al., 2016,Moradi and Kähkönen, 2022).

A conceptual model, based on my understanding of the findings from articles is developed and presented in Figure 2. This model aims to identify the relationships among challenges, success factors, and opportunities in ECI projects, as well as the influential factors affecting them.

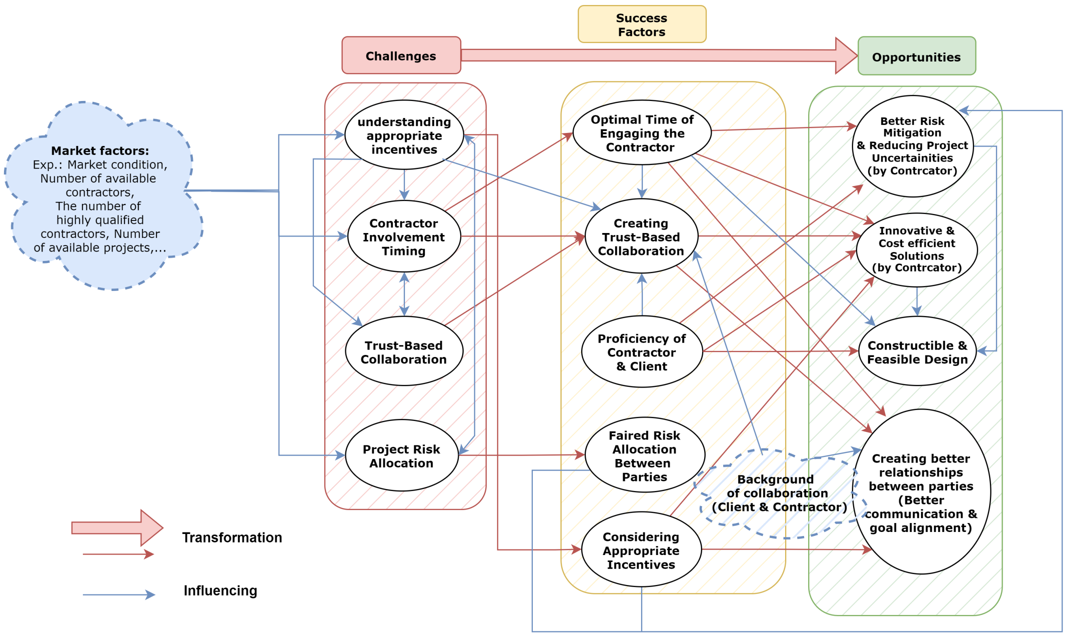

Figure 2: **ECI Opportunities, Challenges & Success Factors**

Challenges in ECI projects can be transformed into opportunities by considering success factors during the project or pre-project phases as shown in Figure 2. Establishing trust-based relationships significantly impacts the decision-making process regarding the type of ECI utilized in a project. Clients may opt to engage the main contractor earlier if creating a better relationship between parties and goal alignment is their priority.

The incentives available to contractors in the market can influence the client's decision-making regarding the ECI project type. Understanding appropriate incentives can help establish trust-based relationships between parties by facilitating win-win collaboration and fulfilling contractors' benefits and goals for participating in projects. Risk allocation also impacts these incentives and goals. Furthermore, market factors such as market structure, the number of highly qualified contractors, and the number of projects announced in the market affect the companies' incentives, the client's choice of ECI project approach (Thanh Luu et al., 2003), and risk allocation.

According to the model provided in Figure 2, qualified contractors can provide feasible designs, innovative and cost-efficient solutions, and effective risk mitigation for a project (qualified clients can also help in this objective) (Wondimu et al., 2016). To create a good relationship between the client and contractor, it is important to have a trust-based relationship and full transparency. The timing of involving contractors also affects the relationship between parties; the earlier the contractor becomes involved, the better the relationship can be created(Wondimu et al., 2016, Song et al., 2009). If the parties have worked together before, they know each other and consequently, trust can be increased. The more competent the contractor is and the more the client is welcome to collaborate and be involved the better collaboration and relationship can be created between parties which can be boosted by having a background of collaboration. If there is no collaboration from before, in case of facing challenges in a project, it is difficult for the client to trust the contractor (Fu et al., 2015). In the model, the 'background of collaboration' is categorized as both a success factor and an opportunity. This factor is embedded in the creation of trust-based collaboration, which is a success criterion, and in the development of better relationships, which is seen as an opportunity.

The timing of involving the contractor influences their capability to provide cost-efficient solutions and better risk mitigation. The earlier contractors become involved in projects the more they have time to do the required investigations, provide innovative solutions, and provide better risk mitigation, also the plan is more flexible to be changed in the early phases. Consequently, it affects providing better and feasible design (Nibbelink et al., 2017).

Last but not least, the success factor of considering appropriate incentives contributes to motivating contractors to provide innovative and cost-efficient solutions, better risk mitigation, and fosters relationship and goal alignment between parties, ultimately leading to the establishment of trust-based relationships (Farrell and Sunindijo, 2022). Appropriate incentives can somehow compensate for the high risks assigned to contractors in ECI projects (Rahmani, 2021, Scheepbouwer and Humphries, 2011). However, the incentives in projects can be varied and should be designed based on companies' motivations and goals. These incentives can be either monetary or non-monetary according to contractors' goals (Wang et al., 2023).

By transforming the challenges of ECI projects into opportunities, and by considering suitable success factors based on project and market requirements, clients can achieve better outcomes. Hiring a proficient and competent contractor at the optimal time allows for the development of an enhanced risk mitigation plan, using the contractor's knowledge and experience, leading to the creation of more feasible and constructible plans and designs. Furthermore, trust-based collaboration facilitates the provision of cost-optimized solutions. This approach also promotes better alignment of the goals among the stakeholders involved.

Since this study focuses on answering the question of which ECI project delivery approach is more beneficial for the client in terms of cost efficiency, as depicted in Figure 2, providing cost-efficient solutions by contractors depends on several success factors. These include the timing of involving contractors, which is specified by the definition in different ECI approaches employed by Nye Veier, contractors' proficiency, which is assessed by the client as a contractor selection criterion, considering appropriate incentives, and trust-based collaboration between parties. Trust-based collaboration as a success factor is influenced by the challenge of considering appropriate incentives. Therefore, this study simulates all the phases of ECI project delivery approaches employed by Nye Veier using GT principles to achieve a detailed analysis of the incentives of parties and contractors. GT simulations can offer profound insights into the interactions, strategies, benefits, objectives, and incentives of the stakeholders involved in projects. The subsequent section provides an in-depth explanation of this simulation method.

2.3 Game Theory

2.3.1 What is Game Theory

The development of the game theory (GT) began in the *"twentieth century"*. It started with the introduction of a model by the mathematical specialist Emile Borel in 1921. Seven years later, John von Neumann, inspired by Borel's model, developed a theory called 'Parlor Games.' The development of the model continued and GT became popular in other disciplines and began to be applied across a wide range of scientific fields after John von Neumann and Oskar Morgenstern published their book *"Theory of Games and Economic Behavior"*. (Burguillo, 2018,p.104).

GT as a mathematical framework analyzes interactions between parties, stakeholders, or entities in a decision-making situation. The mathematical framework is called a game model and provides an in-depth understanding of complex situations and analyzes them in a way that can help in making informed decisions (Burguillo, 2018).

Even though GT was initially applied in the economic area, its application has expanded to many different fields such as politics, philosophy, and social science. As a powerful tool, GT models can help in analyzing and understanding a wide range of real-life situations. For example, debates, interactions between governments, political discussions, and job interviews all involve elements of strategic decision-making and can be analyzed using principles from GT(Burguillo, 2018).

This mathematical framework can be employed for resolving conflict situations as well. GT provides a mathematical framework for studying decision-making in situations where multiple parties interact and have conflicts of interest (Burguillo, 2018). Using GT, we can analyze a game from the perspective of individual players and make informed decisions by estimating other players' strategies. Additionally, a situation can be analyzed as a whole, aiming to make decisions that benefit all stakeholders involved (Kapliński and Tamošaitienė, 2010).

2.3.2 Key Elements in a Game

When designing a game model, several key elements and factors should be taken into account. To understand a situation and develop the game framework, the players involved in the game should be identified, the possible strategies (decisions) that each player can choose should be specified, and the rationality behind the decisions and strategies should be understood. Furthermore, estimating or understanding the probability of choosing a specific strategy for a player, and determining the payoffs or benefits of taking a specific decision by a player is important. Moreover establishing rules that govern the game, and defining the boundaries of the game, help in analyzing the situation productively. Each of these elements is explained in the following:

Players:

In GT, entities, groups, or individuals who can influence or participate in a game by taking actions are the players of the game (Brandenburger and Nalebuff, 1997). GT typically deals with games that have a defined and limited set of "players, moves, events, and potential outcomes" (Kapliński and Tamošaitienė, 2010,p.348). This means that there's a finite number of these elements involved. However, within this constraint, the actual number of players in a game can vary significantly. Some games may involve only a few participants, while others involve a large group. This variation depends on factors such as the nature of the game, and how a game is modeled (Burguillo, 2018).

Rationality:

Rationality in game theory refers to the principle that all involved parties or players in a game have rational motivations for their involvement or actions. A rational player is the one who wants to increase their profits or reach better outcomes in a game and the rational strategy is the action that can lead the player to achieve this objective (Burguillo, 2018).

Strategy of Playing:

Strategies are the actions, decisions, or responses that each player in a game decides to do to increase their benefit or reach their preferences. Usually, there is a wide range of strategies that each player can take in a game but players choose the ones that are rational and align with their goals of playing (Brandenburger and Nalebuff, 1997, Burguillo, 2018, Castillo and Dorao, 2013).

Payoff:

Each player in a game faces potential outcomes, benefits, or losses associated with choosing different strategies. These outcomes, whether beneficial or unfavorable, are the payoffs that a player achieves by playing a specific strategy. Payoffs can be described as the consequences of decisions made by each player or decision-maker within a specific situation (Burguillo, 2018, Kıbrıs, 2010).

Rules:

Rules are the specifiers of the way that each player can play in a game. Football games as an example, include the rules that players must follow during playing time. In situations that include decision-making or conflict, the rules can be contracts, guidelines, or agreements that govern the situation and players must follow and make their decision inside the defined limitations or frameworks (Brandenburger and Nalebuff, 1997).

Game Boundary:

Games, like all decision-making situations, can both be influenced by and have an impact on other decision-making scenarios and environments. By defining the boundaries of a game, one can understand and specify its interactions and influences on other games, the environment, or surrounding areas. This allows for a clearer understanding of how games are influenced by and affect their surroundings(Brandenburger and Nalebuff, 1997).

Game models, based on their defined structures, are categorized into different groups, as explained below:

2.3.3 Game Structures

Game models are structured in two different game structures including Strategic and Extensive (Burguillo, 2018).

Strategic Game: A strategic game is a common type of game theory model. In this model, the game is instructed as a matrix and players make decisions non-cooperatively. An example is presented in Figure 3. In the matrix, players are shown in the two axes, and the words represent different strategies or decisions that each involved player can make.

The numbers within the cells represent the payoffs associated with each combination of strategies chosen by the players (Burguillo, 2018).

Player II

Player I	C	D
A	3,3	0,5
B	5,0	1,1

Figure 3: **"Strategic Game Model Structure"**

Source: (Burguillo, 2018,p.104)

Extensive Game: For modeling games that include sequential actions, and players taking turns making moves and seeing what others have done, an Extensive structure is used. In Extensive game structures, information about players' actions in each phase or stage is provided. In figure 4, lines between circles show the strategies that each player chooses at each stage, and circles show the players. At the end of the extension, the payoffs that each player receives from playing the game are presented (Burguillo, 2018).

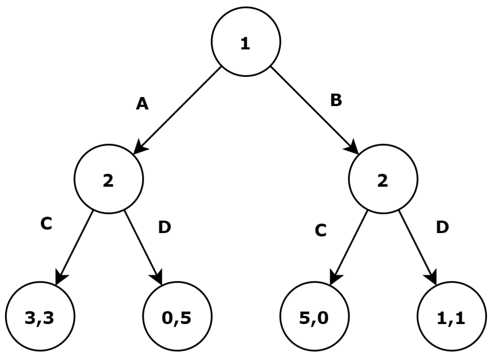

Figure 4: **"Dynamic Game Model Structure"**

Source: (Burguillo, 2018,p.104)

2.3.4 Different Types of Game

GT consists of a wide range of game types. Each type of game is suitable for analyzing a specific aspect of a conflict or interaction. A game can also be a combination of different types to effectively analyze the complexity of a situation. These game types are further explained.

Noncooperative & Cooperative Game:

When players in a game, play only for their own sake and with the goal of reaching the best possible outcome for themselves, even if their benefit leads to other players' loss, the game is called non-cooperative. On the other hand, in a cooperative game, a common goal is pursued, which is beneficial for all players. All involved players work toward reaching a mutual objective and maximizing it. In a cooperative game, the goal cannot be achieved by individual effort, and reaching the objective requires a collaborative effort of all involved players (Burguillo, 2018).

Symmetric & Asymmetric Game:

A game is called symmetric if all involved participants in the game have the same strategy options for playing or have the possibility of taking the same actions during the game. In a symmetric game, the players can reach the same outcome by taking the same action. Like Rock-Paper-Scissor, participants in a symmetric game have the same chance of playing while they have the same opportunity to choose strategies from the same set of options (Burguillo, 2018).

In an asymmetric game, the strategy options are not the same for all the players involved in a game. Consequently, the payoffs are not the same accordingly. Additionally, when a player plays by choosing one strategy, it can influence the payoffs of the other players in the game. For example, in chess, by playing certain moves by one player, the player's opponent's strategy options are affected and limited by those moves (Burguillo, 2018).

Zero-Sum & Nonzero-Sum Game:

In zero-sum games, the total payoff of the game is for all the participants. Each player can reach a portion of the total payoff in accordance with the strategy that they play. Whatever one player reaches deducts from the total payoff and affects the others. It means that when one player achieves a payoff by playing a certain strategy, that amount is deducted from the total remaining payoff available to other players who have chosen their strategies. Poker can be an example of a zero-sum game (Burguillo, 2018).

While, in non-zero-sum games, players are not competing for a single source of payoff. The payoff obtained by one player does not directly affect the payoffs of other players based on their chosen strategies. In non-zero-sum games, the best approach for maximizing the outcome of the game is collaboration among the involved players (Burguillo, 2018, Hawkins, 1945).

Simultaneous & Sequential Game:

A simultaneous game is a game in which players do not have information about each other's chosen strategies, and they select their strategies for playing in the game without any knowledge of the other's choices, similar to a rock-paper-scissors game. To model this type of game, a strategic game structure is suitable (Burguillo, 2018).

On the other hand, in a sequential game, players take actions in different steps. The involved participants in a game are required to choose a strategy for playing in different stages of a game. In this type of game, players have some information about the actions of others (not all the detailed data), similar to chess playing structure. To model this game type, the extensive game structure is suitable (Burguillo, 2018).

Perfect & Imperfect Game:

When a game is characterized as perfect information, the players in the game have information about the previous actions taken by the other players. For example, in chess, every player has the possibility to see the entire board and be aware of the history of chosen strategies. Conversely, in a game with imperfect information, such as a card game, the history of previous actions taken is not available to the players involved. Therefore, the players choose strategies without having knowledge of the history of moves (Burguillo, 2018, Gale, 1953).

Complete Information & Incomplete Information Game:

In complete information games, players become aware of the strategies chosen by others and the payoffs achieved by those strategies at a specific time in the game and players have common knowledge of the game. However, this does not necessarily mean the players have information about previous actions. While, in incomplete information games, players do not receive information about other players' actions and payoffs, and there is not a common knowledge of the game they are playing (Burguillo, 2018).

Perfect Recall Games:

If a game is characterized as a Perfect Recall game, it means that the involved players in the game are capable of remembering the history of actions taken by themselves or other involved players. By using this characteristic, the participants can make informed decisions with lower uncertainty. This feature is applicable for sequential games when the game includes multiple steps for decision-making (Burguillo, 2018).

Static & Dynamic Game:

A game is considered static if all involved players make decisions simultaneously. Static games focus solely on one-time interactions or decision-making situations without considering the time factor and potential changes over time that could influence the game. The static nature of these games is suitable for analyzing competitive situations where future changes are not factored into decision-making and strategy selection (De Giovanni, 2009).

On the other hand, dynamic games consider time and account for all changes in factors that can affect the game. In this type of game, players make decisions sequentially and have multiple opportunities to play. Each decision made by a player can influence the game's payoff for all players involved. Players aim to achieve the best possible outcome by adjusting their strategies throughout the game based on the actions of other players. Dynamic games are commonly used for modeling alliance partnerships and other scenarios where decisions evolve over time (De Giovanni, 2009).

In the following figure (Figure 5), the characteristics of each game structure based on the reviewed literature are specified. For example, strategic games are not sequential and dynamic, whereas these are the characteristics of extensive games.

	Cooperative	Non-Cooperative	Symmetric	Asymmetric	Zero-sum	Non-Zero-sum	Simultaneous	Sequential	Perfect/Imperfect infromation	Complete/incomplete informtaion	Perfect Recall	Static	Dynamic
Strategic Game	☑	☑	☑	☑	☑	☑	☑			☑		☑	
Extensive Game	☑	☑	☑	☑	☑	☑		☑	☑	☑	☑		☑

Figure 5: **Game Types and Structures**

2.3.5 How to Analyze a Game

Games are modeled tailored to the specific decision-making situation and based on specific characteristics of the situation. Analyzing games should also be tailored to the unique features of a game. The optimal outcome of a game can be analyzed by employing various analysis methods, including Best Response, Nash equilibrium, or Pareto Optimal Point (Burguillo, 2018).

Nash Equilibrium:

Nash Equilibrium refers to the scenario in a game where each player, based on the information available to them, selects the best possible strategy, considering the strategies chosen by others. At this equilibrium point, if any player were to change their strategy while the others maintain theirs, they wouldn't achieve a better outcome. Essentially, it's a state where no player has an incentive to change their own strategy. Moreover, it's important to note that in certain games, there could be multiple Nash equilibrium points, reflecting different stable outcomes depending on the players' choices (Burguillo, 2018).

Equilibrium Path:

In a sequential game, when players choose the optimal solutions at each step, the path that includes taking optimal actions at each step represents the Equilibrium Path of the game (Halpern and Pass, 2021).

Pareto Optimality:

When players in a game achieve a payoff by choosing a strategy, and there is no better payoff for the player by choosing other strategies except causing a loss for other players, the point mentioned in a game is called a Pareto Optimal point, which provides a Pareto optimal outcome. The underlying logic is to create a win-win situation where all involved parties can benefit without causing losses for others. However, it's common in a game that one player to achieve a better outcome than the others (Flåm and Jourani, 2006, Burguillo, 2018, Lin and Zhang, 2018).

Best Response:

When an entity takes an action to achieve the best possible outcome in response to another entity's action in a game, or based on the prediction of the future actions that the other game participants might take, it would be the best response for that player in that specific situation (Burguillo, 2018).

Based on the information provided in the literature, it is concluded that the best response in a game is decisions that are made non-cooperatively and can lead to Nash Equilibrium. In a sequential dynamic game, the best response can lead to the equilibrium path, and in a cooperative game, the best response leads the game to a Pareto optimal outcome. This analysis is presented as a conceptual model in Figure 6.

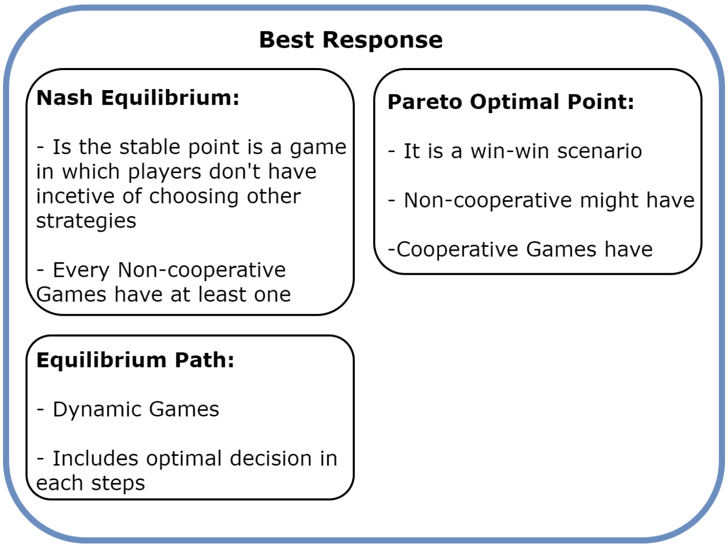

Figure 6: **Analysis in Game Models**

2.3.6 Popular Games

There are some game models that have proven decision-making strategies and rationality, and are commonly used for analyzing different situations. These examples can be helpful either for analyzing a game or for gaining inspiration for creating new models. These examples include Stag Hunt Game, The Battle of Sexes, Hawks and Doves, Prisoner's Dilemma, and cooperative game (Burguillo, 2018). The dynamic and static forms of Prisoner's Dilemma games, as well as the cooperative game form and associated payoffs, are explained below. These popular game forms served as the inspiration for the development of the GT simulations in this study.

Prisoner's Dilemma (PD): Prisoner's Dilemma is a complex decision-making situation that is modeled as a strategic game. In this game, the players are prisoners that have two different options as playing strategies. They can betray each other and confess against each other or they can be silent in their cell (cooperate). If both betray, it is the defect strategy, and they would have to spend 4 years in jail. If one defects and the other does not defect, the betrayer is free, and the other would have to be in jail for 5 years. However, if both remain silent and choose the cooperate strategy, they have to be only 2 years in jail. Since the prisoners in this game are not aware of the other's strategy, they have more incentive to choose the defect strategy, so it is not rational to choose to cooperate in this game. Therefore, the Nash Equilibrium in the game is when both decide to betray (defect strategy)(Burguillo, 2018).

Player I \ Player II	Cooperate	Defect
Cooperate	-2,-2	-5,0
Defect	0,-5	-4,-4

Figure 7: **"Prisoner's Dilemma"**

Source: (Burguillo, 2018,p.118)

Iterated Prisoner's Dilemma (IPD):

If the Prisoners' Dilemma game, instead of being a one-time strategic game, is a continuous game with multiple iterations (dynamic), the most probable strategy to take is cooperation. This is because the prisoners are aware of the consequences of their decision-making in the future. If they cooperate, the result is positive and provides a foundation for collaborating in the future. Conversely, if they betray, they must consider the fact that they will have future interactions, and the consequences will be negative for them. Therefore, as long as the players have the incentive to collaborate in the future and the game includes iteration, the most motivating strategy is cooperation (Burguillo, 2018).

Cooperation Games:

In a cooperative game, when a shared outcome or payoff is distributed, each player can have a utility function in accordance with their degree of risk aversion that represents their achievements and reaching benefit from the game. If a player is risk-neutral, their utility function can be represented by a linear equation ($u = x$). However, if a player is risk-averse, a concave function such as a power function is typically used ($u = x^a$, where $0 < a < 1$) (Fibich et al., 2006).

2.3.7 Game Theory in Project Managment

Game models can be developed as a decision-making framework, to analyze the interaction between two or more parties. These entities act differently in a situation and each action leads to a specific outcome. According to factors such as the nature of the decision-making scenario, goals of involved parties, and level of cooperation or competition among players, a situation can be simulated as a game. By developing a game model the interactions of involved parties in situations can be analyzed effectively (Piraveenan, 2019,Eissa et al., 2021).

Different project phases, including the feasibility study phase the earliest phase of a project, the bidding process for selecting contractors, the implementation phase, and the post-project phase, can be simulated by using GT. Game simulations in different project phases can help to analyze the phase of projects, provide an analysis of complex situations, and help in making informed decisions. Simulating complex situations or project phases by employing GT is done for different goals, such as minimizing the cost of a project, increasing profit, and other reasons (Narbaev et al., 2022).

By simulating stakeholder interactions in a project using game simulations, a project manager can be facilitated with a great insight into stakeholders' interactions. Project managers can have more information on different possible strategies that each party or individual can take, leading to improved stakeholder management in a project (Eissa et al., 2021, Narbaev et al., 2022,Luo et al., 2020). For example, by understanding the incentives and motivations of contractors, game theory can facilitate more efficient and mutually beneficial relationships. By providing a win-win situation better project outcomes can be reached for each involved party (Asgari et al., 2014, Tao et al., 2021).

The objectives of simulating project phases by employing GT are summarized and presented in the following table (Table 1):

Project Phases	**Objectives of GT Simulation**
Early Phase	Analyzing Complex Situations, Analyzing Parties' Interactions, Understanding Parties' Strategies, Understanding Parties' Incentives/Motivation
Tendering Process	
Implementation	
Post-Implementation	

Table 1: **Objectives of GT simulation in Project Phases**

The tendering process is the basis of the collaboration of the parties. In this process, the client selects a contractor for delivering a project (Ho and Hsu, 2014). This process is uncertain for both contractor and client, and as an important phase of a project has been analyzed in a limited number of project management articles by employing GT (Narbaev et al., 2022).

Tendering Process:

In competitive tendering processes, such as bidding for infrastructure projects, contractors often face challenges in providing accurate cost estimations due to uncertainties and competition. Game modeling can be used for simulating various scenarios in the bidding process (Schmidt, 2015). By providing this simulation different outcomes of different strategies can be analyzed. By modeling different approaches, contractors can anticipate the outcomes of selecting particular strategies in terms of cost estimation and other requirements. This enables them to make informed decisions and mitigate the risk of falling victim to the Winner's Curse (Ahmed et al., 2016, Eissa et al., 2021).

Because of high competition, especially in public infrastructure project tendering, contractors often face negative profits or lower-than-minimum required profits to win a project (Ahmed et al., 2022). The winner's curse problem can occur because of market conditions, such as having many highly experienced contractors or new contractors in the market. Bidders might underestimate project costs due to high uncertainty in a project. Lack of project announcements in the market or a low number of projects in the market can also affect contractors' behavior in the tendering process. Additionally, other factors can motivate contractors to set a lower price than the actual in their bid, such as the possibility of claims or change orders after winning the projects (Ahmed et al., 2016). If participants in a tendering process increase their bid prices to avoid the winner's curse and ensure profitability, their chances of winning decrease. This is especially true if there is tight competition and the client has many options to select as the main contractors. Therefore choosing the strategy of considering a low price or closer to the project's actual price depends on many factors such as contractors' objective of participating in the tendering process, contractors' company condition, and market condition (Assaad et al., 2021).

Contractors in a bidding process are selected based on different criteria like price and qualifications. If the contractors have the objective of a long-term business relationship with the same client, their goal affects the price they consider in their bid. The price that they consider in their bid can be lower than it should be in this case, which can cause a loss for the selected contractor. This consideration of a low price by a bidder is because the contractors' preference is winning the competition and reaching their goal of having a long-term business relationship with a client (Le et al., 2021).

The reasons for choosing low prices by contractors in tendering processes (based on the literature) are summarized and presented in the following table (Table 2):

Reasons of Choosing Low Price Strategy
High Competition
Market Condition
Possibility of Claim or Change Orders
Contractors' objectives
Contractors' company's condition

Table 2: **Reasons of Choosing Low Price Strategy**

To achieve a real-life analysis when simulating a situation by employing GT, it is important to consider market structure. Market structure can affect players' power and influence in a game. Consequently, market structure determines players' strategy and the outcome of the game (Ginevičius and Krivka, 2008). For example, bidders' strategies are directly affected by the market condition. Every variation in the market results in changes in bidders' strategies (Connolly, 2006, Ahmed et al., 2016). In the following, different types of market structures are explained.

2.4 Market structures

There are five different market structures categorized based on the competition level and the power of buyers and sellers in the market. In the context of projects, buyers assume the role of clients and sellers assume the role of contractors. The five categories include Monopsonist, Perfect Competition, Oligopoly, Duopoly, and Monopoly.

Monopsonist Structure:

A market structure that includes many sellers or service providers who can offer the same service or product, while there is only one buyer for the specific service or product. This market structure is a Monopsonistic market, in which the buyer dominates the market and has the most influence in price determination. Consequently, the service providers or sellers in the market must adjust themselves to the buyer's demands in order to survive and maintain their market share (Jha and Rodriguez-Lopez, 2021).

Perfect Competition Structure:

If the number of sellers or service providers of a specific product or service is high in a market, and the number of buyers of that service or product is also high, the structure of the market is Perfect Competition. In a Perfect Competition market structure, the price is determined by the market, and neither the buyer nor the seller has more power over the other (Azevedo and Gottlieb, 2017).

Oligopoly Structure:

When there is a limited number of suppliers capable of supplying a specific product and service, the market structure is called an oligopoly. In this market structure, despite the significant power that suppliers have over the buyers, the power of suppliers is interconnected with each other. In other words, one supplier cannot solely affect market factors; all the suppliers together influence price and all the market factors in an interconnected manner (Mazzeo, 2002).

Duopoly Structure:

A duopoly market structure positions itself between monopoly and oligopoly. There are two main suppliers in this market structure who have dominant power to influence market factors such as price and product quality. However, they cannot determine these market factors alone; this effect is interconnected. Both suppliers have an influence on market factors, and the market factors are determined by considering both suppliers' actions and decisions. These suppliers are also subject to external factors like market demand and regulatory constraints. Therefore, while the suppliers have control over the market, their power is affected by the complex interaction between their strategies and external factors (Fang, 2020).

Monopoly structure:

When the market structure is a monopoly, there is one supplier or seller for a specific product or service in a market. In this market structure, the seller dominates the market and has the most impact on price determination and other factors related to the product and service, for example, quality (Davis and Orhangazi, 2021). This market structure is totally opposite of the Monopsonist structure of a market.

According to the characteristics of each market, A conceptual model is developed in this study for analyzing contractors' price strategies in tendering processes under different market conditions (assuming the client is the buyer and the contractor is the seller in the provided market conditions explanations) which is presented in Figure 8. The X-axis represents the market power of each party, and the Y-axis represents the price strategy that contractors might use to win in the tendering process under different market structures. In the diagram, Ph is the highest possible price strategy, and PL is the minimum profitable price strategy for contractors in a tendering process.

As shown in Figure 8, in a monopsonist market, the client dominates the market (Jha and Rodriguez-Lopez, 2021), and as the market structure moves toward a monopoly, more power transfers to contractors (Davis and Orhangazi, 2021). Additionally, it demonstrates that as the client's power increases, the winner price strategy tends to equal or fall below the minimum profitable price, resulting in negative profitability for contractors (Ahmed et al., 2022).

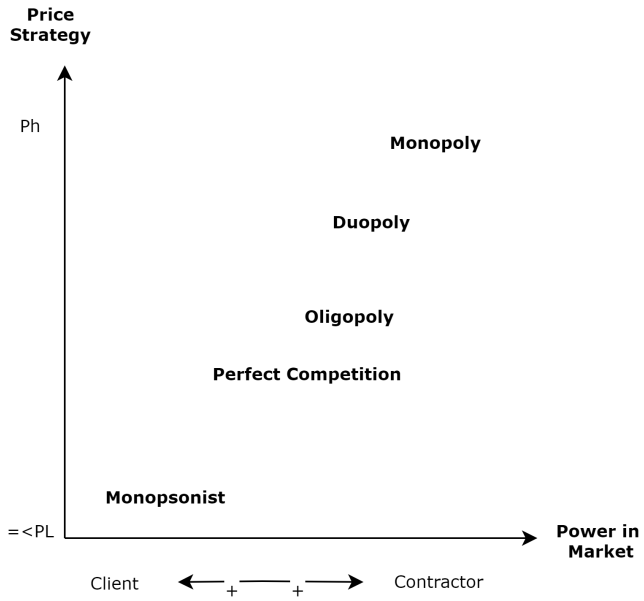

Figure 8: **Contractors' price Strategies under Different Market Structures**

By employing insights from the theoretical frameworks developed in this section, the data gathered through empirical study are analyzed. This approach has enabled me to utilize theoretical perspectives to gain a deeper understanding and insights from the empirical study, effectively addressing the research questions. In the next chapter, the methodologies employed for addressing the research questions and achieving the research objectives will be explained.

3 Methodology

In this chapter, I provided a comprehensive overview of the methodology used in this project. This includes a detailed exploration of the research design, the data collection methods employed, the analytical approaches utilized for data interpretation, data validity and reliability, the generalizability of the project, ethical considerations, and the limitations associated with the chosen methodology.

3.1 Research Design

This research project has been designed with the purpose of addressing the two research questions:

1. '*What are the drivers of the cost increase in the 2-ECI project delivery approach?*
2. *Which project delivery approach (1-ECI or 2-ECI) is more beneficial for Nye Veier in terms of cost-efficiency?*'

To conduct this project and address the research questions, I investigated different data collection methods and analyses. I considered literature review and field study as data collection methods in this project. In the literature review, I reviewed articles and I also used handbooks to reach the main formulas. I reviewed articles related to the project approaches to gain an understanding of the project delivery methods. I also reviewed GT literature to gain insights into the applications of this analysis method.

From the literature review, I identified the theories essential for a comprehensive overview of the subject. Additionally, I gained insights into the key theories important for data analysis. The data analysis approach in this study plays a significant role, as I employed GT for analyzing the project phases. This method helps to achieve a detailed understanding of the parties' incentives, goals, and strategies in projects. Therefore, a major part of the literature review is dedicated to GT.

Initially, a survey was considered for the field study to obtain a larger data set and sample size. However, designing a survey capable of eliciting the required qualitative data proved challenging. Additionally, the 2-ECI project approach, being a novel project delivery method, has not been widely applied, resulting in a limited pool of potential respondents familiar with this method. Consequently, interviews were chosen as the primary data collection method. Interviews allowed for the clarification of questions and facilitated the extraction of relevant data, even if initial responses were not entirely accurate.

The empirical study results, derived from interviews and document reviews conducted during my specialization project, which served as the initial phase of this research, were utilized in this study. Additionally, I reviewed new documents provided by Nye Veier to understand the differences in applying the two project delivery approaches within the company. To obtain detailed data, it was necessary to pose questions to the involved parties. By conducting interviews with the three key stakeholders in the projects—the client, contractor, and consultant—I was able to gather the perspectives and requisite data from each party involved in Nye Veier's projects.

Thematic analysis has been conducted in two chapters of this study: the theory chapter and the empirical study chapter. In the theory chapter, theoretical models have been developed using thematic analysis. Data obtained from document reviews and interviews were also thematically analyzed. By employing the theoretical models developed in the theory chapter, the results of the thematic analysis conducted on the empirical data were analyzed to address the research questions. Each project phase in the two ECI project delivery approaches was also simulated using the results of the thematic analysis on the empirical study data, applying GT principles to achieve a detailed understanding of the interactions, strategies, and incentives, ultimately addressing the research questions and objectives.

Finally, the results of the data analysis, findings from the empirical study and literature review, as well as information about the project process, are discussed and presented in a comprehensive project report, which constitutes my Master's thesis and is presented within this document.

3.2 Data Collection Methods

Since the first part of this project provides a comprehensive database of both theories and empirical works, I had access to relevant articles and handbooks from the reference list of that project. In addition to that database, more data was collected in this study. The data collection methods in this study include literature review, interviews, and document review.

All methods are explained in detail in the following:

3.2.1 Litrature Review

In this study, a thorough review of relevant literature in the areas of ECI, DB, BVP, and GT was conducted. This review not only provided a comprehensive understanding of these research areas but also enabled the extraction of relevant theories from the literature.

Search Strategy:

The data collection in this study was done by searching resources including relevant references to the DB contract method, literature related to GT, literature related to market structures, and incentives in collaborative projects.

The literature reviewed in this study includes journal articles, conference papers, books, and handbooks. To conduct the research, a systematic search across 'Google Scholar,' 'ScienceDirect,' and 'Scopus' research engines was conducted. The following keywords were used to find relevant literature:

Research Area	Key Words
GT	Game Theory AND Project, Game Theory
DB	Design Build AND Project
ECI	ECI AND Project
ECI & GT	ECI AND Game Theory
Market Structure	Market AND (Monopoly OR Oligopoly OR Perfect Competition or Duoboly OR Monopsonist)
Incentives in collaboration	Collaboration AND (Incentive OR Motivation)
Incentives in collaboration	Partnership AND (Incentive OR Motivation)

Table 3: **Key Words**

To find the most relevant data in addition to direct searching, I used forward and backward searching methods. Forward searching involved examining newer publications that cited the initially identified relevant articles. Conversely, backward searching is examining the reference lists of the relevant articles. By using these complementary approaches, I wanted to ensure comprehensive coverage and capture diverse perspectives within the research area.

Since there are no articles that study ECI using GT, reviewing handbooks and books was considered to obtain more information in both areas separately and to combine the gathered information in this study. Handbooks and books, as comprehensive references, were used to obtain formulas, GT models, explanations, and definitions related to GT.

Inclusion and Exclusion Criteria:

As an inclusion criterion, I considered articles covering research areas related to DB and ECI in project management and construction management. To realize the relevancy, I scanned the abstracts of the articles to find out the degree of relevancy of the articles to the area of research in my project.

In the area of collaboration incentives, I scanned the abstracts of the articles and included articles that studied incentives or motivations of contractors in collaboration-based projects.

As another inclusion criterion in the process of selecting articles, I considered peer-reviewed articles, assessed the relevance of the journals or conferences in which they were published or presented, and examined the number of citations received from reliable references. Specifically, I applied criteria related to the relevance of journals and conferences when considering articles on DB and ECI. Additionally, I included articles on GT published in economic journals in addition to journals in the management field. I excluded the articles that studied GT and were published in journals related to political science.

For including and excluding books and handbooks, I assessed the reliability of the publisher, authors, or editors. I included the materials published by reputable publishers, authored or edited by individuals with significant experience in the field and a track record of publishing articles.

I prioritized reviewing newly published materials. I also reviewed articles or books published before 2000 to ensure comprehensive coverage of the subject.

3.2.2 Interviews

In the initial phase (Specialization project), three interviews were conducted with two project managers of ECI projects and the contract manager at Nye Veier. By conducting these three interviews, I reached an understanding of the ECI project delivery approach and obtained detailed information about the challenges that Nye Veier faced in implementing ECI. In this study, I used the data from those three interviews.

In the second phase of the project, I conducted seven interviews. I decided to conduct interviews with three parties, all the involved parties in the two project approaches. This is because I needed all the involved parties' perspectives to prevent biases and obtain accurate information. Therefore, I conducted three more interviews with the client (Nye Veier), two with two different consultant companies that worked with Nye Veier in the two project approaches, and two with the contractors that worked with Nye Veier in the two project approaches. All the interviewees were project managers or leaders of their teams. By having information from all the different involved parties, I was equipped with a multi-aspect view of the project approaches. Additionally, this resulted in a cross-sectional sample of interviewees, representing diverse perspectives from the different stakeholders (Taherdoost, 2022, Silverman, 2015). Overall, in this project, I used information from 10 conducted interviews with three different involved parties in Nye Veier's projects.

The designed interview questionnaires were Semi-structured interviews. The interview objective was to gather the necessary data to address the research questions effectively (Silverman, 2015). Four different interview questionnaires for the three primary stakeholders involved were designed and prepared. One type of questionnaire was tailored to the client, one for the consultants, and two different questionnaires for contractors involved in the two different ECI project delivery approaches.

The questions were designed with the objective of capturing data on each party's preferences within projects, focusing on the strategies they prefer to employ and identifying what they find beneficial for themselves. Additionally, the questions explored the level of information sharing in the collaboration, the impact of trust and future collaboration on project dynamics, and other details essential for analyzing the project delivery approaches.

3.2.3 Document review

In this study, seven project documents received from Nye Veier were reviewed. The results of these document reviews were incorporated into the study. These documents were instrumental in providing detailed data about the two ECI project delivery approaches and in facilitating a comprehensive understanding of the project methodologies adopted by Nye Veier. This included exploring differences between the approaches and understanding the contractors' scope of work within them. The reviewed documents include descriptions of the scope of work, description and quantity lists, requirements for implementation and technical specifications, and published public Governance Policy Papers.

3.3 Data Analysis

In this study, qualitative data analysis and GT simulation methods were utilized to analyze the data. Thematic analysis, a qualitative analysis method, was employed to analyze data collected from interviews, document reviews, and the literature review (Silverman, 2015).

Subsequently, by utilizing the results of the thematic analysis and employing GT, different phases of the two ECI project approaches were simulated and analyzed. Five GT simulations were developed to analyze various phases of the two project delivery approaches, each based on different assumptions (Brandenburger and Nalebuff, 1997). All the GT models developed in this study are grounded in qualitative data extracted from empirical study results.

The data binarization method was employed (Cabrera and Reiner, 2018) to convert qualitative data into comparative quantitative data representing parties' payoffs in the game models (Romanuke, 2016).

3.3.1 Qualitative Data Analysis

Thematic analysis:

A thematic coding analysis was conducted to organize data from interview transcripts and documents into categories. Excel was utilized to create tables containing relevant data from the 10 interviews and seven received documents, which could potentially influence the outcome of this study.

The Excel file consists of three tabs: one for analyzing interview transcripts to gather data for game theory simulation, another for achieving an in-depth understanding of project approaches, and a third for thematic coding of documents to understand project approaches and the parties' scopes of work. Themes include game characteristics and project characteristics.

The thematic analysis of the interview transcripts includes the following themes:

- Projects Characteristics: Advantages and disadvantages of the two ECI project delivery approaches, incentives and motivations, reasons for cost increases in the 2-ECI, information about ECI project delivery approaches (1&2-ECI), when the 2-ECI approach is preferable, and market condition
- Game characteristics: strategies, probability of choosing different strategies, payoffs, dilemmas

The thematic analysis of the document review includes the following themes:

- Contractor scope of work, client scope of work, procurement method, selection criteria, tendering process, contract type, market analysis, bargaining power

GT simulations:

Data obtained from thematic coding, derived from interview transcripts and documents, was used to develop GT simulations of the project delivery approaches. Using theories extracted in the theory sections, the tendering process, collaboration phase, and different phases of the two ECI project delivery approaches were simulated by employing GT principles and presented in the simulation chapter. The results of the GT simulations were qualitatively interpreted.

3.3.2 Converting Qualitative Data to Comparative Quantitative Data

Binary data coding was utilized to convert qualitative data extracted from document reviews and interview transcripts into representations of parties' payoffs (Cabrera and Reiner, 2018, Romanuke, 2016). In the game models, a '1' was assigned to indicate the adoption of a beneficial strategy by a party, while '0' denoted the absence of such a strategy. This method was selected to facilitate a straightforward and comprehensive comparison of outcomes resulting from different strategies adopted by parties. Binarizing the data was intended to mitigate potential biases and subjective interpretations inherent in qualitative data analysis (Mouselli and Massoud, 2018, Cabrera and Reiner, 2018).

3.4 Data Validity, Reliability & Generalizability

Data Validity:

To ensure the validity of the literature data, the journals that published the articles were checked to determine their relevance to management or economics. Additionally, the abstracts of the articles were reviewed to confirm alignment with the study's needs. Furthermore, the relevance of the books and handbooks was verified by checking whether the most cited sources are relevant to the study field or not, as well as if the content includes what is required for the project.

For the interviews, care was taken to ensure that the questions were easy to understand and straightforward. If questions caused uncertainty for an interviewee, they were provided with additional explanations. It was ensured that these questions could get honest and clear responses, representing the perspectives of the participants involved.

In this study, a multifaceted method of data collection was employed. This method includes the use of data from different sources to ensure a comprehensive understanding of the subject. Through the reviewing of documents, relevant literature, and conducting in-depth interviews with key stakeholders, a strategy of data triangulation was implemented to validate the findings (Bryman, 2016).

Data Reliability:

The reliability of references in this study was assessed by examining various factors. For articles, the reliability of the journals in which they were published, the conferences where they were presented, and whether they underwent peer review were checked. The number and quality of citations the articles received were also examined. This comprehensive assessment aimed to ensure the reliability of the articles.

Similarly, the reliability of books and handbooks was evaluated by checking the reliability of the publishers. The author's and editors' backgrounds in the research area were examined to ascertain their expertise and credibility by checking the number of literature they have worked on in the area of research.

The reliability of interviews is also high in this study. Interviews were conducted with all involved parties in projects to gain a comprehensive understanding of each party's perspectives. By recording the interviews and transcribing them afterward, it was ensured that no data was missed. This approach contributes to the overall reliability of the data gathered through interviews.

Furthermore, the reliability of the data and the study's results were enhanced by employing data triangulation (using different sources of data)(Bryman, 2016).

Generalizability:

The results and developed models of this study can be applied to other projects. The game models developed in this study can be utilized in similar situations or serve as a foundation for adapting to tendering processes or collaboration phases in other industries.

While the main finding of this study primarily applies to governmental construction projects, the theoretical models and diagrams developed have broader applicability. They can be employed to analyze project delivery approaches across various industries and assist in decision-making when selecting different project delivery methods under diverse market conditions.

Additionally, this study provides a detailed analysis of the ECI project approach's tendering process and collaboration phase in the road construction industry in Norway. The results of this ECI analysis are applicable not only in Norway but also in other countries' road construction industries, particularly in Europe and Scandinavia, or in the construction industry with similar conditions.

Moreover, given the challenges associated with the ECI project approach as a new project delivery method, the findings and analyses provided in this study can help mitigate uncertainty in similar projects. Therefore, the results of this study have the potential to reduce uncertainties in the adoption of ECI project approaches.

3.5 Ethical Consideration

To ensure that ethical considerations are taken into account in this study, different approaches were employed. Prior to the interviews, the interview questions were sent to participants, ensuring transparency and obtaining informed consent. Information on interview conditions was also provided, and participants were asked to indicate any disagreement with conditions such as recording the interview or the required time for conducting it. Additionally, permission was sought at the beginning of each interview to record it. The entirety of each interview was recorded to accurately capture all points mentioned by interviewees. Subsequently, the recorded interviews were transcribed to ensure comprehensive analysis and inclusion of all points raised during interviews. Furthermore, in accordance with confidentiality principles, the identities of interviewees were safeguarded, and only their roles were mentioned in the report with their permission.

3.6 Limitations

The methodological limitations of this study include the limited number of interviews and the fact that the data obtained from both document reviews and interviews is limited to road construction projects and Norwegian companies.

The total number of conducted interviews in this study is limited to 10. Seven interviews were conducted during my MSc. thesis, and three were conducted during the Specialization project. Overall, six interviews were conducted with employees of Nye Veier. Two interviews were conducted with consultant companies (from two different companies), one interview was conducted with a contractor company that worked on a 1-ECI project delivery approach with Nye Veier and became involved in the project after the zoning plan development, and one interview was conducted with a contractor that was involved in developing the zoning plan in collaboration with Nye Veier as well as project implementation (2-ECI project delivery approach). Since there have been few projects implemented using the ECI approach, there are few people with experience in such projects. Therefore, the number of interviewees is limited to 10 in this study.

In this study, the data from the document review is limited to road construction projects in Norway. All reviewed documents pertain exclusively to projects conducted within the road construction industry in Norway. Additionally, all interviews were conducted with Norwegian companies, including both contractors and consultants. Consequently, the data obtained from interviews is also limited to Norwegian companies.

Through the utilization of these methods, the necessary data was gathered, analyzed, and employed to develop simulations of the project delivery phases. In the subsequent chapter, the results of the thematic analysis from both the document review and interviews are explained and presented. These empirical study results serve as the foundation for analyzing the project delivery approaches and developing GT simulations.

4 Findings from Empirical Study

In this chapter, the results of the document review and conducted interviews are presented. By using the results of the empirical study, required data is provided for analysis by employing theories gathered in the theory chapter to address the research questions.

The reviewed documents include:

- Description of Scope of Works,
- Requirements for implementation and technical specifications,
- OECD Public Governance Policy Papers No. 06,
- Description and quantity lists.

Through reviewing these documents I gained an overview of different project delivery approaches, procurement approaches, contractor and client scope of work, and the tendering process in the ECI projects implemented by Nye Veier.

I conducted 7 interviews with three different parties: the Client (Nye Veier), consultants, and contractors, to reach data from different perspectives. I also extracted data from the three conducted interviews with the client from my specialization project. It helped to analyze the project approaches from various aspects of the parties involved in the project as well as understand interactions, preferences, and strategies of parties involved in projects.

All the results of the document review and the interviews are presented in this chapter.

4.1 Project Approaches

In this section, two types of project delivery methods employed by Nye Veier are explained. For each method, the procurement approach, timing of contractor involvement, and project processes are explained.

There are two types of project delivery approaches implemented by Nye Veier that I am focusing on in this study. They are explained in the following:

1-ECI:

The first type of project delivery method involves the development of a zoning plan by a consultant company in collaboration with the client (Nye Veier). The contractor becomes involved in the project after the zoning plan is approved by authorities. In other words, the tendering process is after zoning plan approval and before the project design and implementation phase.

In this approach, contractors are responsible for the detailed design and the implementation phase of the projects and all the relevant tasks and prerequisites of implementation such as operation and administration, engineering, project planning, commercial terms, and relevant works to execution (Nye Veier, 2021). The contractor can provide suggestions on the zoning plan to make it cost-optimized and reduce potential risks (Nye Veier, 2018b). If the contractor managed to make the zoning plan more optimized, the changes applied in the zoning plan should be approved by the authorities. The main contractor is responsible for the zoning plan changes and despite any changes, the project timeline and cost must be according to the contract (Nye Veier, 2018b).

In this project method, the contract structure is design-build (DB), and the procurement method is BVP. Contractors are selected based on criteria such as price, risk plan, and expertise (OECD, 2021). In the selection criteria, the price has a weight of 25% (OECD, 2021).

The tendering process begins with a market analysis by the client to find out how many contractors are in the national market capable of implementing the project. There is also the possibility of hiring an international contractor. All the bidders are assessed and the selection is done through competition and negotiation(OECD, 2021).

The defined project approach has the features of the 1-ECI explained in the developed model of different ECI project approaches in Figure 1. Same as the 1-ECI (explained in Figure 1), in this project approach, contractors become involved in the design and implementation phase of projects (Wondimu et al., 2020, Pheng et al., 2015), contract structure is DB, and the client selects the contractors based on qualification and price (Wondimu et al., 2020). Therefore I call this method the '1-ECI project delivery approach' in this report.

A model is developed for demonstrating the 1-ECI project delivery approach and presented in Figure 10.

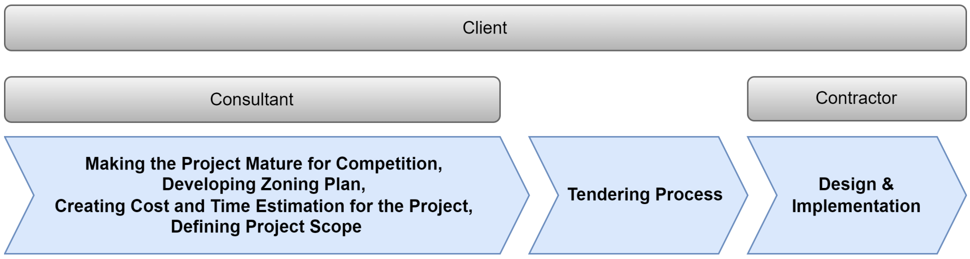

Figure 9: **1-ECI Project Delivery Approach employed by Nye Veier**

2-ECI:

The second type of project delivery approach implemented by Nye Veier involves engaging contractors in the earliest phases of a project (Nye Veier, 2018c). This approach is employed by Nye Veier when they encounter greater complexity in a project and need to assess it in terms of constructability, requiring a more accurate risk assessment. In this approach, the contractor becomes involved before defining the project scope and developing the zoning plan. In this approach the contractor has enough time to investigate the ground, become familiar with the project, and define the project scope and zoning plan in collaboration with the client (Nye Veier, 2018a).

After the project is defined and evaluated, the tendering process begins. The tendering process, similar to the 1-ECI project delivery approach, begins with a market analysis to identify capable contractors for implementing the project. Criteria such as contractors' qualifications (experience, expertise, etc.) and price are considered. In this type of project delivery approach, the price includes the contractor's markup on the project cost and their hourly pay rates for completing the work. Since there is no cost estimation due to the absence of a zoning plan in this approach, the client reveals the dedicated budget for the project. The contractor is selected through competition and negotiation (OECD, 2021).

The selected contractor as the main contractor enters the project and collaborates with the client (Nye Veier) for two to three years to define the project scope and develop a zoning plan, which is called the collaboration phase in this project approach (Nye Veier, 2018c). After the collaboration phase and estimating the cost of the project based on the developed zoning plan, the client might decide to continue with the same contractor and sign a contract for implementation (Nye Veier, 2019) or terminate the collaboration and initiate a tendering process to hire a different contractor for the project (OECD, 2021). However, if the client is satisfied with the plan and project cost estimation, they continue with the same contractor. In this project method, the contract structure is also DB.

This defined project method has the features of the 2-ECI which is explained in Figure 1. Same as 2-ECI (explained in Figure 1) contractors are involved from the planning phase in a project which is the earliest possible phase in which contractors can be involved (Wondimu, 2019). The contract structure is DB and the selection criteria are based on qualifications and price (Wondimu et al., 2018). Because of the similarities between this approach and the 2-ECI approach that was modeled according to ECI definitions extracted from literature in Figure 1, I call this project method '2-ECI project delivery approach' in this report.

A model is developed for demonstrating the 2-ECI project delivery approach which is presented in Figure 10. The model is an adopted model from Nye Veier's ECI project process.

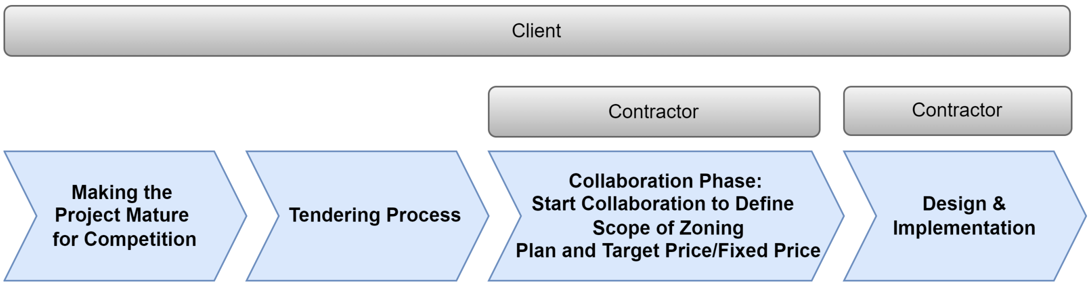

Figure 10: **2-ECI Project Delivery Approach employed by Nye Veier**

Source: Adopted from Nye Veier's ECI model

In this project delivery approach, contractors are provided with a contractual monetary incentive. Specifically, if the contract is based on a target price and the contractors manage to keep the project cost below a predetermined minimum, they receive a limited bonus. However, the bonus amount is relatively low compared to the level of risk assigned to contractors in this project delivery method. Furthermore, it has not yet occurred that project costs have fallen below the minimum threshold using this method.

4.2 Market Condition

There have always been enough competitors in Nye Veier project bids. Before issuing calls for bidders, Nye Veier conducts market analysis to ensure there are sufficient competent contractors capable of implementing projects in the market. According to an OECD published paper about the two projects implemented by Nye Veier (OECD, 2021), there have been enough competitors in the two projects' tendering process.

In almost all of the interviews conducted with contractors and consultants, the issue of having fewer projects in the market in the year 2023 compared to 2022 was mentioned. However, interviews with the client revealed that there are sufficient contractors bidding on Nye Veier's projects, resulting in healthy competition. Furthermore, the client has the option to hire contractors from outside the Scandinavian market, which often leads to contractors reducing their bid prices to secure projects.

4.3 Strategies

Tendering Process:

In the tendering process, due to the high competition for projects, contractors often reduce their bid prices to increase their chance of winning the competition.

Consulting companies strive to find the most cost-optimized solutions to satisfy their clients. They aim for increased collaboration with Nye Veier in the future, so they make every effort to find cost-optimized solutions to meet client expectations and enhance their chances of future collaboration. Additionally, because of a lack of project implementation experience, details, or some points that are required to be considered in the plan to increase constructability and reduce implementation risks are overlooked. Consequently, the cost estimation, particularly when there is already an approved zoning plan (1-ECI project delivery approach), may not be sufficiently accurate. The client allocates a budget to the project based on this estimation, which might be lower than the required budget for project implementation.

The winning contractor, after working on the zoning plan, notices the need for applying changes and always provides comments on the zoning plan. However, since they accept the plan, they assume the risks associated with it and implement the project within the specified time and budget.

Party	Strategies
Contractor	setting a low price in their bid
Contractor (winner)	Taking the risks of the zoning plan despite cost increasing

Table 4: **Tendering process strategies**

1-ECI Project Delivery Approach:

If the developed zoning plan by the consultant and the client is unsatisfactory or expensive, the client has enough time to redesign it and obtain approval from authorities. However, if it exceeds the expected or allocated budget, the project remains in the portfolio, and implementation is postponed based on the company's portfolio strategy.

After the tendering process, the selected contractor is asked to provide a cost-optimized solution for the zoning plan to make it more constructible and optimized within the project budget and timeline. Therefore, the contractor has limited chances to improve the zoning plan. Any changes are the contractor's responsibility and must adhere to the project timeline and defined budget.

Contractors can anticipate cost increases by considering details in the plans. However, by signing the contract and accepting the zoning plan, they also accept the risk of potential cost increases for implementing the project. The contractor does not claim for cost increases in the project and delivers the project by considering the risks.

Party	Strategies
Contractor	Providing cost-optimize solutions, Accepting the risk of potential cost increasing Presents a good performance in the implementation phase

Table 5: **contractors' strategies in the 1st Project Approach**

2-ECI Project Delivery Approach:

When the client finds a project too complex to be planned and requires assessment by a contractor in terms of constructability, the 2-ECI project delivery approach is employed. In this approach, the scope of work for the selected contractor is expanded to the earliest phase of the project, and the contractor is involved in all project phases including zoning plan development, design, and implementation (Nye Veier, 2019). The client expects the contractor to develop a feasible zoning plan that is cost-optimized and minimizes risks as much as possible (Nye Veier, 2018a).

In the 2-ECI approach, when the contractor is involved in developing the zoning plan, they dedicate their best resources and expert staff to this phase, ensuring their team is competent enough to find the most cost-optimized solutions for the project and assess and mitigate risks.

However, if the increased technical quality of the zoning plan leads to cost overruns, even though it may be the best version possible, it is not beneficial for the client. While it is advantageous in terms of preventing risks during implementation, the same strategy as the first approach cannot be employed due to the contractor's involvement, and the project implementation cannot be postponed based on the portfolio strategy.

This increase in expense may occur because:

- The contractor focused more on risk reduction than on finding the most cost-optimized solutions, which may happen when the contractor is not hopeful for future collaboration with the same client.
- The reason can also be a lack of contractors' expertise and competence.
- The reason can be lack of enough information or investigation of the ground condition.
- Alternatively, it may occur because the project budget was underestimated initially, and the contractor developed a plan with the best solutions in terms of cost optimization and risk reduction, driven by the hope of future collaboration with the client.
- Another reason could be receiving conditional approval from authorities, which requires an extra budget for implementation.

In such cases, if the project expenses remain within the defined budget or cost-acceptable range, the client prefers to continue collaboration with the contractor despite potential cost optimization opportunities in the zoning plan. Redesigning takes time, and with the contractor already onboard, this time is costly for the client. However, if the project cost exceeds the dedicated budget and the accepted cost range, the client prefers to terminate the collaboration, change the zoning plan, and make it cost-optimized. Termination of collaboration is not common and is considered the last option for the client. So far, out of the eight projects implemented by the 2-ECI project delivery approach, five continued with the same contractor after the collaboration phase.

If the zoning plan turns out to be expensive, even though it falls within the acceptable range of project cost, but the client could see the potential improvement in terms of cost-efficiency, the client won't work with the same contractor or consultancy in the future.

Party	Strategies
Contractor	Focusing only on risk reduction and increasing their own benefit and project costs
Contractor	Providing the most cost-optimized solutions while reducing risks
Client	Continuing collaborating after the collaboration phase
Client	Terminating the collaboration after the collaboration phase

Table 6: **Parties' strategies in the 2-ECI Project Delivery Approach**

4.4 Payoffs

Tendering Process:

Price is an important criterion in selecting a contractor. When all the bidders are experienced and expert, the one that sets the lowest price in their bid has a higher chance of winning the competition. This situation is also beneficial for the client since the client prefers to spend less money on their projects.

Strategies	Payoffs
Low project price	Beneficial for client (budget saving)
Low project price	Beneficial for contractors (higher chance of winning the competition)

Table 7: **Parties Payoffs in Tendering Process**

1-ECI Project Delivery Approach:

If the selected contractor provides cost-optimized solutions for the zoning plan, demonstrating their competency and professional performance, it can lead to higher benefits for the client. Additionally, it is beneficial for the contractor as well because the implementation is improved by providing risk reduction solutions for the zoning plan. Furthermore, by delivering better performance, contractors have a higher chance for potential collaboration in the future with Nye Veier.

Strategies	Payoffs
Providing cost-optimized solutions by contractors	Beneficial for client (budget saving)
Providing cost-optimized solutions by contractors	Beneficial for contractors (higher chance of future collaborating)
Providing cost-optimized and risk reduction solutions by contractors	Beneficial for contractors (Preventing facing risks in implementation)

Table 8: **Parties Payoffs in the 1-ECI Project Delivery Approach**

2-ECI Project Delivery Approach:

In the 2-ECI project delivery approach in case of terminating a collaboration after the collaboration phase, it is a total loss for both parties, the client and the contractor. If a client is not satisfied with a zoning plan and does not want to implement it, they ask for replanning from other companies, not the same contractor. While the client retains the fund, the termination causes conflicts and legal disputes for the client. The contractor, on the other hand, finds the termination a loss for themselves because they dedicate their best resources to develop the zoning plan in collaboration with the client. Therefore, if the project is not implemented, this investment is wasted, and the expert resources lose their project and should start over.

If the plan turns out to be an expensive project out of the acceptable range of project cost, the client considers it a loss since they lose more budget from their total budget. Even though the project is implemented, the client has to allocate more budget, which may not align with their portfolio strategy at that specific time.

If the zoning plan is developed in a way that is not cost-optimized but equipped with high technical quality, and the cost is within the acceptable range, the client doesn't prefer to do replanning. Instead, the client prefers to continue collaboration with the same client since the contractor is paid hourly and any delay in projects causes cost for the client. This scenario is not beneficial for the client, but it is better than termination.

In the 2-ECI project delivery approach, the relationship between parties is also an important factor. During the collaboration phase, the client and contractor work together for two to three years. The relationship is trust-based since there is clarity of expectations and scope of work. Therefore, better stakeholder management can be provided. If the contractor is not willing to consider future potential collaboration with the client, the trust can be misused. The contractor may focus only on risk reduction in this scenario (not considering possibilities of future collaboration) to maximize their benefit in a project.

Strategies	Payoffs
Terminating collaboration	Loss for client (conflicts and legal dispute)
Terminating collaboration	Loss for contractors (Wasting the investment by dedicating expert resources)
Implementing an expensive project	Not beneficial for client, (better than terminating)
Implementing an expensive project	Beneficial for contractors, Not beneficial for contractors if they want to collaborate with Nye Veier in the future
Providing the most cost-optimized solutions (by contractor)	Beneficial for client
Providing the most cost-optimized solutions (by contractor)	Beneficial for contractors if they want to collaborate with Nye Veier in the future

Table 9: **Parties Payoffs in the 2-ECI Project Delivery Approach**

In this chapter, data extracted from interviews and documents was coded. The results of the thematic coding were used to explain the two project delivery approaches utilized by Nye Veier. Strategies that each involved party can take in the projects and the beneficial results for them were also identified. The project approaches were simulated using the data from this chapter and the theory chapter, and the simulations are presented in the fifth chapter of this report.

5 Simulations

In this section, the two project delivery approaches were analyzed by employing GT. Five GT models were developed to simulate the tendering process, collaboration, and project process in the two project methods. The models were developed utilizing the results of the empirical study and the literature review. The objective of providing the simulations was to gain insight into interactions, strategies, motivations, and incentives of the parties, and to investigate the difference between having the incentive of future collaboration and not having this incentive in the collaboration dynamic and the outcome of the game.

Firstly, the market structure was analyzed to develop the game model based on the current structure of the market. Then, the tendering process was analyzed under two different conditions: one in which contractors compete for one-time collaboration, and the other in which contractors consider future collaboration with the same client. The collaboration phase of the 2-ECI project delivery approach was also analyzed as a one-time collaboration (static model). Finally, all the phases of the two ECI project delivery approaches were simulated as dynamic game models to investigate the effect of incentives on the outcomes.

Two different types of game theory analysis were used: static and dynamic analysis (De Giovanni, 2009). Static games, which include simultaneous decision-making and one-time collaboration games, were utilized to reach an understanding of the collaboration between the client and the contractor in the collaboration phase, as well as the competition between bidders in scenarios where future potential collaboration is not considered. In the dynamic game models of different project phases, contractors' incentives including the hope of future collaboration were considered (De Giovanni, 2009).

Both static and dynamic analyses were considered due to the impact of incentives on developing cost-efficient solutions by contractors (Farrell and Sunindijo, 2022), as explained in the theory chapter. According to the theoretical analysis presented in Figure 2, four success factors facilitate the provision of cost-efficient solutions. The first is the timing of involving the contractors, which is defined in the studied project delivery methods. The second is the contractors' proficiency, which serves as the criteria for selecting contractors by the client. The third factor is the consideration of appropriate incentives (Wondimu et al., 2016, Song et al., 2009). Furthermore, the fourth success factor, a trust-based relationship, is influenced by the challenge of understanding appropriate incentives. Since incentives are an immeasurable factor in Nye Veier's projects and all interviewees mentioned the incentive of future collaboration, the simulation was compared under two conditions: considering the future collaboration incentive and not considering it. Therefore, the tendering process and collaboration between parties in the two project approaches were analyzed under both conditions to observe the differences. In the following, all the analyses are explained in detail and the outcomes of the games are presented.

5.1 Market Analysis

Nye Veier is a governmental agency owned by the Norwegian Ministry of Transport. As a state-limited company, Nye Veier serves as a government instrumentality tasked with planning, developing, and executing road construction projects across the country. Nye Veier's goal aligns closely with national infrastructure goals and policies ('Nye Veier', n.d.).

Based on the results of empirical studies, there have been enough contractor companies that could bid on Nye Veier's projects (OECD, 2021). According to the interviews conducted with contractors and clients, it was mentioned that there have always been enough competitors in clients' calls. Additionally, based on the results of the document review, Nye Veier conducted a market analysis before each tendering processes (OECD, 2021) and there were enough contractors capable of implementing the projects in the national market. Besides, Nye Veier has the possibility of hiring international contractors to implement their projects.

Besides, the results of interviews conducted with contractors and consultancies show that the number of projects was reduced in 2023 compared to 2022, leading to fewer opportunities for contractors to bid on projects.

Assuming contractors as sellers or service providers, and the client as the buyer in the existing market, there are many sellers capable of providing the same service to one main buyer, Nye Veier. Nye Veier as a governmental agency in road construction is the sole buyer in the market. The market structure for the current situation is a Monopsonist market, in which one buyer and many sellers are involved. The characteristics of this market structure are the buyer dominating the market and there is high competition between sellers (Jha and Rodriguez-Lopez, 2021). In this market structure, the client (Nye Veier) has the major influence on determining the price (Jha and Rodriguez-Lopez, 2021).

In a Monopsonist market condition, the client (buyer) holds more power than the contractors (sellers). The client determines the price, and contractors must adjust themselves to meet the client's demands in order to win projects and maintain their market share (Jha and Rodriguez-Lopez, 2021). The decline in the number of projects in the market has made the tendering process even more competitive.

The project delivery approaches are analyzed by GT simulations and considering the market structure as a monopolistic market. The analysis is presented in the following.

5.2 Static Game Moldels

To understand the strategies and payoffs in one-time collaboration, static game models are developed for the tendering process and the collaboration phase of the 2-ECI approach employed by Nye Veier.

5.2.1 Tendering Process Simulation

In a Monopsonist market structure, the total market demand is coming from the sole Buyer (Li and Szeto, 2021). In this study, assuming Nye Veier is the sole buyer, all demand is created by Nye Veier:

$$Q = D(p) = \text{Nye Veier's projects}$$

(*Note: Demand is not solely dependent on price; many other factors in the market can affect demand. However, in this study, the price factor is only considered, as this study focuses on the project cost-efficiency and cost-optimized zoning plans, to answer the research questions.*)

Based on the results of the document review and interviews, there are several contractors in the market willing to work on projects announced by Nye Veier. The number of contractors in the market is denoted as "i":

$$i = 1, 2, ..., n$$

By considering the explained assumptions, the best response in both project delivery approaches can be examined by employing GT.

1-ECI:

In the 1-ECI project delivery approach, which involves developing a zoning plan by the client and consultancy and then engaging the contractor after zoning plan approval, the selection criteria for contractors are based on price and qualifications. This procurement approach is called the BVP method(OECD, 2021). In this procurement approach, Nye Veier assesses contractors based on their experiences, expertise, and the set price in their bid with a weight of 25% (OECD, 2021, Wondimu, 2019, Narmo et al., 2018).

Due to the competitive dynamic in the tendering process, and participating highly competent contractors in the competition, each contractor aims to increase their chances of winning the project and the price strategy that they employ plays an important role (Ahmed et al., 2016).

There is a game in the tendering process which is a simultaneous and complete information game (Narahari et al., 2009). In this game, the players have all the information about the game rules and selection criteria in the tendering process. They play without having knowledge of their competitors' chosen strategies(Burguillo, 2018). This is because they are not aware of the prices that other contractors are considering in their bids.

The developed game model for the tendering process of the 1-ECI project delivery is as follows:

Game Key Elements:

Players:

The players in this game are all the contractors who are competing non-cooperatively to win a project. Assuming there are several contractors (entreprenører) in the competition, the players would be as follows:

$$E_i \text{ and } i = 1, ...n$$

Strategies:

Setting the project price in this game depends not only on the benefits and preferences of each contractor or bidder, but also it depends on the strategies of other players in the game (Tremblay and Tremblay, 2019).

The set of the different strategy options in price setting (Brandenburger and Nalebuff, 1997) that players can adopt in this game is specified by P_i, and the price strategies are explained in the following:

$$Pi = \begin{cases} 1 : Pi = Ph \\ 2 : Pi = Ci \\ 3 : Pi < Ci \end{cases} \tag{1}$$

As outlined in the strategy set 1, each player E_i can employ three different price strategies in the tendering process. The P_i represents the price set by each player in their bid, while C_i represents the estimated project cost (C) plus a minimum markup (M). The minimum markup should be specified to ensure that winning the project remains rational for contractors by securing the minimum rational profit for them (Laryea and Hughes, 2011,Burguillo, 2018). Therefore, C_i is defined as follows:

$$C_i = C + M$$

$$C = \text{Estimated Project Cost}$$

$$M = \text{Minimum rational markup}$$

Additionally, there is another strategy that each contractor involved in the game can play. In this strategy, players can set a price that provides the highest possible profit (Rubinstein and Tirole, 1989) and is specified by P_h in the price strategy set (P_i).

$$P_h = \text{The price strategy that provides the highest profit for contractors}$$

The third strategy, $P_i < C_i$, involves setting a price lower than the project cost plus the minimum markup, and it is not rational in a static game and contradicts the rationality of the players' goal of playing in a game, (achieving the highest possible outcome) (Burguillo, 2018). Therefore the third strategy in the strategy set (P_i) is not considered as a strategy option.

Payoffs:

If a player chooses to set a price equal to P_h to reach the highest profit, they would probably lose the competition due to their competitors' strategies and the high probability that the competitors would set a lower price than the player (Tremblay and Tremblay, 2019).

By utilizing binary codes to specify the payoffs, '0' is assigned to a strategy that results in losing the competition, and '1' is assigned as the payoff to a strategy that can result in winning in the competition (Cabrera and Reiner, 2018, Romanuke, 2016). By employing this coding method, the payoffs for the strategies listed in the strategy set No. (1) are specified as follows:

$$\pi_1 : \begin{cases} 0 & \text{if } Pi = P_h, \\ 1 & \text{if } Pi = C_i, \\ \text{irrational} & \text{if } Pi < C_i. \end{cases} \tag{2}$$

The only Nash equilibrium in this game is when all the players choose the second strategy in the strategy set No. (1), which is setting the price equal to C_i.

In the monopsonist market structure, where the client has the most power in determining the price, there are no incentives for contractors to deviate from the strategy of setting a price equal to C_i (if it is only one-time collaborating)(Dastidar, 1995, Burguillo, 2018). Because the contractors know that by setting a price more than C_i they lose the competition. By choosing this strategy ($P_i = C_i$) the player may win the project and reach sufficient profit beyond the project costs which would be the best outcome of this game for the involved players.

2-ECI:

In the 2-ECI project method employed by Nye Veier, there is a tendering process before the zoning plan development. Since the zoning plan is not developed in the phase of the tendering process, there is no project cost estimation. The only available cost estimation for the project is the dedicated budget that Nye Veier considered for the project as the maximum target price. Therefore, the selection criteria, in addition to the experience and expertise of the contractor, are the considered markup by contractors on the cost, as well as hourly rates for working on the project with the weight of 30% (OECD, 2021).

the tendering process of the 2nd approach is also a simultaneous, static, and complete information game (Narahari et al., 2009). In this game, all the players play at the same time and without having information about other players' chosen strategies (Burguillo, 2018). While the players have all the information about the tendering process and selection criteria.

In this game, the contractors participating in the tendering process compete to win the project, and price strategy plays an important role in this competition (considering the contractors who participate in the tendering process are highly qualified). The bidder can consider either the lowest possible price (C_i) or the highest (P_h) as their price strategy.

The developed game model for the tendering process for the 2-ECI project delivery approach is as follows:

Game Key elements:

In this model, the key elements are the same as those defined in the previously developed game model for the tendering process in the 1-ECI project delivery approach:

Players:

The players are the Contractors participating in the tendering process or bidders: E_i

$$E_i \text{ and } i = 1, ..., n$$

Strategies:

The strategies that all the bidders can play are the same as the strategy set 1, with the difference of having uncertain project cost estimation. The uncertainty in cost estimation is because of not having a developed zoning plan in the tendering process. Therefore, instead of having estimated costs, the dedicated budget for the project is considered as the project cost.

If a bidder chooses to set the highest price to maximize the project's benefit (P_h), they risk losing the project to competitors offering lower prices. Therefore, the pricing decision not only depends on the bidder's strategy but is also influenced by the strategies of other bidders (Tremblay and Tremblay, 2019). Setting a price equal to C_i, which includes the minimum beneficial markup for the contractor, may increase the contractor's chances of winning the project in a one-time collaboration game.

Payoffs:

The payoff set in this game is also the same as the payoff set 2 that was previously defined for the tendering process game of the 1-ECI project delivery approach (one-time collaboration).

The only Nash equilibrium in this game is when all the bidders (players) take the second strategy from the strategy set 1. Since all the bidders want to win the project, there is no incentive to choose the first strategy, because the bidders know that there are many competitors in the tendering process who want to win the competition (Burguillo, 2018, Laryea and Hughes, 2011). Additionally, considering the market structure as a monopsonist market (Jha and Rodriguez-Lopez, 2021), if the bidders set a high price (P_h) they definitely lose the competition to other bidders. Therefore, the only Nash equilibrium in this game is the second strategy in the strategy set 1, which is setting the lowest price while the price is still beneficial for the contractor and rational in a one-time game ($P_i = C_i$).

Even though the strategies and Nash equilibrium in both project delivery approaches seem to be similar, there is a major difference between them that can lead to contradictory outcomes. This difference lies in the uncertainty in cost estimation due to not having a developed zoning plan for the project in the 2-ECI project delivery approach. Before having cost estimation, a contractor is selected to develop a zoning plan in collaboration with the client (OECD, 2021). The effects of engaging a contractor before having cost estimation on the cost-efficiency of a project in the 2-ECI project delivery approach are analyzed in detail in the following simulation.

5.2.2 Simulating Collaboration Phase in the 2-ECI Project Delivery Approach (one-time collaboration)

When a contractor is selected in the tendering process, the collaboration phase begins. During this phase, the client's major expectation from the contractor is to conduct a risk assessment and consider all possible risks in developing the zoning plan (Nye Veier, 2019).

At the end of the collaboration phase, based on the zoning plan developed by the client and contractors, a cost estimation is prepared. If it is within the defined budget for the project, the client continues working with the contractor, but if not, the client may terminate the collaboration. According to the conducted interviews with the client, terminating collaboration with the contractor has happened in three out of eight total projects implemented by the 2-ECI project delivery method.

Based on data from interviews and document studies, A game in the end collaboration phase is identified, between two parties: the client and the contractor. This game has features of an asymmetric game since the strategies available to each player are not the same, and the strategies chosen by the contractor affect the client's payoff. Furthermore, it is assumed to be both a non-zero-sum and zero-sum game. If the client decides to terminate the collaboration, the game is non-zero-sum since there is nothing to allocate to the project if there is no collaboration. But if the client decides to collaborate, the game is zero-sum (Burguillo, 2018), as increasing project costs means the client must allocate more from its total budget. Therefore, if the zoning plan developed by the contractors turns out to be expensive due to high technical quality and risk mitigation, it may be beneficial for both parties in terms of preventing risks during implementation but not cost-beneficial for the client.

(Note: In a real-case scenario, many factors can affect the payoffs of the parties. However, for answering the research question, I only considered cost-efficiency and, to simplify, did not consider other factors.)

This game model is considered a simultaneous, asymmetric, complete information, and developed as a strategic static game (Burguillo, 2018, Kıbrıs, 2010).

This simulation draws inspiration from the Prisoner's Dilemma illustrated in Figure 7. It adapts the Prisoner’s Dilemma model to reflect the identified dilemmas faced by clients and contractors at the end of the project’s collaboration phase, aligning strategies and payoffs accordingly. The cooperative payoff system (Fibich et al., 2006) is employed, allowing players to potentially adopt cooperative strategies in a non-cooperative manner, leading to payoffs in the results of cooperative outcomes. Moreover, to address risk aversion within the contractor’s operational scope in the second project delivery approach (Nye Veier, 2019), the risk aversion cooperative payoff system is utilized in scenarios where both parties opt to cooperate.

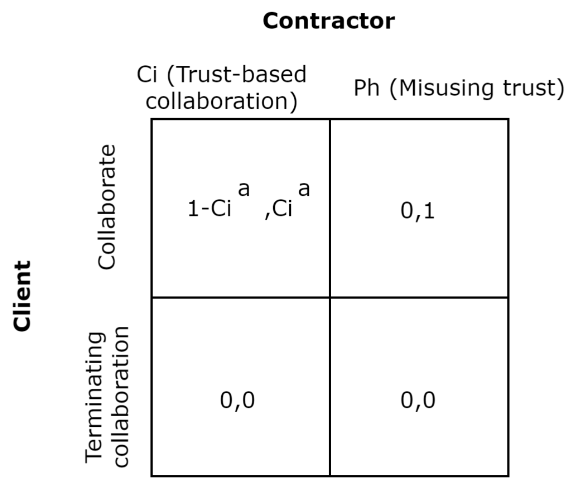

Figure 11: **GT Simulation of the Collaboration Phase in 2-ECI**

In the game modeled in the Figure 11, game key elements are as follows:

Players:

The players in the game are the client (Nye Veier) and the selected contractor for developing the zoning plan.

Strategies:

- The Client’s strategies involve either continuing collaboration with the same contractor during the implementation phase of the project or terminating the collaboration.
- Contractor’s strategies are:

  - By solely prioritizing risk reduction in the plan without concurrently seeking cost-optimized solutions, the contractor misuses the trust within the collaboration, potentially resulting in increased project costs up to a maximum price (P_h) that maximizes profit for the contractor but not for the client.

  - Trying to find the most cost-optimized solution while considering mitigating the risks in implementation, which can be represented as C_i, and it is similar to the optimum price in the strategy set No. 1. In this strategy, the contractor chooses to have a trust-based collaboration with the client in the zoning plan development.

Payoffs:

(By utilizing a binary coding system, cost-beneficial payoffs are considered ‘1’, otherwise ‘0’ is assigned to payoffs (Cabrera and Reiner, 2018)).

In Figure 11, the payoffs on the left side of each cell are assigned to the client's payoffs, while those on the right side belong to the contractor.

In the event of terminating the collaboration, as mentioned in the interviews, this strategy is considered as the last option by the client. Despite the possibility of saving the budget, terminating the collaboration could lead to major conflicts and potential legal disputes. Therefore, '0' is assigned to the client's payoffs in the event of choosing the termination strategy.

If the client chooses to terminate the collaboration, the contractor will not receive any benefit. According to an interview conducted with a contractor experienced in working with Nye Veier on projects implemented using the 2-ECI approach, the contractor engages expert individuals for the collaboration phase for an extended period. In the event of contract termination, this investment could leave them without work, necessitating a restart. Therefore, a payoff of '0' is assigned to the contractor in the case of collaboration termination by the client.

If the contractor chooses a strategy of trust-based collaboration with the client and successfully identifies the most cost-optimized solutions, the project cost would be equivalent to the optimized cost denoted as 'C_i' in Figure 11. In this strategy, the contractor engages in a trust-based relationship with the client, striving to deliver outcomes that satisfy the client's expectations. The client, aiming for risk aversion, expects the contractor to develop a zoning plan with the most cost-optimized solutions (Nye Veier, 2019). Consequently, the utility functions for both parties, when the client chooses the 'Collaboration' strategy and the contractor develops a cost-optimized zoning plan, resemble those of a cooperative game (Leng and Parlar, 2005), presented as follows:

Contractor's payoff: C_i^a

According to the literature (Fibich et al., 2006), the utility function of the risk-averse player's payoff is a power function considering the power '$0 < a < 1$'.

Client's Payoff: $1 - C_i^a$

If the client decides to collaborate, the game changes to a zero-sum game, and the payoffs that the contractor would earn are deducted from the client's payoff.

If the developed zoning plan results in a costly project (misusing trust strategy), it is not cost-beneficial for the client. Adopting this strategy would require Nye Veier to allocate more budget from their general funds to cover the higher costs. Therefore, a payoff of '0' is assigned to the client. In contrast, the contractor stands to gain the most from this strategy in a one-time collaboration, thus receiving a payoff of '1'. This strategy is likely to be favored by the contractor in a static game due to its potential for maximizing benefits.

Nash Equilibrium:

The only Nash equilibrium of this game is when the contractor decides to focus on risk reduction and increasing project cost (P_h), and the client decides to collaborate. Considering one-time collaboration, neither player has an incentive to unilaterally deviate from their chosen strategy.

Pareto Optimal Point:

The Pareto-optimal point in this game occurs when the client chooses to collaborate, and the contractor also decides to have trust-based collaboration with the client and finds the most cost-optimized solutions and risk reduction (C_i^a). This represents Pareto optimality as it benefits both players, and neither can improve their payoff without causing a loss for the other (Lin and Zhang, 2018).

Trust-Based Collaboration (C_i)-Collaboration Payoffs:

In this strategy combination, the total budget that the client has is assumed to be '1', and they want to allocate '0.8' for this project. 'C_i' is the project cost plus markup. For simplicity, the markup is considered to be '0'. Therefore, 'C_i' is the dedicated budget for this project. By considering these assumptions the payoffs in this strategy combination is simulated in Figure 12. As depicted in Figure 12, the higher the risk aversion parameter 'a', the more diligently the contractor considers project risks in the zoning plan and provides cost-optimized solutions, increasing the likelihood of achieving project costs close to '0.8'. Conversely, lower risk aversion indicates that the contractor may be less inclined to prioritize cost-optimized solutions while managing project risks ('P1' denotes the client's payoff). In the scenario where the total budget is '1', if the contractor exhibits maximum risk aversion and successfully identifies the most cost-optimized solutions, the client could potentially save '0.2' of the total budget, representing the optimal outcome for the client.

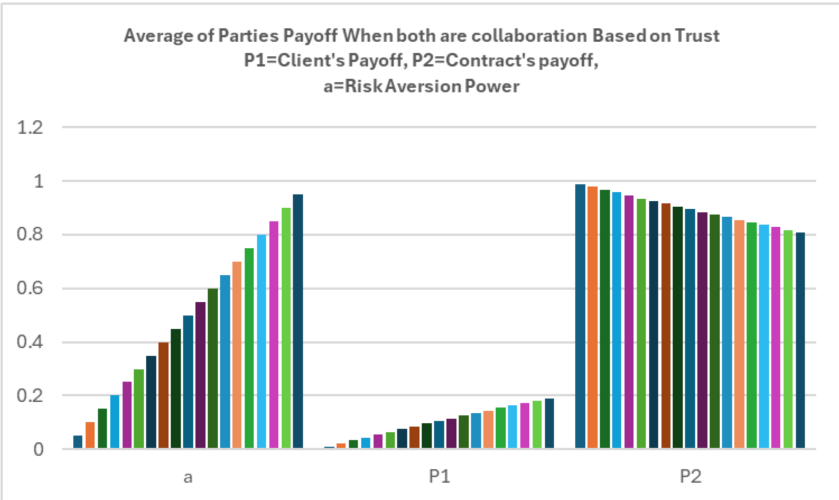

Figure 12: **Trust-Based Collaboration (C_i)-Collaboration Payoffs (in terms of cost-benefit**

According to the results of the interviews, the ability to find the most cost-effective solutions depends on several factors: the complexity of the project, the proficiency of the contractors, and the presence of a trust-based relationship between the parties involved. As a result, the level of risk aversion ('a'), which indicates how much parties prioritize avoiding financial losses when assessing risks, can vary.

(*Note: The developed payoff functions are tailored to this situation. Since in this study binarization is used, the developed payoff functions can represent the analysis results.*)

5.3 Dynamic Game Models

According to the results of the empirical study, there are many contractors, especially from the Scandinavian market, hope to collaborate with Nye Veier. Collaborating with Nye Veier can be contractors' incentive to participate in the tendering process and their aim to win the projects (Wang et al., 2023). In this scenario, the situation is not static and should be modeled as dynamic games, considering the contractors' incentives of collaborating with

Nye Veier and the possibility of increasing the chance of collaborating in the future (De Giovanni, 2009).

5.3.1 Tendering Process

In the case of hoping for future collaboration, bidders participating in the tendering process have more motivation to win the project in both project approaches. Even though the markup is not considered as the minimum beneficial markup for the contractor, winning the project holds more value for the contractor due to the increased chance of collaborating with Nye Veier in the future. In this scenario, the strategies in strategy set No. 1 change to the following strategy set:

$$Pi = \begin{cases} 1 : P_i = P_h \\ 2 : P_i =< C_i \end{cases} \quad (3)$$

As shown in set No. 3, there are two strategies that all the bidders participating in the tendering process, as the game players (E_i, $i = 1, ..., n$), can choose. The first one is, the same as the static tendering process game model, setting a high price in their bid. The second one is setting a price equal to or lower than C_i, which means setting a price lower than the minimum beneficial price for the contractors is also rational in a dynamic game simulation of the tendering process.

The only Nash Equilibrium in this game for all the involved players is to set a price equal to or lower than the minimum beneficial amount for the bidders, thus increasing the chance of winning the game.

5.3.2 Dynamic Simulation of the 1-ECI Project Approach

A dynamic game model for the 1-ECI project delivery approach is developed and presented in Figure 13, to understand parties' interactions and strategies by considering future collaboration as contractors' incentive (Narbaev et al., 2022). The whole model is divided into three sections. Each part represents a project phase. In this project approach, contractors are involved in three phases of projects including the tendering process, the project design and implementation phase, and the post-implementation phase (Rahman and Alhassan, 2012). In each phase, the parties have different preferences that determine their strategy options.

The game is modeled in an extensive format (De Giovanni, 2009). It is a sequential game because the players do not play at the same time. It is a complete information game since the players have a common understanding of the game rules (Burguillo, 2018). The payoff system in this game is also binary-coded. If the payoff is beneficial for a party, '1' is assigned to its payoff, otherwise the payoff is '0' (Cabrera and Reiner, 2018, Romanuke, 2016).

The game players, strategies, and payoffs are explained as follows:

Players:

The players in the game are specified in the circles. As shown, there are two players in the simulated game:

- Ei: Contractors (Entreprenør)
- NV: Nye Veier (Client)

Strategies:

Tendering phase:

In the tendering phase, the player's (Ei) strategies are explained in the strategy set No. 3.

NV strategies in response to the contractor's strategies are either selecting the contractor or not selecting them.

In the Project Implementation phase:

The selected contractor (Ei) can either have a good performance by designing and implementing the project in the best possible way within the specified time, budget, and quality standards that are specified in the contractor scope of works description documents (Nye Veier, 2021), or they can present poor performance, resulting in time and budget overruns.

In the post-implementation phase:

In response to the performance of the contractor in the implementation, the client can either consider the contractor for future projects or exclude them from the list.

Payoffs:

The payoffs same as the static models are binary data (Cabrera and Reiner, 2018), if the outcome is beneficial for a party the associated payoff is considered as '1' otherwise the payoff is considered as '0' (Cabrera and Reiner, 2018, Romanuke, 2016). The top number in the bracket represents the contractors' (Ei) payoff, and the bottom one represents the client's (NV) payoff.

If the contractor (Ei) sets a high price (P_h) in their bid, they aren't selected by the client considering the monopsonist market structure and competitive tendering process. Whereas the contractor prefers to consider a price equal to or even lower than (C_i) to win the project. If the contractor is selected and gets the opportunity to work with NV, the contractor will try to do their best, especially if they are hopeful about future collaboration opportunities. The more hopeful the contractor is, the better performance they may provide, and the lower price they set in their bid.

The equilibrium path of this game which includes choosing optimal solutions in each step (Halpern and Pass, 2021), is specified in Figure 13. This path includes selecting a contractor that chooses the strategy price of $P_i =< C_i$ by NV. Then, the contractor presents good performance based on the described standards in their scope of work and project plan, and the client is satisfied with their work performance. Consequently, the contractor may have more chances to work with NV on NV's future projects.

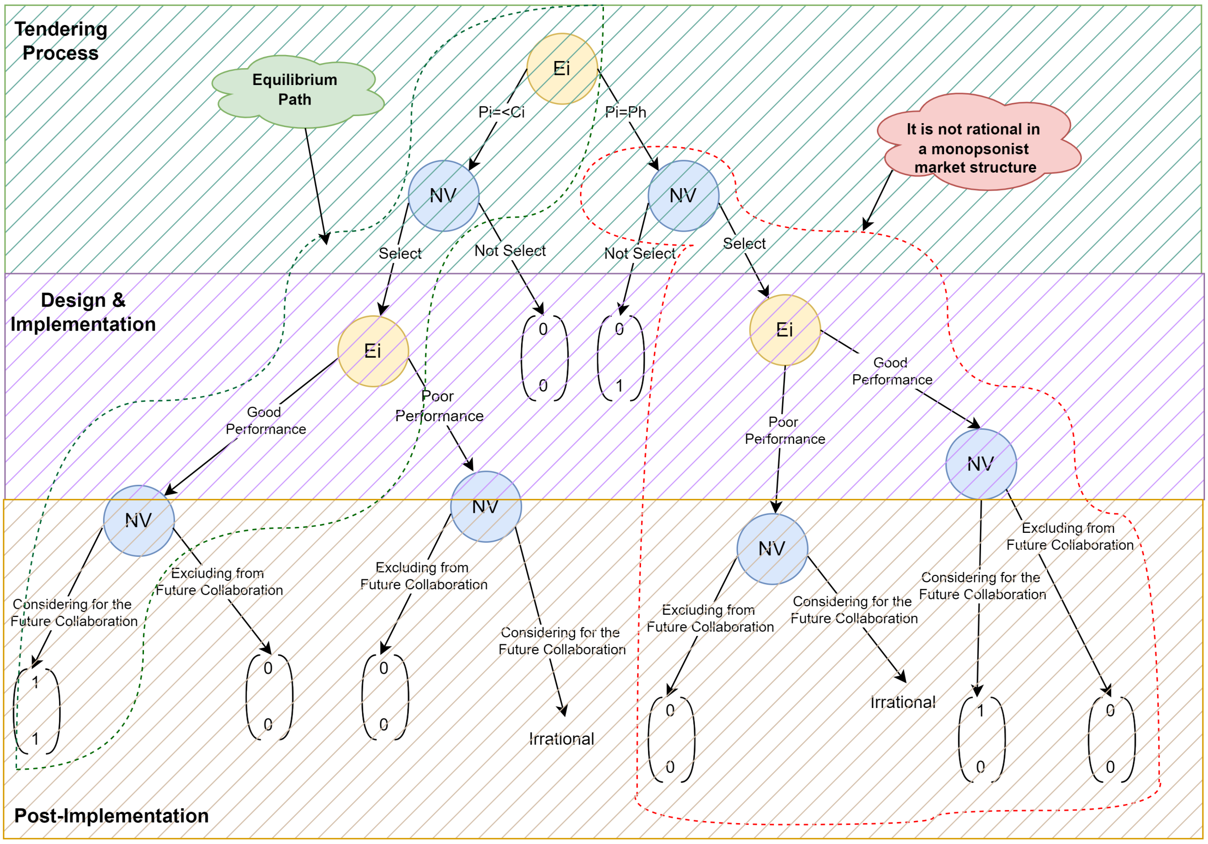

Figure 13: **Dynamic Game Model of the 1-ECI Project Delivery Approach**

5.3.3 Dynamic Simulation of the 2-ECI Project Delivery Approach

A dynamic game model is created for the 2-ECI project delivery approach and presented in Figure 14. The model includes four different phases of a project in which contractors are involved in projects. The phases include the tendering process, the collaboration phase (zoning plan development phase), the project design and implementation phase, and post-implementation phase (Narbaev et al., 2022). In each phase, the players have different strategy options.

Similar to the model presented in Figure 13, this model is also an extensive game model, characterized by sequential play, complete information (Hawkins, 1945, Burguillo, 2018). The game is modeled as non-zero-sum except for the collaboration phase. In the collaboration phase, if the parties decide to collaborate and choose the collaboration strategy, the payoff is considered zero-sum. The reason is that the cost factor is considered the payoff in the collaboration phase; thus, if a project is more expensive, a larger portion of the client's budget has to be allocated to it.

The game players, strategies, and payoffs are explained as follows:

Players:

The players are the same as the players described in the dynamic game model presented in figure 13.

Strategies:

In the tendering process, project design and implementation phase, and post-implementation phase, the strategies are the same as explained for the dynamic model of the 1-ECI project delivery approach presented in Figure 13.

In the collaboration phase:

The selected contractor in the collaboration phase can either try to do their best to find the most cost-optimized solutions while developing a zoning plan with the lowest possible risks (Trust-based collaboration), or misuse the trust and focus on reducing risks and increasing project costs.

Payoffs:

If a contractor sets a low price ($=< C_i$) in their bid, would have a higher chance of winning the project. In case of being selected for zoning plan development, if the contractor and the client have a trust-based collaboration and the contractor does their best to find the cost-optimized solutions and develop a zoning plan with the lowest risks, the client (NV) continues collaborating with them in the implementation phase. If the contractor implements the project according to the client's expectations and project plan and presents a good performance, there will be a high potential for future collaboration. This is an equilibrium path of the simulated game model which is specified in Figure 14.

The more hopeful the contractor is for future collaboration, the less markup they consider in their bid. This motivation can lead to increased efforts in finding cost-optimized solutions and mitigating risks, fostering a better relationship between the parties, and improving the contractor's performance in the implementation phase. According to interviews, the implementation phase proceeds more smoothly when a good relationship between the parties is established.

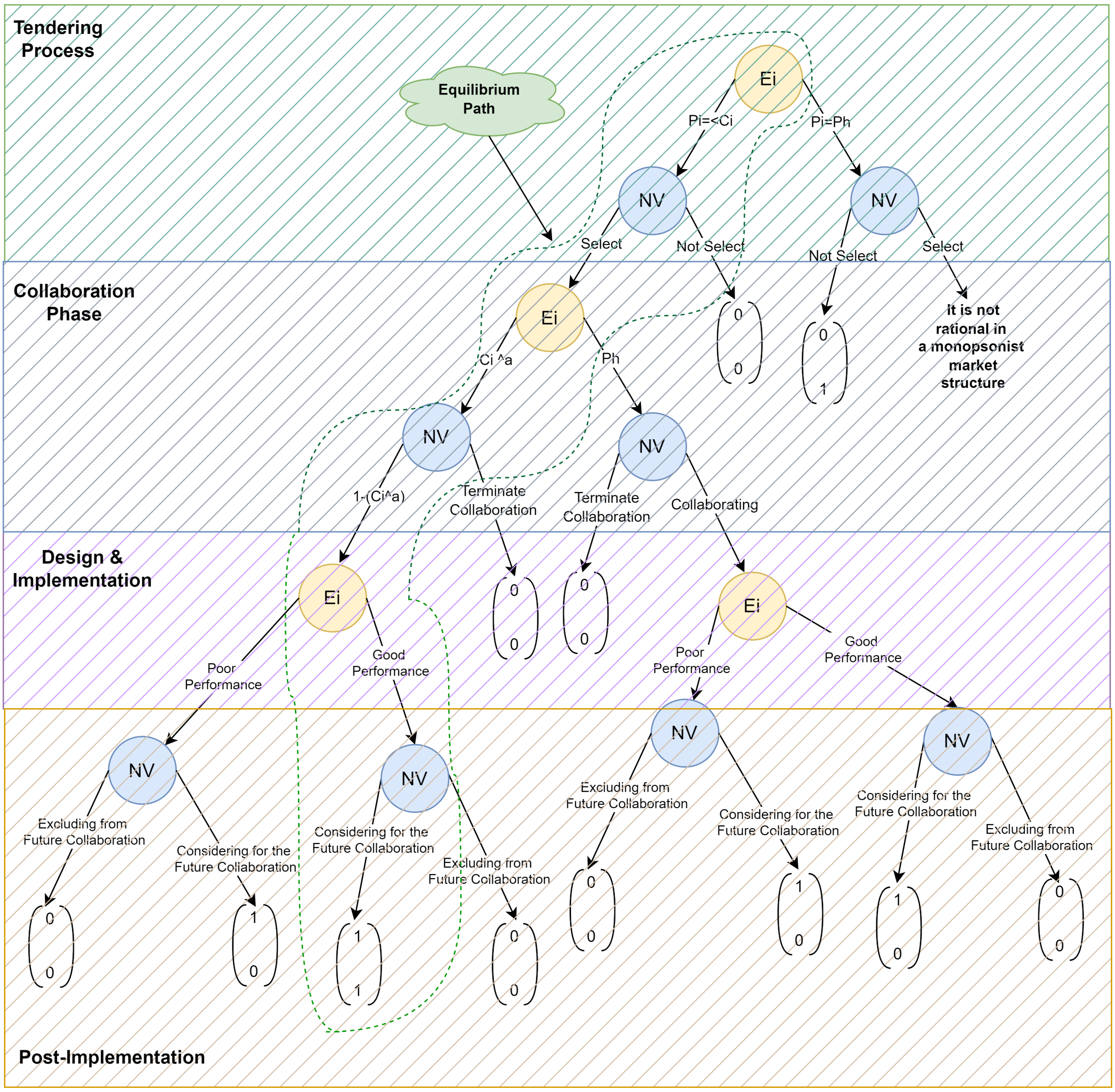

Figure 14: **Dynamic Game Model of the 2-ECI Project Delivery Approach**

Based on the provided simulations, the results of the data analysis by employing GT are concluded in the following:

5.4 Results

According to the analysis of the developed game models in this study, the results of the simulations are concluded in the two developed diagrams that are explained in the following.

Optimal Project Approaches: Winning Contractor Pricing Strategies in Different Market Structures:

According to the results of tendering process simulations in different project delivery approaches within both dynamic and static game simulations, and based on the analysis provided in the theory section in Figure 8 derived from the literature, the following diagram was developed and is presented in Figure 15. This diagram demonstrates the relationships between price strategies and market structures, and it indicates which project approach is more appropriate for different market structures in terms of cost-benefit for the client.

As shown in Figure 15, the dominant player in a monopsonist market is the client. In such a market, factors like price are determined by the client. As the market structure shifts toward a monopolistic nature, the contractors gain more power while the client's power diminishes.

The price strategy employed by each bidder in the tendering process is influenced by the market structure. In a monopsonist market, as previously explained, the Nash Equilibrium for all bidders in the tendering process is the strategy of $P_i =< C_i$. However, as the market structure changes towards a monopolistic form, the Nash Equilibrium for the price strategy changes to $P_i = P_h$.

Therefore, if the market structure is monopsonistic and the client dominates the market, the best project delivery approach in terms of cost-benefit for the client to employ is the 1-ECI, which involves contractors' engagement after the zoning plan approval. Conversely, if the market structure is monopolistic and contractors have more power, the 2-ECI project delivery approach is more beneficial for the client, as it involves engaging contractors from the earliest possible phase of projects. If the market structure falls between these two extremes, such as in Perfect Competition, Oligopoly, and Duopoly, both approaches can be suitable depending on the project's complexity. The 2-ECI approach is more recommended for more complex projects(Wondimu, 2019, Song et al., 2009)).

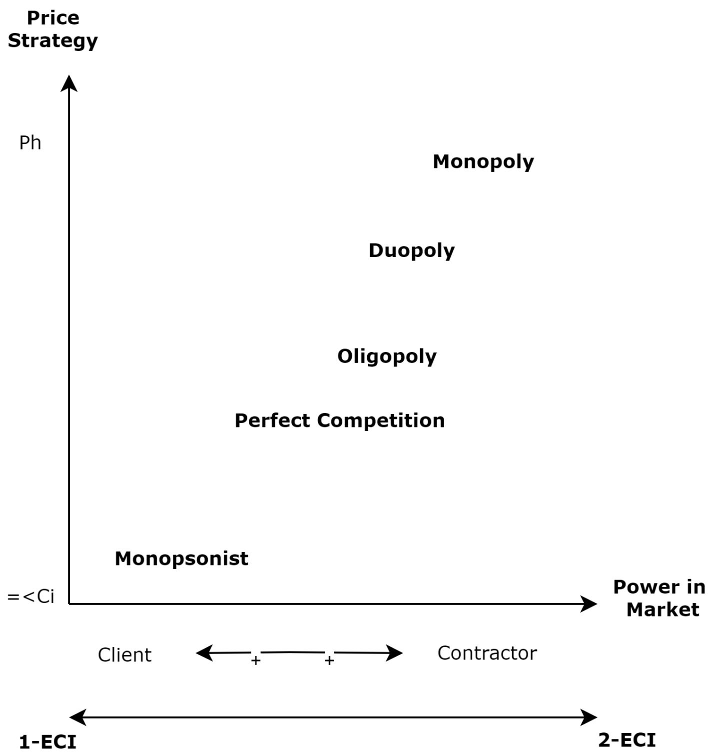

Figure 15: **Market Structures and Project Approaches: Price Strategies in Tendering**

Project Cost Dynamics: Relation between Tendering Outcomes in the 1-ECI Delivery Approach or Outcome of Collaboration Phase in the 2-ECI Delivery Approach with Future Collaboration Incentives:

The relationship between contractors' preferred pricing strategies in the tendering process, their efforts in providing cost-optimized solutions in the collaboration phase of the 2-ECI project delivery approach, and their incentive for future collaboration with Nye Veier is presented in Figure 16.

In both project approaches, if bidders are incentivized by the prospect of future collaboration, the pricing strategy tends to align with '$=< C_i$'. However, if no incentive for future collaboration is present, a pricing strategy closer to 'Ph' is preferred by contractors.

During the collaboration phase of the 2-ECI project delivery approach, the higher the contractors' optimism about future collaboration opportunities with Nye Veier, the greater the possibility of establishing a trust-based relationship between the parties. Consequently, efforts to find the most cost-optimized solutions while mitigating project risks are made to satisfy the client and increase the likelihood of future collaboration. As a result, project costs may be more optimized in this scenario.

The diagram illustrating the relationship between project cost and contractors' incentives for future collaboration in both project delivery approaches implemented by Nye Veier is shown to be convex (Figure 16). The reason is that project costs depend on many factors beyond future collaboration incentives. Additionally, the future collaboration incentives of contractors are influenced by other project and market factors that are not considered in this analysis. Because of these uncertainties, the relationship is not linear.

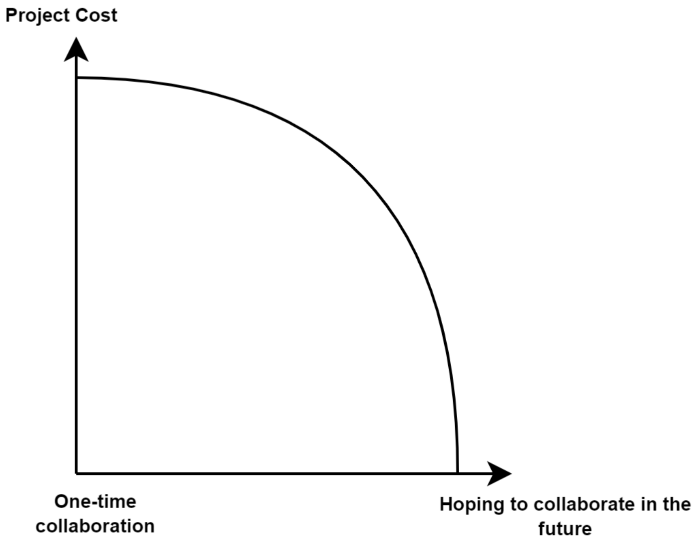

Figure 16: **A Schematic Representation of The Relation Between Project Cost and Motivation for Future Collaboration in Both Project Delivery Approaches**

In this chapter, GT simulations of the two project delivery approaches employed by Nye Veier were developed to gain an in-depth understanding of the parties' strategies, interactions, and incentives in collaboration. The results of these simulations were then presented to compare the project delivery approaches in terms of project costs. The simulation results from the GT models presented in this chapter are used to provide recommendations for Nye Veier and to discuss the findings of this study in the next chapter.

6 Discussion

In this chapter, the interpretation of the results from the conducted analysis of the empirical data, the literature review, and the GT simulations is presented. Firstly, the project delivery approaches under study are explained and compared with the described ECI approaches from the literature. Then, these delivery approaches are analyzed, and the developed GT simulations tailored to these project delivery approaches are explained. Finally, the manner in which these results address the research questions is discussed.

6.1 Project Approaches

In this section, the identified project delivery approaches employed by Nye Veier are compared with the identified ECI approaches from the articles. This comparison is facilitated by combining the developed ECI project delivery models presented in the theory section (Figure 1) and the developed ECI models in the empirical study chapter of this study (Figures 9, 10). By integrating these models, a new conceptual comparison model is provided to clearly compare the ECI project delivery methods. This comparison model is presented in Figure 17.

As shown in Figure 17, the 'Developing a Project' phase defined in the literature is equivalent to 'Making the Project Mature for Competition' in Nye Veier's ECI projects. The 'Planning' phase corresponds to 'Developing a Zoning Plan, Creating Cost and Time Estimation, Defining Project Scope, and Target/Fixed Price (in 2-ECI)' in Nye Veier's ECI projects. Additionally, the 'Design' and 'Implementation' phases are integrated into a single project phase in Nye Veier's ECI projects.

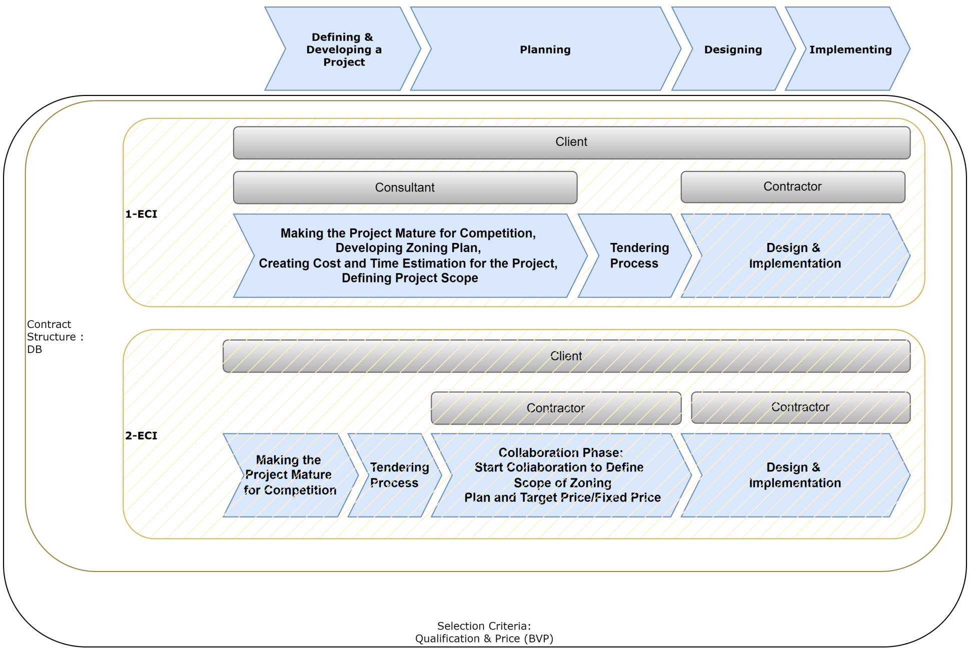

Figure 17: **Comparing Nye Veier's ECI Project Delivery Models with the Described ECI Approaches From Articles**

From the results of the empirical study, it is found that both project delivery approaches implemented by Nye Veier that are studied here, are ECI delivery methods (Wondimu, 2019), which are labeled as 1&2-ECI in this study. Both project delivery methods include a DB contract structure, which means the main contractor is responsible for both the design and implementation of the projects (Riksheim et al., 2020, OECD, 2021, Perera et al., 2022, Riksheim et al., 2020). The selection method in both project delivery methods is based on BVP, which means the contractor selection criteria are based on contractor qualifications and their price strategy (Högnason et al., 2019, OECD, 2021, Narmo et al., 2018).

The two ECI approaches differ in the timing of engaging contractors in projects (the timing of contractor engagement is specified in the model in Figure 17). In the 1-ECI, the timing of engaging the contractors is after the zoning plan development and receiving approval from authorities. In this approach, the main contractor is responsible for the design and implementation of the projects (According to Figure 9)(Wondimu et al., 2020, Scheepbouwer and Humphries, 2011, Nye Veier, 2021, Nye Veier, 2018b). The 1-ECI project method is similar to '1-ECI' in Figure 1 of the developed model in the theory chapter.

The second project method has the same features as '2-ECI' in Figure 1. Contractors are involved in projects from the planning phase (Molenaar et al., 2007, Wondimu, 2019). In the 2-ECI project delivery approach, the main contractors become engaged in projects before zoning plan development. In this approach, the main contractors are responsible for zoning plan development, design, and implementation of the projects (as shown in Figure 17) (Nye Veier, 2019, Nye Veier, 2018c). 2-ECI approach, where the contractors are engaged from the planning phase, is employed due to the high complexity of projects and the requirement for execution knowledge and experience in zoning plan development (Molenaar et al., 2007, Song et al., 2009, Scheepbouwer and Humphries, 2011).

In summary, according to the comparison model presented in Figure 17, Nye Veier employs two different ECI project delivery approaches. In both, the selection criteria in the tendering process are based on quality and price (BVP) (OECD, 2021, Wondimu, 2019, Narmo et al., 2018), and the contract structure is DB. The key difference is the timing of contractors' engagement, contractors' scope of work, and the uncertainty in cost estimation due to the lack of project scope and zoning plan in the tendering process in 2-ECI (Nye Veier, 2019, Nye Veier, 2018c).

6.2 Challenges, Success Factors, & potential opportunities in the 1&2-ECI project Approaches employed by Nye Veier

To reach an understanding of the challenges and opportunities in both ECI project delivery approaches employed by Nye Veier and the required success factors, the theoretical model developed in the theory section is used (as shown in Figure 2). By adjusting the theoretical model to the empirical data, the ECI delivery approaches are analyzed. Subsequently, two new models are developed, tailored to the ECI project delivery approaches, and presented in Figures 18 and 19.

1-ECI

In the 1-ECI approach, there are two challenges from the conceptual model in figure 18 that parties are facing. One of these challenges is considering appropriate incentives for contractors (Bresnen and Marshall, 2000). Understanding contractors' motivation and objectives in the project is crucial (Asgari et al., 2014, Tao et al., 2021). In the 1-ECI approach, Nye Veier does not offer either monetary or non-monetary incentives (excluding small bonuses for HSE purposes). Whereas, contractors' primary incentives for participating in the tendering process in the current market condition are maintaining their market share and enhancing their prospects for future collaboration with Nye Veier (Le et al., 2021). The second challenge is the challenge that contractors face in the 1-ECI project approach employed by Nye Veier, and this challenge is project risks. The selected contractor through the tendering process accepts the risk of cost increases without subsequent claims, driven by the incentive to secure future collaborative opportunities (Assaad et al., 2021, Le et al., 2021), in addition to the other project risks allocated to the contractors. Consequently, a greater proportion of risks is assigned to the contractors (Rahmani, 2021, Scheepbouwer and Humphries, 2011, Moradi and Kähkönen, 2022).

Within the 1-ECI approach employed by Nye Veier, the success factors include the timing of contractor involvement (Wondimu et al., 2016), which is determined to be the definition of this project delivery approach. The selection of the 1-ECI approach signifies that the project's zoning plan can be developed by the client and consultants (Nye Veier, 2018b, Nye Veier, 2021) without necessitating the execution knowledge and experience of contractors during this phase. Therefore engaging contractors after zoning plan approval is the optimal time of contractor engagement in the project in the 1-ECI. Trust-based collaboration is another critical success factor in this project approach (Farrell and Sunindijo, 2022, Wondimu et al., 2016); the client's trust in the contractor during the implementation phase minimizes client interference in the process. The contractor's proficiency as another success factor in the 1-ECI approach, is evaluated by the client (OECD, 2021), given that the selection criteria are based on BVP (Högnason et al., 2019). Considering appropriate incentives is also a success factor that Nye Veier has not addressed in their projects that have been implemented by employing 1-ECI. The incentive of enhancing future collaboration opportunities is a significant motivator for contractors (Le et al., 2021, Wang et al., 2023). Additionally, companies may have different objectives for participating in a project based on their corporate strategies (Bresnen and Marshall, 2000), which would be beneficial for the client to consider when hiring them.

Considering the challenges and success factors inherent in this project delivery approach (1-ECI) and the characteristics of this approach, there is limited flexibility for incorporating contractors' suggestions aimed at optimizing costs and mitigating risks through innovative solutions (Wondimu, 2019). Nonetheless, a contractor highly motivated to collaborate with Nye Veier will endeavor to provide such innovative solutions to the extent permitted by the zoning plan's flexibility. Additionally, due to the non-collaborative nature of the relationship between the parties, there is no opportunity to work on goal alignment between parties despite the presence of appropriate incentives. Furthermore, the contractor does not have the opportunity to contribute to a more constructible zoning plan owing to the timing of their involvement in the 1-ECI approach (post-zoning plan approval), despite their proficiency in this area (Scheepbouwer and Humphries, 2011, Wondimu, 2019).

The tailored theoretical model to the features of the 1-ECI approach, including challenges, opportunities, and success factors, is presented in Figure 18.

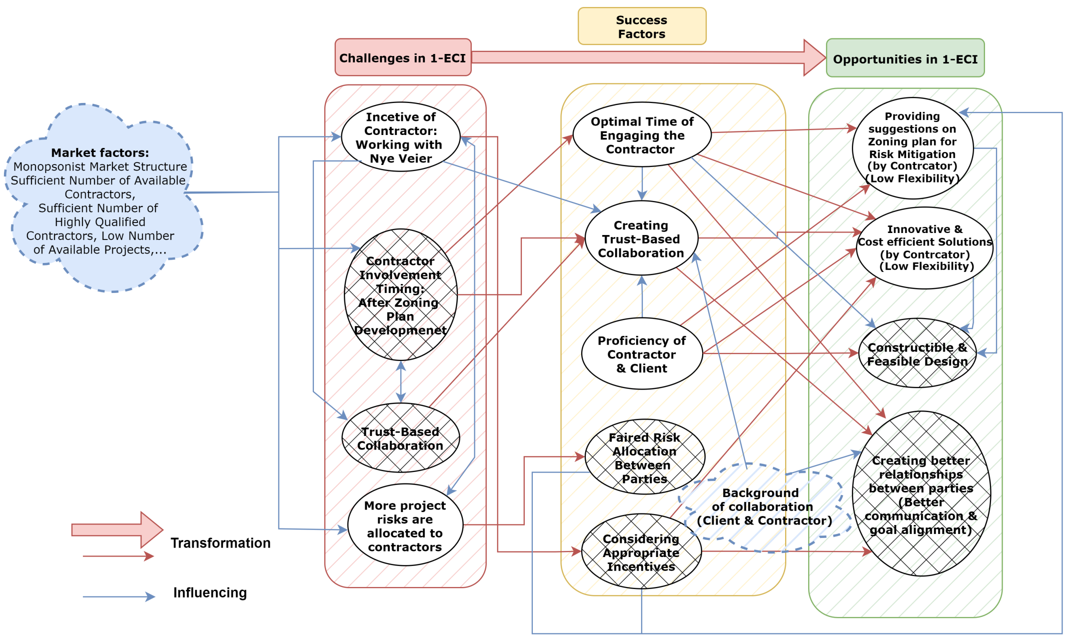

Figure 18: **Challenges, Success Factors & Opportunities in 1-ECI**

2-ECI

In the 2-ECI project delivery model, engaging a contractor prior to zoning plan development is considered optimal due to the high complexity and uncertainty of the project (Song et al., 2009), facilitating collaboration between the client and contractor during the zoning plan development phase (OECD, 2021). However, it is challenging to decide if a project is complex enough to employ 2-ECI. The second challenge that the client faces in the 2-ECI project delivery approach is realizing the incentive of the contractor that is selected in the tendering process. Given the current market conditions, contractors are incentivized to enhance their prospects for collaboration with Nye Veier (Le et al., 2021), fostering a trust-based collaborative relationship, particularly during the collaboration phase. However, as mentioned previously, the objectives of companies may be different based on their corporate strategies (Bresnen and Marshall, 2000). The goal of developing a zoning plan by contractors is to mitigate project risks, thereby preventing potential issues during the implementation phase (Molenaar et al., 2007, Wondimu, 2019). However, this approach can lead to increased project costs, which cause challenges for the client.

In the 2-ECI delivery approach employed by Nye Veier, all the required success factors for delivering an ECI project successfully have been considered except considering appropriate incentives. The optimal time to involve contractors in highly complex projects is before zoning plan development (Song et al., 2009, Luo et al., 2017). However, if the project is not complex enough, it is not beneficial for the client to employ 2-ECI (OECD, 2021, Wondimu et al., 2016). In this project delivery approach, the client uses BVP as the selection criteria in the tendering process. Therefore a skilled and qualified contractor is selected to have a long-term collaboration with Nye Veier (Molenaar et al., 2007, Högnason et al., 2019). Since Nye Veier is also a proficient client, the contractor, and the client's proficiency contribute to project success (Wondimu et al., 2016). A trust-based relationship can be established during the collaboration phase since the contractor and client are expected to work together for a long time (2-3 years) to develop the zoning plan. Consequently, due to the early involvement of the contractor and the long-term collaboration between the parties, there is a high probability of creating a trust-based relationship (Rahman and Alhassan, 2012, Rahmani, 2021). This relationship can be further fostered if the contractor has the incentive of future collaboration. However, this trust may be misused if there is a lack of incentive for future collaboration with the client. The history of collaboration is also one of the determining factors that greatly affect trust in the collaboration (Fu et al., 2015). In the case of having the background of collaborating, it is easier for parties to trust and consequently better relationships can be created. In terms of the success factor of fair risk allocation, in the 2-ECI approach, the contractors face lower risks in comparison with 1-ECI. since the contractor develops the zoning plan in 2-ECI, they can reduce execution risks as much as possible (Nibbelink et al., 2017). Therefore, in this method, the project risks faced by the contractor are lower. Additionally, besides limited monetary incentives that the client considers in 2-ECI (if the project cost is below the target, the savings are shared between the parties) (OECD, 2021, Molenaar et al., 2007), the significant motivation of the contractor which is increasing the chance of collaboration with Nye Veier in the future, has not been considered by the client.

The 2-ECI approach offers some opportunities by considering the success factors and addressing challenges. The 2-ECI project delivery method provides high flexibility, allowing contractors to provide cost-efficient and innovative solutions (Lenferink et al., 2012, Eadie and Graham, 2014). It also helps reduce project risks and uncertainties in the early stages by using the contractor's knowledge and experience (Nibbelink et al., 2017). In the 2-ECI project delivery model, the zoning plan can be developed more constructible because of the contractor's involvement (Nibbelink et al., 2017, Scheepbouwer and Humphries, 2011). Additionally, the long-term collaboration and early involvement of the contractor facilitate a better relationship between the parties and help align their goals in the project (Song et al., 2009, Rahman and Alhassan, 2012, Rahmani, 2021, Marius et al., 2022). If the parties have a history of collaboration, this goal alignment and their relationship can be enhanced (Fu et al., 2015).

The tailored theoretical model to the features of the 2-ECI approach, including challenges, opportunities, and success factors, is presented in Figure 19.

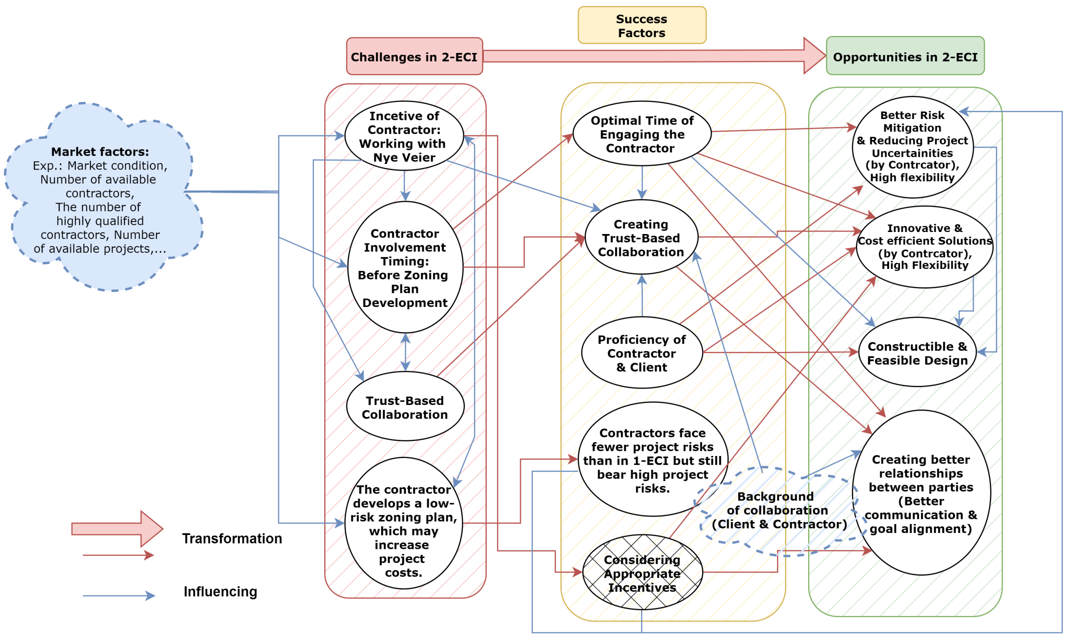

Figure 19: **Challenges, Success Factors & Opportunities in 2-ECI**

In summary, the 2-ECI project delivery approach provides more opportunities compared to the 1-ECI approach if the project is complex enough to employ 2-ECI (Rahman and Alhassan, 2012, OECD, 2021). On the other hand, the 2-ECI approach is more challenging than the 1-ECI, with the challenges being more on the client side. However, in both project approaches, considering appropriate incentives by the client is crucial and plays an important role in successfully delivering projects (Rahmani, 2021, Wang et al., 2023). In the current market conditions, the appropriate incentive for contractor companies can be the motivation to increase their chances of collaboration and potential future collaboration with Nye Veier.

6.3 What Type of Games Are In Play in the Project Delivery Approaches (1&2-ECI)

In this study, different phases of the ECI project delivery approaches employed by Nye Veier are analyzed to comprehend the complex situations inherent in these approaches (Narbaev et al., 2022). From the comparative analysis of challenges, success factors, and opportunities, it is found that the incentive of contractors' motivation for future collaboration plays a crucial role in the ECI project delivery approaches employed by Nye Veier. Through a detailed analysis of GT simulations, deeper insights were gained into this incentive in different project phases. These GT analyses aimed to understand the interactions between parties (Piraveenan, 2019), their strategic responses in different contexts, and their perceptions of benefits, motivations, and incentives (Asgari et al., 2014, Tao et al., 2021).

The project phases were modeled as either static or dynamic games. When considering the incentives for future collaboration — identified as a primary motivator for contractors — a dynamic game model is applicable. Conversely, in the absence of future collaboration incentives, a static game model provides relevant simulation results. By employing both types of simulations (static and dynamic), the results of the collaboration and tendering process in terms of cost efficiency for the client were compared, both when the contractor has a future collaboration incentive and when they do not.

6.3.1 Static Game Types

The tendering process of both ECI approaches was simulated as a simultaneous complete information game (Narahari et al., 2009). In this context, contractors participate in a static strategic game where they must make their decisions simultaneously (Burguillo, 2018), without knowledge of the strategies chosen by other players but with full awareness of the rules and criteria governing the game (Narahari et al., 2009). In this game, the rational strategies for contractors are to either choose a high-price strategy or a minimally beneficial price strategy. According to Nash Equilibrium, the stable strategy in this context is to choose the minimally beneficial price to increase the chance of winning the projects (Ahmed et al., 2016).

The collaboration phase of the 2-ECI approach which includes client and contractor collaboration to develop a zoning plan (OECD, 2021, Nye Veier, 2019), was also simulated statically. This simulation aims to understand potential outcomes if contractors lack the incentive to work with the client in the future. Under these conditions, this phase can be modeled as a static strategic game characterized by simultaneous, asymmetric, and complete information. The client's strategies are to either terminate the collaboration or decide to collaborate with the contractor. Conversely, the contractor's strategy options are to either collaborate and develop the most cost-optimized solutions or misuse the trust by not optimizing the zoning plan and prioritizing their own interests. If the parties decide to collaborate, the payoff is zero-sum; otherwise, the payoff is non-zero-sum.

Without the incentive for future collaboration, the most stable strategy combination is the client deciding to collaborate and the contractor misusing the trust (Nash equilibrium (Burguillo, 2018)). However, the win-win situation occurs when the client decides to collaborate and the contractor engages in a trust-based collaboration, developing the most cost-optimized zoning plan (Pareto optimality (Flåm and Jourani, 2006)). In conclusion, providing a win-win situation depends on the contractor's chosen strategy.

In Table 10, types of game simulations of different project phases that were simulated as static games are presented. Additionally, the stable strategies of different games are specified within the table (Nash equilibrium (Burguillo, 2018)).

ECT Method	Phase	Game Type	Player	Stable Strategy
1&2-ECI	Tendering	Simultaneous, Complete Information	Contractors	Minimum Beneficial Price
2-ECI	Collaboration	Simultaneous, asymmetric, complete information, zero-sum (collaboration), non-zero-sum (termination)	Client Contractor	Collaborate-Misusing trust

Table 10: **Static Game Features of ECI Projects (Contractor's Lack of Future Collaboration Incentive)**

6.3.2 Dynamic Game Types

In this study, two dynamic game models were developed, for the two ECI project delivery approaches. Both models were designed as extensive forms with features of sequential and complete information (De Giovanni, 2009), as the rules are available to the parties during the tendering process and in the subsequent contract. The incentive of future collaboration was considered in strategy selection across all project phases in the simulations. The payoff is non-zero-sum since the overall outcome in this game type is achieving future collaboration opportunities for the contractor and successfully delivering the project at an optimized cost for the client. However, in the collaboration phase of the 2-ECI, the payoff is zero-sum if parties decide to collaborate.

The stable strategy (equilibrium path) for the parties in the 1-ECI approach involves the client selecting a contractor who offers a price lower than the minimum (may result in a negative profit for the contractor) during the tendering process (Ahmed et al., 2022, Wang et al., 2023), the selected contractor performing well in the implementation phase, and the client considering the contractor for future collaboration (Le et al., 2021).

In the dynamic model developed for the 2-ECI project delivery approach, stable strategies in the project phases include selecting a contractor that offers a lower-than-minimum profit price in their bid during the tendering process (Ahmed et al., 2022), engaging in trust-based collaboration in the collaboration phase (Rahmani, 2021) and developing the most cost-optimized zoning plan, having good performance of contractors in the implementation phase, and the client considering the contractor for future collaboration (Le et al., 2021).

If the client works with a contractor who has previously worked with them, there would be a background of collaboration between the parties, facilitating trust-based collaboration. The client would have knowledge of the contractor's work methods and proficiency, allowing them to rely on and trust the contractor even in challenging situations (Fu et al., 2015). Therefore, if collaboration results in the contractor being considered a preferred partner for future projects by the client, both parties would benefit from the relationship. Consequently, the client can be assured that the contractor develops the most cost-optimized zoning plan and does not misuse the trust.

The types of dynamic game models developed in this study in terms of game types and stable strategies (equilibrium path) are presented in table 11.

ECT Method	Phase	Game Type	Player	Stable Strategies
1-ECI	Tendering	-Sequential, -Complete Information, -Non-Zero-Sum	Client & Contractor	Lower than Minimum Profit (Price strategy)
	Design & Implementation			Good Performance (by contractor)
	Post-Implementation			Considering for future collaboration (by client)
2-ECI	Tendering	-Sequential, -Complete Information, -Non-Zero-Sum, -Zero-Sum (in Case of Collaborating)	Client & Contractor	Lower than Minimum Profit (Price strategy)
	Collaboration			Trust-Based Collaboration (developing cost-optimized zoning plan)
	Design & Implementation			Good Performance (by contractor)
	Post-Implementation			Considering for future collaboration (by client)

Table 11: **Dynamic Game Features of ECI Projects (Considering the Incentive of Future Collaboration With the Client**

By comparing GT simulations in both static and dynamic forms, it is found that if the contractor has the incentive to increase their chances of collaborating in the future, they choose a lower-price strategy in the tendering process (Ahmed et al., 2022) and provide the most cost-optimized solutions for the development of the zoning plan. However, in cases where the future collaboration incentive is lacking, the contractor chooses a higher price in their bid (Ahmed et al., 2016) and focuses more on risk reduction and increasing their own benefit in the collaboration phase rather than cost optimization.

6.4 What are the drivers of the cost increase in the 2-ECI project delivery approach?

According to the results of the market analysis, the identified market structure based on the current market condition, is Monopsonist market. In the Monopsonist market, the client has the most power in the market in price determination (Jha and Rodriguez-Lopez, 2021).

Tendering Process:

In the identified market structure, contractors have the incentive to enhance their likelihood of future collaboration with Nye Veier (Wang et al., 2023). Due to this incentive, contractors may adopt pricing strategies that could lead to zero or even negative profits during Nye Veier's project tendering process (Ahmed et al., 2022, Atkinson et al., 2023). If the bidder lacks the incentive of future collaboration with Nye Veier, the pricing strategy does not result in a negative profit. Consequently, the bidder prioritizes monetary profit when setting the pricing strategy. In this scenario, selecting a pricing strategy that leads to negative profit for the contractors is deemed irrational.

2-ECI:

In the 2-ECI project delivery approach, an additional phase exists beyond the tendering phase, which can increase the overall project cost. Since the zoning plan is not developed when the contractor is selected in the 2-ECI approach, the project's cost is uncertain (OECD, 2021). The selected contractor is responsible for finding feasible and cost-optimized solutions for the zoning plan (Nye Veier, 2018c, 2019). In this phase, contractors might misuse the client's trust by focusing solely on their risk reduction rather than cost containment. However, providing contractors with the incentive of future collaboration mitigates this issue.

According to the literature, providing innovative and cost-optimized solutions by contractors depends on four factors (Figure 2). The first factor is the timing of engaging the contractor, which occurs at the earliest possible stage (planning phase) in the 2-ECI project delivery approach (OECD, 2021). This early engagement provides high flexibility in the zoning plan to be adopted based on the innovative solutions provided by contractors. The second factor is the proficiency of both the client and the contractors. The contractor's proficiency is assessed by the client during the selection process in the tendering phase (OECD, 2021; Perrenoud et al., 2017; Wondimu, 2019). Nye Veier is assumed to be a proficient client in these projects. The third factor, as illustrated in Figure 2, is the consideration of appropriate incentives for contractors, which can be either monetary or non-monetary (Atkinson et al., 2023; Wang et al., 2023). Moreover, having a trust-based relationship between parties facilitates the provision of cost-efficient solutions by contractors. With such a relationship, contractors do not misuse the client's trust and focus on optimizing the project's cost. The client can then rely on the solutions provided by the contractors, trusting that they are the most cost-optimized solutions.

On the one hand, the provision of cost-efficient and innovative solutions by contractors in the 2-ECI, according to the interview results, depends on various factors. These include the contractors' proficiency and expertise, access to adequate information and thorough conducting sufficient ground investigation, and the incentive for future collaboration with Nye Veier. Apart from the presence of limited monetary incentives in the 2-ECI project delivery approach, such as sharing the saved budget amount if the project is delivered below the target (an eventuality that has not occurred), there are no monetary or non-monetary incentives provided by the client. However, the presence of an incentive for potential future collaboration with Nye Veier (which is not formal or contractual) motivates contractors to exert greater effort in providing cost-efficient and innovative solutions (Bresnen and Marshall, 2000, Wang et al., 2023, Fu et al., 2015).

Furthermore, the analysis of GT simulations presented in this study demonstrates that the incentive for future collaboration positively influences the contractor's pricing strategy and their motivation to provide cost-optimized solutions to meet the client's needs.

Drawing from the outcomes of game theory simulations, as it is demonstrated in Figure 16, contractors' aspirations for future collaboration with Nye Veier influence both their pricing strategy in bids and their provision of cost-efficient solutions in project approaches. The more motivated contractors are to collaborate with the client in the future, the less they prioritize pricing in their bids and the more they may focus on delivering cost-optimized solutions. Additionally, a high level of contractor interest in future collaboration with Nye Veier corresponds to possible greater efforts to optimize project costs, aiming to enhance client satisfaction with their collaborative experience.

In addition to the mentioned reasons, according to the empirical study, the cost of projects employing the 2-ECI method can increase due to the client underestimating the project budget or receiving expensive conditions on the zoning plan from authorities.

The drivers for cost increases in Nye Veier's 2-ECI project delivery approach are listed in the following table:

Cost-Increasing Drivers in 2-ECI
Lack of Appropriate Incentives
Lack of Proficiency of Contractors
Lack of Information and Sufficient Ground Investigation
High Uncertainty & Complexity
Misusing Trust in Collaboration Phase
Project Budget is Underestimated
Receiving Expensive Conditions on Zoning Plan from Authorities

Table 12: **Cost-increasing Drivers in 2-ECI Project Delivery Approach**

6.5 Which project delivery approach (1-ECI or 2-ECI) is more beneficial for Nye Veier in terms of cost efficiency?

According to the analysis provided in Figure 15, in a Monopsonist market, the client has the most power in determining market factors, and contractors adjust themselves to the client's expectations (Jha and Rodriguez-Lopez, 2021). Therefore, if the client develops zoning plans in collaboration with consultancies and then hires a contractor for design and implementation (Wondimu et al., 2016, Song et al., 2009, Rahman and Alhassan, 2012, Pheng et al., 2015), it is more cost-beneficial for the client. The reason is that, due to the high competition in tendering processes (Ahmed et al., 2022), the low number of projects in the market (Ahmed et al., 2016), and the sufficient number of qualified contractors in national and international markets from which the client can select (Le et al., 2021), contractors may consider prices that are even lower than the minimum beneficial price for them to win the project (Assaad et al., 2021).

It was also mentioned in the interview that contractors can always see the potential for cost increases by considering details in the zoning plan, but they do not make claims once they have approved the zoning plan and signed the contract. Therefore, even though the 1-ECI project delivery method includes more risks for contractors, it includes opportunities for clients and is more cost-beneficial for the client under the current market structure and conditions.

In the case of employing the 2-ECI project approach, contractors develop a zoning plan considering the client's expectation that the selected contractors will mitigate the project risks in the plan (Nye Veier, 2018c, Nye Veier, 2019). Therefore, contractors have the incentives to address all possible risks in the zoning plan that they would have to take on if the project were implemented using the 1-ECI approach (OECD, 2021). Because the contractor's scope of work includes risk mitigation, the zoning plan developed by contractors is more constructible than a zoning plan developed by the client and consultant but it might be more expensive.

Furthermore, according to the results of the empirical study, in the 2-ECI project delivery approach, due to high uncertainty in the projects, the dedicated budget might not be realistic, and the cost of the project might increase because the client underestimates the budget. Additionally, costs may rise due to expensive conditions imposed by authorities on the zoning plan. However, in this method (2-ECI), since the contractor is already hired, the client cannot postpone the project implementation to a more appropriate time based on their portfolio strategy in case of a cost increase. In contrast, in the 1-ECI approach, the client can postpone the project implementation based on their portfolio strategy because contractors are not yet on board.

In summary, the 1-ECI seems to be more cost-beneficial for the client in the current market conditions. However, if the market conditions change, the incentives of the contractors would also change, therefore the client should adjust their strategies accordingly. However, when facing a highly complex project or high uncertainty in projects, using execution knowledge and experience of contractors in developing zoning plans is highly beneficial (Eadie and Graham, 2014, Nibbelink et al., 2017). In the case of facing highly complex projects, the 2-ECI project delivery approach is preferable.

A diagram is developed and presented (Figure 20) to demonstrate the relationship between project complexity, the possibility of increasing project costs, and the timing of involving contractors in projects. Based on the diagram presented in Figure 20, if a project is highly complex, involving contractors early in the project is more beneficial, as their construction expertise and knowledge can reduce project uncertainties in the early phases (Molenaar et al., 2007). However, the possibility of a cost increase when contractors are engaged in zoning plan development (early phases of a project) is high due to the high uncertainty in the projects or the possibility of misusing trust in the collaboration phase or any other mentioned reasons in table 12. Conversely, if a project is not highly complex, contractors can be engaged in later phases (Wondimu et al., 2016; Rahman and Alhassan, 2012), and the possibility of a cost increase is reduced accordingly.

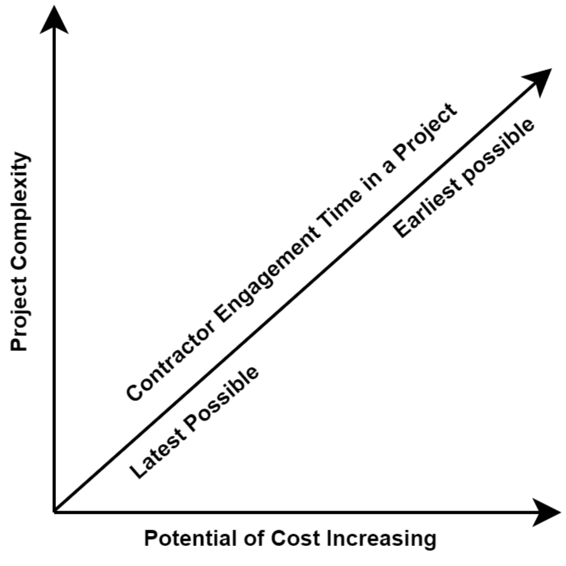

Figure 20: **"Relation Between the Timing of Engaging Contractors in a Project, Project Complexity, and the Possibility of an Increase in Project Costs"**

In this section, the findings of this study, including the theoretical models, empirical models developed, and GT simulations, are explained. Also, how the findings contribute to answering the research questions is discussed. In the next chapter, a conclusion of the overall process and key findings of this study is provided.

7 Conclusions

In this chapter, a conclusion of this study is provided by summarizing the process of conducting the study, and answering the two research questions:

1. What are the drivers of the cost increase in the 2-ECI project delivery approach?
2. Which project delivery approach (1-ECI or 2-ECI) is more beneficial for Nye Veier in terms of cost efficiency?

Following answering the research questions, the contributions of this study are explained, theoretical and practical implications are discussed, and suggestions for future work are provided.

To achieve the objectives of this project, a thorough literature review and an empirical study were conducted. The literature review covered areas such as ECI, DB, GT, market structures, and collaboration incentives. From this review, two theoretical models were developed: one demonstrating the various types of ECI project delivery approaches identified in the literature, and another illustrating the challenges, opportunities, and success factors in ECI projects, along with their interrelations and influential factors. The empirical study utilized data from ten interviews, comprising six with clients, two with consulting companies, and two with contractors involved in both ECI approaches. Additionally, six project documents provided by Nye Veier were reviewed. A thematic analysis was conducted to identify the motivations, strategies, and benefits for each party involved in the ECI projects, analyze market conditions, and assess the characteristics of project delivery approaches. This analysis resulted in tailored models for each ECI project delivery approach employed by Nye Veier. Furthermore, GT principles were applied to develop simulations of the project phases in both the 1-ECI and 2-ECI approaches, aiming to provide a more detailed analysis. These simulations were based on empirical data derived from the analysis results.

The results of the thematic analysis of the document review indicate that Nye Veier employs two different ECI project delivery approaches, both of which utilize a DB contract structure. In the 1-ECI approach, Nye Veier, as the client, develops a zoning plan with a consulting company and then hires a contractor for project design and implementation. The selection criteria for contractors in this approach are based on BVP, with contractors being selected based on price and qualifications. In the 1-ECI approach, the winning contractor has the opportunity to provide suggestions to optimize the already developed and approved zoning plan, as long as these suggestions stay within the specified budget and timeline. However, the flexibility for implementing innovative solutions is limited since the zoning plan has already received approval from authorities before contractor engagement. On the other hand, in the 2-ECI approach, the zoning plan is developed by the contractors and the client collaboratively, and the client hires the contractor at the earliest phase of the project (planning phase). The selection criteria in the 2-ECI approach also follow BVP, but without a project cost estimation due to the undefined project scope in the early phases (only the budget of the project is specified by the client). Therefore, contractors are selected based on their markup and qualifications. The 2-ECI provides high flexibility for contractors to reduce project risks and apply cost-optimized and innovative solutions in zoning plan development. Nye Veier employs the 2-ECI approach when a project is too complex for the client and consultant to plan, necessitating execution knowledge for developing the zoning plan.

7.1 What are the drivers of the cost increase in the 2-ECI project delivery approach?

Based on the results of GT simulations and the empirical study, several drivers of cost increases in the 2-ECI project delivery approach employed by Nye Veier were identified. One major factor is the lack of contractor proficiency, where contractors are not skilled enough to provide cost-optimized solutions in zoning plan development. Another significant reason for cost increases is the absence of identifying and considering appropriate incentives. This study highlights that the hope for future collaboration is a crucial incentive that can impact ECI projects. Without this incentive, contractors may misuse the trust placed in them during the collaboration phase, focusing solely on their risk reduction and their own benefit rather than cost optimization. Therefore, it is important to identify the contractors' motivations and incentives in projects. Additionally, project costs can rise due to inadequate ground investigation and insufficient information during the development of the zoning plan, which prevents contractors from proposing the most cost-efficient solutions. Furthermore, in highly uncertain and complex projects, the client may underestimate the project budget, leading to budget overruns despite the contractors providing cost-optimized solutions. Moreover, due to receiving expensive conditions on the developed zoning plan by contractors and the client from authorities, the project costs can be increased in the 2-ECI project delivery approach.

7.2 Which project delivery approach (1-ECI or 2-ECI) is more beneficial for Nye Veier in terms of cost efficiency?

In this study, by analyzing the two ECI approaches (1 & 2-ECI) employed by Nye Veier, market analysis, theoretical analysis of ECI approaches, empirical study results, and the results of GT simulations on the ECI project phases, it is found that contractors are incentivized by the opportunity to work with Nye Veier and increase their chances of future collaboration. This incentive causes contractors to set low prices, even at a negative profit, during the tendering process. It also motivates them to provide the most cost-optimized solutions in the collaboration phase, deliver good performance during implementation, and establish trust-based relationships with the client.

The market structure in which Nye Veier and contractors operate is monopsonist market (since very few actors provide large projects in the type of Nye Veier in Norway). In this market structure, the client has the most power in determining prices, and contractors may even prefer negative profits to win projects and collaborate with Nye Veier, hoping that by providing their best performance, they can increase their chances of future collaboration in future projects. The most cost-efficient project approach for Nye Veier in this market structure is the 1-ECI, where the contractor becomes engaged after zoning plan approval and a project cost estimation in the tendering process. However, selecting contractors who are highly motivated by the prospect of future collaboration with Nye Veier is more beneficial for the client in both ECI project delivery methods, especially in the 2-ECI because of the high risk of cost increases.

On the other hand, based on the analysis of the two ECI project delivery approaches employed by Nye Veier in this study, it is found that if a project is highly complex, the 2-ECI approach offers more opportunities compared to the 1-ECI approach. Although the 2-ECI approach is more challenging for the client to implement in terms of the high probability of project cost increasing, it provides fewer risks in the implementation phase since the contractor works on risk reduction during the early phases (zoning plans are more constructible in this method). Additionally, the 2-ECI approach fosters better relationships between parties due to the extended collaboration between the client and contractors in the early phases.

In conclusion, the most cost-efficient delivery approach for Nye Veier in the current market conditions is the 1-ECI approach, which involves developing a zoning plan by the client and consultants and engaging the contractor after zoning plan approval. However, it is important to note that changes in market conditions may necessitate a reassessment to determine the most cost-beneficial project delivery approach for the client. Furthermore, for highly complex projects requiring contractors' expertise in zoning plan development, it is crucial to consider future collaboration incentives in addition to qualifications and markup, when selecting contractors.

7.3 Contributions

In this study, two theoretical and conceptual models were developed. The first model, presented in Figure 1, illustrates different ECI approaches based on the timing of contractors' involvement in projects, selection criteria, and contract structure. This model was constructed based on theories extracted from relevant articles. The second model was developed to identify connections between ECI approach challenges, success factors, and opportunities that are mentioned in different articles (Song et al., 2009; Moradi and Kähkönen, 2022; Wondimu et al., 2016). The influential factors on these challenges, success factors, and opportunities were also specified in the model. This model was presented in Figure 2. Additionally, based on the analysis conducted on empirical data, two models for the two types of ECI project delivery approaches employed by Nye Veier, were developed and presented in Figures 9 and 10.

Utilizing empirical data, different phases of the two types of project delivery approaches (1&2-ECI) were simulated, using GT principles to attain a detailed understanding of the effective factors in the project phases, particularly focusing on future collaboration incentives of the contractors. The major contribution of this study is the development of GT qualitative simulations tailored to the two types of ECI approaches based on empirical data. These models were developed in both static and dynamic forms and were presented in the simulation chapters.

A decision-making framework based on the extracted theories and empirical study results was provided to assist in decision-making regarding the adoption of ECI project delivery approaches, particularly concerning the timing of contractors' involvement under varying market conditions. This framework was presented in Figure 15.

Furthermore, in this study, three research gaps were addressed, in the area of using GT in project management that are mentioned in the study conducted by Narbaev et al. (2022).

This study contributes to filling the research gap in analyzing bidding strategies in complex projects by using GT simulations (Narbaev et al., 2022). Previous works have examined the effect of different factors on bidders' pricing strategies (Ahmed et al., 2016; Assaad et al., 2021). In this study, GT simulations were developed for the tendering process of two types of ECI project delivery approaches and the effect of future collaboration incentives on the price strategy choices of bidders was investigated. The results of the analysis are similar to those provided by Le et al. (2021). In the study conducted by Le et al. (2021), the effect of the objective of long-term business relationships with the client on bidders' pricing strategies was investigated. However, in this study, GT simulation models were developed to investigate the effect of the future collaboration incentive on bidders' pricing strategies within the two types of ECI project delivery approaches, in addition to considering the governed market conditions.

This study also contributes to filling the research gap in studying financial problems in projects by utilizing GT analysis (Narbaev et al., 2022). In this study, two types of ECI project delivery approaches were simulated, and a detailed analysis of the project phases was conducted. Through these simulations, insights into project approaches were gained, and the drivers of cost increases in the 2-ECI project delivery approach were understood. Additionally, by simulating the collaboration phase of 2-ECI both statically and dynamically (with and without considering future collaboration incentives for the contractors), the effect of future collaboration incentives on cost increases in this project delivery approach was identified.

Furthermore, this project contributes to bridging the research gap by connecting GT simulation with empirical study in the project management area (Narbaev et al., 2022). In this study, real-life data were utilized to develop GT simulations, and a comprehensive understanding of projects was acquired. The primary contribution of this study lies in the development of GT models for various phases of the two ECI project delivery approaches within both static and dynamic game frameworks using real-life data.

7.4 Theoretical and Practical Implications

The results of this study and the detailed analysis of ECI approaches can facilitate the adoption of the ECI project approach as an innovative project method. A better understanding of the relationships between challenges, success factors, and opportunities in ECI project delivery methods can be provided by using the results of this study. A better understanding of cost-increasing factors in ECI project methods can also be achieved. The GT simulations developed in this study can be applied to similar situations and inspire other academic works in simulating empirical data qualitatively by using GT. Additionally, the three theoretical models developed in this study (Figures 1, 2, and 8) can be used as a foundation for future research in the areas of ECI, project management, and economics when the study is related to assessing or analyzing project delivery approaches.

In practice, the results of this work provide guidelines for parties to identify incentives, determine the optimal time for contractor engagement, and make more informed decisions in planning and choosing the appropriate project delivery approach under different market conditions. The results of this study help clients identify incentives for contractors and consider appropriate incentives as a selection criterion to enhance ECI project success and optimize project costs. Moreover, by using the theoretical models from this study (Figures 2, and all the GT simulations in the simulation chapter), parties are able to analyze complex situations and assess the ECI projects they are employing, consequently making more informed decisions.

7.5 Future Works

The relationship between choosing the type of ECI delivery approach and Nye Veier's portfolio strategy would be a good topic of study. It was mentioned in the interviews, that when an ECI project turns out to be expensive at the end of the collaboration phase, it affects the company's portfolio and total budget since the contractor is onboard and the implementation cannot be postponed. By studying Nye Veier's portfolio strategies, suggestions can be provided on when it is a good time to employ the 2-ECI based on their portfolio strategy.

As noted in the limitations of this study, the GT models are inherently more complex than those developed here. Future research could investigate the effects of additional games and other influential factors on the dynamic game models presented in this study (Brandenburger and Nalebuff, 1997). Such research aims to achieve a deeper understanding of the project delivery phases and to offer more comprehensive analyses by considering other significant environmental factors or different games in which the parties participate.

The results of this study, including the analysis of ECI projects, empirical work results, and qualitative GT simulations of ECI project delivery approaches, can be used as a foundation for the two suggested future studies.

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Appendix

Interview Questionnaire

Interview Questions Designed for Interviewing the Client

Date:

Position:

1. Could you please explain your role in the company and in particular your role in the design and implementation of construction projects for Nye veier?
2. In general, do you think there is a sufficient number of contractors bidding to your/Nye veier calls in the Norwegian/Scandinavian market or not? In other words, is there sufficient competition in your calls?
3. Could you please explain in which situations you think is best to use the ECI approach (tidlig entreprenørinvolvering) as opposed to DB (total entreprise). What are the advantages and disadvantages of these two methods?
4. In particular, are there specific types of projects – or project features – that render the ECI-method more advantageous for you to use as opposed to DB-method, and in that case which are these features?
5. If an ECI project were implemented by DB method, do you think it would be more beneficial, more cost-efficient, and more time-efficient or less? Are there other potential advantages of using a DB method as opposed to ECI-method that you think of in addition to the three mentioned?
6. Does the collaboration with contractors in ECI method induce trust and a common understanding of the realities of the project? And if yes, is this trust important for ultimately achieving the goals of the project?
7. If it is trust-based, do you think this trust could be misused, and what may be the incentives for misusing trust?
8. In general, do you think an expensive zoning plan (that is larger projects developed by either method – i.e. ECI or BD) tends to have a higher or lower likelihood of getting approved by the municipality/authorities?
9. If there was a rule that the contractor wouldn't be employed by the same client for other projects, how that do you think would affect the dynamics of the collaboration in the ECI-process?
10. If the developed zoning plan by contractors/consultants has the features of high implementation cost compared to initial rough estimations, then what is the likelihood for this plan to be approved by Nye Veier?
11. If the developed zoning plan by contractors/consultants has the features of reasonable implementation cost compared to initial rough estimations (close to the initial estimation), then what is the likelihood for this plan to be approved by Nye Veier?
12. If the developed zoning plan by contractors/consultants has the features of low implementation cost compared to initial rough estimations, then what is the likelihood for this plan to be approved by Nye Veier?
13. In an ECI-contract process, how often do you reject the zoning plan of the collaborating contractor and terminate this collaboration? What are usually the implications of terminating the collaboration – are there only disadvantages or there are also some advantages too (learning, assessment of contractors, other potential benefits)? What is the likelihood of facing this situation?

14. In DB projects, do you usually find the developed zoning plan by consultants satisfactory? Especially when it comes to the more precise estimates of the cost of the projects, how accurate are these estimates compared to those you could get from an ECI-process?
15. What normally happens if you/Nye veier do not approve the plan developed by the consultant?

Notes:

DB: Design-Build (Totalentreprise)

ECI: Early Contractor Involvement (Tidlig entreprenørinvolvering)

Zoning Plan: Reguleringsplanen

Interview Questions Designed for Interviewing Consultants

Date:

Position:

1. Could you please explain your role in the company and in particular your role in the design and zoning plan (Reguleringsplanen) development for Nye veier's projects?
2. Do you believe there are sufficient consultant companies capable of developing zoning plans (Reguleringsplanen) in the Norwegian/Scandinavian market? Alternatively, are there many projects in need of zoning plan development by consultants in the Norwegian/Scandinavian market?
3. Could you please explain the process of developing a zoning plan by the consultant in terms of duration, and how the process starts and finishes? In the process of zoning plan (Reguleringsplanen) development, how much do the consultant and client (Nye Veier) communicate, have meetings, and share their expectation and ideas?
4. What is the likelihood of developing a zoning plan that has the feature of high implementation cost compared to initial rough cost estimations?
5. What is the likelihood of developing a zoning plan that has the feature of reasonable implementation cost compared to initial rough cost estimations (the implementation cost is close to the initial rough cost estimations)?
6. What is the likelihood of developing a zoning plan that has the feature of low implementation cost compared to initial rough cost estimations?
7. In a DB-Project (Totalentreprise), how often zoning plan developed by a consultant be rejected by the client (Nye Veier), and for what reasons? If a developed zoning plan is rejected by the client (Nye Veier), does this result in the termination of collaboration, or does it necessitate redesigning the zoning plan by the consultant? What are usually the implications of receiving rejection (from the client) on a developed zoning plan – are there only disadvantages or there are also some advantages too (learning or other potential benefits)? What is the likelihood of facing this situation?
8. How much do you think the developed zoning plans (Reguleringsplanen) by the consultant are accurate especially when it comes to cost estimates of the projects? Do you think if the zoning plans (Reguleringsplanen) were developed by a contractor would they be more precise in cost estimation?

Notes:

DB: Design-Build (Totalentreprise)

Zoning Plan: Reguleringsplanen

Interview Questions Designed for Interviewing Contractors (Involved in 2-ECI project delivery approach in Nye Veier's Projects)

Date:

Position:

1. Could you please explain your role in the company and in particular your role in the design and implementation of construction projects for Nye veier.
2. In general, do you think there is a sufficient number of road construction projects calling for bidding in the Norwegian/Scandinavian market or not (either ECI or DB project method)?Do you think there is a sufficient number of contractors bidding on clients' calls in the Norwegian/Scandinavian market or not (either ECI or DB project method)? In other words, is there sufficient competition in these types of projects?
3. Does the collaboration with clients in ECI method induce trust and a common understanding of the realities of the project? And if yes, is this trust important for ultimately achieving the goals of the project?
4. If it is trust-based, do you think this trust could be misused, and what may be the incentives for misusing trust?
5. If there was a rule that the contractor wouldn't be employed by the same client for other projects, how that do you think would affect the dynamics of the collaboration in the ECI-process?
6. What is the likelihood of developing a zoning plan in the collaboration phase in ECI-projects that has the feature of high implementation cost compared to initial rough cost estimations?
7. What is the likelihood of developing a zoning plan in the collaboration phase in ECI-projects that has the feature of reasonable implementation cost compared to initial rough cost estimations (close to the initial rough cost estimations)?
8. What is the likelihood of developing a zoning plan in the collaboration phase in ECI-projects which has the feature of low implementation cost compared to initial rough cost estimations?
9. In an ECI-contract process, how often zoning plans developed in the collaboration phase of client-contractor, might not be satisfactory for the client, and lead to the termination of this collaboration? What are usually the implications of terminating the collaboration – are there only disadvantages or there are also some advantages too (learning, or other potential benefits)? What is the likelihood of facing this situation?
10. If an ECI project were implemented by DB (contractor be involved after the zoning plan development) method, do you think it would be more beneficial, more cost-efficient, and more time-efficient or less? Are there other potential advantages/disadvantages of using a DB method as opposed to ECI-method that you think of in addition to the three mentioned?
11. In DB projects, do you usually find the developed zoning plan by consultants satisfactory? Especially when it comes to the more precise estimates of the cost of the projects, how accurate are these estimates compared to those you could get from an ECI-process (compare a developed zoning plan by a contractor in collaboration with a client)?

Notes:

ECI: Early Contractor Involvement (Tidlig entreprenørinvolvering) is the method in which the contractor is involved in developing the zoning plan in collaboration with the client.

DB: Design-Build (Totalentreprise) is the method in which the contractor is involved in the project after zoning plan development by a consultant company.

Zoning Plan: Reguleringsplanen

Interview Questions Designed for Interviewing Contractors (Involved in 1-ECI project delivery approach in Nye Veier's Projects)

Date:

Position:

1. Could you please explain your role in the company and in particular your role in the design and implementation of construction projects for Nye veier.
2. In general, do you think there is a sufficient number of road construction projects calling for bidding in the Norwegian/Scandinavian market or not (either ECI or DB project method)? Do you think there is a sufficient number of contractors bidding on clients' calls in the Norwegian/Scandinavian market or not (either ECI or DB project method)? In other words, is there sufficient competition in these types of projects?
3. In DB projects, do you usually find the developed zoning plan by consultants satisfactory? Especially when it comes to the more precise estimations of the cost of the projects, how accurate are these estimations?
4. If an DB project was implemented by ECI method (contractor be involved in the zoning plan development), do you think it would be more beneficial, more cost-efficient, and more time-efficient or less? Are there other potential advantages/disadvantages of using a ECI method as opposed to DB-method that you think of in addition to the three mentioned?
5. What is the likelihood that the implementation cost of a project will be higher than the initial estimation provided by the zoning plan developed by a consultant? If it were to happen, how would it affect the contractor's benefit in a project?
6. What is the likelihood that the implementation cost of a project will be close to the initial estimation provided by the zoning plan developed by a consultant? If it were to happen, how would it affect the contractor's benefit in a project?
7. What is the likelihood that the implementation cost of a project will be lower than the initial estimation provided by the zoning plan developed by a consultant? If it were to happen, how would it affect the contractor's benefit in a project?
8. In a DB project process, how often might it happen that the contractor perceives the need for a change in the zoning plan, which could result in increased costs and lead to disagreements between the client and contractor? What is the likelihood of encountering this situation? How is it typically resolved?
9. How involved is the client in the implementation phase, and what contributions does the client make during this phase?

Notes:

ECI: Early Contractor Involvement (Tidlig entreprenørinvolvering) is the method in which the contractor is involved in developing the zoning plan in collaboration with the client.

DB: Design-Build (Totalentreprise) is the method in which the contractor is involved in the project after zoning plan development by a consultant company.

Zoning Plan: Reguleringsplanen

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