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The Added Value of Bouwteams: An Analysis from Stakeholder-Expert Perspectives

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The Added Value of Bouwteams: An Analysis from Stakeholder-Expert Perspectives

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Abstract

This thesis is conducted at TAUW under the department of Inkoop Advies and Contractmanagement (IACM). The thesis aims to address the problems related to bouwteam consultancy. The consultants within IACM are lacking adequate empirical data to support their advice on the use of bouwteams in infrastructure.

The main research question that is addressed is:

How do bouwteams compare to traditional contracting methods in infrastructure projects?

The focus is on the added value of bouwteams in terms of qualitative benefits and the cost implications from the stakeholder-expert's perspective.

The thesis introduces the approach of the research, including the problem statement, the research questions, and the methodology. The second chapter provides a literature review on bouwteams and traditional contracting methods, including their definitions, characteristics, advantages, and disadvantages. The third chapter presents expert opinions and experiences on the use of bouwteams. The fourth chapter identifies the most important drivers for choosing bouwteams. In the fifth chapter, the thesis provides recommendations for the use of bouwteams. This includes the most essential factors that contribute to the success of bouwteams (with visual representation). In the last chapter, limitations of the study and suggestions for future research are discussed. The conclusion evaluates how the main research question is answered. Furthermore, it assesses how the findings contribute to the existing body of knowledge on bouwteams in infrastructure projects.

On the basis of this study, bouwteams should be used in infrastructure projects where the client is looking for a collaborative approach, early involvement of the contractor, and a project with characteristics that benefit from the early involvement of the contractor. The study also highlights requirements for successful bouwteam projects because it is not universally suitable for all projects. The study emphasises the importance of a good project team, clear communication, and a well-defined scope of work by critically evaluating stakeholder-expert perspectives. On the consultancy process on a bouwteam from the client perspective, the study suggests that consultants should focus on understanding the project context, the client's needs, and the potential benefits of a bouwteam approach. It also emphasises the importance of providing empirical data to support the advice on the use of bouwteams in infrastructure projects.

The thesis offers valuable insights for both practitioners and researchers in the field of infrastructure projects, particularly in the context of collaborative contracting approaches.

Preface

This thesis was written to complete the Bachelor of Science degree in Industrial Engineering and Management at the University of Twente. The research was conducted at TAUW, under the supervision of dr. Dipl.-Ing. M. Sharma (Mahak), dr. H. Chen (Hao) and company supervisor A. Hoevink (Arno).

During my studies, I developed a solid foundation in the field of Industrial Engineering and Management. This thesis is the culmination of my academic journey, in which the theoretical knowledge I obtained through my studies has been applied to real-world challenges.

I want to express my gratitude to my supervisors for their guidance and support throughout the process, as well as their valuable feedback. I would also like to thank the colleagues at TAUW for their insights and contributions to this research. Their expertise and perspectives have enriched the quality of this thesis.

Additionally, I acknowledge the use of AI-based writing and coding aids (ChatGPT and GitHub Copilot), which supported me in improving the grammar, clarity, code refinement, and structure of this thesis. After using them, I carefully reviewed all suggestions and incorporated them as appropriate. The content, analysis, and conclusions are entirely my own.

Lastly, I would like to thank all the people who have supported me during my studies and this research. Their encouragement and aid have been invaluable in completing this thesis and have helped me to grow both personally and academically.

Enschede, July 1, 2025

Joep Seinen

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Table 1: Overview of Key Concepts & Definitions

Abbreviation/Term	Definition
AHP	Analytical Hierarchy Process – a decision-making tool used to rank and weight criteria based on pairwise comparisons.
Bouwteam	A Dutch collaborative contract form involving early cooperation between client and contractor during the design phase.
DNR	De Nieuwe Regeling – standard legal framework used by, among others, architects and engineers in the Netherlands.
ECI	Early Contractor Involvement – a project delivery method where the contractor is involved early in the design phase.
IACM	Inkoop Advies en Contractmanagement – the procurement advice and contract management department at TAUW.
MPSM	Managerial Problem-Solving Method – a structured approach to solving organisational and technical problems.
RAW	Rationalisatie en Automatisering Grond-, Water- en Wegenbouw – a specification system used in Dutch civil engineering contracts. In this thesis UAV-Contracts and RAW-Contracts are used interchangeably.
TAUW	A European consultancy and engineering firm, host of the graduation project.
UAV	Uniforme Administratieve Voorwaarden – Dutch standard administrative conditions for construction works. In this research UAV-Contracts and RAW-Contracts are used interchangeably.
UAV-GC	UAV Geïntegreerde Contracten – integrated Dutch contracts where design and execution are the responsibility of the contractor.
Traditional Contract	A contract form where design and construction are separated, typically with the client responsible for design and the contractor for execution.
VTW	Verzoek Tot Wijziging – a request for change in a project (agreement), often leading to additional costs or delays.

1

Introduction

This chapter elaborates on the context and motivation of the research. The problem that is to be solved is described as well as what the approach to solving this problem is. The chapter concludes with remarks on ensuring the validity and reliability of the research; also, the scope and limitations of the research are described.

1.1 Introduction: The Added Value of Bouwteams

1.1.1 Company Description

The research is conducted within TAUW. TAUW is a European consultancy and engineering firm with several locations in the Netherlands and throughout the rest of Western Europe. TAUW is primarily dedicated to designing public spaces in rural as well as urban areas. Some sectors TAUW is active in are, among others, water, infrastructure, and environment (TAUW, 2025a). Research is conducted in the team of procurement and contract management ("Inkoopadvies & Contractmanagement"). This team is occupied with consultancy, such as procurement and tender advice, but is also responsible for drafting contracts. TAUW furthermore has a lot of experience with tendering procedures and with the drafting of legal justifications (TAUW, 2025b). One of those tendering procedures is the tendering of projects where bouwteams are used. In these bouwteams (a form of early contracting), the design phase of a project is executed with the client as well as the contractor. An important starting point is that the relevant contractor is also the executor of the project (TAUW, 2025c). The use of these partnerships in infrastructure projects is the main topic of the thesis.

1.1.2 Motivation of the research

In the dynamic and complex world of infrastructure projects, the choice of partnership and contract type can significantly influence project outcomes. As public and private sector clients seek more integrated and efficient ways to deliver infrastructure projects, the use of bouwteams has gained traction. This approach involves collaboration between clients and contractors from the early stages of project design. However, it has a drawback: there is a lack of empirical data to support the claims of added value associated with bouwteams. Especially compared to traditional contracting methods such as solely using UAV-RAW and UAV-GC. (Lagemaat, 2015)

This thesis investigates different partnerships and contract types used in infrastructure projects. The popularity of bouwteams has been increasing in the past few years; take 2019, in which the public tenders with bouwteams were 111 compared to 2017, where this was only 27 (CROW, 2020). Although the popularity of this contract type increases, there is thought to be a lack of justification for this trend. Bouwteam projects are often perceived to be more expensive due to reduced competition (Hoevink, 2021). Although a counterargument could be that fewer costs are incurred because of an optimal risk distribution that is determined in this form of contracting approach (Hoevink, 2021). There are several other arguments to use or not use a bouwteam in projects, but still no concrete policy is established that indicates when to use this form. Especially considering the potential added value that working with bouwteam might give. Added value is defined as the benefits that bouwteams have over the traditional contracting methods (RAW & UAV-GC).

1.1.3 The Problem to Be Solved

Initially the assignment was described as getting insight into the pros and cons of bouwteam projects; however, this is already a "broad" solution. After contacting the consultants in the IACM department, it became clear what the underlying problem within the IACM department of TAUW is. TAUW has a lot of expertise in determining when to use what kind of procurement strategy regarding what partnership and accompanying contracts to use. The problem is, however, that their clients often ask if they can back up their advice with data. Especially when there is a recommendation to use bouwteams, consultants can only rely on personal expertise and experience. The lack of data of bouwteam projects to back up the recommendations of TAUW is especially important considering personal preference towards certain partnerships. Especially considering the increased popularity, see Section 1.1.2. Also, TAUW recognises that stigmas do exist about ECI contracts being more expensive. Literature also recognises that there are issues around the use of bouwteams. There is simply not enough data on whether the often mentioned benefits and negatives are true and whether they motivate the choice of bouwteams. This lack also causes the inability to make data-driven recommendations for the IACM department of TAUW. The problem is not only recognised at TAUW but also recognized by other

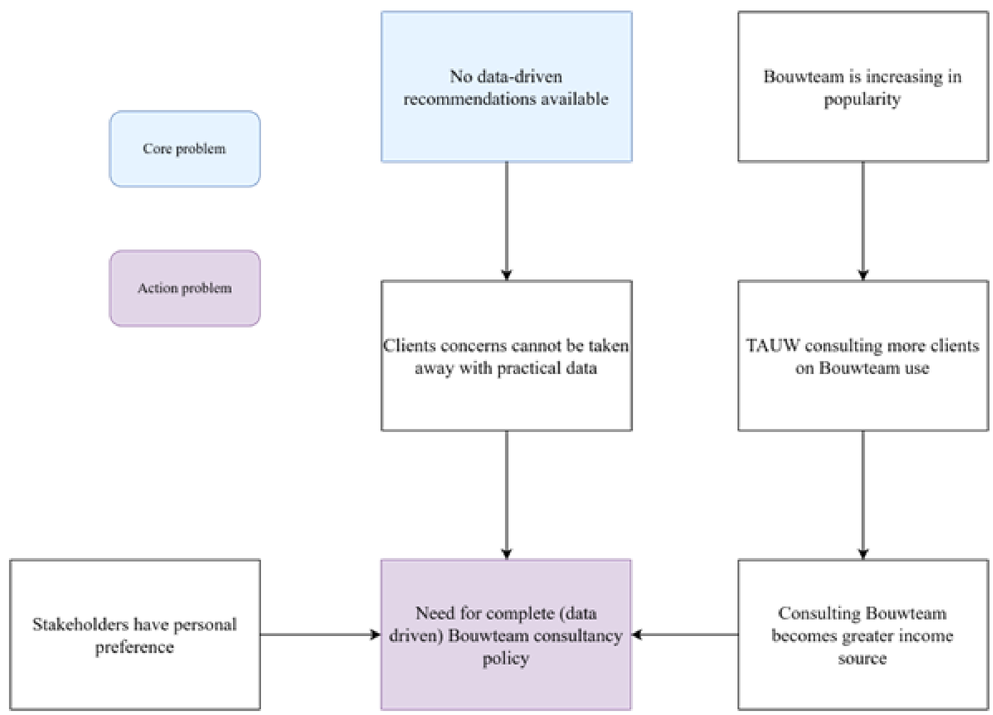

Figure 1.1: Problem Cluster

stakeholders. Rijkswaterstaat (2023) recognises that more experience is key to advising on follow-up projects. CROW (2020) recognises that there are challenges, for example with the lack of competition in two-phase contracts. Furthermore, earlier research recognises the difficulty of quantifying the benefits of bouwteams against the lack of competition (Lagemaat, 2015). These are all indications that more data on the use of bouwteams is needed to make accurate decisions. To solve the problem, there should be the possibility of referring to data-based findings when consulting which contract to use. This is currently not the case since there are no data-driven recommendations available.

Table 1.1: Norm and Reality

Reality	**Norm**
The recommendations on whether to use bouwteams or not are solely based on the expertise/experiences of the TAUW contract consultants	The recommendations on whether to use bouwteams should be based on consultant expertise/experience as well as data-driven insights

1.2 Problem-solving Approach

1.2.1 The MPSM

The thesis focuses on the main research question: "How do bouwteams compare to traditional contracting methods in infrastructure projects?"

The focus is on the added value of bouwteams and the cost implications that are associated with their use. To solve the given problem, the Managerial Problem-Solving Approach (MPSM) is used. This is a structured approach for solving practical problems, often used in the field of industrial engineering and management. The approach consists of seven phases (Heerkens & Van Winden, 2021).

- **Problem identification:**

This phase was performed in Section 1.1.3. The phase identifies the problem that is to be solved.

- **Solution planning:**

In this phase a plan of approach is set; it entails what to do, discover, and decide on to come to a solution. This phase is divided into six steps, in which a structured plan for generating a solution is made. It consists of gaining knowledge and developing methods, as well as collecting data and giving recommendations.

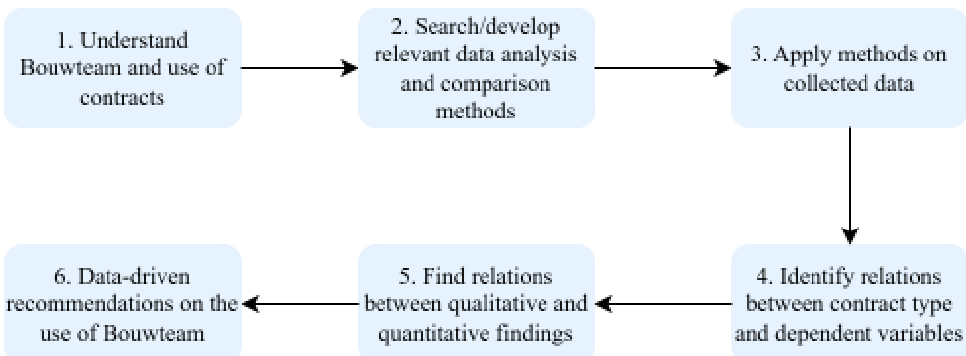

Figure 1.2: Solution Generation

1. Here a deep understanding of a bouwteam approach and the more traditional contracts is obtained. By traditional contracts is meant UAV with RAW specifications and UAV-GC (integrated contract). [See Chapter 2]
2. Data is obtained from experts in the field. Interviews with stakeholders are conducted to find/confirm the (perceived) added value of a bouwteam, driver criteria, negatives, and added value relationships to costs. As well as the analytical hierarchy process, which is utilised to weight and rank the most important drivers of using a bouwteam. [See Chapter 3 and Chapter 4]
3. Researched suitable methods are applied to the collected data. This contains an analytical hierarchy process to weight and rank the most important drivers of using a bouwteam. [See Chapter 4]
4. Relationships between the contract type (independent variable) and the dependent variables costs and added value are made, as well as the relation between added value and costs. [See Chapter 3, Chapter 4, and Chapter 5]
5. Integrate both the findings of the interview and literature (qualitative) with the results of the analytical hierarchy process (quantitative). [See Chapter 5]
6. Give data-driven recommendations regarding when to use a bouwteam over UAV-GC and UAV-RAW. [See Chapter 5]

The following research questions are answered in the solution planning phase:

Table 1.2: Research Question 1: Comparison of Bouwteam and Traditional Contracting Types

RQ 1	**How does a bouwteam approach relate to traditional contracting types (what makes it unique)?**
This question is answered by searching for relevant literature to give insight into how the main researched partnership form (bouwteam) differs from UAV-RAW and UAV-GC. This question aims to provide a thorough understanding of a bouwteam project, such that research of a quantitative as well as qualitative nature can be performed more targeted. Focus is on project structure and what kinds of added value a bouwteam has compared to traditional contracted projects.	
Variable of interest	Added Value, Costs - Identifying what is considered added value for a bouwteam - Identifying where and how costs could be different
Data gathering method	Literature research

This first RQ is answered in Chapter 2. This second RQ is answered in Chapter 3.

Table 1.3: Research Question 2: Methods for Analysing Qualitative Interview Data

RQ 2	**What are methods suggested by literature to draw conclusions from qualitative interview data?**
This question aims to provide relevant methods to evaluate the qualitative data that is to be obtained from interviews with relevant stakeholders (for example, project managers).	
Variable of interest	Not applicable
Data gathering method	Literature research

- **Analysing the problem:**

The problem is dissected further in this phase to make the solution relevant to the company problem. The following research questions are answered in this phase:

Table 1.4: Research Question 3: Relation between Contract Type, Added Value, and Costs

RQ 3	What is the relation between the contract type/partnership used in an infrastructure project and its added value and costs?
To find the answer to this question, both literature research and qualitative interview data, as well as data obtained from the AHP, are used to describe the relation between contract type, added value, and costs. This question tries to find the structure of the costs as well as the implications of it for different contracted projects (with the focus on the bouwteam partnership). The interviews are focused on the perception of using bouwteams regarding added value, what drives the decision for bouwteams in projects, and getting insight into the relationship with costs. The importance of the added value of motivating the choice for bouwteams is measured using AHP.	
Variable of interest	Contract type, Costs, Added value - Tries to find the relation between the variables contract type, added value, and costs - Tries to confirm found added value indicators found in literature, as well as find the not identified indicators for this variable - Is measured/derived with interviews, literature, and an AHP survey
Data gathering method	Empirical quantitative data, literature, interviews, AHP weights and ranks

This third RQ is answered in Chapter 2, Chapter 3 as well as Chapter 4.

Table 1.5: Research Question 4: Most Important Drivers for Choosing Bouwteams in Infrastructure Projects

RQ 4	What are the most important drivers for choosing bouwteams in infrastructure projects?
Tries to find the most important drivers for when to use bouwteams by using input from expert surveys and literature. The surveys use identified driver criteria from the previous RQs, the input is handled with AHP. The result is the ranking and weighting of main and sub-criteria (the drivers) from the interviewees, who are considered experts in the field.	
Variable of interest	Added value, Costs, Drivers - Drivers are weighed and ranked - Added value and costs are most likely (global) drivers
Data gathering method	Literature, Interviews, AHP (with survey input)

The fourth RQ is answered in Chapter 4.

- **Solution generation:**

In this phase, solutions that represent the outcomes of phases two & three are generated, guided by the knowledge obtained from phase three. Specific requirements are formulated on what the presentation and content of the recommendations should entail, as well as their importance.

Table 1.6: Research Question 5: Recommendations on the Use of Bouwteams in Infrastructure Projects

RQ 5	**What recommendations on the use of bouwteams in infrastructure projects can be made, and how should they be presented?**
Aims to summarise the findings in a cohesive way and describe them explicitly to TAUW. To answer this question, a helicopter view is needed to see the bigger picture of the findings. The recommendations are formulated and presented in such a way that they are useful for the consultation of a bouwteam.	
Variable of interest	All variables - Variables should be connected when applicable; for example, "Bouwteam contracted projects facilitate technical innovation, but this causes higher realisation costs."
Data gathering method	Selection of all gathered data

This fifth RQ is answered in Chapter 5.

- **Choosing a solution**

In this phase the best way of presenting the findings to TAUW is selected; this is done by consulting the IACM department. This is done by asking them what they find the most useful way for their consulting process. The best solution is highly dependent on the findings in the previous phases and the preferences of the IACM department.

Table 1.7: Research Question 6: Integration of Findings into TAUW's Current Policy

RQ 6	**In what way should the findings be integrated into TAUW's current policy?**
This question evaluates the best way of how the conclusions/findings should be used within the IACM department of TAUW.	
Variable of interest	Stakeholder satisfaction - In which way the solution is going to be integrated is based on stakeholder satisfaction
Data gathering method	Consultation of the IACM department

This sixth RQ is answered in Chapter 5.

- **Implementing the solution:**

This is the phase where the IACM department is consulted to identify where the findings on bouwteams can be best implemented in their current bouwteam consultancy policy.

- **Evaluation of the solution:**

When there is sufficient time, consultants could be asked about the quality and usefulness of the recommendations that have been implemented in the consultancy process.

1.2.2 Variables of interest

- **Costs**

Costs are an important variable in the research, since they are one of the most important drivers for choosing which contract(s) to use. Specifically, TAUW is interested in the costs in the bouwteam phase, costs that are incurred with rework (failure costs), and the overall costs of the project. Costs are not measured in absolute numbers but rather in relative terms, defined by experts in the field.

- **Added Value**

Added value refers to the benefits that are obtained from using bouwteams. “Added value” is a broad term; it can be defined as the value that is added to a project by using bouwteams. This can be in terms of time, quality, costs, and other benefits. Added value is measured in relative terms, defined by literature and experts in the field.

- **Contract/Partnership Type**

Contract/partnership type is the type of working that is used in a project; this can be a bouwteam, UAV-RAW, or UAV-GC contract. It is considered an independent variable since the type of contract is influenced by the costs and added value of a project.

- **Drivers**

Drivers are the factors that influence the choice of contract type; they can be seen as the reasons why a certain contract type is chosen. Drivers can be both qualitative and quantitative; they are measured in relative terms, defined by experts in the field. The drivers are identified in the interviews with experts and are used to weight and rank the most important drivers for choosing bouwteams.

1.2.3 Deliverables

The deliverables of this research include:

- A comprehensive report summarizing the findings of the research (this thesis document)
- Recommendations for TAUW on the use of bouwteams in infrastructure projects (with a flow chart on the decision-making process)

The recommendations are based on the findings of the research and include factors to consider which contracts the use of bouwteams for clients in the field of infrastructure projects. Key success factors are considered in this flowchart.

- A presentation of the findings to the IACM department of TAUW

It is agreed upon within the department that the most important findings in this research are delivered in a presentation to the IACM department of TAUW.

1.3 Theory and Models

1.3.1 Theoretical Perspective

The research is conducted from a post-positive empirical perspective, which means that the research is based on empirical data and aims to find objective truths. However, the research also acknowledges the subjective nature of human experience and the role of context in shaping understanding. (Trochim & Cornell University, 2007) The research is conducted in a structured way, using the MPSM as a framework for the research. The research is conducted in a qualitative and quantitative way, using literature research, interviews with experts in the field and AHP to rank and weight drivers for choosing bouwteam.

1.3.2 Sequential Mixed Methods

Since the nature of the data is both qualitative and quantitative, a sequential mixed methods approach is used. This two-phase approach was used to ensure an informed AHP setup (informed by the first phase), as done in similar studies (Sharma et al., 2021). The research starts with qualitative data collection (literature and interviews) to identify the most important added value, costs (implications), and drivers for bouwteams. This is followed by quantitative data collection (AHP) to weight and rank those drivers. The qualitative data is used to inform the quantitative data collection, and the quantitative data is used to validate the qualitative findings. This approach is suitable for this research since it allows for a comprehensive understanding of the problem and the drivers for choosing bouwteams. The research instruments used are thus:

- Literature research to identify the most important added value, costs, and drivers for bouwteams
- Interviews with experts in the field to confirm and expand on the findings from the literature research
- AHP to weight and rank the most important drivers for choosing bouwteams

1.3.3 Qualitative: Thematic Analysis

Thematic analysis is used following the guidelines of Braun and Clarke (2006); the method was found suitable after conducting systematic literature research. The following considerations were made for the use of thematic analysis:

- Ability to identify themes as well as generate new themes (for added value of bouwteams) (i.e., deductive and inductive)
- Measuring the subjective experiences of stakeholders
- Applicable to diverse datasets
- Easy to use for researchers with no experience in qualitative analysis
- Qualitative analysis is suited for policy recommendations
- Useful in triangulation

1.3.4 Quantitative: Analytical Hierarchy Process (AHP)

The identified and evaluated drivers derived from the interviews, literature research, and consultants within TAUW are measured on their relative importance. This is done to determine what motivates contractors, clients, and consultants to choose bouwteams in infrastructure projects. For this, an Analytical Hierarchy Process (AHP) is utilised, which falls under the Multiple-Criteria Decision-Making (MCDM) methods. This method can narrow down a complex decision problem into a hierarchical model (T. Saaty, 2008). Furthermore, this approach can convert qualitative expert judgement into reproducible quantitative data. The goal of using this technique is formulated as:

"To weigh and rank the typical importance of driver criteria for a bouwteam"

An important consideration for the reliability of the comparison is the consistency ratio (CR). To ensure reliable results, the ratio should not exceed 0.10 (Ishizaka & Labib, 2011; Saaty, 2012). In cases where this value is exceeded, the concerned experts are asked to revise their survey input. Since the pairwise comparisons can become an overwhelming amount (Ishizaka & Labib, 2011), the main criteria are limited to seven with at most three accompanying sub-criteria.

For the mathematical background of the AHP, the process is outlined in Appendix E.

1.3.5 Triangulation: Combining Qualitative and Quantitative Data

The findings from the different methods are integrated using method triangulation. This refers to using different methodologies to obtain data on the same phenomenon and can result in a broader understanding of a phenomenon of interest (Carter et al., 2014). By using this technique, recommendations can be made considering multiple data sources and increasing validity (Carter et al., 2014).

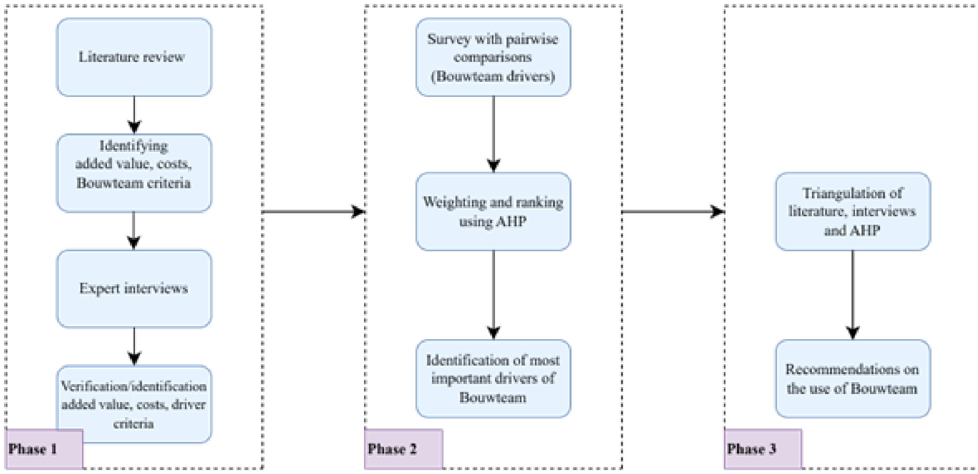

Figure 1.3: Overview of the Research Process

1.4 Reliability and Validity

1.4.1 Reliability

Reliability is ensured by using multiple data-gathering methods and clearly describing how conclusions are made. Furthermore, the interviews conducted follow a semi-structured format and are analysed in a structured way. Due to the semi-structured interview questions, reliability is ensured (because it becomes reproducible). Lastly, the steps undertaken to attain the results are documented precisely so that reproducing them will be straightforward and yield the same results. In the documentation of the interviews, subjectivity could occur in interpreting the answers of the stakeholders. This is why, after completely new initial code/topic identification, already evaluated transcripts are re-evaluated. In this way reproducibility is guaranteed. A sensitivity analysis is performed on the AHP results to ensure robustness and implementation ability of the AHP results (Saaty & Vargas, 2013). For this, a Monte Carlo simulation is used to see how sensitive the results are to changes in the input data (considering ranks and weights). If the results change significantly, it could indicate that the results are not robust and that the implementation of the AHP in the decision-making process can be difficult.

1.4.2 Validity

Validity refers to how well the results represent what we initially wanted to measure (Cooper & Schindler, 2013). This is ensured by deeply understanding the problem of bouwteam consulting and what insights are aimed for. So that the research questions can be formulated accordingly, and results solve the right problems. Furthermore, the interviews are conducted with a clear goal and focus on the relevant research question(s). In the AHP, (almost) every criterion is backed up by literature; this ensures there are few interpretation errors and criteria are valid (measured as intended). Lastly, validity is ensured by identifying relevant stakeholders; not only is the current function important, but also experience should be a factor.

1.4.3 Scope & Limitations

This research aims to improve the knowledge of the applicability of bouwteams so that TAUW can make better decisions regarding recommending and executing this way of working. This is done by investigating projects with different contracts on their qualitative and quantitative implications. To interpret and conclude on findings, a deep understanding of the process of the project phases in infrastructure is needed. Furthermore, an understanding of the relevant contracts and the process of recommending within TAUW is critical. Especially a comprehensive understanding of bouwteam is essential, within TAUW's consultancy as well as the broader context of infrastructure projects. Since procurement in the infrastructure is complex regarding its data, stakeholders, and unique characteristics for every distinct project, the research is narrowed with the following demarcations. Concerning costs, the cost is considered from the employer's perspective. The points of consideration are defined as the moment that the VO ("voorlopig ontwerp") is started until the moment that the project is executed (delivered). The initialisation, definition, and maintenance of the project are thus outside the scope of this research. Furthermore, the research is aimed at drawing conclusions from literature and experts, not from quantifiable project data.

- The execution of the thesis has a time constraint of 420 hours, which could impact the completeness/presence of the implementation and evaluation phase.
- There is looked at the costs from the originator's point of view; this means that the costs of other parties are not or only briefly looked at.
- Results from the AHP could be less generic due to the small number of experts participating in the survey.
- Results of the interview are limited to the expertise of the interviewed expert and how much this expertise is valued.

The above limitations should be considered when interpreting the results of the research.

1.5 Summary/Conclusion

This chapter has provided an overview of the context and motivation of the research. The approach to the research has been outlined. As well as its methods and theoretical perspective. Furthermore, the scope of the research was described, as well as its limitations and accompanying deliverables. The research finds data-driven recommendations for the use of bouwteams in infrastructure projects. By using a sequential mixed methods approach, in which stakeholder-expert perspectives are integrated. The research provides a comprehensive understanding of the added value and cost implications of bouwteams.

2

Literature Review: The Bouwteam

In this chapter a thorough examination of bouwteams within infrastructure projects is performed. The chapter highlights added values found in literature as well as cost implications of bouwteams. The focus is on how it differs from other ways of working in infrastructure projects. Specifically, the differences between solely contracting according to the UAV under RAW specifications and projects that solely use UAV-GC are investigated. This is done by answering the first research question.

1. How does a bouwteam relate to traditional contracting types (what makes it unique)?

2.1 What Is a Bouwteam?

An unambiguous definition of a bouwteam is not easily given, although some themes are always recurring: samenwerken (collaboration), teamwork (teamwork), integrale aanpak (integral approach), and project gebonden (project bonded) (Laeven et al., 2023). Laeven et al. (2023) define bouwteams as a partnership between the employer and contractor in construction projects. In which the contractors are involved as a collaboration partner early in the project. This collaboration starts in the preparation phase or the design phase of the project. The goal of the bouwteam is to develop an integral design and agreements about realisation and the realisation phase of the project. This design and these agreements are developed in collaboration and are supported by every stakeholder (Laeven et al., 2023).

An important term in the definition of a bouwteam is the common thread: collaboration. Collaboration is a key aspect of the bouwteam; its definition within the bouwteam, following Laeven et al. (2023), state that collaboration is a form of organisation in which individuals from autonomous organisations commit to establishing sustainable agreements to align parts of their work. It results in a diversity of collaborative relationships that are enduring yet finite. This collaboration is characterised by mutual trust, open communication, shared decision-making, and the exchange of information and knowledge between the involved parties (Scheper, 2024).

A bouwteam is an example of a two phase-contract, in which the first phase is executed under a bouwteam agreement. The second phase is subject to a traditional UAV contract or a UAV-GC (CROW, 2020).
In a traditional contract (UAV), the employer is responsible for the design of the project and the contractor for the realisation of the project. Whereas in integrated contracts (UAV-GC), the contractor is responsible for the design as well as the execution of the project. Furthermore, can a bouwteam be considered as a form of Early Contractor Involvement (ECI) following the definition of (Ishtiaque et al., 2024). Which defines ECI as any collaboration that takes place before the detailed design is finalised, typically involving contractors. Bouwteams are fitting this description. However, bouwteams are subject to Dutch bouwteam agreements and legal justifications, which make them a subcategory of ECI. A lot more research has been done on ECI than on the specific Dutch partnership bouwteam; this helps find added value that is not subject to the Dutch contractual context for a bouwteam. In this study, the definition of bouwteam (projects) must include the following points of interest:

– The contractor has a significant role in the design phase of the process.

Figure 2.1: Two-Phase Project Process

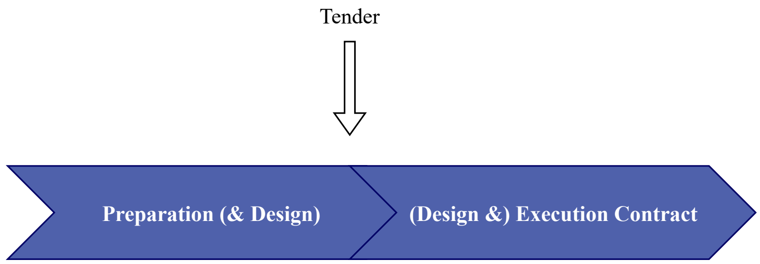

Figure 2.2: RAW and UAV-GC Project Process

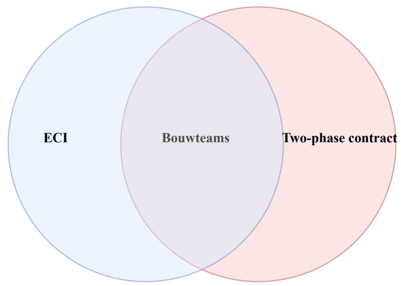

Figure 2.3: Overlap Between ECI, Two-Phase Contracts, and Bouwteams

- The contractor is involved in the design phase of the project as well as the realisation phase.
- The contractor is invited to submit a proposal for the realisation phase, typically being the sole bidder.
- The goal of the bouwteam is to cooperatively come to an implementation-oriented design that is executable.
- The bouwteam project is executed under a (Dutch) bouwteam agreement and a contract for realisation (UAV or UAV-GC).

2.2 Legislation

For the bouwteam agreement, several models can be used; Laeven et al. (2023) state three:

Table 2.1: Bouwteam Agreements

Agreement Name	**Organisation**
VGBouwmodel 1992	Bouwend Nederland
Modelovereenkomst Bouwteam DG 2020	Duurzaam Gebouwd
KBNL Model Bouwteamovereenkomst 2021	Bouwend Nederland

The KBNL Model Bouwteamovereenkomst 2021 is a modernised version of the VGBouwmodel 1992. The common thread in this model is the added value of the contractor and a fair and consistent role and risk distribution. The model is suitable for both small but also bigger projects in the infrastructure. This model is constructed by the juridical specialists within the organisation Bouwend Nederland. (Laeven et al., 2023).

The model of Duurzaam Gebouwd (DG) 2020 is made in the belief that a set of practical game rules was needed for the collaboration in a bouwteam. The model entails tasks and roles, but also what the requirements are regarding attitude and behaviour. In this model sustainability and construction safety are among the provisions. DG 2020 is applicable to a broad range of projects but does need some further elaboration for every project. (Laeven et al., 2023)

The most important differences between the model of KBNL 2021 and DG 2020 are that DG 2020 gives more textual explanation on the bouwteam process, and KBNL 2021 is more compact. The DG 2020 not only gives room for price negotiation but also on aspects that affect this price (such as risks). (Laeven et al., 2023)

In the year 2025, the revision of the DG 2020 model is presented, the DG 2025. The most essential changes and improvements are clearer guidelines to facilitate communication, shared goals, and joint vision. Risk mitigation and cost control: extended agreements to identify risks earlier and mitigate them better as well as avoid unexpected cost overruns. Furthermore, does the new model strive to be more flexible than its predecessor. (PAO Techniek en Management, 2025)

Clients and contractors are, however, not limited to the model agreements that are available on the market. Laeven et al. (2023) state that there are several models written by clients (mostly for a specific project). It is important to note that the nature of the bouwteam agreement can affect the performance of the project.

Regarding the legislation of the realisation phase, as already stated, it is usually performed under a UAV or a UAV-GC. Uniform Administratieve Voorwaarden (UAV) (Uniform Administrative Conditions) contains a set of rules that can be applied to contraction works in construction and technical installation works. A new model has been introduced (UAV 2012 (version 2025)); this was needed because of changes in the civil code. UAV-GC (UAV Geïntegreerd Contract) (UAV integrated contract) are rules that are applicable to integrated contracts. In 2025 a new model is introduced that is intended to substitute the version of 2005. (MKB INFRA, 2025)

The bouwteam officially stops after the project has been transitioned into the realisation of the work (in which the project is now subjected to the legislation of the UAV or UAV-GC). Therefore, the collaborative dynamics established during the bouwteam phase risk breaking down if they are not deliberately maintained. Laeven et al. (2023) state that keeping the collaborative environment could be essential. It is important that the involved parties are not taking over each other's defined tasks, but keep supporting and thinking along is essential in this phase. There is also the possibility to make agreements in the bouwteam agreement model on how to proceed after the bouwteam or design phase.

In the bouwteam agreement, it is also possible to include other parties such as architects or subcontractors. The parties' liability is captured within the DNR (De Nieuwe Regeling), which is a legal framework.

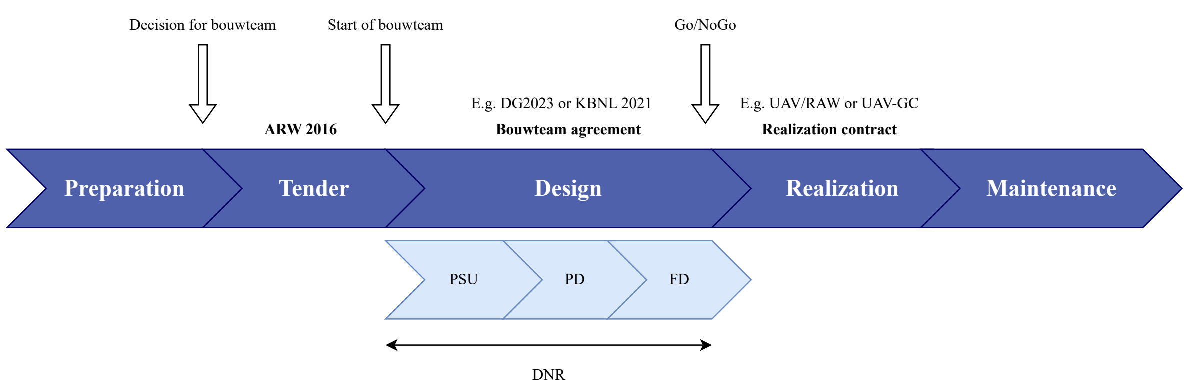

Figure 2.4: Process of a Bouwteam

The main differences between a bouwteam and solely working with a UAV contract or UAV-GC are thus the stage in which the contractor joins the project. In a bouwteam project, the contractor is very early involved in the project, often at the start of the design phase, and then designs together with the client. Furthermore, in a bouwteam project, there is a focus on collaboratively working towards a constructible solution that meets the project's requirements.

2.3 Added Value of Bouwteams

According to the literature, working with a bouwteam in a project does come with several benefits, which could make the bouwteam an interesting option for a lot of projects. An overview of the benefits associated with the use of bouwteams is given in Appendix A.

Main found benefits:

Innovation
Innovation seems to be a commonly identified added value. Multiple studies have found a link between innovation and ECI (Chan et al., 2003; Farrell & and, 2022; Mosey, 2009). Especially the fostering of innovative solutions is thought to be a benefit (Scheepbouwer & Humphries, 2011). Rijkswaterstaat (2023) mentions that due to an integral collaboration in which both parties can share their thoughts on different aspects of the project. The chance of innovative solutions is high.

Collaboration
Collaboration is not only a requirement when working within a bouwteam. It is also seen as an important benefit within bouwteam projects. Due to collaboration, the transition to the realisation phase becomes smoother (Rahman & Alhassan, 2012). Conflicts are also less prominent due to transparency considering the costs and a collaborative environment (Bayliss et al., 2004; Mosey, 2009; Rahmani, 2020). The intensive collaboration in the design phase also leads to knowledge gains (Stichting Innovatie & Arbeid, 2012).

Quality
Studies show that there could be a higher quality of the solution (Farrell & and, 2022; Lenferink et al., 2012; Rahmani, 2020), when quality is defined as satisfying the legal, aesthetic, and functional requirements (that were defined in the contract) (Arditi & Gunaydin, 1997). There is also found to be less rework and defects due to the close integration of the participants.

Scope Changes & Complexity Reduction
In literature there is often mention of constructability within collaborative partnerships. Constructability is thought to be higher (Eriksson et al., 2019). This is due to the long collaboration between client and contractor (Eriksson et al., 2019) and especially due to the expertise that the contractor brings within the design phase of the project (Rahmani, 2020). Laeven et al. (2023) also state that the contribution of the contractor in the design phase could be a driver for using bouwteam to increase constructability.

Risk Management
Regarding risks, literature mentions that there is a greater ability to identify risks, allocate them among the actors, and mitigate them. This is due to the collaborative environment in which contractors and clients can combine their knowledge to identify (Rahmani, 2020) and then allocate them more balanced (Laeven et al., 2023). Furthermore, does the fact that the contractor and client know each other's risks create the ability to help each other with mitigating each other's risks (Rijkswaterstaat, 2023).

Sustainability
Sustainability is becoming increasingly important in the delivery of projects in infrastructure (Kivilä et al., 2017). Laeven et al. (2023) state that the involvement of contractors in the design phase can be a driver to reach sustainability goals. Kivilä et al. (2017) state that collaboration can make the fulfilment of project goals easier. This could, for example, be the case with coming up with innovative solutions, which would help in achieving sustainability (Ishtiaque et al., 2025).

2.4 Cost Implications of Bouwteams

Regarding the costs of a bouwteam, there are several aspects that are mentioned in the literature. These aspects are discussed below:

Lack of Competition
As literature mentions, there are various benefits that the use of bouwteams in infrastructure projects has. There are also concerns about the use of bouwteams, especially considering bouwteams' costs. One of the most important concerns is the lack of competition (Laeven et al., 2023). Contractors cannot be played off against each other (Stichting Innovatie & Arbeid, 2012).

Total Costs and Design Phase Costs
Furthermore, some studies claim ECI tends to have higher overall costs (Eadie & Graham, 2014; Owen, 2009). Rijkswaterstaat (2023) acknowledges that two-phase contracts require intense effort in the design phase combined with increased expenses. Ishtiaque et al. (2025) also recognise that preconstruction costs are higher in ECI. In some cases, the overall cost of using ECI is reported to be lower than the initial estimate because of coming up with innovative solutions requiring fewer resources (Song et al., 2009).

Failure Costs
Consider costs in the realisation phase; the use of bouwteams is thought to reduce the failure costs due to a better design (Stichting Innovatie & Arbeid, 2012).

Cost Control
Another positive effect on the costs is a higher level of cost control in the project. Due to the involvement of the contractor in the design phase, it is believed that there is greater predictability in the costs (Finnie et al., 2021; Lenferink et al., 2012; Song et al., 2009). Especially the construction expertise of the contractor is stimulating this control (Rahmani, 2020).

Tender Costs
According to Klakegg et al. (2020), the costs associated with the tender could be less due to the shorter contracting process. However, these costs could also be higher due to the time invested in prequalification of a suitable contractor (Marius et al., 2022).

Whether the use of a bouwteam leads to higher or lower costs is thus not unambiguous. Project complexity, the specific project context, and the execution of the bouwteam approach all play a role in determining the overall cost of the project.

2.5 Summary/Conclusion

In this chapter the bouwteam has been defined, and the differences with other traditional contracting types have been highlighted. The added value of bouwteams has been discussed, as well as the cost implications of using a bouwteam. The bouwteam is a unique form of collaboration in infrastructure projects, characterised by early contractor involvement in the design phase. The use of bouwteam is noted to lead to various benefits such as innovation, improved quality, and better risk management. However, it also raises concerns about costs, particularly due to the lack of competition and potentially higher design phase expenses. The overall cost implications can vary depending on the project's context and execution. The findings in this chapter inform the following chapters, where expert opinions and AHP analysis further validate and prioritise the identified benefits and costs.

In summary, the bouwteam approach offers significant advantages in terms of collaboration and project outcomes, but it also necessitates careful consideration of the associated costs and potential trade-offs.

3

Stakeholder Analysis

This chapter discusses the opinions and experiences of various stakeholders (who are considered experts) on the added value and costs of bouwteam projects. These are compared to traditional projects, which solely use RAW or UAV-GC contracts. The stakeholders that are discussed are mainly stakeholders on either the client's or contractor's side. The output of the chapter gives insights into the perspectives of these stakeholders, which provide a more nuanced and practical understanding of the benefits and cost implications bouwteams possess. In addition, the relationships between added value and costs are explored. This is all done by analysing interviews conducted with various stakeholders in the infrastructure. The chapter also discusses the methodology used for the analysis, which mainly considers the thematic analysis approach. The chapter concludes with a summary of the key findings of the thematic analysis and their implications for the use of bouwteams in infrastructure projects.

The research questions answered in this chapter are:

2. What are methods suggested by literature to draw conclusions from qualitative interview data?
3. What is the relation between the contract type used in an infrastructure project and its added value and costs?

3.1 Thematic Analysis

As a result of a systematic literature review (SLR), a suitable method for analysing the obtained interview data was chosen. The method is thematic analysis following six steps (Braun & Clarke, 2006). Thematic analysis is a method for identifying, analysing, and reporting patterns (themes) within data. It minimally organises and describes the data set in rich detail. It goes beyond this and interprets various aspects of the research topic. Thematic analysis is not tied to any specific theoretical framework, making it a flexible tool for the qualitative part of this research. Main considerations for the use of thematic analysis are:

- Ability to identify themes as well as generate new themes (for added value of bouwteams) (i.e., deductive and inductive)
- Measuring the subjective experiences of stakeholders
- Applicable to diverse datasets
- Easy to use for researchers with no experience in qualitative analysis
- Qualitative analysis is suited for policy recommendations
- Useful in triangulation

Thematic analysis is a method that can be used to analyse qualitative data, such as interviews, focus groups, or open-ended survey responses. It involves identifying patterns or themes within the data and interpreting their meaning. Thematic analysis is a flexible method that can be applied to various types of data and research questions. It is particularly useful for exploring subjective experiences and perspectives of stakeholders, making it suitable for this research on bouwteams.

Braun and Clarke (2006) state that the theoretical position used for the thematic analysis is essential to make a good analysis. The following aspects were considered for the analysis:

1. Theme Demarcation
Theme demarcation is the process of defining the boundaries of what is considered a theme. In this research, themes are identified when the initial code predecessor is mentioned at least 5 times. For example, once by five stakeholders, indicating its relevance and importance in the context of bouwteams. Due to the semi-structured nature of the interview, some themes are predetermined. This is because questions on them were included in the interview topic guide; see Table 3.1. However, the thematic analysis also allows for the emergence of new themes that may not have been anticipated at the outset. This flexibility is particularly useful in exploring the subjective experiences and perspectives of stakeholders involved in bouwteams, as it allows for a comprehensive understanding of their views on added value and costs.

2. Semantic vs. Latent
Semantic themes focus on the explicit meanings of the data (i.e., on the words of the interviewees), while latent themes go beyond the surface level of the words used to explore underlying meanings and assumptions. In this thesis, mostly semantic, but also latent, themes are identified. Semantic themes are identified based on the direct statements made by stakeholders, while latent themes are derived by interpreting the underlying meanings and assumptions behind those statements. This approach allows for a comprehensive understanding of the data, capturing both the explicit content and the deeper implications of the stakeholders' perspectives.

3. Inductive vs. Deductive
Regarding the inductive vs. deductive approach, this research mainly uses a deductive approach. This means that the analysis is guided by existing theories and concepts related to bouwteams, such as the added value and costs of bouwteams. However, an inductive approach is also used to identify new themes that may emerge from the interview data. These are themes that arise from the data itself; it is expected to be on the tendency of specific introduced added value and cost implications. Furthermore, there is attempted to identify more kinds of added value that have not been guided on. This combination of deductive and inductive approaches allows for a comprehensive analysis that builds on existing knowledge identified in Chapter 2 while also being open to new insights.

4. Epistemological Position
The epistemological position of this thematic analysis is critical realist. This entails that the analysis acknowledges the existence of an objective reality while also recognising that our understanding of that reality is influenced by our subjective experiences and interpretations (Sayer, 1992). This position allows for a nuanced understanding of the data, recognising that while there are objective facts about bouwteams, the meanings and implications of those facts are shaped by the perspectives of the stakeholders involved. The analysis aims to uncover both the objective realities of bouwteams and the subjective interpretations of those realities by the stakeholders.

The topics of added value and costs were predetermined for the interviews, which were based on literature research; see Chapter 2. The topics that are discussed in the interviews are shown in Table 3.1. These were chosen based on their relevance to the research questions and the existing literature; see Chapter 2. The interviews were designed to explore these topics in depth, allowing stakeholders to share their perspectives and experiences related to the added value and costs of bouwteams. The semi-structured format of the interviews allowed flexibility in the conversation while still ensuring that all relevant topics were covered.

Table 3.1: Interview Topics

Main Topic	Subcategory
Stakeholder Experience	–
Added Value	Innovation & Sustainability
	Risk Management
	Collaboration
	Cost Efficiency
	Time Efficiency
	Quality
	Project Complexity Reduction
	Exploring Added Value
Costs	Cost Structure
	Cost Control
	Cost Overruns
	Exploring Cost Implications
Differences with Traditional Projects	vs. UAV
	vs. UAV-GC
Key & Driving Factors	Requirements
	Drivers
	Barriers/Disadvantages
Conclusion	Summary
	Key Takeaways

Example questions: What are your thoughts on the presence of innovations in bouwteam projects?
What are the differences with traditional contracting methods?
What do you think are the most important motivations to opt for a bouwteam?

With the predetermined theoretical position and topics, the following steps were taken to analyse the data (Braun & Clarke, 2006):

1. Familiarisation with the data: The first step involved reading and re-reading the interview transcripts to become familiar with the content. This included noting initial impressions and potential themes.

2. Generating initial codes: The next step involved systematically coding the data, identifying relevant features that could form the basis of themes.

3. Searching for themes: After coding, the next step was to collate codes into potential themes. This involved grouping related codes and identifying overarching themes that captured the essence of the data.

4. Reviewing themes: The identified themes were then reviewed to ensure they accurately represented the data. This involved checking if the themes worked in relation to the coded extracts and the entire dataset.

5. Defining and naming themes: Once the themes were finalized, they were defined and named to reflect their content accurately. This involved writing detailed descriptions of each theme and its significance in relation to the research questions.

6. Producing the report: The final step involved writing up the analysis, integrating quotes from the interviews to illustrate each theme, and providing a comprehensive overview of the findings.

It is important to note that the thematic analysis is iterative, meaning that the researcher may go back and forth between the steps as new insights emerge.

3.2 Stakeholders

In this section, the stakeholders are discussed. The stakeholders are divided into three groups: stakeholders from the client's side, stakeholders from the contractor's side, and external consultants. Each stakeholder has their unique perspective on the added value and costs associated with bouwteam projects. The participants were selected based on their expertise and experience in the field of bouwteams, ensuring that the insights gathered would be relevant and valuable for the research.

Table 3.2: Stakeholders Interviewed for This Research

ParticipantID	Role	Function
N1	Contractor	Rayonmanager
N2	Client	Projectleider domein mobiliteit
N3	Contractor	Commercieel manager
N4	Client	Sr. Contractmanager
N5	Client	Projectleider uitvoering fysiek
N6	Contractor	Hoofd verwerving
N7	Client	Programmamanager infrastructurele uitvoeringsprojecten
N8	Consultant	Sr. Contractmanager
N9(1)	Client	Opdrachtgever en teamleider stadsdeelbeheer
N9(2)	Client	Projectcontroller Fysieke Projecten
N9(3)	Client	Projectmanager, Gebieds- en Projectontwikkeling (GPO)

The last interview/discussion was conducted with three experts from the client side

Experience of Stakeholders:

N1: Rayonmanager with more than 20 years of experience in the infrastructure industry. Started as a project manager in which he at the time was already involved in the projects were the bouwteam concept was used but not officially labelled as bouwteam. Currently working a lot with bouwteams as a Rayonmanager, also has experience in the guidance of bouwteams.

N2: Project leader in the mobility domain with approximately 15 years of experience at his current organisation. Has been involved in several big bouwteam projects. The organisation started using bouwteams approximately 5 years ago (2020).

N3: Commercial manager with over 30 years of experience in the sector. He has been involved in a lot of bouwteam projects; he has not only been on projects on the contractor's side but also on the client's side before his current function (approximately 5 years).

N4: Senior contract manager with over 25 years of experience in the infrastructure sector, for both small and big projects. Approximately 15-20 years with contract types within the sector. Regarding bouwteams, he has been involved for around 5-8 years.

N5: Project leader with approximately 15 years of experience at his current organisation. Having been involved in various bouwteam projects (~10), the organisation is still mostly using RAW contracts.

N6: Head of acquisition with over 30 years of experience in the sector. Has been involved with almost all types of tendering and contracting types within the Dutch infrastructure.

N7: Program manager with over 20 years of experience in his current organisation. Former senior project leader and has a lot of experience with the use of UAV-GC within projects. Has been involved in big bouwteam projects in which the organisation is gaining experience for about ~5 years.

N8: Senior contract manager with over 14 years of experience with bouwteams. In his role, he is responsible for advising clients on what kind of partnership or contract type to use. This includes advising on the use of bouwteams.

N9: Three experts from the client side, the organisation has been using bouwteams for approximately 7 years. N9(1) has obtained bouwteam experience for approximately 7 years. The second expert, N9(2), has been involved in the use of bouwteams for around 3 years at the current organisation. Lastly, N9(3) has been involved in the use of bouwteams for around 15 years.

Due to the expertise from the stakeholders in working directly with bouwteams in infrastructure projects. The interviewees are experts in the field of bouwteams. By the diversity of the stakeholders, a balanced view on the added value and costs of bouwteams is created.

3.3 Results of the Thematic Analysis

In this section, the results of the thematic analysis are presented. For every six steps presented in Section 3.1, process and/or results are briefly discussed.

3.3.1 Familiarisation With the Data

The first step of the thematic analysis involved familiarizing oneself with the data. This was done by reading and rereading the interview transcripts to become familiar with the content. Initial impressions and potential themes were noted during this process, with the help of highlighting the transcribed texts. The interviews were conducted in Dutch and were initially not translated into English to ensure that the nuances of the language were preserved.

3.3.2 Generating Initial Codes

The next step involved systematically coding the data, identifying relevant features that could form the basis of themes. The initial codes were generated based on the predetermined topics and the stakeholders' responses. Since the interview structure contained predetermined topics, the initial codes were directed at the general tendency of these topics. The codes were generated by highlighting relevant sections of the transcripts and assigning codes to them. The codes (which are connected to the quotes of the respondents) were then saved and organised in Excel.

Table 3.3: Example of Initial Code

Transcript highlighting	**Initial Code**	**Description**
Dan heeft hij op één gegeven moment ook heel veel dingen zelf al doorgelopen, hebben allerlei beslissingen genomen, een contract document gemaakt. Daarop is het gegund. Ja, dan is heel vaak geen ruimte meer om nog innovatieve. Ik zeg niet dat het niet kan hoor, maar dan is er minder ruimte om nog innovatieve ideeën in te brengen.	Less Innovation in RAW	Because client has already determined several aspects of the project, there is less room for innovative ideas during the execution.

3.3.3 Searching for Themes

After coding, the next step was to combine the codes into potential themes. This involved grouping related codes and identifying overarching themes that captured the essence of the data. The themes were identified based on the frequency of the codes and their relevance to the research questions in this chapter. After that, the themes were grouped into overarching categories.

3.3.4 Reviewing Themes

The identified themes were then reviewed to ensure they accurately represented the data. This involved checking if the themes worked in relation to the coded extracts and the entire dataset. The themes were refined based on this review, ensuring that they were coherent and meaningful.

3.3.5 Defining and Naming Themes

A thorough description of every defined theme was written, which included the essence of the theme and illustrative quotes from the interviews. The themes were named to reflect their content accurately, ensuring that they were easily understandable and relevant to the research questions. The themes were also linked to the predetermined topics, ensuring that they aligned with the overall structure of the analysis. Finally, the themes were used as input for a concise summary of experts' perspectives on bouwteam and input for the AHP, of which the latter is discussed in the next chapter. An overview of the defined themes, descriptions, and illustrative quotes is shown in Appendix B.

3.3.6 Producing the Report: The Most Important Findings of the Thematic Analysis

The final step involved writing the summary of the analysis, which synthesised the findings coherently presented them. This included discussing the themes shortly and providing a clear, concise description of the relevant findings from the stakeholder interviews.

The thematic analysis of the conducted interviews revealed that most of the qualitative benefits of bouwteams that were found in Chapter 2 were also considered benefits by the experts in the field; they experienced them in practice or thought them to be true. The most insightful finding of the thematic analysis was the nuance in how the added value is perceived. Most experts were enthusiastic about the use of bouwteams but also had some concerns about the correct use of the bouwteams. This involved a lot of requirements from both the contractor and the client's side, but also dangers were discussed that could arise if these requirements were not met. Relations were also identified between the added value and costs of bouwteams. As well as what cost implications bouwteams and traditional projects (UAV and UAV-GC) have in general.

The most important findings consist of both added value and perceived critical risk in the use of bouwteams:

- The collaboration in bouwteams is perceived to be better than in traditional projects. It is seen as a reason for other qualitative benefits in the project, such as increased capacity and expertise in the design phase. But also seen as a benefit on its own, leading to more satisfaction among stakeholders.
- Bouwteams are believed to foster innovation and sustainability, although literature in Chapter 2 states that these values are also emerging simultaneously. Experts mainly think it is required in the scope of the project.
- The cost implications of bouwteams are perceived to be higher, especially the bouwteam phase, but experts state that this does not always have to be the case. Experts also note that the added value of bouwteams can justify the higher costs (if any). One thing stakeholders do agree on is that the control over costs is much better in bouwteams.
- Risk management in bouwteams is better due to the involvement of the contractor in the design phase, leading to better risk identification and management.
- Added value that has not been identified from the literature in Chapter 2, such as the beneficial impact on the community, has been captured.
- Time implications of bouwteams are generally positive but can be negative if the contractor is not intrinsically motivated to be efficient in the design phase.
- A successful bouwteam is not guaranteed; it requires intensive care and a different mindset from both contractor and client compared to traditional projects. According to experts, there are several pitfalls when using a bouwteam.
  - A bouwteam requires a new mindset from both contractor and client, which is not always present. This mindset should be focused on collaboration and transparency. Not on trying to make as much profit as possible, which is often leading to conflicts.
  - The contractor is not always intrinsically motivated to be efficient in the design phase. This can lead to increased costs and delays.
  - The client does not provide enough input and guidance during the bouwteam phase.
  - There is a lack of transparency and openness between the parties.
  - The parties do not have a good match, and collaboration is not optimal.

- There is a lack of trust between the parties, which can hinder collaboration.
- Changes in the bouwteam composition during the project can lead to disruptions in the workflow (e.g., loss of knowledge or a different mindset from bouwteam members).
- The bouwteam is constructed inefficiently (e.g., too many people involved, or not the right people involved).

For an overview of the defined themes, descriptions, and illustrative quotes, see Appendix B. The findings of the thematic analysis, considering drivers, are used as input for the AHP in the next chapter.

3.4 Conclusion/Summary

In conclusion, the thematic analysis provided valuable insights into the perspectives of stakeholders on the added value and costs of bouwteams in infrastructure projects. The analysis revealed that while bouwteams are generally perceived to have significant qualitative benefits, there are also concerns about their implementation and the potential for increased costs. Especially the fact that when a bouwteam is not implemented correctly, it can lead to increased costs and risks. When experts note a relation between costs and the use of a bouwteam, the most given reason is the increased cost in the bouwteam phase. Considering the cost drivers for the traditional ways of working (RAW & UAV-GC). The experts/stakeholders generally attribute this to the high amount of VTWs.

4

Method: Analytic Hierarchy Process (AHP) for Bouwteam Drivers

This chapter explores the motivations for using a bouwteam in infrastructure projects. The chapter answers the research question:

4. What are the most important drivers for choosing bouwteam in infrastructure projects?

The chapter answers this research question by using the results of the Analytic Hierarchy Process (AHP), for which the criteria (consisting of bouwteam drivers) are determined with the help of the thematic analysis performed in Chapter 3 and literature in Chapter 2. The AHP in this study is aimed at determining the relative importance of the drivers and sub-drivers for each expert that participated. The participants are instructed to base their answers on what the project scope is for an average bouwteam project. Furthermore, are they instructed to consider what they find important drivers, so not what the common practice is in their organisation. To see the participants' instructions, see Appendix D. The results of the AHP are presented in this chapter, followed by a sensitivity analysis and a discussion. The chapter concludes with a concise summary and a recap of the results.

4.1 Setup of the AHP

To assess the relative importance of the drivers identified through interviews, literature review, and input from TAUW consultants, an Analytic Hierarchy Process (AHP) was conducted. The purpose is to understand what motivates contractors, clients, and consultants to select bouwteam arrangements in infrastructure projects. The AHP, a well-established Multiple-Criteria Decision-Making (MCDM) method, structures complex decision problems into a hierarchical framework (T. Saaty, 2008). The objective of applying this method in this study is as follows:

"To weigh and rank the typical importance of driver criteria for a bouwteam"

The data is collected through an AHP survey; see Appendix D. The AHP survey is designed to collect data from experts in the field of infrastructure projects. The survey requires input using the T. Saaty (2008) 1-9 scale:

Table 4.1: Fundamental Scale of Pairwise Comparisons in AHP

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

Values 2, 4, 6, and 8 are intermediate values between the adjacent levels.

4.2 Driver Selection for the AHP Survey

Not all drivers and sub-drivers that were identified in the literature research in Chapter 2 and the interviews in Chapter 3 are included in the AHP survey. The drivers that are included in the AHP survey are the drivers that were identified as most important by the literature review, interviews, and earlier studies on defining drivers for ECI. The selected drivers were also reviewed with a contract manager within TAUW to ensure all the relevant drivers were included.

Cost Benefits

The driver **Cost Benefits** is included in the AHP survey, as it is a frequently mentioned driver and benefit in literature, see Appendix A. Furthermore, it is also mentioned in the interviews, see Appendix B. Within the main driver, the sub-drivers *Design cost savings*, *Realisation phase cost savings*, and *Cost control* are included. The sub-driver cost control is thought to be the most important sub-driver. Quotes such as “Ja omdat je veel meer sturing hebt vanuit je proces op de kosten” ~N1 and “Meestal zijn de faalkosten minder” ~N2 indicate that cost benefits and especially cost control are a reason to choose a bouwteam.

Sustainability

The driver **Sustainability** is included in the AHP survey, as it is a key consideration in infrastructure projects. Especially in the last years, has it become an increasingly important area in construction projects of all kinds (Ishtiaque et al., 2024). Also, is working in bouwteams related to the ability to foster sustainability, see Appendix A. The sub-drivers *Long-term viability*, *Less environmental impact*, and *Stakeholder satisfaction* are included to capture the three aspects of sustainability. Quotes such as “Als je vroeg aan tafel zit, kun je waarschijnlijk nog wel wat duurzaamheid in oplossingen of innovatieve ideeën inbrengen” ~N3 and “Er zit een beetje overlap in met innovaties. Maar je kunt gezamenlijk kijken wat de mogelijkheden zijn om duurzamer te werken en daar de juiste keuzes in maken. Bouwteam helpt daar echt bij.” ~N8 confirms the importance of sustainability in the context of a bouwteam.

Quality

The reason to include **Quality** as a main driver in the AHP survey is that literature often mentions quality as an important benefit of working in a bouwteam; see Appendix A. Also is it mentioned in the interviews as an important driver to choose for a bouwteam, see Appendix B. The sub-drivers *Compliance with standards*, *Durability / performance*, and *Reduced defects* are included to capture the different aspects of quality. Experts confirm the literature: “Prijs voor de realisatiefase die niet in concurrentie tot stand is gekomen, heeft de aannemer ook een prijs. Waar binnen die het werk gewoon goed zou moeten kunnen uitvoeren en niet tijdens het werk nog op zoek hoeft naar allerlei besparingsmogelijkheden die eventueel ten koste gaan van kwaliteit.”~N8 and “Waar ik wel mee eens ben. Is dat een bouwteam sowieso niet voor minder kwaliteit zorgt.”~N2.

Innovation
The driver **Innovation** is included in the AHP survey, as it is often mentioned in literature as a benefit of working in a bouwteam; see Appendix A or Chapter 2. Especially, the fostering of innovation is highly valued in the context of a bouwteam; see appendix A. Innovation is split into two sub-drivers in the AHP: *Technical innovation* and *Process innovation*. Experts confirm the importance of innovation in the context of a bouwteam: "Je kunt innovaties makkelijker in een via een bouwteam in uiteindelijk in de uitvoering krijgen, omdat je van tevoren met elkaar afspreekt en van tevoren dat ook afgeprijsd hebt en dergelijke."~N2 and "Ja waar een stukje innovatie nodig is. "~N1 **On what kind of projects are suitable for bouwteam*.

Risk Management
The driver **Risk Management** is included in the AHP survey, as it is a key consideration in infrastructure projects. (Early) *Risk identification*, *Risk allocation*, and *Risk mitigation* are frequently mentioned benefits in literature; see appendix A. Interview quotes that confirm the ability of better risk management are: "Ander voordeel is dat de beheersmaatregelen voor zowel de opdrachtgever als aannemer eigenlijk gezamenlijk worden bepaald. Hoe kunnen we dit risico het beste mitigeren?"~N8 and "Dat is dat de meerwaarde van een bouwteam dat je samen vanaf het begin die risico's goed in beeld hebt."~N3.

Project Clarity & Complexity Reduction
Regarding **Project Clarity & Complexity Reduction**, this is considered an important benefit of working in a bouwteam. Especially the fact that due to the contractor, the project's constructability is improved, leading to a clearer understanding of the project requirements and potential challenges; see Appendix A. This aligns with the sub-drivers used in the AHP survey: *Constructability*, *Increase transparency*, and *Reduce scope changes*. Quotes that confirm the importance of this driver include "Alleen doordat je het vanuit meerdere perspectieven en belangen goed bekijkt, wordt er een vorm gecreëerd, dan krijg je meer zekerheid en voorspelbaarheid dat een gezamenlijke keuze is: één goede keuze waar je je allebei verantwoordelijk voor gaat voelen."~N4 and "Maar daar zie je dus het aantal meerwerken drastisch minder is dan bij een traditionele aanbesteding."~N2.

Collaboration
The driver **Collaboration** is included in the AHP survey, as it is a key consideration in infrastructure projects and seen as a fundamental mean, end, requirement, and success factor in bouwteam, see table in Appendix A and Section 2.3. The ability to collaborate effectively is often mentioned as a benefit of working in a bouwteam, see Appendix A. Concerning collaboration, there is typically reference to the importance of the collaboration early in the project. This ensures expertise from both parties in the project, increased capacity, and fewer conflicts. The sub-drivers are therefore *Workforce optimisation*, *Conflict reduction*, and *Better communication*. Quotes that confirm the importance of this driver include "Het allerbelangrijkste is dat die aannemer in die bouwteamfase iets van zijn kennis en expertise kwijt kan."~N1 and "Je kent het proces beter en dan is er meer begrip voor elkaar, dus dat is het sociale, dan is een aannemer ook sneller bereid en ook een gemeente, om iets te doen hè voor elkaar, omdat je elkaar beter kent."~N1.

Not Included
A driver that is not included in the AHP survey is *Time Management*. This driver was identified in the literature review and interviews, but it was not included in the AHP survey. This is because it is partly overlapping with other main drivers, such as **Project Clarity & Complexity Reduction** and **Collaboration**. The AHP survey focuses on the most distinct drivers to avoid redundancy and cognitive overload for the participants. Also does it score a relatively low importance in similar studies (Ishtiaque et al., 2024).

An overview of the AHP hierarchy is presented in Figure 4.1. The hierarchy consists of the main goal, which is to weight and rank the drivers for a bouwteam, followed by the seven main drivers identified and their respective sub-drivers, which were both identified in this research 3. The participants were asked to compare the seven main drivers, followed by the respective sub-drivers of each main driver. The AHP survey was distributed to five experts in the field of infrastructure projects, including contractors, clients, and consultants. For the exact definitions of the drivers and sub-drivers, see Appendix C and Appendix D for the Dutch translations used in the survey.

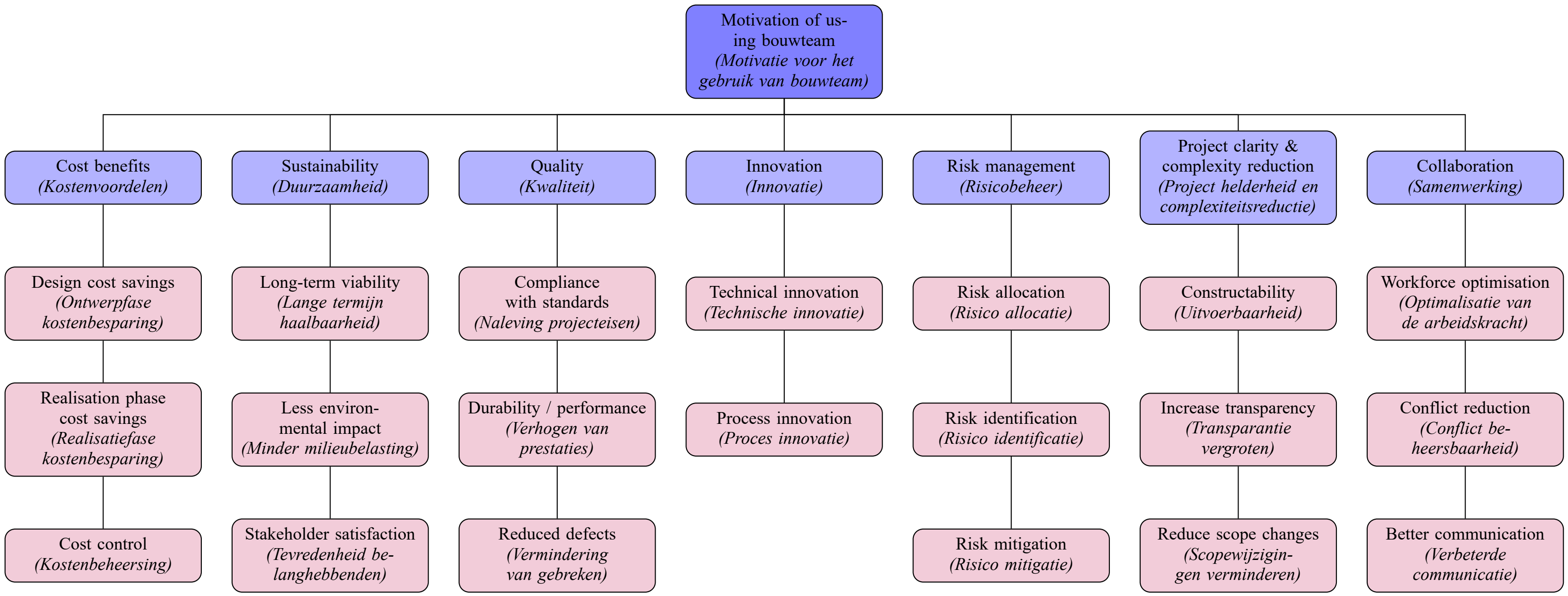

Figure 4.1: AHP Hierarchy of Drivers and Sub-Drivers for Using Bouwteam in Infrastructure Projects

4.3 Outcomes of the AHP

The mathematical calculations of the AHP that lead to the results can be seen in Appendix E, matrix weights are calculated using the eigen vector method (EVM). The matrices from the individual experts are aggregated into a single representative geometric mean (GM) matrix. This provides a value for each driver and sub-driver by calculating weights using EVM. The participants consist of two clients, one consultant, and one contractor. For a more detailed description of the experts who performed the pairwise comparison, see Section 3.2.

Table 4.2: Weights of Drivers and Sub-drivers per Participant

Driver	**P1 (N3)**	**P2 (N5)**	**P3 (N7)**	**P4 (N8)**	**GM (EVM)**
Cost benefits	**0.049**	**0.088**	**0.068**	**0.039**	**0.061**
Design cost savings	0.013	0.006	0.005	0.003	0.007
Realisation cost savings	0.006	0.045	0.019	0.009	0.016
Cost control	0.030	0.037	0.044	0.027	0.038
Sustainability	**0.039**	**0.053**	**0.079**	**0.051**	**0.057**
Long-term viability	0.027	0.024	0.029	0.034	0.034
Lower environmental impact	0.006	0.024	0.043	0.003	0.014
Stakeholder satisfaction	0.006	0.005	0.007	0.014	0.009
Quality	**0.181**	**0.217**	**0.116**	**0.310**	**0.202**
Compliance with standards	0.026	0.014	0.014	0.019	0.019
Reduced defects	0.129	0.161	0.072	0.142	0.131
Increased durability/performance	0.026	0.042	0.030	0.149	0.052
Innovation	**0.040**	**0.057**	**0.071**	**0.031**	**0.051**
Technical innovation	0.010	0.047	0.018	0.015	0.023
Process innovation	0.030	0.010	0.053	0.016	0.028
Risk management	**0.296**	**0.376**	**0.286**	**0.198**	**0.300**
Risk allocation	0.042	0.105	0.031	0.028	0.052
Risk identification	0.127	0.027	0.099	0.016	0.056
Risk mitigation	0.127	0.244	0.156	0.154	0.192
Project clarity & complexity reduction	**0.135**	**0.161**	**0.223**	**0.263**	**0.201**
Constructability	0.034	0.106	0.110	0.159	0.102
Increase transparency	0.021	0.025	0.044	0.016	0.028
Reduce scope changes	0.080	0.030	0.069	0.088	0.071
Collaboration	**0.260**	**0.048**	**0.157**	**0.108**	**0.128**
Conflict reduction	0.168	0.004	0.093	0.010	0.037
Better communication	0.070	0.032	0.039	0.030	0.055
Workforce optimisation	0.022	0.012	0.025	0.068	0.036

Table 4.2 shows the weights of the drivers and sub-drivers per participant, as well as the aggregated results of the weights.

Table 4.3: Ranking of Main Drivers GM (EVM)

Rank	**Main Driver**	**GM (EVM)**
1	Risk management	0.300
2	Quality	0.202
3	Project clarity & complexity reduction	0.201
4	Collaboration	0.128
5	Cost benefits	0.061
6	Sustainability	0.057
7	Innovation	0.051

To get insights into the most and least important drivers, the main drivers are ranked based on aggregated results in Table 4.3. The results show that *Risk management* is the most important driver, followed by *Quality* and *Project clarity &*

complexity reduction. The least important driver is *Innovation*, which still has a significant weight but is less prioritised compared to the others.

Table 4.4: Ranking of Sub-Drivers GM (EVM)

Rank	**Sub-Driver**	**GM (EVM)**
1	Risk mitigation	0.192
2	Reduced defects	0.131
3	Constructability	0.102
4	Reduce scope changes	0.071
5	Risk identification	0.056
6	Better communication	0.055
7	Increase durability/performance	0.052
8	Risk allocation	0.052
9	Cost control	0.038
10	Conflict reduction	0.037
11	Workforce optimisation	0.036
12	Long-term viability	0.034
13	Process innovation	0.028
14	Increase transparency	0.028
15	Technical innovation	0.023
16	Compliance with standards	0.019
17	Realisation cost savings	0.016
18	Lower environmental impact	0.014
19	Stakeholder satisfaction	0.009
20	Design cost savings	0.007

The same is done for the sub-drivers in Table 4.4, where the sub-drivers are ranked based on the aggregated results of the expert input. The results show that *Risk mitigation* is the most important sub-driver, followed by *Reduced defects* and *Constructability*. The least important sub-driver is *Design cost savings*, with a weight of 0.007.

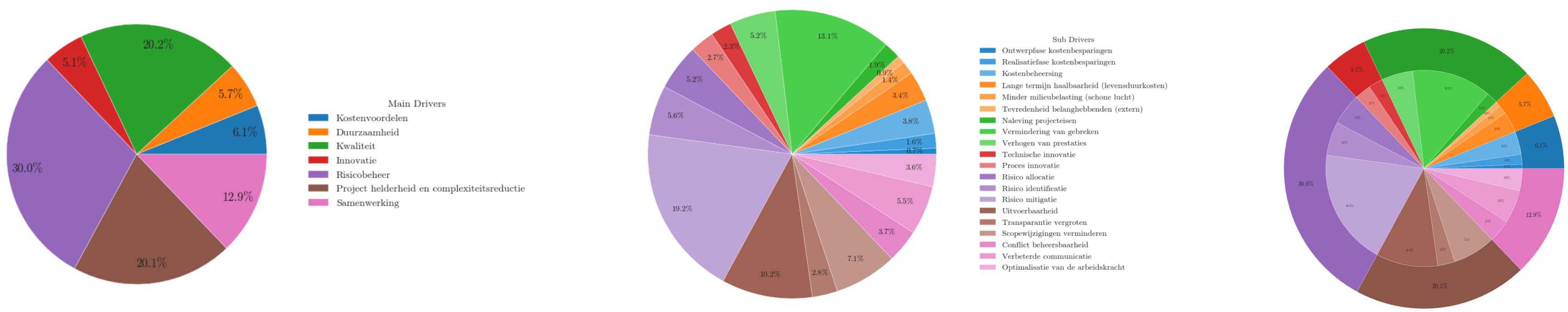

Figure 4.2: Nested View of Drivers and Sub-Drivers

Figure 4.2 visualises the distributed weights of the drivers and sub-drivers. The first two pie charts show the distribution of weights for the main drivers and sub-drivers, respectively. The third chart provides a nested view, illustrating how the sub-drivers contribute to their respective main drivers. This visualisation helps to understand the relative importance of each driver and sub-driver in the context of a bouwteam.

4.4 Sensitivity and Variability Analysis

4.4.1 Setup of the Sensitivity Analysis

Sensitivity analysis was conducted to assess how changes in the input of the drivers and sub-drivers impact the overall AHP results. This analysis helps to identify which drivers are most sensitive to changes in their weights (considering their rankings) and which drivers are more stable. For this analysis, a Monte Carlo simulation was performed; this way of simulating is considered way more revealing than traditional sensitivity analysis (Hauser & Tadikamalla, 1996). Furthermore, the Monte Carlo simulation is a well-established and frequently used method in multiple criteria decision-making (MCDM) methods, such as AHP (Sadati et al., 2024).

The simulation was run with 10,000 iterations, where the weights of the drivers and sub-drivers were varied by perturbing the matrices of main and sub-drivers. The matrices are perturbed following a normal distribution in which the mean is the original input, and the standard deviation is set to 0.3. The normal distribution is chosen to ensure that the weights remain within a reasonable range while still allowing for significant variations. These variations in judgment are assumed to be due to epistemic factors, such as lack of process understanding. The underlying distribution of (Gaussian) Normal is used in similar studies to account for this variation in judgment (Wicaksono et al., 2020). The weights for individual and aggregated matrices follow the same approach as in the deterministic case. First, geometric mean matrices are calculated (from the perturbed matrices) across experts. The eigen vector method is used to calculate the weights of these matrices. To compare statistics across simulations, arithmetic means are used. The choice of 0.3 as standard deviation assumes that the weights can vary significantly, but not excessively, within the context of the AHP. The individual perturbed matrix entries are mapped to the closest valid AHP entry. The simulation was performed using Python; the code for performing the Monte Carlo simulation can be found in Appendix F. For the process flow of the Monte Carlo simulation, see Figure 4.3.

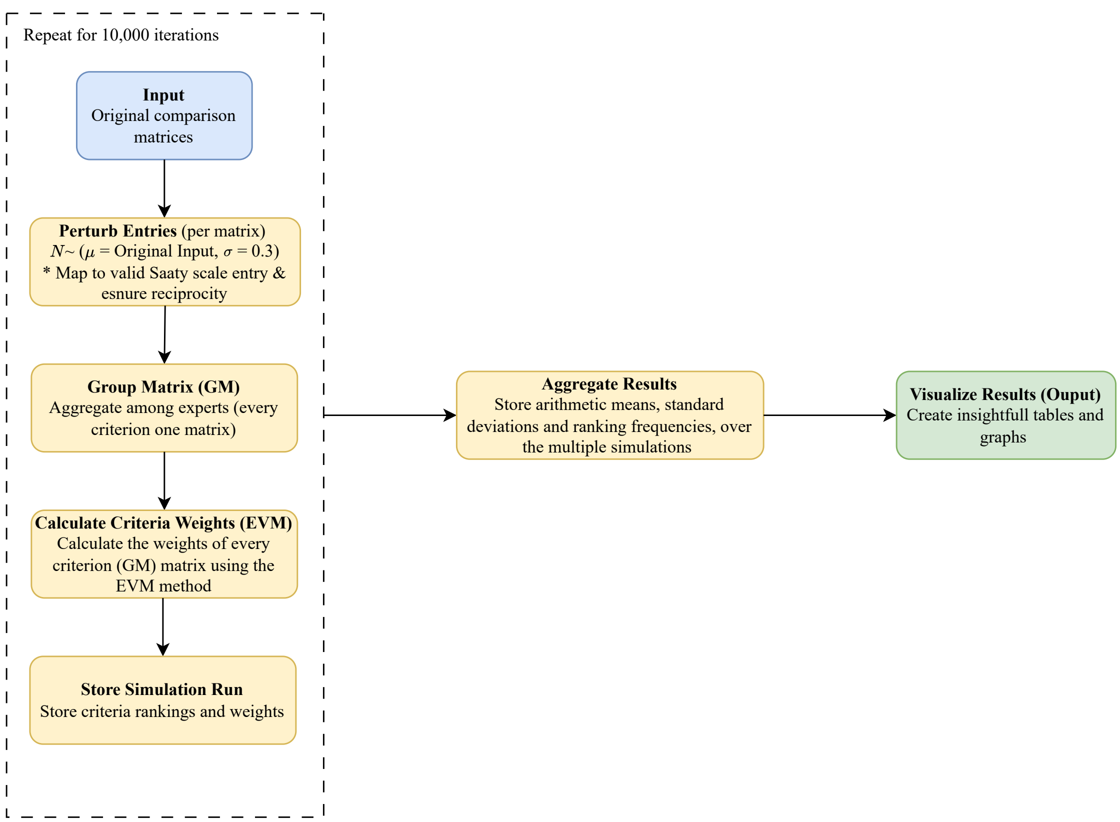

Figure 4.3: Process Flow of the Monte Carlo Simulation

Table 4.5: Key Choices for Monte Carlo Simulation

Choice	**Value**
Number of Iterations	10,000
Perturbation Distribution	Normal (Gaussian)
Mean of Perturbation	Original Input
Standard Deviation	0.3
Mapping of Perturbed Entries	Closest Valid AHP Entry

4.4.2 Results of the Sensitivity Analysis

Table 4.6: Probability of Rank Number (Monte Carlo simulation, $n = 10{,}000$) and Global Mean Weights

Driver	**Rank 1**	**Rank 2**	**Rank 3**	**Rank 4**	**Rank 5**	**Rank 6**	**Rank 7**
Kostenvoordelen	0.00	0.00	0.00	0.00	0.70	0.23	0.06
Duurzaamheid	0.00	0.00	0.00	0.00	0.22	0.49	0.30
Kwaliteit	0.02	0.40	0.58	0.01	0.00	0.00	0.00
Innovatie	0.00	0.00	0.00	0.00	0.08	0.28	0.64
Risicobeheer	0.95	0.04	0.00	0.00	0.00	0.00	0.00
Project helderheid en complexiteitsreductie	0.03	0.56	0.41	0.00	0.00	0.00	0.00
Samenwerking	0.00	0.00	0.01	0.99	0.00	0.00	0.00

Global mean weights ± std:
Kostenvoordelen: 0.064 ± 0.009 Duurzaamheid: 0.056 ± 0.008 Kwaliteit: 0.200 ± 0.023
Innovatie: 0.051 ± 0.007 Risicobeheer: 0.293 ± 0.030 Project helderheid en complexiteitsreductie: 0.208 ± 0.024
Samenwerking: 0.128 ± 0.016

Regarding the main drivers, the sensitivity analysis shows that **Risk Management** is the most stable driver, consistently ranking first in 95% of the iterations. This indicates that even with variations in inputs (and thus weights), **Risk Management** remains a key driver for choosing a bouwteam. Considering the other ranks, they are less robust (except for **Samenwerking (Collaboration)**), considering their initial ranking position; see Table 4.3. This indicates that their position is more sensitive to minor changes in the input, which is logical considering their weights are closer together; again, see Table 4.3. Visually a bar graph representation of the ranks can be seen in Figure 4.4.

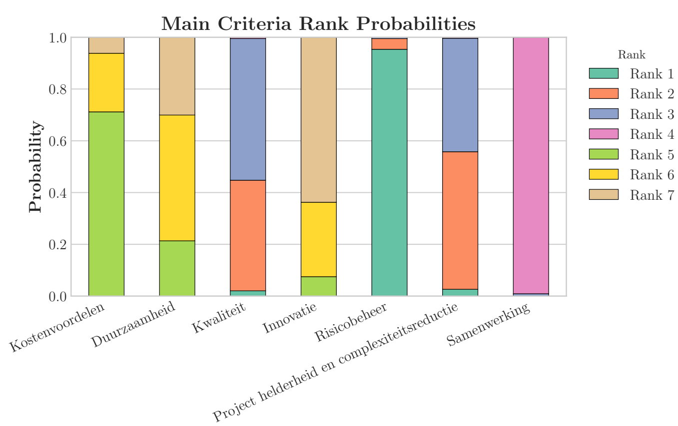

Figure 4.4: Ranks of Main Drivers Simulation Results

4.4.3 Variability of Sub-Drivers

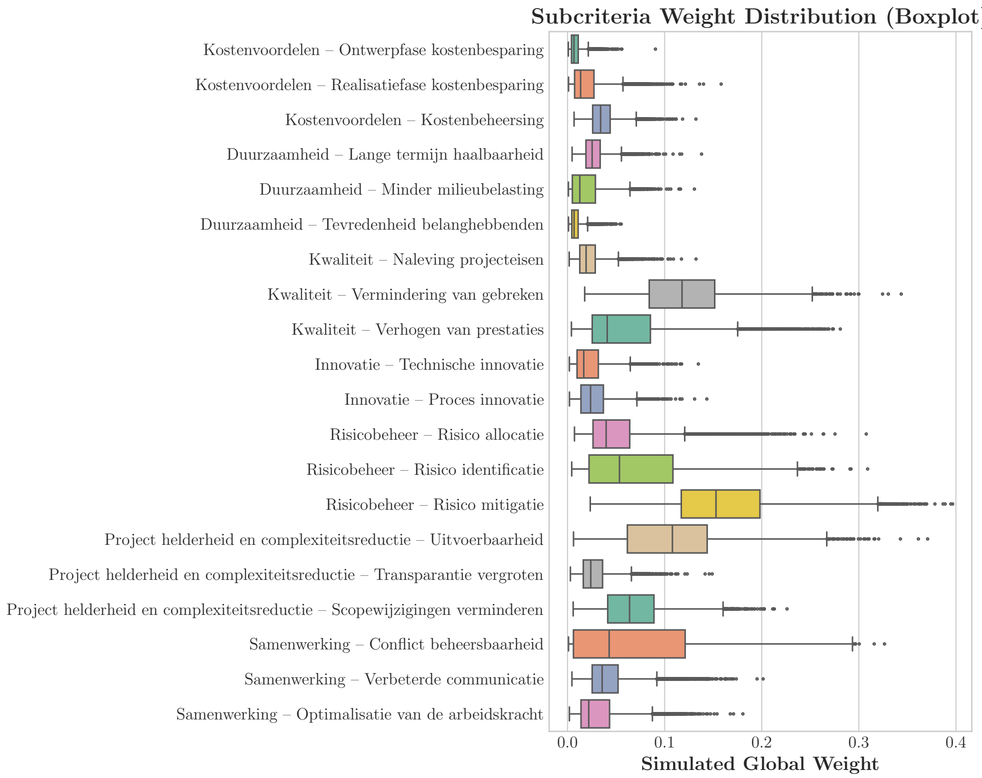

Figure 4.5: Boxplot of Sub-Drivers Simulation Results

The boxplot in Figure 4.5 shows the distribution of the weights of the sub-drivers as the result of the Monte Carlo simulation. The boxplot shows a random sample of 10,000 out of 40,000 sub-driver weight rows (10,000 rows per expert, n = 10,000 iterations). The aggregation among experts (using geometric mean matrices) is not performed within this visualisation. This is to highlight the differences in judgment between experts. The boxplot provides insights into the variability of the sub-driver weights, with the interquartile range (IQR) indicating the spread of the weights. The median line within each box represents the central tendency of the weights for each sub-driver. The whiskers extend to show the range of the data, while any points outside this range are considered outliers. This visualisation helps to understand how spread the weights for sub-drivers are based on initial expert input before aggregating to a final consensus.

The results of the sample from the Monte Carlo simulation show an emphasis on the significant variability of sub-driver *conflict reduction* (Dutch: *conflict beheersbaarheid*). This highlights the disagreement between experts regarding whether this sub-driver is a key driver for choosing a bouwteam. See also table 4.2, in which the weights within collaboration vary significantly between the experts.

4.4.4 Conclusion of the Sensitivity and Variability Analysis

The sensitivity analysis has provided valuable insights into the stability and variability of the sub-drivers identified in the AHP survey. While most main drivers, such as **Risk Management** and **Collaboration**, have a robust place in the ranking, others like **Quality** and **Sustainability** are more sensitive to rank changes (due to their close initial aggregated weights). The samples of the Monte Carlo simulations show that some sub-drivers, such as *Conflict reduction*, exhibit significant variability in their weights, indicating that there is a lack of consensus among experts regarding their importance. This suggests that while the drivers are generally stable in ranking position, there should be caution in interpreting the weights, as they can vary significantly based on expert judgment.

4.5 Discussion and AHP results

Risk Management as Key Driver
The results of the AHP survey provide valuable insights into what experts, who are involved in the decision-making process of choosing to work in a bouwteam, find important drivers. The most important driver among the seven main drivers that were identified is **Risk Management**. This driver received the highest weight of all participants, indicating a strong consensus on its importance. The sub-driver *Risk mitigation* received significant attention, highlighting that bouwteams are selected to be able to effectively address potential risks throughout the project lifecycle. This aligns with the findings from the interviews, where risk management was also identified as a key factor in the decision to use a bouwteam; see Appendix B. Also is the importance of risk minimization (slightly different formulation) highlighted in similar studies, such as *Ranking the benefits of early contractor involvement: a client's perspective* by Ishtiaque et al. (2024). It is the fourth most important benefit of early contractor involvement among 12 identified benefits.

Quality, Project Clarity & Complexity Reduction, and Collaboration
The second, third, and fourth most important drivers are **Quality**, **Project Clarity & Complexity Reduction**, and **Collaboration**. These drivers received substantial weights, indicating that experts value the ability of bouwteams to enhance project quality, reduce complexity, and collaborate with each other more intensively. The sub-drivers *Reduced defects* and *Constructability* are being particularly noteworthy within the main drivers. This suggests that experts believe that bouwteams can lead to better project outcomes by ensuring lower defects and a design that is executable in practice. In a similar study of Ishtiaque et al. (2024), improved collaboration was identified as the most important driver. While also obtaining significant weight in this study. It is not as significant as the other three main drivers. Potentially due to its controversy among experts, see Table 4.3 and Figure 4.5.

Cost Benefits
The driver **Cost Benefits** received the lowest weight among the main drivers, indicating that while cost benefits are important, they are not the primary motivation for choosing a bouwteam. This is in line with the findings from the literature review in Section 2.4 and the interview data from Chapter 3. This is because although cost savings are mentioned in literature and sometimes experienced by experts, there are also concerns about the financial performance of bouwteams, especially considering the bouwteam phase. The sub-driver *Cost control* received the highest weight within the main driver, indicating that experts value the ability to manage costs effectively throughout the project lifecycle. In line with the study of Ishtiaque et al. (2024), where cost control was prioritised higher as a benefit of early contractor involvement than cost savings. This suggests that experts believe that the bouwteam approach can lead to better cost management, even if it does not always result in significant cost savings.

Sustainability and Innovation
The drivers **Sustainability** and **Innovation** received moderate weights, indicating that while they are important, they are not the primary drivers for choosing a bouwteam. Although there are a lot of sources and interview responses that indicate that sustainability and innovation are important drivers, they do not seem to be the focus for experts when selecting a bouwteam. This could be since sustainability and innovation are seen as project-specific and not necessarily inherent to the bouwteam arrangement itself. The sub-driver *Long-term viability* received the highest weight within the sustainability driver, indicating that experts value the long-term financial viability of bouwteam projects. The sub-driver *Process innovation* received the highest weight within the innovation driver, indicating that experts value the ability of bouwteams to innovate the process. The relatively low weight of innovation is supported by the findings of Ishtiaque et al. (2024), where innovation was ranked as the least important benefit of early contractor involvement. This suggests that while innovation is valued, it is (generally) not seen as a primary driver for choosing a bouwteam.

4.6 Summary/Conclusion

This chapter has provided an overview of what the most important drivers are for choosing a bouwteam approach in infrastructure projects. The AHP survey results indicate that the most important driver is **Risk Management**, followed by **Quality**, **Project Clarity & Complexity Reduction**, and **Collaboration**. The driver **Cost Benefits** received the lowest weight, indicating that while cost savings are important, they are not the primary motivation for choosing a bouwteam. The drivers **Sustainability** and **Innovation** received moderate weights, indicating that while they are important, they are not the primary drivers for choosing a bouwteam. The sub-drivers within each main driver provide further insights into what experts value when selecting a bouwteam approach. The sensitivity analysis has shown that while the main drivers are generally stable, small changes in the input data could lead to some shifts in the ranking of the main drivers.

Some sub-drivers, such as *Conflict reduction*, exhibit significant variability in their weights, indicating that there is a lack of consensus among experts regarding their importance. The results of this chapter provide valuable insights for practitioners and researchers in the field of infrastructure projects, highlighting the key drivers that influence the decision to use a bouwteam approach, linking to a similar study by Ishtiaque et al. (2024).

5

Recommendations and Implementation

This chapter draws conclusions and provides recommendations based on the findings of this research. The chapter answers the last two research questions:

5. What recommendations on the use of ECI teams in infrastructure projects can be made, and how should they be presented?
6. In what way should the findings be integrated into TAUW's current policy?

The chapter bases these results on findings from the literature review in Chapter 2, the thematic analysis in Chapter 3, and the AHP analysis in Chapter 4. This is done by combining them in a comprehensive manner. Furthermore, the chapter provides a flowchart that can be used as a practical tool for decision-making regarding the use of bouwteams in infrastructure.

5.1 Recommendations for Practice

Based on the findings of this research, several recommendations can be made for the IACM department at TAUW and other stakeholders involved in infrastructure projects. The three main categories identified in this research are:

- **Client's (Organisational) Characteristics:**

As noted in the results of the thematic analysis (see Chapter 3), the client's organisational characteristics play a crucial role in the success of bouwteam projects. When considering the use of a bouwteam, it is essential to assess the client's organisational readiness and willingness to embrace collaborative approaches. Important requirements (for clients) discussed in this research include:

- A mindset and culture that embraces collaboration and is willing to collaborate: An essential requirement and term for the use of bouwteams is collaboration. This means that all stakeholders involved must be open to sharing information, ideas, and resources to achieve common goals.
- Willingness to come clean, no hidden agenda: Transparency is a key requirement for the success of bouwteams. All parties involved must be willing to share information openly and honestly, without hidden agendas or ulterior motives.
- Leadership capabilities that support and promote collaborative practices: Effective leadership is crucial for the success of bouwteams. Leaders must be able to foster a collaborative environment, encourage open communication, and facilitate decision-making processes that benefit all involved stakeholders.
- Adequate resources and expertise to manage the bouwteam process effectively: The client must have sufficient resources and expertise to manage the bouwteam process effectively. This includes having a resolute team with the necessary skills and knowledge to oversee the project, as well as the financial resources to support the collaborative approach.

An important controversial requirement is the need for adequate resources and expertise to manage the bouwteam process effectively. While some experts argue that the client should have sufficient resources and expertise to manage the bouwteam process. They indicate that clients sometimes lack the necessary resources and expertise to effectively manage the bouwteam process and use this lack as a driver to use a bouwteam. Quotes such as “Opdrachtgever moet ook leiding geven aan het bouwteam, die moet besluiten nemen, moet input leveren. Het vraagt best wel van de opdrachtgever, maar je ziet wel dat het vaak als reden wordt aangevoerd om voor een bouwteam te kiezen.”~N8, which translates to “The client must also lead the construction team, must make decisions, must provide input. It does require quite a bit from the client, but you do see that it is often cited as a reason to choose a construction team.” in the thematic analysis, see Chapter 3. Indicate that clients sometimes use the lack of resources and expertise as a reason to use a bouwteam, which can lead to challenges in managing the process effectively. This highlights the importance of ensuring that clients have the necessary resources and expertise to manage the bouwteam process effectively. For the use of a bouwteam, early involvement and the collaborative environment lead to several benefits, but the client should be aware of its leadership role in the bouwteam process. One expert stated: “Veel opdrachtgevers in mijn beleving onderschatten wat het van hun vraagt om in een bouwteam te werken.”~N8, which translates to ”In my opinion, many clients underestimate what it takes from them to work in a bouwteam.” This shows that the client should be aware of the requirements and challenges of using a bouwteam, especially considering the leadership role they have in the process.

- **Project Characteristics:**

The project characteristics are another crucial factor in determining the suitability of a bouwteam approach. While in the AHP in Chapter 4, the drivers for an average bouwteam project were prioritised. In the literature in Chapter 2 and in the analysis of the interviews Chapter 3 it became clear that not all projects are suitable for a bouwteam approach. The following project characteristics should be considered when deciding whether to use a bouwteam:

- Complexity and uncertainty of the project: Bouwteams are particularly beneficial for complex and uncertain projects where early contractor involvement can lead to benefits, such as better risk management and innovation.
- Need for collaboration and innovation: Projects that require a high level of collaboration and innovation are well-suited for bouwteam approaches, as they facilitate open communication and knowledge sharing among stakeholders.

Suitable projects for the use of a bouwteam are thus projects in which the early involvement of the contractor can have a significant impact on the project outcome. This includes projects with high complexity, uncertainty, and a need for collaboration and innovation. On the contrary, projects that are relatively straightforward and do not require significant collaboration or innovation may not benefit from a bouwteam approach. This is recognised by literature and experts, who indicate that the use of a bouwteam in such projects may not be necessary or beneficial. As one expert stated: “Wat simpel is wat afgekaderd is, waarbij de kwaliteit in de RAW al geborgd is.”~N5, which translates to “What is simple and well-defined, where the quality is already guaranteed in the RAW.” The use of a bouwteam must be justified: “Als je als opdrachtgever precies weet wat je wil, waardoor er weinig ontwerpvrijheid is. En de uitvoering rechttoe rechtaan is weinig risico’s. Ja, dan wegen de voordelen van het bouwteam niet op tegen het nadeel van minder marktwerking, denk ik.”~N5, which translates to: “If you as a client know exactly what you want, which means there is little design freedom. And the execution is straightforward with few risks. Then the advantages of the bouwteam do not outweigh the disadvantages of less market competition, I think.” This shows that the use of a bouwteam should be carefully considered and justified based on the specific characteristics of the project. Especially since literature associates the use of a bouwteam with less market competition, which can lead to higher costs. This is also supported by the AHP analysis in Chapter 4. Experts believe that cost benefits, which some literature and experts associate with the use of a bouwteam, are not a primary driver for choosing a bouwteam. This is also supported by the thematic analysis in Chapter 3, which indicates that experts believe that cost benefits, especially in terms of savings, are not always guaranteed when using a bouwteam.

- **Client Objective:**

The last important criterion is the client’s objective in a project. The client’s objective should align with the collaborative nature of bouwteams. If the client is primarily focused on cost savings and does not prioritise collaboration, a RAW-contract or UAV-GC might be more suitable. However, if the client values collaboration, innovation, sustainability, high quality, and long-term relationships with contractors, a bouwteam can provide significant benefits. The following objectives should be considered when deciding whether to use a bouwteam:

- Having high control over the project: Clients who prioritise control over the project and its outcomes may find that a bouwteam approach provides them with the necessary oversight and involvement in the design and construction process. Especially risk management is considered an important motivation for choosing a bouwteam, with the highest score on importance in the AHP analysis in Chapter 4. This means that experts think that risk management is the most important motivation for choosing a bouwteam (among the other motivations). This is also supported by literature, which indicates that the early involvement of contractors in the design phase allows for better risk management; see Chapter 2.

- Desire for collaboration: Clients who prioritise collaboration in their projects are more likely to benefit from a bouwteam approach. Collaboration is given a high priority in the AHP analysis in Chapter 4, indicating that experts believe that collaboration is an important motivation for choosing a bouwteam. This is also supported by literature, which indicates that the collaborative nature of bouwteams leads to improved communication and knowledge sharing among stakeholders; see Chapter 2.
- Innovation and sustainability goals: Literature and experts in the field are controversial about whether innovation and sustainability are a spurious relation with the use of a bouwteam. However, it is clear that if the objective of the client is to achieve innovation and sustainability goals, a bouwteam can facilitate this through its collaborative nature and early contractor involvement.
- Focus on long-term relationships: Bouwteams are well-suited for clients who value long-term relationships with contractors and stakeholders, as they foster trust and open communication.
- Desire for quality in the project: To ensure good quality of the results in the project, bouwteams can be beneficial. As they are associated with better quality outcomes, see Chapter 2 and the thematic analysis in Chapter 3. This is also supported by the AHP analysis in Chapter 4, which indicates that experts believe that quality is an important motivation for choosing a bouwteam.

It is thus important for clients to carefully consider their objectives and how they align with the collaborative nature of bouwteams. If the client's objectives prioritise collaboration, innovation, sustainability, high quality, and long-term relationships with contractors, a bouwteam can provide significant benefits. However, if the client's objectives are primarily focused on cost savings, they do not want to work in a collaborative environment and want a more traditional way of allocating the risk; a RAW-contract or UAV-GC might be more suitable.

Visually, these recommendations that help TAUW and other stakeholders are represented globally in the following flowchart:

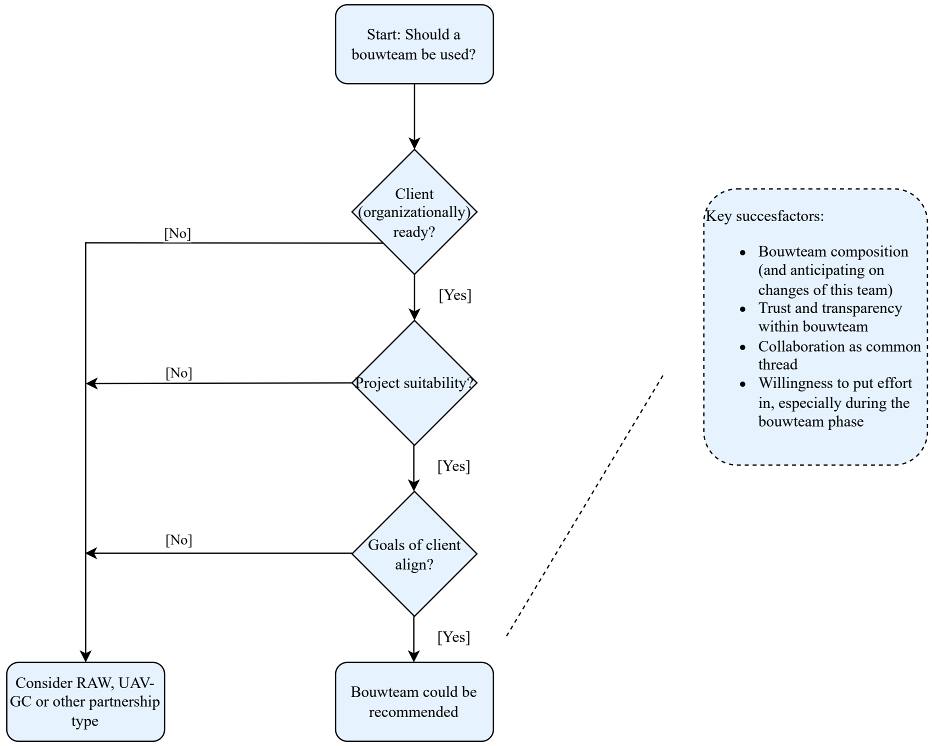

Figure 5.1: Decision Flowchart for Bouwteam Suitability

An important note is that the flowchart does not consider external factors, such as market conditions, which can also influence the decision to use a bouwteam (Rahmani et al., 2022). The flowchart is thus a simplified representation of the decision-making process (focusing on the findings in this study) and should be used in conjunction with other factors and considerations. The flowchart can be used as a practical tool for decision-making, guiding the consultancy of TAUW for the client's side.

5.2 Implementation

TAUW can use the findings in this research to improve their consultancy on the use of bouwteams over other contracting approaches. The research highlights the perception of experts in the field regarding the benefits and challenges of bouwteams, as well as the most important drivers for choosing a bouwteam. The findings indicate that bouwteams can provide significant benefits over traditional contracting methods, especially in terms of collaboration, risk management, complexity reduction, and quality. However, the suitability of a bouwteam approach depends on various factors, including the client's organisational characteristics, project characteristics, and client objectives. As well as external factors, such as market conditions. TAUW can use the recommendations and flowchart as a checklist and decision support tool for their consultancy on the use of bouwteams.

6

Discussion, Limitations, and Conclusion

This chapter evaluates the findings of the research, discusses the methodology used, and reflects on what the limitations of the research are. This is done by assessing earlier research, the validity and reliability of the research, and the implications of the findings for TAUW. In this chapter also suggestions for future research are made that could build on the conducted research. The chapter ends by referring to the main research question and summarising the main findings of this research.

6.1 Discussion

While the findings are thought-provoking, it is essential to address the strong and weak points as well as the limitations of this research and the need for further investigation. Also, the usefulness of the findings for TAUW is discussed.

6.1.1 Validity & Reliability of the Research

To ensure the validity and reliability of the research, several measures were taken. The use of a thematic analysis allowed for a systematic and transparent approach to assess the perception and experiences of experts in the field. Considering the AHP analysis, only experts who filled in the questionnaire consistently (consistency ratio < 0.10) were included. Furthermore, a sensitivity analysis was applied to assess the robustness of the ranking among the main drivers for small input changes. Besides, the simulated samples of the sub-drivers showed how experts differ in their opinions on the importance of the sub-drivers. This, too, adds nuance to the rankings and obtained weights in the final consensus result of the deterministic survey results (such as controversy within the collaboration driver). Also, multiple data-gathering methods were applied to ensure the comprehensiveness of the findings.

6.1.2 Discussion of Methodology

Considering the methodology, the research relied on a combination of literature review, expert interviews and a AHP analysis. The thematic analysis provided valuable insights into the perceptions and experiences of experts in the field, highlighting, among others, the benefits considering collaboration, risk management, and the early involvement of contractors. This was achieved by using the six-phase framework suggested by Braun and Clarke (2006). However, there are also concerns regarding the inconsistency that the flexible nature of the thematic analysis can lead to (Holloway & Todres, 2003). The flexibility of the thematic analysis allows for a more nuanced understanding of the data, but it also raises concerns about the reliability and validity of the findings. To increase consistency, the epistemological position of the researcher should be clearly defined (Holloway & Todres, 2003), and the analysis should be conducted systematically and transparently (Braun & Clarke, 2006). With this kept in mind, the thematic analysis provided valuable insights into the perceptions and experiences of experts in the field.

The AHP analysis provided a structured approach to prioritise the drivers for choosing a bouwteam, allowing for a more objective assessment of the factors influencing bouwteam decisions. AHP is widely applicable in a lot of different fields (Vargas, 1990). A lot of research has been done on the use of AHP in general, with entire books discussing its practices and applications. Take the book of Saaty (2012): *Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World*. Furthermore, AHP is thought to be a good trade-off between perfect modelling and usability of a model representing a complex decision problem (Ishizaka & Labib, 2011). However, AHP also has its limitations and concerns. The pairwise comparisons can be more than in other weighting methods (Pamučar et al., 2018). The amount of pairwise comparisons in the AHP can be overwhelming (Ishizaka & Labib, 2011). Also, the AHP is highly dependent on the subjective judgments of the experts involved, which can introduce bias and variability in the results. To mitigate these concerns, it is essential to ensure that the experts involved in the AHP analysis are knowledgeable and experienced in the field of bouwteams and infrastructure projects. This is ensured in this research by selecting experts with experience in the field and a deep understanding of the complexities involved in bouwteam projects. Furthermore, is triangulation of the results from the thematic analysis and the AHP analysis used to validate the findings and ensure a more comprehensive understanding of the drivers for choosing a bouwteam (Carter et al., 2014).

6.1.3 Link to Earlier Research

The findings of this research contribute to the existing body of knowledge on bouwteams and their role in infrastructure projects. The results align with previous studies that have highlighted the benefits of collaborative contracting approaches, such as Scheper (2024). Also, do the bouwteam drivers align with the findings in studies on early contractor involvement such as Ishtiaque et al. (2024). What this study makes unique is the focus on the specific context of infrastructure projects and the empirical evidence gathered through expert interviews and AHP analysis. This research provides a more nuanced understanding of the factors influencing the choice of bouwteams and their potential benefits, addressing a gap in the existing literature. Furthermore, it enables TAUW to improve their consultancy on the use of bouwteams.

6.1.4 Limitations of the Study and Future Research

Since the research is conducted in a specific context, the findings may not be generalizable to all infrastructure projects or organisations. The study primarily focused on the perspectives of experts within the IACM department at TAUW and from clients' side in the Netherlands. While this provides valuable insights, it may not fully capture the diversity of experiences and opinions across different regions or sectors. Additionally, the sample size of experts interviewed was relatively small, which may limit the robustness of the findings. Future research could expand the sample size and include a broader range of stakeholders to enhance the generalizability of the results. Also, was the AHP limited to only 4 experts, which may limit the robustness of the findings. Future research could expand the sample size and include a broader range of experts to enhance the generalizability of the results. Furthermore, the study relied on qualitative data from expert interviews, which may be subject to bias and interpretation. While efforts were made to ensure the validity and reliability of the findings (for example, through triangulation and thematic analysis), it is important to acknowledge that qualitative research inherently involves subjective interpretations. Another limitation is the lack of quantitative data to support the findings. While the qualitative insights provided valuable context and depth, the absence of quantitative metrics makes it challenging to draw definitive conclusions about the cost implications and overall effectiveness of bouwteams compared to traditional contract forms. Future research could incorporate quantitative data to complement the qualitative findings and provide a more comprehensive understanding of the impact of bouwteams on project performance (especially in retrospect to RAW and UAV-GC projects).

6.2 Conclusion

This thesis was conducted at TAUW under the department of Inkoop Advies and Contractmanagement (IACM). The aim of the thesis was to address the problems related to bouwteam consultancy. The consultants within IACM are lacking adequate empirical data to support their advice on the use of bouwteams in infrastructure. The main research question that was addressed is *How do bouwteams compare to traditional contracting methods in infrastructure projects?*

To address this problem and answer the main research question, the thesis was structured according to six research questions, divided over six chapters. The first chapter introduced the approach of the research, including the problem statement, the research questions, and the methodology. The second chapter provided a literature review on bouwteams and traditional contracting methods, including their definitions, characteristics, and advantages and disadvantages. The third chapter presented expert opinions and experiences on the use of bouwteams. The fourth chapter identified the most important drivers for choosing bouwteams. In the fifth chapter recommendations and an implementation flow chart were highlighted. Finally, the sixth chapter reflected on the research process, discussed the limitations of the study, and concluded the research.

The findings of this research provide valuable insights into the benefits and challenges associated with the use of bouwteams in infrastructure projects. By highlighting the importance of collaboration, early contractor involvement, and data-driven decision-making, this thesis contributes to a better understanding of the factors that influence the success of bouwteam projects. Furthermore, the research underscores the need for organisations to adopt a more flexible and context-specific approach to contract selection and project management.

The recommendations provided in this thesis can help TAUW and other stakeholders make informed decisions about the use of bouwteams in infrastructure projects. By considering the client's organisational characteristics, project characteristics, and client objectives, organisations can better assess the suitability of a bouwteam approach and maximise its potential benefits. The flowchart presented in Section 5.1 serves as a practical tool for decision-making, guiding stakeholders through the process of evaluating the appropriateness of a bouwteam for their specific project context.

In conclusion, this thesis serves as a foundation for further research on bouwteams and their role in infrastructure projects. It serves as a valuable resource for TAUW, and other stakeholders involved in infrastructure projects, providing empirical evidence and practical recommendations for the effective use of bouwteams, especially considering their benefits. By addressing the problems related to bouwteam consultancy, this research contributes to the ongoing efforts to improve project delivery and outcomes in the field of infrastructure development. This work can be taken forward by TAUW to enhance their consultancy services and provide more data-driven advice on the use of bouwteams in infrastructure projects. The findings of this research can also serve as a basis for future studies exploring the long-term impacts of bouwteams on project outcomes.

Connecting again to the main research question: *How do bouwteams compare to traditional contracting methods in infrastructure projects?* The findings of this research indicate that bouwteams can provide significant benefits over the use of contracts that use competitively procured methods such as collaboration, risk management, and innovation benefits. However, the suitability of a bouwteam approach depends on various factors. Considering the client's perspective, it is important that they consider their organisational structure, the characteristics of the project, and their objectives. By carefully evaluating these factors and using the flowchart presented in Section 5.1, TAUW can make informed decisions about the use of bouwteams in infrastructure projects. The research highlights the importance of a data-driven approach to contract selection and project management, emphasising the need for empirical evidence to support decision-making in the field of bouwteams.

This research is not only relevant to TAUW's consultancy practice but also contributes to the broader understanding of collaborative contracting in the Dutch infrastructure sector.

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Appendix A

Appendix: Benefits of Bouwteams

Table A.1: Benefits of bouwteams (1)

Category	Benefits	Source	Cause of Benefit	Source
Cost benefits	Lower project costs	(Song et al., 2009)	Due to innovative solutions	(Song et al., 2009)
	Saving on tender costs	(Klakegg et al., 2020)	–	–
	Lower probability of budget overruns	(Rahmani, 2020; Stichting Innovatie & Arbeid, 2012)	Due to improved collaboration	(Rahmani, 2020)
	Price certainty in realization phase	(Stichting Innovatie & Arbeid, 2012)	–	–
	Cost control	(Finnie et al., 2021; Song et al., 2009)	Due to open book approach	(Finnie et al., 2021; Song et al., 2009)
	Reduction in failure costs	(Stichting Innovatie & Arbeid, 2012)	Due to a reduction in design failures	(Stichting Innovatie & Arbeid, 2012)
Sustainability	Ability to increase sustainability	(Laeven et al., 2023)	Due to mutual trust and intense collaboration	(Laeven et al., 2023)
	Easier to comply with project objectives, such as sustainability	(Ferme et al., 2018; Ishtiaque et al., 2025; Kivilä et al., 2017)	Due to mutual trust and intense collaboration between parties, also due to innovative solutions	(Ferme et al., 2018; Ishtiaque et al., 2025; Kivilä et al., 2017)
Quality	Fewer defects	(Farrell & and, 2022)	–	–
	Better legal, aesthetic and functional requirements	(Lenferink et al., 2012; Rahmani, 2020)	–	–
	Better quality of the construction	(Kleinhuis, 2016)	Due to client and contractor work together and are early involved in the project	(Rahman & Alhassan, 2012; Scheepbouwer & Humphries, 2011)
	Better project quality	(Lenferink et al., 2012)	Due to the room for innovation in ECI	(Lenferink et al., 2012)
Innovation	Higher innovation potential	(Eadie & Graham, 2014; Scheepbouwer & Humphries, 2011)	The design is not yet determined when collaboration starts. Critical thinking on old techniques of multiple parties.	(Eadie & Graham, 2014; Scheepbouwer & Humphries, 2011)
	Presence of Innovation in project (solution)	(Chan et al., 2003; Mosey, 2009; Rijkswaterstaat, 2023)	Due to integral collaboration, proposal is made for every part of the project, with all involved parties	(Rijkswaterstaat, 2023)
	Facilitating Innovation	(CROW, 2020; Farrell & and, 2022; Herzog, 2019; Lenferink et al., 2012; Stichting Innovatie & Arbeid, 2012)	–	–

Table A.2: Benefits of bouwteams (2)

Category	Benefits	Source	Cause of Benefit	Source
Risk management	Better risk identification	(Rahmani et al., 2022)	Due to the expertise of the contractor	(Rahmani et al., 2022)
	Better risk allocation	(Laeven et al., 2023)	Due to collaboration in the design process	(Laeven et al., 2023)
	Balanced risk mitigation	(Laeven et al., 2023)	Due to collaboration in the design process	(Laeven et al., 2023)
	Better risk mitigation	(Rijkswaterstaat, 2023)	Due to better allocation, identification and quantification of risks, which is done with all involved parties	(Rijkswaterstaat, 2023)
Project clarity & complexity reduction	Time Savings	(Scheepbouwer & Humphries, 2011)	Due to increased project delivery time	(Scheepbouwer & Humphries, 2011)
	Reduction in design-phase time	(Mosey, 2009; Pheng et al., 2015; Gransberg, 2013)	Due to simultaneous development of project aspects and the input of the contractor	(Gransberg, 2013; Mosey, 2009; Pheng et al., 2015)
	Reduction of arbitrary tendering	(Love et al., 2014)	–	–
	Transparency	(Finnie et al., 2021)	Due to the utilization of open book pricing	(Finnie et al., 2021)
	Predictable and clear project	(Laeven et al., 2023)	Due to a more balanced risk allocation and mitigation	(Laeven et al., 2023)
	Sustainable solutions in the project	(Lenferink et al., 2012)	Due to room for innovation, sustainable solutions can be obtained	(Lenferink et al., 2012)

Table A.3: Benefits of bouwteams (3)

Category	Benefits	Source	Cause of Benefit	Source
Increased constructability	Increased constructability	(Beach et al., 2005; Eriksson et al., 2019; Farrell & and, 2022; Rahmani, 2020)	Due to longer collaboration and the expertise/contribution of the contractor in the design phase	(Beach et al., 2005; Eriksson et al., 2019; Farrell & and, 2022; Rahmani, 2020)
	Improved constructability	(Farrell & and, 2022)	Due to the expertise of the contractor in the design phase	(Farrell & and, 2022)
Collaboration	Smoother design-realization transition	(Rahman & Alhassan, 2012)	–	–
	Improved collaboration	(Beach et al., 2005; Ng et al., 2021; Rahmani, 2020)	–	–
	Conflict reduction	(Mosey, 2009; Rahmani, 2020)	Due to the collaborative environment and the transparency considering cost	(Bayliss et al., 2004; Mosey, 2009; Rahmani, 2020)
	Better communication and exchange of information (in early phase of the project lifecycle)	(Rahmani et al., 2022)	–	–
	Participant enjoyment	(PublicSpaceInfo, 2016)	Due to collaboration in bouwteam phase	(PublicSpaceInfo, 2016)
	Capacity enhancement	–	–	–

Appendix B

Appendix: Theme Overview

Table B.1: Defined Themes and Illustrative Quotes (1)

Theme	Description	Illustrative Quotes
Collaboration in Bouwteam	Experts in the field believe that the collaboration in a bouwteam is better, it is associated with better project results, the ability to increase capacity and leads to more expertise in the design phase of the project. Also do the experts think and experience more satisfaction cause of the increased collaboration in the bouwteam.	“We nemen meer tijd, we werken samen en we komen dus tot mooie resultaten.” ~N6 “Het is puur, de expertise die die je binnen hebt gehaald.”~N7 “Omdat ze het meer naar hun zin hebben dan wanneer ze al in allerlei vecht contracten zitten.”~N8
Bouwteam Drivers	This theme explicitly captures the drivers of using bouwteam in the data, this among others included: stakeholder satisfaction, the ability to increase capacity and to realize innovation & sustainability.	“En de derde drijfveer. Misschien moeten we wel bovenaan zetten, want dat is een gezamenlijk convenant. Wat aannemers en opdrachtgevers met elkaar gesloten hebben. Het moet weer met je leuk worden In de sector.”~N6 “Ja waar een stukje innovatie nodig is.”~N1 “Op het moment dat jij een capaciteitstekort hebt.”~N5
Complexity Reduction in Bouwteam	The complexity of the project is thought to be reduced in a bouwteam, this among others because the executing party is already on board in the design phase, parties are transparent and there is taken more time for the design phase.	“Kijk, je maakt direct wel maakbare ontwerpen hier omdat je in een vroegtijdig stadium ook de personen van de uitvoering daarin betrekt” ~N1 “Of minder geheimen dan in een traditioneel bestek.”~N2 “Alleen bij een bouwteam zie je wel dat het ontwerp veel intensiever wordt doorgesproken”~N8
Cost Control & Cost Trend	The use of a bouwteam is believed to contribute to better cost control and a different cost trend then RAW and UAV-GC projects.	“Ja omdat je veel meer sturing hebt vanuit je proces op de kosten.”~N1 “Er, zijn of zullen waarschijnlijk wel meer kosten zijn. Maar dat is juist de essentie dat je die gaat terugverdienen”~N4 “Maar het zijn wel. Dat we nog wel kosten die die ja die deels normaliter in de realisatie zitten, maar dat trek je eigenlijk naar voren toe”~N7

Table B.2: Defined Themes and Illustrative Quotes (2)

Theme	Description	Illustrative Quotes
Efficiency in Bouwteam	Regarding efficiency, there is thought that in bouwteam the process can be more efficient, but in practice this is not always the case. A reason for this is, among others, that the contractor is not always intrinsically motivated to be efficient in the design phase. There are nevertheless also experts who experienced the efficiency in practice. Furthermore they give arguments on why contractor could be more efficient in a bouwteam setting.	"Daar zie je dat je eigenlijk met hetzelfde team van mensen in bouwteam tegelijkertijd meerdere projecten kan voorbereiden. Meerdere groot onderhoud bedrijven. Over meerdere groot onderhoudsprojecten. Daar levert het wel echt een efficiëntie slag op waardoor ook de opdrachtgever minder capaciteit nodig heeft omdat ze niet voor al die verschillende projecten verschillende bestekken voor te bereiden allemaal apart aan te besteden."~N8 "Dan moeten de aannemers gaan uitvoeren. Alles wat niet goed is gegaan komen ze zelf weer tegen in de uitvoering." ~N9(2) "En nu, omdat een bouwteam erop zit, die gaat wel heel ruim van te voren, kijken naar alle planningen en naar van, wanneer het dan afvalt, wanneer kan die weg dicht. Wanneer zijn wij beschikbaar. Dus dan krijg je dus dat er veel meer vooruitgang zit.En komt een plek niet ook stil te liggen."~N9(1) "Die kosten wat lager zouden kunnen zijn, maar dat juist bij bouwteam projecten je vaak ziet dat ze niet goed gemanaged worden. Dat opdrachtgever teveel achterover leunt, het bij de aannemer niet echt een kostenprikkel ligt om de bouwteamfase efficiënter te doen."~N8
Effort in Bouwteam-phase	The data indicated that the effort in the bouwteam-phase is more intensive, among others because there is more certainty for the contractor that he is also the party executing in the realization phase. This also leads to better project execution. To attain often mentioned benefits or added value, intense effort is needed.	"En nou, heb je mooi alles voor die tijd getackeld. Dus het is aan de voorkant wat meer investeren in de voorbereiding. Ja, dat levert wel een betere realisatie op."~N7 "Ja, voor een aannemer dan veel acceptabeler om daar meer tijd en aandacht aan te besteden."~N4 "Je steekt er meer energie in aan de voorkant, in dat contract en dat ontwerp. Maar dat moet zich wel weer een beetje terugvertalen in een soepele uitvoering."~N7 "Ja, maar dan moet je wel wat verdoen, dan moet je wel voor inrichten"~N9(3)

Table B.3: Defined Themes and Illustrative Quotes (3)

Theme	Description	Illustrative Quotes
(Fostering) Innovation / Sustainability in Bouwteam	The data revealed that the use of a bouwteam can foster innovation and sustainability. These aspects depend on the specific project scope but can also emerge spontaneously.	“In die zin denk ik dat het in een bouwteamverband wel een betere kans heeft om iets innovatiefs te doen.”~N7 “Dat het ook kan voorkomen dat je in de bouwteamfase zelf met de aannemer op een innovatie komt, terwijl dat misschien niet de bedoeling was, maar dat je het wel kan toepassen, juist omdat je geen strak gekaderde scope hebt.”~N8 “En dan heb je nog natuurlijk de project specifieke voordelen die afhangen van wat je projectdoelen zijn. Dus dat kan zijn innovatie of duurzaamheid.”~N8
Cost in Bouwteam	The data contained a lot of information on the cost of bouwteam projects. Answers were divergent among the experts/stakeholders. Most statements suggest that costs are higher in a bouwteam project (especially in the bouwteam phase), but this could be justified by the added value. There are also experts that think costs are lower in a bouwteam setting, even in the design phase.	“Het algemene beeld wat ik haal en wat ik ook terugkrijg van opdrachtgevers is dat de prijzen bij bouwteams een stukje hoger liggen.”~N8 “Kosten van een bouwteam zijn meestal wat hoger.”~N2 “Meestal zijn de faalkosten minder.”~N6
Disadvantages RAW/UAV-GC	The data revealed several disadvantages associated with traditional RAW and UAV-GC contracts. These include a lack of flexibility, many project deviations, and wasted effort. Costs are also reported to be higher in some cases, due to inefficient work, for example.	“Je gaat niet heel veel geld en tijd hierin stoppen als je er onzekerheid over hebt of je de opdracht wel of niet krijgt.”~N4 “Op het eind van het liedje kwamen we toch weer op die 1 miljoen uit die geraamd was, door allerlei meerwerk en andere dingen die erbij kwamen.”~N2 “En gaat conform de contractstukken buiten aan de slag. Ik denk dat in 99 van de 100 gevallen er afwijkingen zijn.”~N3 “En daar zaten we vroeger op, als je kijkt naar voorbereidingskosten, etc, Het is dus wel 20% aan kosten in de voorbereiding.”~N9(1)

Table B.4: Defined Themes and Illustrative Quotes (4)

Theme	Description	Illustrative Quotes
Quality in bouwteam	The transcribed interview data, indicated that the quality of bouwteams is at least perceived to be equal to the quality of traditional projects. Sometimes experts even think it is higher, especially when formulating it as: value for money. Among others is the margin that contractor gets on the work, one of the reasons given that leads to this increased quality.	"Waar ik wel mee eens ben. Is dat een bouwteam sowieso niet voor minder kwaliteit zorgt"~N5 "Betere prijs kwaliteitsverhouding."~N3 "Dan moeten de aannemers gaan uitvoeren. Alles wat niet goed is gegaan komen ze zelf weer tegen in de uitvoering."~N9(2) "Prijs voor de realisatiefase niet die concurrentie tot stand is gekomen, heeft de aannemer ook een prijs. Waar binnen die het werk gewoon goed zou moeten kunnen uitvoeren en niet tijdens het werk nog op zoek hoeft naar allerlei besparingsmogelijkheden die eventueel ten koste gaan van kwaliteit."~N8
Risk Management in Bouwteam	The data indicated that risk management in bouwteams is better than in traditional projects. This is because the contractor is involved in the design phase, which leads to better risk identification and management (due to that both parties are assessing risk together). Also, the risk are discussed more intensively, which leads to a more optimal and proactive approach to risk management.	"Kijk dat wat wel een voordeel is, is dat je in bouwteamverband. Ja Samen het risicodossier kan maken. En ja je houdt elkaar wel op in scherpe daarop. Uiteindelijk leidt dat Natuurlijk tot een beter, een beter contract en een beter ontwerp."~N7 "Maar ze zijn beter beheersbaar. Ze zijn voorspelbaarder, ze zijn beter inzichtelijk gemaakt."~N4 "Dat zien we trouwens op onze bouwteams. Ook de mate waarin we aanspraak maken op onze risico-pot minimaal is."~N6
Time Implications in Bouwteam	The data revealed that the time implications of bouwteams are generally perceived to be positive. The use of bouwteams can be time efficient, this is especially due to the design phase as there is already a contractor on board. This leads to faster decisions and changeovers. However, the time implications can also be negative, especially when the contractor is not intrinsically motivated to be efficient in the design phase.	"Ja kon je kon je ook in een bouwteam kun je ook vrij snel beslissen, namelijk."~N2 "Maar tegelijkertijd moet je kanttekening maken dat zij dus op het algemeen veel beter in het proces zitten, sneller kunnen realiseren en uiteindelijk geen gedoe krijgen in die uitvoering. "~N3 "Ik denk dat de projectduur redelijk goed wordt ingeschat."~N1

Table B.5: Defined Themes and Illustrative Quotes (5)

Requirements & Dis-advantages/Concerns for Bouwteam	The data revealed that although experts were quite enthusiastic about the use of Bouwteams. A successful bouwteam is not guaranteed and needs intensive care. A big concern among experts is among others that a different mindset that is required from contractor and client compared to the traditional way of working. Also do some experts believe that bouwteam has some fundamental small disadvantages.	"Ja en succes hangt wel samen met de samenwerking van beide partijen, dus de match onderling. Daar is natuurlijk het bouwteam wel op gebaseerd. Is er voldoende commitment"~N3 "Dus eigenlijk als een soort oplossing voor personeelskrapte ik. Ik heb daar wel een beetje mijn twijfels bij. Want ja, net al gezegd. Opdrachtgever moet ook leiding geven aan het bouwteam, die moet besluiten nemen, moet input leveren. Het vraagt best wel van de opdrachtgever, maar je ziet wel dat het vaak als reden wordt aangevoerd om voor een bouwteam te kiezen"~N8 "Ook in die bouwteam samenwerking goed dat je open, eerlijk en transparant bent. Vanaf het begin "~N3
Other Added Value in Bouwteam	The data revealed several other qualitative benefits of using bouwteams which were initially not a main part of the topic lists, so is the absence of a complex tender considered an advantage as well as the positive effect on social costs.	"Ik denk dat je daar bepaalde dingen voor terug krijgt, wat ik zei van begrip bij de burgerij maatschappelijke kosten. Die kunnen ook wat waard zijn"~N5 "Nou, en scheelt heel veel aanbestedingen.~N9(1) "Kijk wat gewoon echt een voordeel is, is dat dat we het niet hoeven aan te besteden"~N7 "Dat is ook een voordeel overigens van bouwteams. Je hebt In de aanbestedingsfase heb je gewoon minder inspanning. Dat maakt het voor één aannemer ook aantrekkelijk hè? Je hoeft niet nog niet helemaal inhoudelijk dat werk te doorgronden, je hoeft er nog niks te engineeren."~N6
Other Relevant Data	The data also contained some other relevant information that did not fit into the predefined themes. This among others included insights on the structure of bouwteam and the intermediate deliverables.	"En, wat wil ik zien niet één werkomschrijving of een plan van aanpak, ik wil bestekken en tekeningen zien, want die die ik in het slechtste geval als wij je straks er prijstechnisch niet uitkomen met die aannemer, dat we echt gedoe hebben, dan moeten wij wel kunnen zeggen van, nou ja een ander maakt het af, bouwteam periode is klaar"~N7 "Wij hebben ook gezegd dat er een van onze uitgangspunten is, ook wel dat de aannemer gewoon een eerlijke boterham mag verdienen. hij mag ook, hij mag ook gewoon een goede winst maken en."~N7 "Zeer complexe projecten waarbij jij als als opdrachtgever totaal het risico niet overziet en waarbij je volledige risico bij een aannemer wil neerleggen. Dat dan kies je weer een UAV-GC."~N5

Appendix C

Appendix: Criteria Overview

ID	Criteria	Defined as	Key Sources
1	Cost benefits	Refers to the extent costs benefits are present. In terms of measurable advantages in the project, (financial) gains against incurred costs. This considers design or realization costs savings and control on the costs in the project.	(Rahmani, 2020)
1a	Cost control	Refers to the extent costs can be controlled and costs in the project are more certain.	(Rahmani, 2020)
1b	Design cost savings	Refers to the extent cost in the design phase are beneficial with regards to the amount	(Song et al., 2009)
1c	Realization cost savings	Refers to the extent costs in the realization phase are beneficial with regards to the amount	(Song et al., 2009)
2	Sustainability	Refers to the extent sustainability (people, planet, profit) is facilitated in the project	(Finnie et al., 2023)
2a	Long term viability (life cycle costs)	Refers to the extent that the way of working is viable for the long run (financial)	-
2b	Less environmental impact (clean air)	Refers to the extent impact on the environment is reduced with regards to greenhouse gases (planet).	(Kivilä et al., 2017)
2c	Stakeholder satisfaction (extern)	Refers to the extent stakeholders are satisfied with their way of working and results, note that this considers stakeholders who are not actors	(Gibson, 2000)
3	Quality	Refers to the extent the final product complies with standards, performs and reduces defects	(Arditi & Gunaydin, 1997; Rowlinson & McDermott, 2005)
3a	Compliance with standards	Referring to the extent requirements in the contract are satisfied (legal, aesthetic, and functional requirements).	(Arditi & Gunaydin, 1997)
3b	Reduced defects	Refers to the extent defects are reduced in the delivered end-product.	(Farrell & and, 2022)

Continued from previous page

ID	Criteria	Defined as	Key Sources
3c	Increase durability/performance	Refers to the extent performance is increased in the delivered end-product.	(Pocock et al., 2006)
4	Innovation	Refers to the extent new techniques are facilitated; this includes process innovation as well as the innovation of technique itself (e.g., due to using a bouwteam new collaboration methods were utilized)	(Blayse & Manley, 2004)
4a	Technical Innovation	Refers to the extent product innovation is facilitated.	(Ishtiaque et al., 2024)
4b	Process Innovation	Refers to the extent process innovation is facilitated.	(Ishtiaque et al., 2024)
5	Risk management	Refers to the extent risks are optimal, by identifying, mitigating, and distributing them.	(Rahman & Alhassan, 2012)
5a	Risk allocation	Refers to the extent risks are divided more optimally between the parties involved in the project.	(Rahman & Alhassan, 2012)
5b	Risk identification	Refers to the extent risks can be identified, also could refer to the accuracy of the identified risks	(Ma & Xin, 2011)
5c	Risk mitigation	Refers to the extent the risks are mitigated, (e.g., how well risk is managed, prepared for)	(Rahmani et al., 2013)
6	Project Clarity & Complexity reduction	Refers to the extent non-simple interdependent behaving variables/project characteristics can be made simpler as well as the ability to make the scope have a clearer goal.	(Ma & Xin, 2011; Rahmani et al., 2013)
6a	Constructability	Refers to the extent to which the design is executable	(Beach et al., 2005; Rahmani, 2020)
6b	Increase transparency	Refers to the extent transparency is given in the costs and motives of the parties involved in the project.	(Finnie et al., 2023; Mosey, 2009)
6c	Reduce scope changes	Refers to the extent scope changes are reduced in the realization phase of an infrastructure project.	(Beach et al., 2005; Rahmani et al., 2013)
7	Collaboration	Refers to the enhancement of collaboration	(Beach et al., 2005; Ng et al., 2021; Rahmani, 2020)
7a	Workforce optimization	Refers to the extent knowledge and capacity is obtained	(Gordon, 1994)
7b	Conflict reduction	Refers to the extent conflicts are reduced in terms of probability and handling	(Rahmani, 2020)
7c	Better communication	Refers to improved communication between the parties involved in the project	(Rahmani et al., 2022)

Appendix D

Appendix: Analytical Hierarchy Process (AHP) Survey

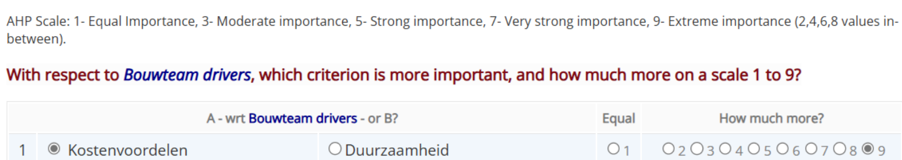
AHP Survey drijfveren bouwteams vergelijken

U bent uitgenodigd voor het invullen van een AHP-enquête voor het onderzoek "The added value of Bouwteams in infrastructure projects". Deze studie is uitgevoerd door Joep Seinen, van de faculteit Behavioural, Management and Social Sciences van Universiteit Twente. De Analytical Hierarchy Process (AHP) is een beslissingshulpmiddel om meerdere criteria te analyseren door ze op te breken in een hiërarchische criteria structuur. Dit wordt gedaan door criteria relatief aan elkaar te prioriteren.

In deze enquête is het doel om drijfveren voor het gebruik van een bouwteam in de infrastructuur te vergelijken op basis van hun importantie. Drijfveren zijn geïdentificeerd met behulp van literatuur en expertinterviews van zowel opdrachtgevers als opdrachtnemers perspectief. Hierbij zijn hoofd drijfveren en sub-drijfveren binnen de hoofddrijfveer gedefinieerd. Indien niet helemaal duidelijk is wat de definitie van een drijfveer is, is op pagina 2 een overzicht van gedefinieerde drijfveren gegeven (wellicht handig om deze naast de AHP-enquête te houden).

Let op! De enquête gaat dus over wat u de meest belangrijke voordelen van bouwteams vindt die het gebruik van bouwteams zouden kunnen motiveren. Niet om de mate waarin u denkt dat dit voordeel (gemiddeld genomen) voorkomt in een bouwteam project (maar hangt natuurlijk wel samen). Ook is het de bedoeling dat het prioriteren wordt gedaan ongeacht of uw organisatie deze drijfveer toepast. Stel u vindt kostenvoordelen een belangrijkere drijfveer dan innovatie, maar uw organisatie gebruikt doorgaans bouwteams om innovatie te faciliteren: prioriteer dan toch kostenvoordelen over innovatie. Ook ben ik er me van bewust dat het type bouwteam project andere belangrijkheid van de drijfveren heeft, probeer de enquête in te vullen voor een gemiddeld bouwteamproject.

Stel u vindt kostenvoordelen een extreem belangrijkere drijfveer dan duurzaamheid, selecteer kostenvoordelen en het nummer dat aangeeft hoeveel belangrijker (9 in dit geval):



Wanneer vergelijkingen inconsistent zijn, Consistency Ratio (CR) > 0,10, wordt u gevraag uw antwoorden te herzien (door het programma) doe dit dan ook alstublieft. U wordt gevraagd dan weer eerst "Calculate" te klikken voordat u uw antwoorden instuurt "Submit".

Dit is de link naar de AHP-enquête: https://bpmsg.com/ahp/ahp-hiergini.php?sc=ESeWeT

De ingevoerde naam is alleen voor mij zichtbaar. De enquête is volledig vrijwillig, u kunt op elk moment stoppen. Er zijn geen erkende risico's met betrekking tot de enquête, echter is (zoals met elke web-activiteit) gegevensbreuk nooit uit te sluiten. Data zal worden opgeslagen in een ISO 27001 gecertificeerd MS Teams kanaal. Uw naam zal worden weggelaten in de scriptie. U kunt de enquête in meerdere sessies invullen, klik dan wederom op de link en vul uw naam weer identiek in, u gaat dan verder waar u was gebleven.

Succes en alvast bedankt voor het invullen!!!

Criteria	Definitie
Kostenvoordelen	Refereert naar kostenvoordelen, kan betreffen ontwerpfase besparingen, realisatiefasebesparingen, betere kostenbeheersing.
Ontwerpfase kostenbesparingen	Refereert naar kostenbesparingen in de ontwerpfase van een project. (Gedefinieerd vanaf de initialisatie van het voorlopig ontwerp tot en met het begin van de uitvoering)
Realisatiefase kostenbesparingen	Refereert naar kostenbesparingen in de realisatiefase van een project. (Gemeten tot aan de oplevering van een project)
Kostenbeheersing	Refereert naar een betere grip op de kosten binnen het project.
Duurzaamheid	Refereert naar het faciliteren van duurzaamheid (mens, planeet, winst) in een project.
Lange termijn haalbaarheid (levensduurkosten)	Refereert naar het op de lange termijn haalbaar (toekomstbestendig) zijn van de werkwijze.
Minder milieubelasting (schone lucht)	Refereert naar het minder belasten van de omgeving met betrekking tot broeikasgassen (planeet).
Tevredenheid belanghebbenden (extern)	Refereert naar het tevreden zijn van de belanghebbenden, dit omvat belanghebbenden die niet direct in het project zijn betrokken, (bijv. omwonenden hebben minder overlast)
Kwaliteit	Refereert naar het voldoen van projecteisen, de prestaties en minder defecten/gebreken.
Naleving projecteisen	Refereert naar het beter naleven/voldoen van projecteisen, betreft (juridisch, esthetisch en functioneel).
Vermindering van gebreken	Refereert naar het minder voorkomen van gebreken in het opgeleverde eindproduct.
Verhogen van prestaties	Refereert naar het verhogen van de prestaties van het op te leveren product (bijv. hogere kwaliteit constructie)
Innovatie	Verwijst naar het bevorderen van nieuwe technieken, beschouwt procesinnovatie en innovatie van de techniek zelf (bijv. door het gebruik van een bouwteam werden nieuwe samenwerkingsmethoden toegepast).
Technische innovatie	Refereert naar het faciliteren van technische innovatie.
Proces innovatie	Refereert naar het faciliteren van proces innovatie, (bijv. binnen het bouwteam werd geopperd voor een gezamenlijk BIM-model, waardoor de samenwerking gedurende het project nog beter verliep)
Risicobeheer	Refereert naar een optimaler risicobeheer (risico verdeling, risico herkenning, risico mitigatie).
Risico allocatie	Refereert naar een betere verdeling van risico's in het project tussen de betrokken partijen.
Risico identificatie	Refereert naar een betere risico identificering, inclusief de nauwkeurigheid van het geïdentificeerde risico.
Risico mitigatie	Refereert naar een betere risico mitigatie, (bijv. het verminderen van de impact of waarschijnlijkheid van het desbetreffende risico).
Project helderheid en complexiteitsreductie	Refereert naar het vereenvoudigen van projectkenmerken (bijv. onderling afhankelijke projectkenmerken) evenals het vermogen het project helderder te maken (bijv. scope verduidelijking, of motieven delen).
Uitvoerbaarheid	Refereert naar het uitvoerbaar worden/zijn van een project, met andere woorden het goed kunnen realiseren van het ontwerp.
Transparantie vergroten	Refereert naar het transparanter maken van kosten en motieven van de betrokken partijen in een project.
Scopewijzigingen verminderen	Refereert naar het verminderen van scopewijzigingen gedurende het project.
Samenwerking	Refereert naar het verbeteren van de samenwerking gedurende het project.
Conflict beheersbaarheid	Refereert naar het verbeteren van het risico op- en het behandelen van conflicten tussen de betrokken partijen.
Verbeterde communicatie	Refereert naar het verbeteren van communicatie tussen de betrokken partijen in het project.
Optimalisatie van de arbeidskracht	Refereert naar het verkrijgen van meer kennis en capaciteit door het samenwerken van een aannemer en opdrachtgever vanaf de ontwerpfase.

Appendix E

Appendix: Mathematical Background of the AHP

The mathematical background of the AHP is based on pairwise comparisons, where each driver and sub driver is compared against each other to determine their relative importance. The AHP uses a matrix to represent these comparisons, where the elements of the matrix are filled with the values from the fundamental scale of pairwise comparisons (Table 4.1). The matrix is then used to calculate the priority vector, which represents the weights of each driver and the sub driver. The pairwise comparisons are represented in an $n \times n$ matrix $\mathbf{A}$, where n is the number of criteria. Each element a_{ij} of the matrix indicates the relative importance of criterion i over criterion j according to the fundamental scale. The normalized matrix is calculated as:

$$a'_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} \tag{E.1}$$

The priority vector (weights) $\mathbf{w}$ is then obtained by averaging the rows of the normalized matrix:

$$w_i = \frac{1}{n} \sum_{j=1}^{n} a'_{ij} \tag{E.2}$$

A key aspect of AHP is the consistency of the pairwise comparisons, measured by the Consistency Ratio (CR). Following Ishizaka and Labib (2011) and Saaty (2012) a value of $CR < 0.1$ is considered acceptable. To derive CR first the Consistency Index needs to be calculated, the Consistency Index (CI) is calculated as:

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(\mathbf{A}\mathbf{w})_i}{w_i} \tag{E.3}$$

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{E.4}$$

The Consistency Ratio is then:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{E.5}$$

where RI is the Random Consistency Index, which depends on n (T. Saaty, 2008).

Table E.1: Random Consistency Index (RI) values for different matrix sizes n

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

If CR exceeds the threshold of 0.10, the expert is asked to revise their judgments.

For group AHP, the geometric mean is used to aggregate the individual pairwise comparison matrices from multiple participants into a group matrix. For each element (i, j), the aggregated value is:

$$a_{ij}^{\text{group}} = \left(\prod_{k=1}^{m} a_{ij}^{(k)} \right)^{1/m} \tag{E.6}$$

where $a_{ij}^{(k)}$ is the (i, j)-th entry from participant k's matrix, and m is the number of participants.

After constructing the aggregated group matrix, the eigen vector method is then applied to each row to determine the group priority weights as described previously. To limit cognitive load, the number of main criteria is restricted to seven, each with at most three sub-criteria.

Appendix F

Appendix: Monte Carlo Code

```
"""
This script performs a Monte Carlo simulation, this in order to verify the robustness of the AHP
    input of 4 experts considering bouwteam projects.

Note: Some parts of this code were rewritten with the help of AI models such as ChatGPT 4.1 and
    GitHub copilot. All logic and final implementation decisions were reviewed and made
    independently by the author. Missing expertise on Python programming to implement the logic
    was obtained from programming help platforms such as GeeksforGeeks and Stack Overflow.

The purpose of AI assistance in this code was to:
- Improve code readability (e.g., variable names & insightful print statements)
- Increase code efficiency (e.g., operations on vectors/matrices, loops & suggesting optimizations
    )
- Debugging (e.g., prompting for edge cases and suggesting fixes as well as evaluating unexpected
    behaviour/outcomes)
- AI-generated suggestions were only used for non-theoretical components (e.g., syntax, pandas/
    numpy optimizations)

All AI generated code/suggestions were checked and verified before implementation by the author:
- Cross-checked against programming help platforms (e.g., GeeksforGeeks, Stack Overflow) for
    correctness and efficiency
- Stepped through code logic to ensure it aligns with theoretical principles (such as AHP)

!Final implementation decisions and theoretical adherence remain author-driven.!

References:
- GeeksforGeeks: https://www.geeksforgeeks.org/
- Stack Overflow: https://stackoverflow.com/
"""

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.stats import norm
import random

# For reproducibility
np.random.seed(42)
random.seed(42)

def compute_gm_matrix(matrices):
    stacked = np.stack(matrices, axis=-1)
    gm_matrix = np.prod(stacked, axis=-1) ** (1/len(matrices))
    return gm_matrix

def load_ahp_matrices(csv_path):
    # Read data from CSV file.
    data = pd.read_csv(csv_path, sep=',', header=None, engine='python', skiprows=1, encoding='utf
        -8')
    experts = {}
    idx = 0
    current_expert = None
```

```
    # CSV file has consistent structure, but just in case, we parse carefully.
    while idx < len(data):
        row = data.iloc[idx]
        if str(row[0]).strip() == "Participant":
            current_expert = str(row[1]).strip()
            experts[current_expert] = {}
            idx += 1
        elif str(row[0]).strip() == "Node":
            node_name = str(row[1]).strip()
            size = int(str(row[2]).split('x')[0])
            matrix = []
            for i in range(size):
                idx += 1
                matrix_row = data.iloc[idx][2:2+size]
                matrix_row = [float(x) for x in matrix_row if pd.notnull(x)]
                matrix.append(matrix_row)
            experts[current_expert][node_name] = np.array(matrix)
            # Data loaded in dictionary format
            idx += 1
        else:
            idx += 1

    print(f"Loaded {len(experts)} experts with matrices.")
    print("Experts:", list(experts.keys()))
    return experts

def perturb_matrix(matrix, noise_level=0.3):
    # Add noise and snap to valid Saaty-scale values (1-9 and reciprocals).
    valid_values = np.array([1/9, 1/8, 1/7, 1/6, 1/5, 1/4, 1/3, 1/2, 1,
                             2, 3, 4, 5, 6, 7, 8, 9])
    perturbed = matrix.copy()
    n = len(matrix)
    for i in range(n):
        for j in range(n):
            # Skip diagonal elements (self-comparisons)
            if i == j:
                continue
            # N~(original value = aij, sd = noise_level = 0.3)
            noisy_val = norm.rvs(loc=perturbed[i, j], scale=noise_level)
            # index of closest valid value
            idx = np.argmin(np.abs(valid_values - noisy_val))
            noisy_val = valid_values[idx]
            perturbed[i, j] = noisy_val
            # Ensure reciprocal property holds
            perturbed[j, i] = 1 / noisy_val
    return perturbed

def ahp_weights(matrix):
    # Calculate AHP weights using the principal eigenvector method, (all matrices are square).
    eigvals, eigvecs = np.linalg.eig(matrix)
    max_index = np.argmax(np.real(eigvals))
    principal_eigvec = np.real(eigvecs[:, max_index])
    weights = principal_eigvec / np.sum(principal_eigvec)
    return weights

def monte_carlo_ahp_geometric_aggregation(expert_matrices, n_simulations=10000, noise_level=0.3):
    # Run simulations using geometric mean aggregation across experts.
    results = {}
    all_nodes = set()
    for expert in expert_matrices:
        all_nodes.update(expert_matrices[expert].keys())

    for node in all_nodes:
        weights_dist = []
        for _ in range(n_simulations):
            perturbed_matrices = []
            for expert in expert_matrices:
                if node in expert_matrices[expert]:
                    # For each expert, perturb their matrix for this node
                    perturbed = perturb_matrix(expert_matrices[expert][node], noise_level)
                    perturbed_matrices.append(perturbed)
```

```
            if not perturbed_matrices:
                print("No matrices for driver/node")
                continue
            # Compute geometric mean of perturbed matrices across experts
            gm_matrix = compute_gm_matrix(perturbed_matrices)
            # Calculate AHP weights from the aggregated matrix
            weights = ahp_weights(gm_matrix)
            weights_dist.append(weights)
        # Store results for this node
        results[node] = np.array(weights_dist)
    return results

# Main analysis
if __name__ == "__main__":
    # Load all expert matrices from the CSV
    # Ensure the path is set to the input file
    experts = load_ahp_matrices(r'C:\Users\joeps\Thesis Sensivity Analysis\Input.csv')

    # Run Monte Carlo simulation with geometric mean aggregation
    results = monte_carlo_ahp_geometric_aggregation(experts, n_simulations=10000)

    # Define the main criteria in the correct order
    main_drivers = [
        "Kostenvoordelen", "Duurzaamheid", "Kwaliteit",
        "Innovatie", "Risicobeheer", "Project helderheid en complexiteitsreductie",
        "Samenwerking"
    ]
    # Main driver matrices: 10,000 simulations r times 7 main drivers (columns, in correct order)
    bouwteam_weights = results["Bouwteam drivers"]

    # For each simulation, rank the main criteria
    ranks = np.argsort(-bouwteam_weights, axis=1)

    # Calculate rank probability
    rank_probability = np.zeros((len(main_drivers), len(main_drivers)))
    for alt_idx in range(len(main_drivers)):
        for rank in range(len(main_drivers)):
            # For each alternative and each rank, count how often that alternative is at that rank
            rank_probability[alt_idx, rank] = np.mean(ranks[:, rank] == alt_idx)

    # Store and print the rank probability matrix
    rank_df = pd.DataFrame(rank_probability, index=main_drivers, columns=[f"Rank {i+1}" for i in range(len(main_drivers))])
    print("\nRank probability matrix:")
    print(rank_df.round(2))

    # Calculate and print the mean and standard deviation of weights across all simulations (arithmetic mean)
    mean_weights = np.mean(bouwteam_weights, axis=0)
    std_weights = np.std(bouwteam_weights, axis=0)
    print("\nGlobal mean weights & std:")
    for driver, mean, std in zip(main_drivers, mean_weights, std_weights):
        print(f"{driver}: {mean:.3f} & {std:.3f}")

    # Print the mean weights and the most likely rank for each main criterion
    print("\nMean weights and most likely rank:")
    for i, driver in enumerate(main_drivers):
        most_likely_rank = np.argmax(rank_df.loc[driver].values) + 1
        print(f"{driver}: {mean_weights[i]:.3f} (Rank {most_likely_rank})")

    # Export results to CSV files for further analysis/visualization
    rank_df.to_csv("main_criteria_rank_prob.csv")
    pd.DataFrame({
        "Label": main_drivers,
        "Mean Weight": mean_weights,
        "Std Dev": std_weights
    }).to_csv("main_criteria_mean_weights.csv", index=False)
```

Listing F.1: Monte Carlo simulation for AHP sensitivity analysis

Note: For the code to run correctly, the input file path in the code needs to be set to the location of the input file. The input file should be a CSV file with a specific, consistent structure.

For the boxplot, see Figure 4.5, in the main text similar code was used. However, the code was adapted to store sub-driver weights, and not aggregate weights among experts. The code in order to create the input for the boxplot is not included here, as it is similar to the code used for the main drivers and can be easily adapted from the provided code. The most important changes were:

- To not to aggregate the weights of the sub-drivers, but to store them in a matrix, write them to a CSV, and plot the results.
- Multiply the sub-driver weights with the main driver weights to get the final sub-driver weights.