Department of the Built Environment
Construction Management and Engineering

The relationship between project delivery methods for primary school buildings, and project success factors.

Master Thesis

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Preface

The competitive nature of the construction industry has always captured my interest, driven by my competitive spirit. When looking for a master's thesis topic, I was instantly drawn to how this competitive element influences who is responsible for what part of a construction project and how this could lead to more project success, especially for user-oriented buildings like schools. This thesis was not only an opportunity to perform academic research, but also an opportunity for great personal development where I could experience what working in this field could be like.

I reached out to several different companies to exchange ideas and create a framework for research around this topic. It was during the last of these conversations that I met Winifred van den Bosch, who eventually became my company supervisor. Winifred's unending enthusiasm, optimism, and problem-solving mentality, and HEVO's general working atmosphere provided me with the perfect environment to tackle this research. Because of this thesis's specialized and complex nature, I looked for external academic guidance outside the TU/e and eventually found Ad Straub. Who, out of a passion for the subject, committed to guiding me through this process. Ad's academic expertise, coupled with his knowledge of the subject, helped me shape the research academically, and add depth to the project. They allowed me to develop the project largely independently, with both giving me the freedom to explore and structure the thesis in a way that I thought fit the research gap. This not only allowed me to delve deep into the subject, but also helped me develop my professionalism, independence, and career orientation.

The main goal of this research was to collect empirical data that could contribute to making construction projects more efficient and goal-oriented. I am proud to say that I believe this object has been achieved, as the project provides not only data but also a framework for additional research on other projects. I believe that this thesis provides valuable insights to both academia and the construction industry in general.

Finally, I would like to thank my family, friends, girlfriend, roommates, colleagues, and team members for their support, especially for ensuring I didn't spend every minute of the last six months obsessing over this thesis. I am very grateful for your distractions; you know who you are.

Summary

This thesis explores the relationship between Project Delivery Method (PDM) and project success factors, specifically within the context of primary school construction. Construction projects are becoming increasingly complex, driven by increasing regulatory demands and a need for more sustainable projects. The main objective of this study is to improve clients' and stakeholders' decision-making regarding the choice of suitable PDMs for projects, thereby improving the projects' success.

It is centred around the main research question: ***What is the relationship between the chosen PDM for primary school buildings, and project success factors?*** To address this, a series of subquestions were developed, which focus on methodologies for comparing PDMs, gathering and analysing project data, and understanding how these methods influence various project success factors. The research is structured in four phases: forming a theoretical framework, quantitative analysis, qualitative analysis, and a synthesis. As this study finds relationships between PDMs and project success factors, it is important to consider that correlation does not mean causation. The results should be interpreted with this in mind.

The research starts by developing a theoretical background through a literature review. It reviews outlines of the phases of construction projects, emphasizing unique challenges in constructing primary school buildings. It also discusses different PDMs, their historical context, their assumed strengths and weaknesses, and the need for careful selection based on project needs. The literature review also covers risk allocation, procurement, and current expectations of the effect of PDMs on project success factors.

The quantitative analysis involved the collection and normalization of data from various projects. This data was used to identify trends and patterns of project success factors throughout the project phases. The project success factors are expressed in metrics such as cost per square meter and project duration. The analysis revealed distinct patterns: traditional PDMs struggled with both cost and time metrics, while integrated PDMs exhibited strong cost efficiency and consistency from early design phases onwards. RPM projects managed cost-effectively but encountered significant issues with time metrics.

Quantitative research analysis was done by collecting data on a selection of projects analysed during the quantitative research. The data was collected through semi-structured interviews with project managers and client representatives. The interviews discussed their views on the success of the specific project they worked on, their general view of PDMs, and their influence on project success factors. It focused more on project quality and sustainability aspects of the analysed projects. The qualitative findings complemented the quantitative data by highlighting the importance of client control and all the different factors that can influence the success of a project, such as communication quality and stakeholder alignment. This provided knowledge on the quality performance of PDMs and a nuanced understanding of what factors influence the success of construction projects.

A synthesis of the quantitative and qualitative research provided an understanding of the

relationship between PDMs and project success factors. The quantitative data offered objective and measurable insights into the performance of PDMs throughout the project, while the qualitative findings provided more information on quality, context, and why specific trends occur. This allowed for the research question, and its subquestions, to be answered. The identified relationships of PDMs and project success factors for primary schools can be summarized as follows: Traditional PDMs excelled in quality but faced significant cost and construction time management challenges; Integrated PDMs showed strong cost efficiency and time management, but long-term quality varied; RPM projects performed well in cost management and quality but struggled with extended project timelines.

A reflection of this synthesis shows that a large part of the findings align with the existing literature on the subject, but some differences are also found. The literature agrees that traditional projects encounter significant problems with time management, integrated projects perform better on cost and time metrics, and that management contracting is effective in management and quality control. This research finds significant deviations from the literature, such as the cost performance of RPM projects and the time performance of traditional projects.

This comprehensive research approach allowed the study to better understand the influence of PDMs across different project phases. This offers insights for clients and other stakeholders to make more informed decisions when selecting the PDM best suited for a project. It highlights the importance of tailoring the PDM selection process to project-specific priorities, resources, and stakeholders. It concludes by stating a PDMs significant impact on the success of primary school construction projects, while emphasizing the importance of data-driven, empirical decision-making in selecting PDMs. Suggesting that future research should focus on expanding on what data is used and what types of projects are analysed.

Samenvatting

Deze scriptie onderzoekt de relatie tussen bouworganisatievormen en succesfactoren, specifiek in de context van de bouw van basisscholen. Bouwprojecten worden steeds complexer door toenemende regelgeving en de behoefte aan duurzamere projecten. Het hoofddoel van deze studie is om de besluitvorming van opdrachtgevers en belanghebbenden te verbeteren bij de keuze van geschikte bouworganisatievormen, en zo het succes van de projecten te vergroten.

De studie draait om de hoofdonderzoeksvraag: *Wat is de relatie tussen de gekozen bouworganisatievormen voor basisschoolgebouwen en succesfactoren?* Om deze vraag te beantwoorden, zijn er een aantal subvragen ontwikkeld die zich richten op methoden voor het vergelijken van bouworganisatievormen, het verzamelen en analyseren van projectgegevens, en het begrijpen van hoe deze methoden verschillende succesfactoren beïnvloeden. Het onderzoek is gestructureerd in vier fasen: het vormen van een theoretisch kader, kwantitatieve analyse, kwalitatieve analyse en een synthese. Aangezien deze studie relaties vindt tussen bouworganisatievormen en succesfactoren, is het belangrijk er rekening mee te houden dat correlatie geen oorzakelijk verband betekent. De resultaten moeten met dit in gedachten worden geïnterpreteerd.

Het onderzoek begint met het ontwikkelen van een theoretische achtergrond door middel van een literatuuronderzoek. Dit onderzoek bespreekt de fasen van bouwprojecten en legt de nadruk op de unieke uitdagingen bij het bouwen van basisscholen. Het behandelt ook verschillende bouworganisatievormen, hun historische context, hun veronderstelde sterke en zwakke punten, en de noodzaak van zorgvuldige selectie op basis van projectbehoeften. Het literatuuronderzoek omvat ook risicoverdeling, aanbesteding en de huidige verwachtingen van het effect van bouworganisatievormen op succesfactoren.

De kwantitatieve analyse omvatte het verzamelen en normaliseren van gegevens van verschillende projecten. Deze gegevens werden gebruikt om trends en patronen van succesfactoren gedurende de projectfasen te identificeren. De succesfactoren worden uitgedrukt in maatstaven zoals kosten per vierkante meter en projectduur. De analyse onthulde duidelijke patronen: traditionele methoden hadden moeite met zowel kosten- als tijdsfactoren, terwijl geïntegreerde methoden een sterke kosten-efficiëntie en consistentie vertoonden vanaf de vroege ontwerpfasen. Risicodragende projecten beheerden de kosten effectief, maar ondervonden aanzienlijke problemen met tijdmanagement.

De kwalitatieve analyse van het onderzoek werd uitgevoerd door gegevens te verzamelen over een selectie van projecten die werden geanalyseerd tijdens het kwantitatieve onderzoek. De gegevens werden verzameld door middel van semigestructureerde interviews met projectmanagers en vertegenwoordigers van opdrachtgevers. Tijdens de interviews werden hun opvattingen over het succes van het specifieke project waaraan zij werkten besproken, evenals hun algemene mening over bouworganisatievormen en hun invloed op succesfactoren. Er werd vooral gefocust op projectkwaliteit en duurzaamheid. De kwalitatieve bevindingen vulden de kwantitatieve gegevens aan door het belang van invloed van de opdrachtgever en de verschillende factoren die het succes van een project kunnen beïnvloeden, zoals communicatiekwaliteit en afstemming van

belanghebbenden, te benadrukken. Dit leverde kennis op over de kwaliteitsprestatie van bouworganisatievormen en een genuanceerd begrip van welke factoren het succes van bouwprojecten beïnvloeden.

Een synthese van het kwantitatieve en kwalitatieve onderzoek bood inzicht in de relatie tussen bouworganisatievormen en succesfactoren. De kwantitatieve gegevens boden objectieve en meetbare inzichten in de prestaties van bouworganisatievormen gedurende het project, terwijl de kwalitatieve bevindingen meer informatie gaven over kwaliteit, context en waarom specifieke trends zich voordoen. Hierdoor konden de onderzoeksvraag en de subvragen worden beantwoord. De geïdentificeerde relaties tussen bouworganisatievormen en succesfactoren voor basisscholen kunnen als volgt worden samengevat: traditionele methoden blonken uit in kwaliteit, maar hadden aanzienlijke uitdagingen op het gebied van kosten- en tijdmanagement; geïntegreerde methoden toonden sterke kosten-efficiëntie en tijdsbewaking, maar de langetermijnkwaliteit varieerde; risicodragende projecten presteerden goed in kostenbeheersing en kwaliteit, maar hadden te kampen met langere projectdoorlooptijden.

Een reflectie op deze synthese toont aan dat een groot deel van de bevindingen in overeenstemming is met de bestaande literatuur over het onderwerp, maar er zijn ook enkele verschillen gevonden. De literatuur is het erover eens dat traditionele projecten aanzienlijke problemen ondervinden met tijdmanagement, dat geïntegreerde projecten beter presteren op kosten- en tijdsfactoren, en dat management effectief is in beheersing en kwaliteitscontrole. Dit onderzoek heeft echter significante afwijkingen in verwachtingen ten opzichte van de literatuur, zoals de kostenprestaties van risicodragende projecten en de tijdprestaties van traditionele projecten.

Deze uitgebreide onderzoeksaanpak stelde de studie in staat om het effect van bouworganisatievormen in verschillende projectfasen beter te begrijpen. Dit biedt inzichten voor opdrachtgevers en andere belanghebbenden om beter geïnformeerde beslissingen te nemen bij het selecteren van de meest geschikte bouworganisatievorm voor een project. Het benadrukt het belang van het afstemmen van de keuze van de bouworganisatievorm op project-specifieke prioriteiten, middelen en belanghebbenden. Het besluit met de stelling dat bouworganisatievormen een aanzienlijke impact hebben op het succes van basisschoolbouwprojecten, terwijl het belang van op data gebaseerde, empirische besluitvorming bij de selectie van bouworganisatievormen wordt benadrukt. Een suggestie voor toekomstig onderzoek is om zich te richten op het uitbreiden van de gebruikte data en het analyseren van andere soorten projecten.

Abstract

Due to regulatory demands and sustainability goals, primary school construction projects are becoming more complex. The structure of a project is formed by a Project Delivery Method (PDM), which is a framework that organizes different stakeholders in a project. Therefore, selecting an appropriate PDM is crucial for a project's success. This study aims to improve decision-making by analysing how different Project Delivery Method (PDM)s impact key success factors, such as cost, time, and quality, by providing an empirical understanding of the relationship between these project success factors and PDMs for primary school building projects.

A mixed-methods approach combined a literature review, quantitative data analysis, and qualitative interviews was used to achieve this. Quantitative data was collected and normalized from various primary school projects to identify performance patterns across delivery methods. Qualitative insights were obtained through interviews with industry experts, focusing on the practical implications of these methods. The synthesis of these insights revealed that traditional methods struggle with cost and time management, but excel in quality. Integrated methods showed strong cost efficiency and time management despite varying long-term quality outcomes. Risk-carrying Project Management (RPM) managed costs effectively, but encountered significant challenges with project timelines.

The findings suggest that the choice of PDM is significantly related to the project success factors of primary school construction projects. The results of the thesis provide a novel and innovative understanding of how project success factors develop during project phases. The study emphasizes the need for data-driven decision-making and recommends expanding the scope of future research to include a broader range of project typologies, or combining different project success factor metrics into a general 'value' metric describing the overall success of a project.

Keywords: *Project Delivery Method (PDM), Project success factor, Primary schools, Risk-carrying Project Management, Project Management*

Contents

List of Abbreviations

ALIB 2007 ‘Algemene Leveringsvoorwaarden Installerende Bedrijven 2007’. xv, 22

AVA 2013 ‘Algemene Voorwaarden voor Aanneming van werk 2013’. xv, 22

BM Build and Maintain. xiv, xv, xix, 13, 14, 83

CM/GC Construction Manager/General Contractor. 14, 71

CMR Construction Manager (at) Risk. xvi, xviii, xix, 15, 16, 20, 22, 25, 26, 33, 36, 37, 39, 71, 84

DB Design and Build. xv, xvii–xix, 12–14, 17, 20, 21, 25, 26, 31, 37, 39, 82

DBB Design-Bid-Build. xvii, 10, 12, 21, 25, 26, 33, 37, 39

DBFMO Design, Build, Finance, Maintain, and Operate. xv, xvi, xix, 13, 14, 22, 36, 84

DBM Design, Build, and Maintain. xv, xviii, xix, 13, 14, 36, 39, 61, 83

DBMO Design, Build, Maintain, and Operate. xix, 14, 36, 61, 83

DNR 2011 ’De Nieuwe Regels’. xvi, 22

DO Definitive Design. xiv, xvi, 5–7, 21, 40, 41, 50, 51, 53–58, 63, 65, 72, 86

EB Engineer and Build. xv, xix, 12, 14, 39, 82

GFA Gross Floor Area. xviii, 33, 42, 43, 47–50, 54–57, 64, 86–88

HVAC heating, ventilation, and air conditioning. 7

MRQ Main Research Question. xi, 2, 27, 67

PDM Project Delivery Method. iv, v, viii–x, xiv–xviii, xxi, 1–6, 8–40, 44, 45, 47–53, 56–68, 70–75, 81, 88

POE Post-Occupancy Evaluation. xvi, 24, 30

PoR Programme of Requirements. 5, 6, 14, 19, 21, 40, 41, 43, 51–53, 55–57, 63, 64, 66–68, 86

RPM Risk-carrying Project Management. iv, v, viii, xviii, xix, 4, 15, 16, 22, 26, 36, 39, 40, 48–59, 61–64, 67–72, 75, 85

SO Sketch Design. xvi, 5, 6

SPV Special Purpose Vehicle. xv, xvi, 13

SQK Sub Question Knowledge. 3, 27–30, 34–36, 57, 63–68, 72

SQM Sub Question Methodology. 3, 27, 30, 32, 33

TO Technical Design. xvi, 5, 7, 21, 40, 41, 50, 53, 55, 65, 72, 86

UAV 2012 ‘Uniforme Administratieve Voorwaarden voor de uitvoering van werken en van de Technische installatiewerken 2012’. xvii, 22

UAV-GC 2005 ‘Uniforme Administratieve Voorwaarden voor Geïntegreerde Contracten 2005’. xvii, 22

VAT Value Added Tax. 44

VO Preliminary Design. xiv, xvi, 5, 6, 40, 41, 49–52, 55–57, 60, 63, 65–67, 86

Glossary

'Hoofdaanneming' A 'Hoofdaanneming' in the Dutch construction industry refers to a main contractor PDM where a main designer oversees the design process and a main contractor handles the realization phase, both hiring subcontractors for their respective tasks. The main construction contractor coordinates all aspects of construction, and typically operates under a fixed price agreement to improve communication and define responsibilities clearly. xiv, xvii–xix, 10, 11, 39, 81

'Nevenaanneming' In the Dutch construction industry, a 'Nevenaanneming' refers to a PDM where the client individually contracts multiple contractors for different parts of the project. This involves separate contracts with each contractor, with independently negotiated prices and terms. xiv, xvii, xix, 10, 11, 81

Build and Maintain In a Build and Maintain (BM) format, the client contracts the BM party after the design phase, focusing on construction and subsequent maintenance. Contrary to other integrated formats discussed, BM starts with the construction phase and involves the contractor in maintaining the project for a certain amount of time after completion. xiv, 13

Conceptual building is a PDM aiming to create a conceptual design that outlines the project's scope, feasibility, and preliminary cost estimates. The client selects from an existing concept, allowing them to visualize the project's outcome while retaining the ability to make minor decisions regarding materials and size. 17

Construction Manager (at) Risk as a PDM in the construction industry involves a contract manager taking responsibility for construction alone or for parts of the design phase as well. The construction manager, often involved before construction to provide cost estimation, scheduling, value engineering, and constructability reviews, assumes the role of a general contractor during construction, with the financial structure typically including separate fees for risk coverage and construction management services, offering the client complete or partial price certainty. 14

Construction Manager/General Contractor is a PDM that consists of the early participation of an experienced construction manager during the design phase, facilitating better coordination between the design phase and construction activities. 14

Definitive Design DO or 'Definitief Ontwerp' in Dutch, stage enhances the VO into a more detailed, finalized version, focusing on refining the design and adding technical specifications. The main outputs include finalized drawings, a final design document, accurate cost estimates, detailed execution plans, a fire safety concept, and documentation for permit applications. 5

Design and Build In a DB PDM, the client forms a contract with a DB contractor who assembles a team of architects, engineers, and construction experts, taking on all responsibility from the design phase through to project completion. The contract is typically under a fixed price or guaranteed maximum price. 12

Design, Build, and Maintain (DBM) is essentially a combination of the DB and BM PDM's. Within this method, a single contractor is responsible for the design, construction, and maintenance of a project, assembling a team to ensure the project proceeds according to the agreed specifications. 13

Design, Build, Finance, Maintain, and Operate DBFMO is a complex PDM. Similar to other integrated methods, a single contractor is responsible for the design, construction, maintenance, financing, and operation of a project, but a DBFMO makes use of a Special Purpose Vehicle (SPV) to manage all stakeholders. 13

Early Contractor Involvement or 'Bouwteam' in Dutch, is a Project Delivery Method where the contractor is engaged during the early design phase of a project to provide input on construction feasibility, cost, and scheduling. xvii, xix, 10, 11, 82

Engineer and Build (EB) is a PDM that involves the client contracting a single party, but this party only handles the engineering and realization phases, leaving part of the design outside their responsibility. The contractor, typically operating under a fixed price, manages the remaining part of the project with a team of engineers, architects, and construction professionals. 12

General Terms and Conditions for Contracting 2013 or 'Algemene Voorwaarden voor Aanneming van werk 2013' (AVA 2013) in Dutch, is a revised framework from AVA 1992, designed for general conditions in private construction works, particularly suitable for homes and business premises (Adriaanssen et al., 2017). 22

General Terms and Conditions for Installing Companies 2007 or 'Algemene Leveringsvoorwaarden Installerende Bedrijven 2007' (ALIB 2007) in Dutch, is tailored to the installations for new buildings and renovations, or maintenance issues (Adriaanssen et al., 2017). 22

growth is the (expected) value of a metric at a phase of the project compared to the first expectation, expressed in %. It is an indication of the predictability of a metric, but should not be confused with absolute metrics. xviii–xxi, 23, 25, 26, 30, 32–34, 41, 43, 51–60, 63–69, 71, 73, 74, 99

integrated a group of PDMs that aim to create better collaboration and integration between all parties involved in a construction project, potentially improving the final project results. This approach is seen in methods like DB and its variations. iv, v, viii, ix, xiv, xv, 1, 9, 12–14, 17, 19–22, 25, 26, 36, 39, 40, 43, 47, 49–64, 66–68, 70–72, 75

management contracting is a group of PDMs where a single entity is responsible for part or all of the contract management, often including a performance guarantee that provides significant risk benefits to the client. Most work is carried out by external parties, allowing control over team composition, while the managing party organizes tasks and assumes specified risks for budget, time, and quality for the agreed-upon project phases. v, 1, 9, 16, 17, 21, 26, 36, 39, 40, 47, 58, 70, 71

post-occupancy evaluation (POE) involves assessing the performance and effectiveness of a building after it has been occupied, focusing on factors such as user satisfaction, energy efficiency, and functionality. 30, 34

Preliminary Design VO or ‘Voor Ontwerp’ in Dutch, represents the beginning of the design phase, characterized by developing the basic layout and initial sketches to form the foundational vision. This phase focuses on creating a design concept. 5

procurement refers to the purchasing of goods and services from an outside body (Arrowsmith, 2014). Procurement in the context of construction projects refers to the process of obtaining project team members, which may be individuals, firms, or companies that will participate in the completion of the project (Rashid et al., 2006; Wardani et al., 2006). 5, 9, 15, 20, 21, 23, 31, 34, 52, 53

Project Delivery Method or PDM is a vital concept in the construction industry, as it determines how projects are structured, organized, and executed. Carpenter and Bausman (2016) describe PDMs as a “process of assigning contractual responsibilities for designing and constructing a project, which should include the definitions of project scope, contractual responsibilities, interrelationships of the parties, and the processes for managing time, cost, safety, and quality.”. 1

project success factor is a critical element that significantly contributes to achieving a project’s objectives, ensuring its successful completion. Examples of these factors include effective cost, time, quality management, and stakeholder satisfaction. iv, v, viii, 1–5, 22, 23, 27–29, 33–35, 37, 45, 56, 61, 63, 65–68, 70–75

Risk-carrying Project Management is a CMR version that focuses on managing the entire process. The client selects a risk-carrying project manager based on early design stages, who assumes some project risks and covers any cost overruns, selects subcontractors, coordinates with them, handles general project planning, and manages procurement, while maintaining close contact with the client for design decisions. viii, 4, 15

Sketch Design (SO) or ‘Schets Ontwerp’ in Dutch, is characterized by the development of the basic layout and initial sketches, which form the foundational vision of the project. 5

Special Purpose Vehicle (SPV) manages all the different stakeholders involved, and communication with the client in a DBFMO. These stakeholders include SPV the financier, consultants, the D&B party, and the M&O party. xv, 13

supply-driven PDM’s have been developed relatively recently to address the emerging need for solution-oriented delivery methods. They are characterized by providers delivering fully completed projects with minimal client involvement, where the client provides general requirements rather than detailed demands, and providers submit proposals based on standard products, describing their concept and intended performance. 1, 9, 16, 17, 19, 22, 37, 39

Technical Design TO or ‘Technisch Ontwerp’ in Dutch, is the design phase transforms the DO into a design with detailed technical specifications ready for construction. It ensures all elements are executable and meet regulatory requirements. 5

The New Rules 2011 or ’De Nieuwe Regels’ (DNR 2011) in Dutch, are a regulatory framework for agreements between clients and consultants, like architects and engineers. It is used in the Netherlands, merging the SR1997 and RVOI 2001 regulations. It standardizes contracts related to designing, advising, and organizing in the built environment, holding consultants accountable and including a standard task description for various responsibilities (Chao-Duivis et al., 2018). 22

traditional or Design-Bid-Build (DBB), is a group of PDMs with a sequential process where a client has separate contracts with the designer and the contractor. The traditional method includes three main categories: 'Hoofdaanneming', 'Nevenaanneming', and Early Contractor Involvement. iv, v, viii, ix, xvii, 1, 9–12, 14, 16, 17, 19–22, 25, 26, 35, 36, 39, 40, 47, 49–64, 66–68, 70–72, 75

Turn-key is a PDM where the contractor is responsible for both the design and construction, similar to the DB method. The term "turn-key" symbolizes the client simply "turning the key" to a completed project, having little to no responsibilities or influence on the project's progression after the contract is signed. 17

Uniform Administrative Conditions for Integrated Contracts 2005 or 'Uniforme Administratieve Voorwaarden voor Geïntegreerde Contracten 2005' (UAV-GC 2005) in Dutch, is a contract framework designed for integrated, and supply-driven project delivery methods (Chao-Duivis et al., 2018). 22

Uniform Administrative Conditions for the Execution of Works and Technical Installation Works 2012 or 'Uniforme Administratieve Voorwaarden voor de uitvoering van werken en van de Technische installatiewerken 2012' (UAV 2012) in Dutch, is a model contract for construction and technical installation projects in the Netherlands, suited for traditional project delivery methods. Revised from the UAV 1989, it involves a client responsible for the design and a supervising director ensuring compliance during execution (Chao-Duivis et al., 2018). 22

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Chapter 1

Introduction

Complex projects need clear organization, with clear responsibilities and agreements. Otherwise, a construction project runs the risk of becoming incurring large delays and cost overruns. This is why, when a municipality or a school board wants to build a new primary school, these decisions on responsibilities and agreements are considered vital to the success of such a project. The way a construction project is organized is called a Project Delivery Method, or PDM. Miller et al. (2000) define a PDM as "a system for organizing and financing design, construction operations and maintenance activities that facilitates the delivery of a good or service". According to El-Sayegh (2008), the choice of PDM significantly impacts project execution, affecting project success factors such as time, cost, quality, and safety. These project success factors indicate the success or value of a project (Hardie & Saha, 2012). Choosing a PDM for a construction project means deciding which stakeholders get involved and when, and determining how the client and contractors fill their respective roles and responsibilities. This decision significantly impacts the client and user's influence on the project, the way that a client can contribute to the eventual project outcome, and the amount of risk that the client wants to take on (Davis et al., 2008). Typically, PDMs are categorized into four different categories; traditional, integrated, supply-driven, and management contracting (Adriaanssen et al., 2017). When a PDM has been chosen, a contract is signed to put the agreement in writing. Different contract forms supporting a PDM exist within the Netherlands. Depending on the PDM different model contracts are used between different parties (Chao-Duivis et al., 2018). Every project can differ in factors, including volume, expected quality, stakeholders, location, budget, and many others. Because of this, according to El-Sayegh (2008) and Miller et al. (2000), different PDMs are considered to be better suited to specific projects.

1.1 Problem Definition

In recent years, deciding on a PDM to structure the project has become increasingly more complex. This is partly because of an increase in regulatory interventions on topics like the sustainability and circularity of buildings, as well as the health of its users. This has made the construction process of primary school buildings more complicated than ever. Therefore, choosing the most suitable PDM is an essential part of the realization of a project, but it is often severely undervalued by inexperienced clients. These clients often, sometimes without intent, do not make an explicit choice of PDM, resulting in a project where irreversible decisions are taken without proper consideration of the alternatives. This is why a client should have a clear vision of how to progress in terms of PDM, which fits with their knowledge and facilities (Adriaanssen et al., 2017). Adriaanssen et al. (2017) also states that often in the case of utility buildings, the client is less, or sometimes not at all, experienced in the building process. For example, when a client like a smaller municipality or a school board wants to develop a new school building, it might be the first new school building in the area in more than a decade, and therefore they are probably less experienced. On the other hand, bigger municipalities or school boards might be too busy with other tasks to focus on developing a new school building. Therefore, they will also be less experienced in realising these projects. Clients that are experienced often have predetermined expectations on what PDM works best, and as a result, run the risk of disregarding another PDM beforehand, even if that PDM might have been better suited to the project (El-Sayegh, 2008).

Research gap: The decision-making process is currently based on the subjective prior experience of executives and a status quo of expectations, and often not based on quantitative evidence. Research on this problem is also mostly literature studies or interviews with stakeholders of different projects and their subjective experience, while very little empirical research is available (Sullivan et al., 2017). This means that even if clients would want to base their decisions on empirical evidence instead of subjective experience, this is currently next to impossible. Additionally, the quantitative research that has been performed is often not detailed on when the expectations on project success factors change.

1.1.1 Research Objective

Finding a way to improve this decision-making process could help reduce risk, improve financial viability, reduce conflict, and improve client satisfaction in the construction process of primary school buildings. Proving or disproving the current assumptions about the relationship between organization method and project success factors could allow a client to make a more informed decision on this issue. If the empirical understanding of the impact of PDMs is improved, a client would be better informed on the strengths and weaknesses of a PDM. Allowing them to make more informed decisions on what PDM to choose, while also being aware of where and when the most common mistakes result from that decision. This could prevent time and cost overruns, low productivity, poor quality, and poor client satisfaction.

Therefore, the goal of this research is to cover this research gap by providing clients and other stakeholders of construction projects with more empirical insight on the effect that a PDM has on a project's success factors and its expectations throughout a project's development. Allowing for more informed decisions and the prevention of inefficiencies.

1.2 Research Questions

In order to achieve the research objective, a main research question has been formed. This question aims to find the relationship between PDMs and project success factors for primary school buildings. Answering this research question will achieve a significant part of the research objective.

Main Research Question (MRQ)

> *What is the relationship between the chosen PDM for primary school buildings, and project success factors?*

Because of the complexity of this question, some subquestions have been formed. These subquestions are then split into two different parts: methodology-based research questions and knowledge-based research questions. The methodology-based research questions support the main question by determining 'how' the main question could be answered. The knowledge-based research questions assist with 'what' parts needed to be answered before the main research question could be answered.

Methodology based Research Questions (SQM)

SQM 1: What are the useable methodologies to compare construction projects and PDMs?

SQM 2: How can data on primary school building projects be gathered and formatted in such a way that they can be compared effectively?

Knowledge based Research Questions (SQK)

SQK 1: What constitutes project success, and how can it be measured?

SQK 2: What are the current expectations concerning the influence of the chosen PDM on project success?

SQK 3: Which PDMs are used most often for primary school buildings?

SQK 4: What are stakeholder expectations on project success factors, and how do these expectations change over the project duration?

SQK 5: How do primary school buildings differ in terms of usage, stakeholders, costs, and construction time?

SQK 6: What are the average project success factors for primary schools, and how do they relate?

SQK 7: What is the effect of a PDM on the average project success factors for primary school buildings?

1.3 Reading Guide

The structure of this research is visible in Figure 1.1. This study includes an extensive literature review, after which several previously stated research questions are answered. This literature review also helps provide a theoretical framework for the research problem and supports decisions made during the rest of this study. Forming this theoretical framework is done by reviewing the literature on phases of construction projects, PDMs, risk in construction projects, influence during the project, Dutch model contracts, procurement, project success factors, expectations of PDMs, and used methods to compare buildings.

After a review of the subquestions in Chapter 3, the first subquestions are answered in Section 3.2. These subquestions methodology (SQM 1, 2) and (SQK 1-3) help create a framework for the methodology, and therefore be answered at the beginning of Chapter 3. With the use of these subquestions, the methodology was designed. This is followed by an explanation of the different methodological aspects of the performed quantitative research and its data collection, including used databases, file types, data types, phases of a construction project, different collected data points per project, different data transformations per project, and some additional information. This is followed up by an explanation of the methodology for the qualitative research, including a follow-up literature review and an explanation of the interviews with the consultant and the client responsible. After this, a synthesis of both the quantitative and the qualitative research is made.

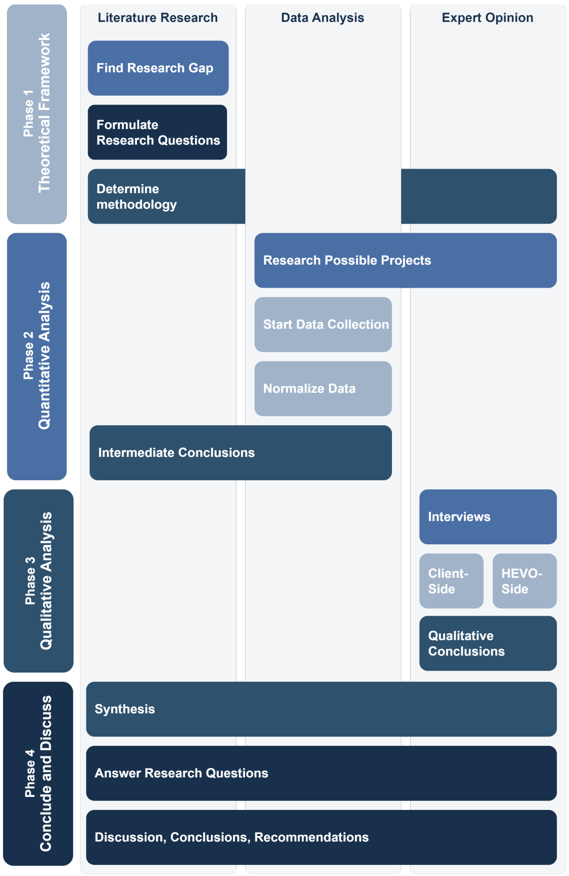


Figure 1.1: The Research Approach

Finally, the research results are discussed, where graphs and tables of the quantitative research are shown and compared to the results of the qualitative research. A synthesis of quantitative and qualitative methods is made, in which the key trends and relationships of the influence of PDMs on project success factors are discussed, which allows for the remaining questions to be answered more completely. This is followed by a discussion of the results and their theoretical and practical consequences. The limitations are then extensively examined, alternative explanations of the results are discussed, and the difference between relationships and causation is highlighted. Finally, the thesis concludes with a discussion of scientific and societal relevance, followed by recommendations for future and improved research.

1.3.1 HEVO

A consultancy company was chosen to assist in forming a possible research framework and collecting data on realised projects. HEVO, a consultancy company that focuses on housing advice and project management, was asked to assist. HEVO helps clients with complex housing issues, focusing on housing issues for education, sports, government, and healthcare. They attempt to do this while striving to make projects that perform sustainably. What sets HEVO apart from other similar consultancy companies is their specialization in guiding clients with Risk-carrying Project Management (RPM) where they guarantee a project that is delivered within budget, on time, and of quality. Even while allowing the client to choose how the project should be managed, including the PDM. HEVO provided general advice and data during the thesis research, including actual project data and interviews with project managers. The results of this research could assist HEVO and its clients to make more informed decisions on what PDM to choose for projects.

Chapter 2

Theoretical Framework

To create a framework for the research questions to be answered and create context around the research problem, it is essential to form an understanding of the different topics of this research; this was done by performing a literature review. This chapter covers the different phases of construction projects (2.1), what distinguishes (primary) school buildings (2.2, different PDMs and their use cases (2.3), risk allocation (2.4), influence throughout a project (2.5), Dutch model contracts 2.3.4, procurement (2.6), project success factors (2.7), and finally current expectations of PDMs (2.8). This literature will help create a knowledge framework on these subjects by answering the research questions in Section 3.2. This framework allowed for the remaining research to be performed, and the remaining research questions to be answered in Section 4.3.

2.1 Phases of Construction Projects

Organizing a construction project entails many different decision moments for many stakeholders and is, therefore, a difficult task. Different countries and parties use different ways to organise these for different use cases. Deviating in detail and time frame. Separate organizational structures might result in different phases. Therefore, it is important to create a reference framework that allows for an analysis of the different decision moments in the construction of a school building. This is why, in the Dutch construction industry, these moments are divided into different phases. These phases include the financing phase, the design phase, and the physical phase (Jacobs et al., 2024). Figure 2.1 depicts these phases and some of their sub-phases.

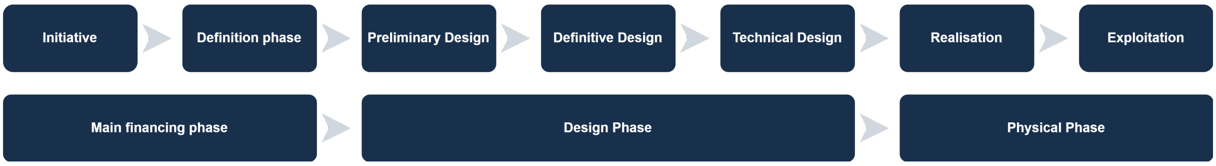


Figure 2.1: Phases in a construction project adapted from Jacobs et al. (2024)

Adriaanssen et al. (2017) defines the four phases in more detail. In the initiation phase ideation occurs, the business case is calculated, and the project strategy is determined. Within the definition phase, the Programme of Requirements (PoR) and wishes for the building are drawn up. The design phase is where the package of requirements and wishes from the previous phase is developed in this phase into a design that can be built. Dutch construction projects typically keep to specific design phases; these include Sketch Design (SO), Preliminary Design (VO), Definitive Design (DO), and Technical Design (TO) (VIB, 2022). This slightly differs from the commonly used international construction standard, as these phases are not as defined internationally. The aforementioned phases ensure that each stage of the project is sufficiently planned and executed. This facilitates better communication and coordination between stakeholders (Davis et al., 2008). And finally, the realization phase is where the design is built.

2.1.1 Financing

Initiation

The initiation phase is the start of most construction projects. In this phase, the idea for a project is researched and further elaborated. The goal of this phase is to research whether the project is achievable. Furthermore, research is done on who could potentially realize the project and who should be involved in the process. Lastly, it is estimated whether there is enough support and need for the project from stakeholders. The (intended) project leader creates a project proposal in which he describes the above subjects. This could entail a business plan or subsidy requests. The potential financiers of this project will then judge the proposal on feasibility. After the proposal is accepted, the project will officially start (Jacobs et al., 2024).

Definition

After the Initiation phase, the Definition phase of a construction project is started, which is essential for creating the project's foundation. This phase creates a detailed Programme of Requirements (PoR) based on the project's goals and objectives. This PoR describes the functional and technical requirements that the project must achieve, which functions as a framework for all the following decision moments. A preliminary project planning is determined, describing the main milestones and phases, expected dates, and deliverables (Davis et al., 2008). Afterwards, risk identification and assessment are conducted to examine potential risks and pitfalls during the project. This risk assessment involves analysing the likelihood and impact of different risks and establishing potential mitigation and prevention methods for these risks throughout the project (Davis et al., 2008; El-Sayegh, 2008). The appropriate PDM is commonly also selected during this phase. Potential reasons for this decision are influenced by factors like project complexity, timeline, budget, and the level of collaboration needed between different stakeholders (El-Sayegh, 2008; Hardie & Saha, 2012).

2.1.2 Design

Preliminary Design

The VO represents the beginning of the project's design phase. It is characterized by the development of the basic layout and initial sketches, which form the foundational vision of the project. This is sometimes considered a separate phase, the Sketch Design (SO), but is most often included in the VO. This phase's main objectives are forming a design concept, a preliminary feasibility assessment, and initial cost estimations. Additionally, a significant emphasis is placed on stakeholder consultation and conversation to incorporate their requirements and requests into the project's design. The main focus in this phase is on-site analysis, initial cost estimation, and design option evaluations. These can then be discussed with other stakeholders until a preliminary solution is determined (VIB, 2022). Resulting in a preliminary design that outlines the key structure, functions, and aesthetics of a building. This is not yet detailed, but typically does provide a clear vision of the potential outcome.

Definitive Design

The DO is what follows. The DO stage enhances the VO into a more detailed, complete and finalized version. This phase aims to emphasize addressing the more specific aspects of the design, such as design development and refining, the addition of technical specifications, and a more detailed cost estimation and budgeting. Drawings are created to determine the main dimensions and material choices. Additionally, environmental permits are often already requested. The main output of the DO phase usually includes finalized drawings and specifications, a final design document encompassing detailed drawings and specifications, an accurate cost estimate verification and validation of design criteria, detailed phasing and execution plans, a fire safety concept, and comprehensive documentation for permit applications. At the end of this phase, the design should be finalized and ready for approval by the client and relevant authorities (VIB, 2022).

Technical Design

The TO transforms the final design of the DO into a design with detailed technical specifications that is completely ready for construction. This phase's objective is to ensure that the design is executable and that these elements also meet the regulatory and functional requirements. This ensures the project can be constructed safely and efficiently, preventing possible mistakes during construction. The TO addresses all project technical aspects, including structural, mechanical, electrical, and plumbing systems. Additionally, it also involves the creation of detailed drawings, specifications, schedules, and other technical documentation required for construction, including the finalization of construction details and structural calculations (VIB, 2022).

2.1.3 Physical

Preparation

The construction-preparation phase ensures a smooth transition from the design process to the actual construction. During preparations, several critical steps must be taken to ensure the construction site is ready and all necessary resources are in place. A detailed planning that ensures the construction will be finished in time is essential for good preparation. Additionally, site preparation, which includes clearing the site, setting up temporary facilities, and ensuring access to all needed facilities, is also essential for a good start to a construction project. Lastly, all permits and approvals from local authorities should be obtained. This ensures that the project fits all rules and regulations. This phase's main goal is to ensure that risks during the construction are mitigated and that the possibility of delays is minimized (Adriaanssen et al., 2017).

Realisation

The realisation phase is where the project's actual construction happens, where the detailed plans are transformed into an actual structure. The execution of the work should be per the technical design and specifications. The realisation phase often knows different stakeholders for different parts of the project, such as a building contractor who is responsible for the construction of structures, separate installing contractors are responsible for the technical installations such as electrical, plumbing, heating, ventilation, and air conditioning (HVAC), and finishing works. The project typically undergoes a final inspection when the construction phase is completed. It is formally handed over to the client, which marks the successful completion of the realisation phase (Adriaanssen et al., 2017).

Aftercare

The last phase of the construction process is the aftercare phase, beginning once a project is completed and handed over to the client. After this happens, this phase ensures that the project meets the client's needs and still functions efficiently. It involves a thorough inspection to ensure all the work has been completed and all systems are operational to the required standards. If needed, the client should also be educated on how to operate and maintain the building. A comprehensive document should also be given, including building drawings, maintenance schedules, and manuals. Usually, this phase contains a warranty and maintenance period, during which any issue that comes up after construction can be solved (Jacobs et al., 2024). Post-occupancy checks can be conducted to check the buildings' performance, and feedback from the client can be collected (Leitner et al., 2020; Sanni-Anibire et al., 2016). This aftercare phase differs in length based on the contract between the client and the contractor, possibly differing per PDM.

2.2 Education/Primary School Buildings

Rules and Regulations: According to Arnoldussen et al. (2020), the construction of primary school buildings often entails unique challenges that set it apart from a more standard construction project. School buildings differ in having more strict safety and regulatory standards because children are the primary users. This means a school requires specialized spaces like classrooms, libraries, and sports facilities. These differences exist because of the differences in needs of the educational environment, the amount of different stakeholders, and the limitations resulting from financial and regulatory factors. Additionally, financial concerns exist because of a limited governmental budget (W. T. Chen et al., 2010). These financial concerns, in combination with regulatory limitations enforced by municipal, provincial and national organizations, result in a complication of the process and a potential increase of the project risk (Carpenter & Bausman, 2016).

Users: Sanoff (2001) states that a school environment plays an essential role in students' and teachers' health, well-being, and performance. Designing a better school environment improves students' lives, supports better education, and positively influences students' emotions, sense of belonging, and overall engagement in learning activities. This means that the design of a school has a great impact on the life of one of its users. A deep connection between the created building and children's education requires careful decision-making during the design and construction of a school building.

Stakeholders: Realising a public school is inherently a complex task, considering the involvement of multiple and diverse stakeholders in the process compared to typical construction projects. These stakeholders include school boards, municipalities, parents, and neighbours living in the surrounding area (Vrieze, 2019). Vrieze states that school building design problems are caused by various stakeholder interest characteristics, with different views on priorities and design-problem solutions. This complex stakeholder landscape requires effective communication between all parties to meet all needs and requirements.

2.3 Project Delivery Methods

PDMs are vital concepts in the construction industry, as they determine how projects are structured, organized, and executed. Choosing a PDM influences stakeholders' roles, responsibilities, and relationships. PDMs encompass both the contractual agreements and the organizational structure used for a construction project. Carpenter and Bausman (2016) describe PDMs as a "process of assigning contractual responsibilities for designing and constructing a project, which should include the definitions of project scope, contractual responsibilities, interrelationships of the parties, and the processes for managing time, cost, safety, and quality". By organizing and financing design, construction, operations, and maintenance activities, PDMs facilitate the delivery of a good or service (Miller et al., 2000).

The importance of selecting the appropriate PDM cannot be underestimated. El-Sayegh (2008) emphasizes that the decision on a PDM, significantly impacts its success later in the project. Mismatched project characteristics and procurement strategies can reduce life-cycle value, reduce innovation, and unfavourably allocate risks (Miller et al., 2000). Therefore, owners must carefully evaluate and rank their objectives to choose the method that maximizes performance based on the needs of that specific project instead of choosing the most familiar method.

Adriaanssen et al. (2017) categorize PDMs into four main types: traditional, integrated, supply-driven, and management contracting. Each category has unique characteristics that determine how parties interact and how their responsibilities are distributed. For instance, the degree of control a client wants over costs and quality should significantly influence the choice for a certain PDM. Aspects such as the client's organizational requirements, personal expertise, project complexity, project quality specifications, wanted project organization, risk allocation, and available time are essential in this decision-making process (Adriaanssen et al., 2017). Additionally, Carpenter and Bausman (2016) states that the PDMs used most commonly for public schools are a part of the traditional, integrated, and management contracting methods. Multiple sources have researched the relation between the selection of PDMs and their impact on project performance outcomes such as cost, schedule, and quality (Gransberg & Villarreal-Buitrago, 2002; Ibbs et al., 2003; Khalil, 2002; Konchar & Sanvido, 1998; Oyetunji & Anderson, 2006; Touran et al., 2011). Mollaoğlu-Korkmaz et al. (2013) highlight that PDMs define when major participants' are involved and what contractual relationships exist among parties, affecting these performance metrics. This will be expanded upon in sections 2.7, and 2.8.

2.3.1 History and Context of PDMs

Understanding the historical context of these methods provides insight into why and how different approaches have developed and become more complex over time. Government legislation on construction projects and their respective required quality, sustainability, and risk, such as those in the Netherlands, has evolved significantly, impacting the relevance and application of various PDMs (Adriaanssen et al., 2017). This constantly developing legal network requires more context on how these methods came to be what they currently are.

Before the Renaissance, a 'master builder approach' dominated most large-scale construction projects. In this system, a single person or responsible party functioned as the architect, engineer, and contractor, overseeing all aspects of the design and the construction (Addis, 2007; Boyer & Fitchen, 1988; Carpenter & Bausman, 2016; Ghavamifar & Touran, 2008). This changed during the Renaissance when the construction industry split into more well-defined disciplines: architecture, engineering, and construction. This segregation of disciplines allowed for more specialization, increasing the possibility for technological advancements through specialization and suiting the increasing complexity of construction projects. The separation of interests of different parties complicated communication and decision-making processes during all the different construction phases. This fragmentation often led to hostile relationships, leading to increased project risks, reduced quality, possible schedule overruns, changing orders, claims, and litigation processes (Carpenter & Bausman, 2016; Saporita, 2006). As a response to these upcoming challenges, new PDMs were developed to define project scope and assign responsibilities more clearly. These aimed to manage the risk of disputes by avoiding, reducing, transferring, or maintaining it within acceptable limits, while assigning this risk to their responsible parties.

2.3.2 Traditional

The Design-Bid-Build (DBB) method, also known as the traditional method, started becoming common practice toward the end of the nineteenth century as a response to various fraud and abuse cases (Heady, 2013; U.S. DOT, 2006). DBB was designed to reduce the risk of corruption and cost overruns by clearly defining the roles and responsibilities of designers and builders working on a project. The traditional method was considered the dominant method up until the late 20th century (Ahmed & El-Sayegh, 2020), and has been a foundational approach in the construction industry for many decades Cantirino and Fodor (1999), Gad et al. (2015) and Ndekugri and Turner (1994). Essential to this method is a sequential process where a client has separate contracts with the designer and the contractor. This traditional method has since then, as the name implies, become the default for many public sector projects due to its clear depiction of responsibilities and its straightforward execution process (Miller et al., 2000).

According to Adriaanssen et al. (2017), the traditional method can be divided into three main categories that all slightly differ in their organisation. These different methods are; 'Hoofdaanneming', where each phase is led by one responsible party and contact point, 'Nevenaanneming', where all parties are under their separate contracts with the client, and Early Contractor Involvement an organisational format explicitly used within the Dutch construction industry where the contractor is already a part of the design team where he can give preventative input. These different methods are depicted below.

'Hoofdaanneming', 'Nevenaanneming', and Early Contractor Involvement

A 'Hoofdaanneming' in the Dutch construction industry refers to a main contractor PDM, in which a leading designer is responsible for the entire design process, and a main contractor is deemed responsible for the whole realisation phase (Figure 2.2). Both generally hire subcontractors to help develop their tasks and are the main ones responsible for their separate parts. In this PDM, the main contractor typically coordinates all aspects of their respective process, including arranging materials, hiring different subcontractors, and managing day-to-day activities. The main building contractor is also responsible for ensuring the building complies with building codes and ensuring its quality and safety. Financially, the 'Hoofdaanneming' often includes a fixed price or similar agreement, where the responsible party agrees to complete their part for a set amount that is agreed upon at the beginning of the contract. In this structure the aim is to clearly define the party responsible for each aspect of the contract, this should improve communication.

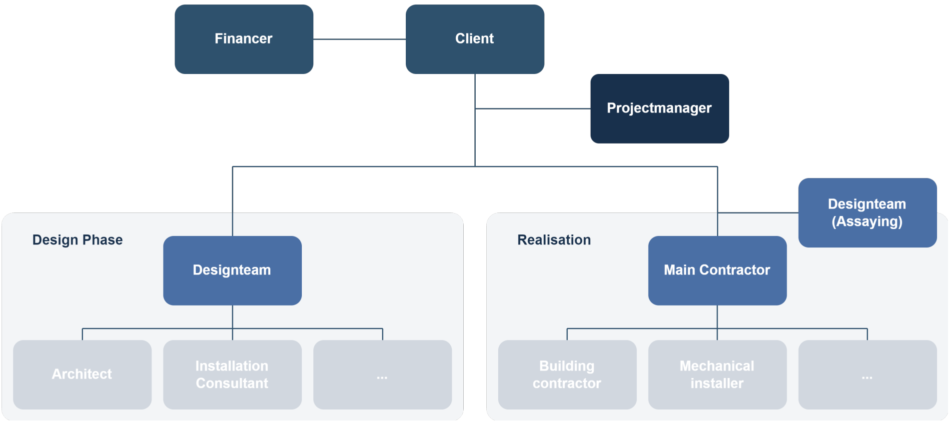


Figure 2.2: 'Hoofdaanneming' diagram adapted from Adriaanssen et al. (2017)

In the Dutch construction industry, a 'Nevenaanneming' refers to a PDM where multiple different contractors are individually and separately contracted by the client to work on different parts of the building project (Figure A.2). Compared to the 'Hoofdaanneming' structure, no single main contractor is responsible for their phase of the project. The responsibility lies with more different parties instead. Each contractor is responsible for their specific part of the project, and coordination and communication go directly to the client. This means that the client typically needs to take on a more active role in managing the project, which includes coordinating the different contractors to ensure that cooperation between the contractors goes smoothly. Because each contractor must work together to avoid mistakes and conflict, this typically involves regular coordination meetings and more active and clear communication by the client. Financially, the agreements in a 'Nevenaanneming' are different contracts between the client and the contractor per contractor involved in the project's development. Prices are negotiated independently, and terms are agreed upon separately. The contracts specify the project specifications, timeline, payment schedule, and quality standards (Adriaanssen et al., 2017).

Early Contractor Involvement is a collaborative PDM commonly used in the Netherlands (Figure A.3). This PDM differentiates itself by involving the building contractor in the design process. Early contractor involvement allows the contractor to assist during the design process and give valuable insights into how the design can be realised regarding logistics, feasibility, costs, and planning. The finances of Early Contractor Involvement are normally split into two phases, where in the first stage, the building contractor is engaged in a separate pre-construction contract. And in the second stage, they transition to a construction contract, often in a guaranteed price format.

Advantages and Disadvantages

One of the primary advantages of the traditional method is that this allows clients to settle obligations and commitments per phase and discipline. This segmented approach can limit financial risks by ensuring commitments are made per phase rather than all at once, particularly for organizations with complex organizational decision-making structures. They also state that because the realization phase only begins after the design is complete, clients have a high influence over the project, even after the design phase. Later in the project, this influence facilitates easier adjustments and development of the specified requirements during and after the design phase, providing possible flexibility to the client. Another significant advantage is the prevention of additional costs. Since clients directly manage each party involved in the project, they can avoid additional costs that contractors might charge for possible coordination tasks. This direct management is evident in specific formats, such as 'Hoofdaanneming,' where the client issues a single tender for a combination of parties, simplifying the process. Additionally, when one party is responsible for an entire phase, it prevents risks associated with poor coordination within that phase, ensuring clearer communication and accountability between parties (Adriaanssen et al., 2017).

Despite its advantages, the traditional method has a few notable disadvantages. Because the construction can only commence after the design is finalized and the tendering process is completed and segregated, projects organized in this manner often face delays; this can be a critical issue for time-sensitive projects. Projects using the traditional method often experience difficulties in integration between parties and, therefore, a potential lack of execution and maintenance knowledge of the project. Contractors and maintenance parties are typically only involved after their respective design and realization phases, which makes it difficult to combine practical insights from both stakeholders in the final project. This separation can lead to inefficiencies and higher long-term maintenance costs. When defects become apparent during construction or maintenance, determining who is responsible can be difficult, often leading to disputes where parties are accused of being responsible. This method also creates significant administrative pressure on the client, who must manage and coordinate all contracted parties. This requires significant knowledge and experience, which not all clients have (Adriaanssen et al., 2017). Designers and contractors often work toward their own goals, and the lack of collaboration between the different parties increases this. (Mehany et al., 2018; Perkins, 2009). Therefore, the culmination of these issues can lead to inefficiencies, project delays, and higher costs (Mehany et al., 2018).

2.3.3 Integrated Methods

At the end of the 1970s, several factors led to the development of new PDMs. These include the increasing size of projects, the high costs of short-term financing, more knowledgeable clients, and large inflation. Some of these new methods were variations of the traditional method, while others adapted old methodologies to these newer challenges (Cantirino & Fodor, 1999). One of these older PDMs, Design and Build (DB), increased in popularity in the late 1980s and early 1990s due to growing dissatisfaction with DBB methods. Clients were after more integrated and collaborative approaches to address the perceived shortcomings of the traditional method (Cantirino & Fodor, 1999; Perkins, 2009). Integrated PDMs aim to create better collaboration and integration between all different parties involved in a construction project, which could improve eventual project results. This approach is seen in methods like DB and many variations or extensions of this concept. The most significant difference in integrated projects is the inclusion of a maintain element in the PDM.

Integrated Without Maintain

In a DB method, visualized in Figure 2.3, the client forms a contract with a design-build contractor that assembles a team including architects, engineers, and construction experts. This DB contractor will take on all responsibility for the delivery of the project, starting from the design phase until after the realisation phase. This allows for concurrent progress on the design phase and construction activities. This typically means a fixed price or guaranteed maximum price. Before a contract is signed, the DB contractor provides the client with a proposal of design and construction costs. This means the client's budget can be managed more effectively later in the project (Adriaanssen et al., 2017).

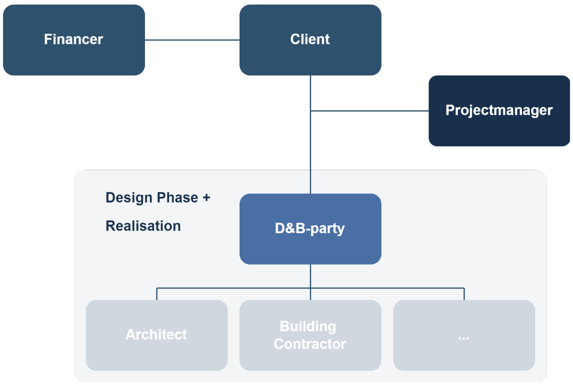


Figure 2.3: Design and Build diagram adapted from Adriaanssen et al. (2017)

Much like DB, an Engineer and Build (EB) delivery method means that the client contracts a single party. This party, however, only does the engineering and realisations phase, leaving a part of the design outside their responsibility (Figure A.5). They manage the remaining part of the project until and after the realisation. The contractor has a team, including engineers, architects, and construction professionals, working together to deliver the project. Again, a fixed price is the commonly accepted method (Adriaanssen et al., 2017).

Integrated With Maintain

In a Build and Maintain (BM) format, the client contracts the BM party after the design phase has been completed (Figure A.6). A BM contract is about the construction of a project and its maintenance afterwards. This means that contrary to the previous integrated formats discussed, BM starts with the construction phase. Once the construction has been completed according to the design and specifications given by the client, the contractor will still be involved in maintaining the project for a certain amount of time. Financially, the BM contract is a combination of both construction and maintenance services and can be structured like the previous integrated formats in a fixed price format or with maintenance fees specified separately. The BM method is generally uncommon, especially for utility buildings like schools (Adriaanssen et al., 2017).

Design, Build, and Maintain (DBM) is essentially a combination of the DB, and BM PDMs. Within this method, a single contractor is responsible for a project's design, construction, and maintenance (Figure 2.4). The client still has a contract with a single DBM contractor that starts at the design phase and ends after a certain time of maintenance. A team assembled by this main contractor consisting of architects, engineers, subcontractors, maintenance parties, and others ensures the project proceeds according to the agreed specifications. Financially, this is often structured in a combined fee covering design construction and maintenance, similar to the BM method (Adriaanssen et al., 2017).

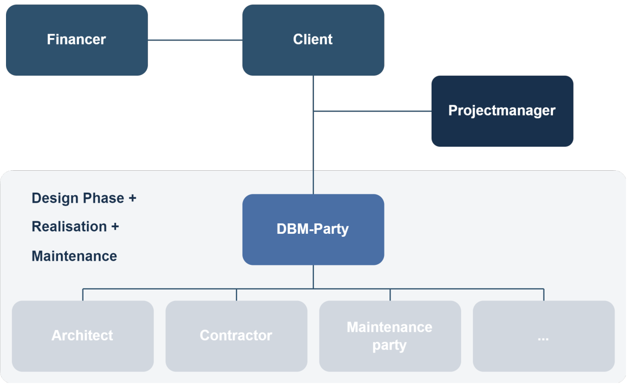


Figure 2.4: Design, Build, and Maintain diagram adapted from Adriaanssen et al. (2017)

A Design, Build, Finance, Maintain, and Operate DBFMO expands even more on the DBM method, which also adds the operation phase of the building into the organization, which means that a single contractor is responsible for the design, construction, maintenance, and operation of a project (Figure A.8). This party oversees the entire project. This method often includes separate fees for the maintenance and operation of the project. Often, only a part of the operation of the building is included; however, often, the client only includes the parts of the operation of the building that they do not want to themselves. The contract is typically for a set amount of years (Adriaanssen et al., 2017).

Compared to other integrated PDMs, the DBFMO is a complex PDM. Similar to the other integrated methods, a single contractor is responsible for a project's design, construction, maintenance, financing, and operation (Figure A.9). However, a DBFMO makes use of a Special Purpose Vehicle (SPV) that manages all the different stakeholders involved; communication with the client goes through this SPV. The SPV manages the financier, consultants, the D&B party, the M&O party, and other stakeholders. In a DBFMO the financing can also arrange the financing of the project, this however does not mean that the client rescinds their ownership. However, this means that the bank/financier often functions as an extra form of control, as they become an extra supervising party. Often, payments to the contractor are made on a monthly basis (Adriaanssen et al., 2017).

Advantages and Disadvantages

One of the main advantages of integrated project delivery is the limitation of the costs of failure. Focusing the design and construction responsibilities on a single party significantly reduces the risk of errors and miscommunications. This responsibility within one party ensures that the different parties within a project are jointly focused on meeting the client's requirements and wishes. This leads to higher project quality outcomes and increased client satisfaction. Having one communication point also simplifies decision-making and coordination between parties, leading to more efficiently executed projects (Adriaanssen et al., 2017). The DB method is also known for its ability to ensure shorter project durations. The intrinsic overlap of the design and construction phases allows a project to be completed in a shorter time than traditional methods (El-Sayegh, 2008; Mehany et al., 2018). The simultaneous progression of phases should also enhance collaboration between designers and building contractors, which would reduce the likelihood of disputes and litigation (Ndekugri & Turner, 1994)

BM, DBM, and DBFMO methods have an additional advantage, which is the optimization of the realization and maintenance phase and processes. Better integration of these phases with the prior phases ensures that there is one responsible party for mistakes in both phases, streamlining accountability and facilitating smoother project management. Additionally, in a DBFMO the client benefits from monthly payments without needing pre-financing, which would improve cash flow management (Adriaanssen et al., 2017).

Despite its many benefits, integrated PDMs also have brought some disadvantages. In the DB method, the client will most likely have less control over design details once the contract is signed because the design and construction are managed by a single entity (Adriaanssen et al., 2017; El-Sayegh, 2008). This can be particularly problematic if changes or adjustments are required, as modifications to the project after signing the contract can be costly and complex to implement (Davis et al., 2008). This means the client should have a clear vision and understanding of how to formulate their requirements. Therefore, a high-quality PoR is necessary to ensure project success, requiring substantial effort and expertise upfront. Additionally, the process of selecting and contracting with a single party that will perform multiple phases in the construction process can result in significant transaction costs, which might counteract the efficiency gains by selecting an integrated PDM in the first place (Adriaanssen et al., 2017).

For methods like EB, BM, and DBM methods, the influence of the client is limited to the design phase, and the ease and impact of changes to the building later on can be a limitation. Resulting in a fixed design that is difficult to make changes to once their respective organizations start, reducing the ability to adapt to unforeseen needs or changes. DBMO and DBFMO methods result in even more limitations on the freedom of the organization and the ability to make changes, which can be restrictive and less suitable for projects that require a high degree of flexibility (Adriaanssen et al., 2017).

2.3.4 Management Contracting

The Construction Manager/General Contractor (CM/GC) method was first implemented in the early 1960s. Its use became more common in the 1970s, motivated by increased costs, larger schedules, and the delays associated with traditional PDMs (Feuer et al., 2015; Mehany et al., 2018). This CM/GC method consists of the early participation of an experienced construction manager during the design phase, facilitating better coordination between the design phase and construction activities. A variation of this approach called Construction Manager (at) Risk

(CMR) was later also developed. Management contracts are contracts where a single entity is responsible for a part of, or the entirety of, the contract management. This is often paired with a performance guarantee, giving the client significant risk benefits. Most of the work is carried out by external parties instead of the management contractor, allowing for team composition control. The managing party organizes the tasks and agrees upon the specified budget, time, and quality risks for the agreed-upon project phases (Adriaanssen et al., 2017).

Construction Manager (at) Risk and Risk-carrying Project Management

CMR as a PDM in the construction industry is used in different formats. A contract manager can take on the responsibility for the construction only (Figure 2.5), or take on parts of the design phase. During the construction phase, this contract manager will assume the role of a general contractor. The construction manager is often brought in before the construction phase to perform pre-construction activities like cost estimation, scheduling, value engineering, and constructability reviews. Thereby offering valuable input in the design phase and optimizing the project for cost, schedule, and quality. The financial structure of a CMR contract typically includes a fee for the risk the management company covers and a separate fee for construction management services during the construction phase. This means that the client will have complete or partial price certainty. The collaborative and management properties of CMR methods are widely recognized for creating better construction products and enhancing service quality during the project, particularly during projects with many different stakeholders and complex requirements, like public schools (Carpenter & Bausman, 2016).

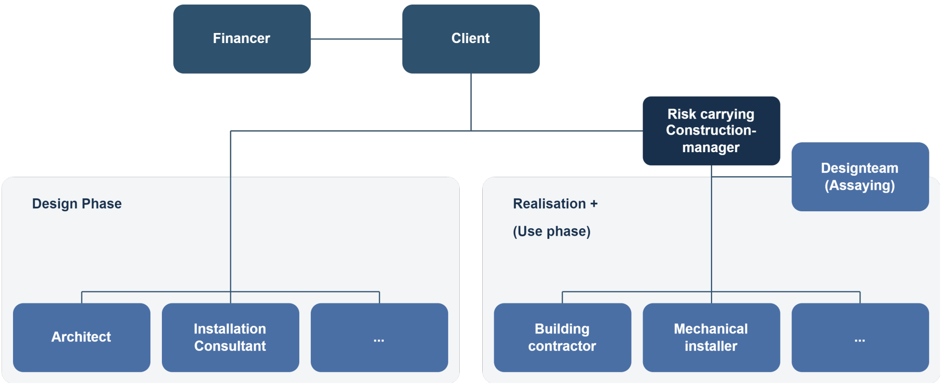


Figure 2.5: Construction Manager (at) Risk diagram adapted from Adriaanssen et al. (2017)

One of the ways that CMR can be implemented is through Risk-carrying Project Management (RPM). Instead of mainly managing the construction, the focus is on the entire process in RPM (Figure 2.6). This gives the contract manager even more responsibility over the project. Based on a program of requirements or one of the early design stages, the client selects a risk-carrying project manager. The project manager assumes some risks associated with the project's success. Similar to CMR, the contract manager will have to cover the difference if the project costs more than the discussed budget. The project manager also selects the different subcontractors, coordinates with them, makes the general project planning, and manages the procurement for the main construction contractor. They remain in close contact with the client for general concerns and design decisions, this way the client remains involved in the design process without the need for expertise on the subject of the construction industry. The project manager's compensation is often tied to the successful delivery of the project within predefined parameters, such as budget, timeline, and quality standards (Adriaanssen et al., 2017).

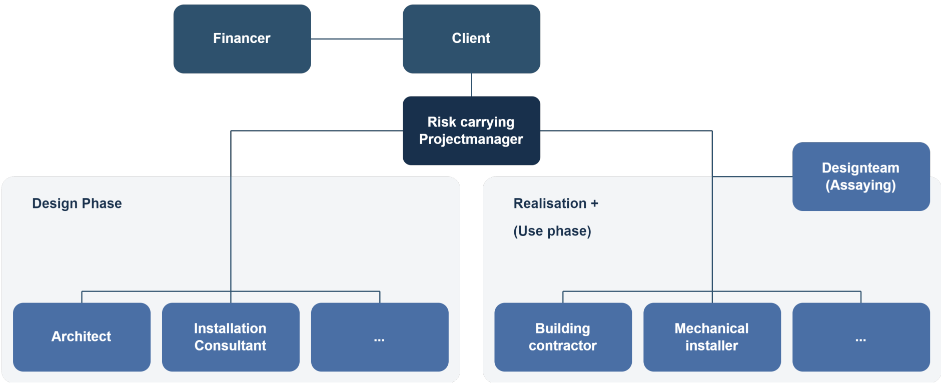


Figure 2.6: Risk-carrying Project Management diagram adapted from Adriaanssen et al. (2017)

Advantages and Disadvantages

Management contracting methods could provide significant advantages in collaboration, integrated planning, and risk management. According to Carpenter and Bausman (2016), these methods are especially beneficial for complex projects that require a high degree of coordination and quality of service. One of the main advantages of CMR or RPM is the responsibility assigned to a single party for both pre-construction and construction services, which also means that there is a central point of contact. The client hires the general contractor early in the design phase, which allows the contract manager to act as an advisor or consultant, providing insight into cost estimates, schedule, design changes, and identifying risks (Cantirino & Fodor, 1999; Farnsworth et al., 2016; Mehany et al., 2018). This integrated team approach at both the design and construction phases should improve collaboration and significantly reduce the number of change orders, a major cause of claims and disputes, according to Farnsworth et al. (2016). Another advantage is the influence the client has on plan development without assuming full responsibility. Performance guarantees offered by the contract manager can also enhance the reliability and quality of the project outcome (Adriaanssen et al., 2017). Furthermore, CMR is particularly beneficial for complex projects like public school constructions, where these collaborative properties could lead to higher product and service quality (Carpenter & Bausman, 2016).

Despite its advantages, CMR and RPM have several drawbacks. One significant disadvantage is that the reduced costs do not benefit the client in every situation. Costs associated with this complex, collaborative, and integrated approach could result in higher construction costs compared to traditional methods (Carpenter & Bausman, 2016). Moreover, the client does not fully realize the benefit of incremental cost savings, which can be a financial disadvantage. Another drawback could be the complexity of the contracts involved. The need for detailed agreements that cover various aspects of the project could lead to complicated and extensive contracts, which can be challenging to manage and enforce. Lastly, for CMR, risks covering different phases of the project could create uncertainties and potential disputes about responsibility, particularly when issues that are not traceable to a single phase or party (Adriaanssen et al., 2017).

2.3.5 Supply-driven

Supply-driven PDMs have been developed relatively recently because of the emerging need for solution-oriented delivery methods. These methods are characterized by providers delivering fully completed projects to clients, with minimal involvement from the client during the development process. With supply-driven PDMs, the client describes their general requirements for the project. Compared to other PDMs where detailed demands are given. Some providers specialize in these projects, and these providers will submit proposals to their clients, often based on their standard products, in which they describe their concept and intended performance. The client then chooses the most suitable concept, after which the project will be completed with minimal involvement from the client (Adriaanssen et al., 2017). According to conversations with experienced project managers within the consultancy firm, supply-driven methods are not typically used for school-building projects because of the lack of adaptability to different stakeholders' demands.

Conceptual building and Turn-key

A Conceptual building PDM approach (Figure A.12) is mainly focused on the beginning stages of project development, as the primary goal is to develop a conceptual design that describes the project's scope, feasibility, and preliminary cost estimates. The client can choose from an existing concept and can, therefore, already see the result of the project because the concept has already been built elsewhere. The client can, however, still make some smaller decisions like materials and size (Adriaanssen et al., 2017).

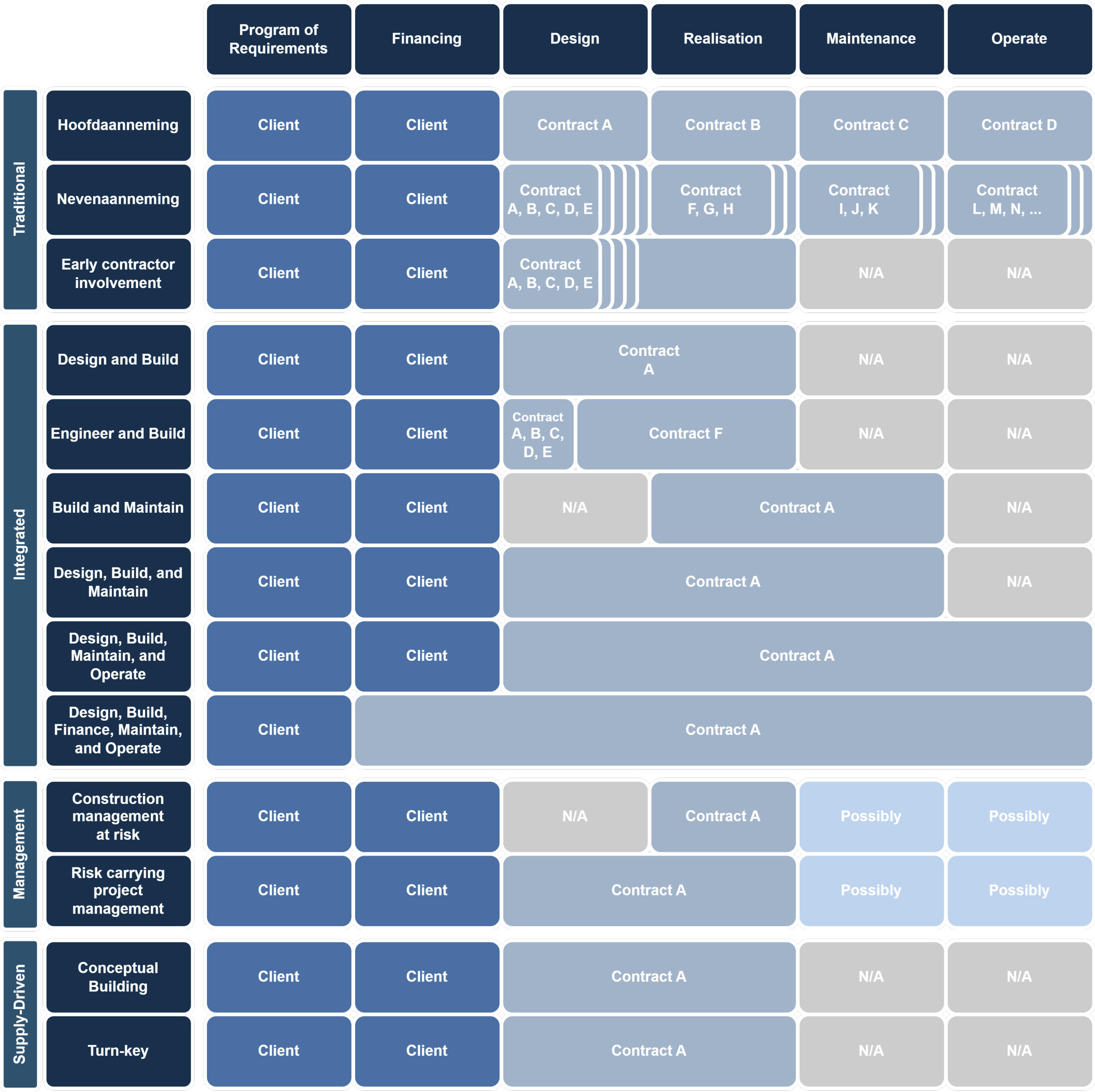
With Turn-key projects, the contractor is responsible for the project's design and construction, similar to a DB method (Figure A.13). The term "turn-key" symbolized the client simply "turning the key" to a completed project. Where it differs from the DB method is that after the contract has been signed, the client will have little to no responsibilities and influence on the further progression of the project, as long as it fits the determined standards (Adriaanssen et al., 2017).

Advantages and Disadvantages

Supply-driven projects reduce risks by transferring any errors to the contractor. This method provides predictability and certainty for a client, especially if that client lacks experience in the construction industry (Loosemore & Richard, 2015). On top of that, integrating the design and construction phase can lead to a streamlined process and a faster completion time (Rose & Manley, 2012). Conceptual building methods also encourage prepared solutions and efficiency by applying solutions that have already proven effective. Turn-key and Conceptual building PDMs both transfer a significant amount of project risk to the contractor. This protects clients from common issues like cost overruns and mistakes due to inexperience. This can be explained by the fact that the contractor manages all aspects of the project after the contract has been signed, including managing subcontractors and other stakeholders (Eriksson & Westerberg, 2011). They are generally not suitable for the complexity of utility buildings like schools.

2.3.6 Summary of PDMs and Responsibilities

Figure 2.7 visualizes the organization and general responsibilities of each PDM. The columns represent the different responsibilities within a construction project, while the rows represent the different PDMs. The PDMs are grouped into the previously discussed groups of traditional, integrated, management contracting, and supply-driven. The stakeholder in that block represents the responsible party for that part of the project. If multiple contractors are represented in one block, the responsibilities for that phase are divided among the different contractors.



		Program of Requirements	Financing	Design	Realisation	Maintenance	Operate
Traditional	Hoofdaanneming	Client	Client	Contract A	Contract B	Contract C	Contract D
	Nevenaanneming	Client	Client	Contract A, B, C, D, E	Contract F, G, H	Contract I, J, K	Contract L, M, N, ...
	Early contractor involvement	Client	Client	Contract A, B, C, D, E		N/A	N/A
Integrated	Design and Build	Client	Client	Contract A		N/A	N/A
	Engineer and Build	Client	Client	Contract A, B, C, D, E	Contract F	N/A	N/A
	Build and Maintain	Client	Client	N/A	Contract A		N/A
	Design, Build, and Maintain	Client	Client	Contract A			N/A
	Design, Build, Maintain, and Operate	Client	Client	Contract A			
	Design, Build, Finance, Maintain, and Operate	Client	Contract A				
Management	Construction management at risk	Client	Client	N/A	Contract A	Possibly	Possibly
	Risk carrying project management	Client	Client	Contract A		Possibly	Possibly
Supply-Driven	Conceptual Building	Client	Client	Contract A		N/A	N/A
	Turn-key	Client	Client	Contract A		N/A	N/A

Figure 2.7: Summary of PDMs and their responsibilities adapted from Adriaanssen et al. (2017)

2.4 Risk

Different PDMs come with different risk allocations. In some cases, the risk is carried by varying parties; in others, it is carried by a single party. Choosing a PDM is therefore closely related to what risk a client can, or wants to, carry and what risks they cannot. According to Lenderink et al. (2022), risk has been defined in many ways in the last few decades, ranging from an uncertain outcome to an event having a negative outcome. In this case, it will be defined as the chance of a negative outcome compared to the original predicted outcome. Lenderink mentions four different reactions one can have to this risk: risk acceptance, risk reduction, risk transfer, and risk rejection. It is important to discuss risk allocation clearly before starting a contract. Additionally, clear communication is needed on how to deal with these risks. Risk allocation in a project is essential, partly because the risks associated with every project differ dramatically (Miller et al., 2000). According to Rubin and Wordes (1998), risk allocation is the distribution or apportionment of the risks associated with a project throughout its life cycle. They argued that risk allocation depends on the PDM used. “Because the project delivery systems organize the building process differently, each system allocates risks differently ... the cost associated with each risk can be minimized if allocated to the party with the greatest ability to understand and control it" (Rubin & Wordes, 1998).

According to Adriaanssen et al. (2017), different PDMs allocate risk to different parties. In traditional methods, the client carries a significant part of the risk due to their responsibility to coordinate multiple contractors. In contrast, the client is responsible for integrating the different parties and any design changes. Integrated methods shift a substantial amount of that risk to the main contractor because the contractor is responsible for the design, construction, and potentially more parts of the process and how these parts integrate. This significantly reduces the risk for the client. In supply-driven methods, the contractor also assumes the most risk by providing a ready-to-build project; in this case, the client's risk is minimal. Lastly, management contracts shift most of the project risk towards the contract manager, who often asks for a fee for assuming this risk. To conclude, each PDM distributes the risks differently. Traditional PDMs place more risk with the client itself, integrated methods shift these to the contractor, while management contracts could lead to the contract manager carrying these risks.

2.5 Clients' Influence Throughout a Project

According to Miller et al. (2000), during the initial phases of the project clients have more flexibility and influence when making changes to the design, this is visualised in Figure 2.8. Early choices, especially during the PoR phase, greatly impact the project's outcome while requiring little extra effort. Once the later stages of a project start, particularly the construction phase, it becomes more and more costly and difficult to make changes due to the fixed nature of work in progress. This emphasises the importance of careful planning and decision-making early in the project life-cycle (Miller et al., 2000). Adriaanssen et al. (2017) also emphasises that a client's capacity to change a project decreases significantly during the progression of a project. They state that during the initial phases of a project, the client often still has substantial influence over the project, and changes can be made relatively cheaply. However, once the later phases of the project start, making changes becomes more challenging and expensive. Any modifications at this stage could lead to significant delays, increased costs, and potential contractual disputes. This consequentially means that a client's influence on a project decreases during its duration.

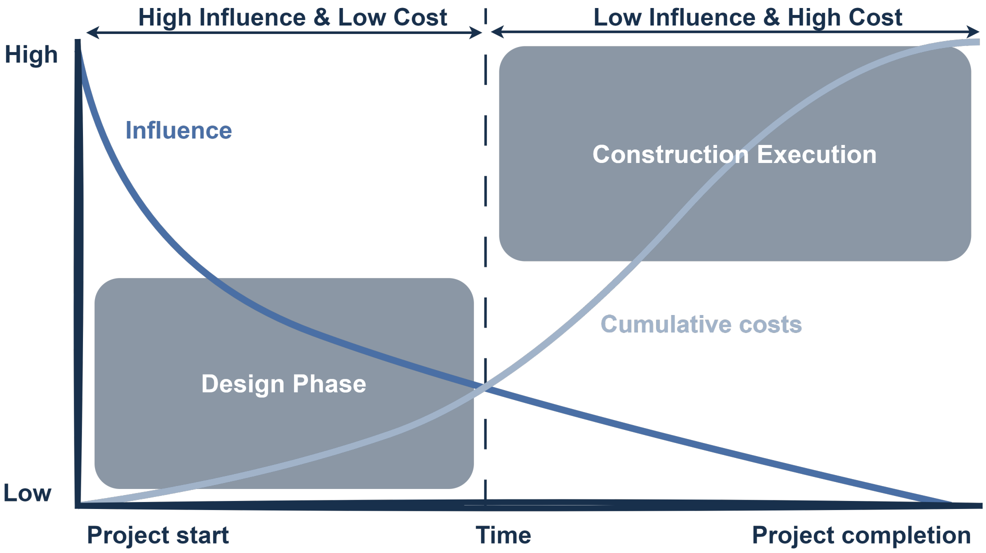


Figure 2.8: Influence during construction projects based on Miller et al. (2000)

Ahmed and El-Sayegh (2008) highlight that a client's ability to make adjustments changes depending on the chosen PDM. Traditional methods generally provide more opportunities for a client to make adjustments during the different design phases, but significantly limit changes during the construction of the building to avoid delays and cost overruns. Integrated methods significantly restrict the client's ability to make changes after the contract is signed, as the contractor takes greater responsibility and control for the project's outcome (Ahmed & El-Sayegh, 2020). Sullivan et al. (2017) provide a comparative analysis of the different PDMs, they note that DB and CMR methods generally result in a limitation on the client's ability to make changes during the development of the project to maintain schedule and budget integrity. But CMR does allow for more flexibility in incorporating client changes because of the collaborative nature of their contract. Carpenter and Bausman (2016) mention the implications of changes that a client makes on public school projects. They found a difference between CMR and traditional methods, where CMR is more flexible for client changes due to a better involvement between the client and the construction manager, as opposed to traditional methods, where projects are less accommodating to change after the construction phase.

Regardless, Salcedo Rahola (2015) emphasizes the importance of good integration and comprehensive project briefs to minimize the need for any changes during the entire process. Rahola notes that, while management contracts can offer flexibility for client changes, they should be well documented and agreed upon by all involved parties to avoid disputes and ensure good project continuity.

2.6 Procurement and Model Contracts

The word procurement refers to the purchasing of goods and services from an outside body (Arrowsmith, 2014). However, the definition of the construction industry is a little more defined. According to Chao-Duivis et al. (2018), the Dutch construction industry refers to the word procurement as the process leading up to the award and conclusion of the contract, the pre-contractual phase when the procuring party as a contracting authority or public body or public entity. It deals with how a public body selects a party it wants to enter into a contract. On the other hand, private individuals are, in principle, at liberty to enter into an agreement with anyone and choose a contractual party however they wish. Offers submitted in the context of a procurement procedure are called 'tenders' or 'bids'. Procurement in the context of construction projects refers to the process of obtaining project team members, which may be individuals, firms, or companies that will participate in the completion of the project (Rashid et al., 2006; Wardani et al., 2006). The procurement process is crucial as it determines how these participants are selected and engaged, which in turn influences the project's overall success.

In the European directive (Article 18) and Section 1.2.2 of the Procurement Act, several principles of procurement are laid down. These principles play an important role in court rulings and form the foundation of procurement law. These principles are; Equal treatment and non-discrimination, transparency that allows parties to verify the actions of the contracting authority, proportionality that ensures that requirements are proportionate to the contract that is awarded, competition should be generated by a call for tenders, the obligation to state reasons or adequate grounds for decisions, and lastly the protection of legitimate expectations and legal certainty of all parties (Chao-Duivis et al., 2018).

European procurement is mandatory above a certain threshold, which changes yearly. The threshold changes based on the contracting authority, whether the authority is a central government, a decentralized government or public law institution, or a special sector company. Additionally, the threshold varies based on the contract; deliveries and services, works contracts, concessions, and social services differ in their limits (Heemskerk, 2018).

2.6.1 Procurement Methods and Limits

Within the construction industry, various procurement methods exist. Choosing the procurement method depends on what suits the project and the European limit concerning this kind of contract. Limits range from €143.000 for deliveries and services to €5.538.000 for works contracts (European Commision, 2024). These different procurement methods are one-on-one or single negotiated procurement, multiple negotiated procurement, national public procurement, national non-public procurement, European public procurement, and European non-public procurement. One-on-one procurement involves direct negotiation with a single contractor and is suitable for low-value contracts or those requiring specialized expertise. The multiple negotiated procedure involves bids from three to six suppliers, offering flexibility through negotiation. The national public procurement, an open procedure, allows all interested suppliers to tender, ensuring wide competition for straightforward projects. The national non-public procurement, a restricted procedure, invites selected suppliers, managing the tender process efficiently for complex contracts. European public procurement, mandated by EU law, ensures transparency and competition for high-value contracts across the EU. Similarly, the European non-public procurement restricts tenders to pre-qualified suppliers, ensuring high-quality submissions for complex projects (Jacobs et al., 2024).

2.6.2 Procurement for different PDMs

In the DBB method, procurement typically takes place in two distinct stages (Davis et al., 2008). First, the owner procures the services of a designer to complete the project design. Once the design is finalized, the second stage involves soliciting bids from contractors based on the completed design. The construction contract is usually awarded to the lowest responsive and responsible bidder (Hardie & Saha, 2012). This means at least two procurement moments exist.

In the DB method, the owner procures a single entity responsible for both design and construction (Wardani et al., 2006). This means there will only be one procurement moment for the entire process. An entity could be a single firm or a consortium that combines design and construction expertise. With this approach, a party will bid for both the design and construction phases, promoting collaboration and potentially reducing the overall project duration. These integrated procedures involve a multi-party agreement where one party signs a contract, and other key project participants (owner, designer, contractor, and sometimes key subcontractors and suppliers) work together as subcontractors, sharing risks and rewards.

A typical project has at least one bidding moment. This bidding can greatly affect the expected cost, time, and quality of a project. This can cause significant shifts in what is expected to be possible within the time frame and budget. Generally, the first bidding moment takes place after the completion of the PoR phase, which could be followed by a second bidding for traditional or management contracting methods. The second bidding moment generally occurs after the DO or TO phases and could significantly influence the project expectations.

2.6.3 Dutch Model Contracts

The definition of ‘contract’ in the Dutch Civil Code (CC), Article 6:213, reads as follows: an agreement in the meaning of this title is a multilateral juridical act whereby one or more parties enter into an obligation towards one or more other parties. (Chao-Duivis et al., 2018). These contracts cannot be overlooked when looking into what affects complex construction projects.

The Dutch construction industry employs various standardized contracts to govern the relationships and responsibilities between clients, contractors, and other stakeholders. These contracts with specific purposes and applications help streamline the construction process and mitigate potential disputes. Below, the primary Dutch building contracts are outlined: DNR 2011, UAV 2012, AVA 2013, UAV-GC 2005, and ALIB 2007 detailing their unique characteristics and applications (Adriaanssen et al., 2017).

DNR 2011

The New Rules 2011(DNR 2011) are a regulatory framework that is designed for agreements between a client and its consultants. These can be architects, engineers, housing advisors, etc. It merges the earlier used SR1997 for architects and RVOI 2001 for engineers, and updated this in 2011 and 2013 (Chao-Duivis et al., 2018). The DNR 2011 is used for contracts related to designing, advising, and organizing in different built environment sectors. It holds consultants accountable for their designs and advice and sets a limit for their liability in case of a dispute, a cap of a one million euro liability is in place. The framework also includes a standard task description (STB DNR), describing the details of several tasks and responsibilities between the different parties.

UAV 2012

Uniform Administrative Conditions for the Execution of Works (UAV 2012) are a model contract made for the execution of the construction and technical installation of projects. It is primarily suited for traditional PDMs where the client provides the design and the contractor then executes the work (Chao-Duivis et al., 2018); it is, however, also used in CMR and RPM methods. It is deemed less suitable for maintenance-specific projects. The structure of a UAV 2012 contract involves a client who is responsible for the design and a supervising director who ensures that the contractor complies with the design during execution. The UAV 2012 is not a new set of general terms and conditions, as it is a revised version of the UAV 1989 (Chao-Duivis et al., 2018).

UAV-GC 2005

Uniform Administrative Conditions for Integrated Contracts 2005, (UAV-GC 2005), are a contract framework that is designed for integrated, and supply-driven PDMs. This contract is made with a high degree of integration between phases in mind. The UAV-GC 2005 includes model agreements that cover different project-specific topics comprehensively, minimizing gaps and overlapping responsibilities (Chao-Duivis et al., 2018). The contract is made in such a way that it should promote cohesiveness and coordination in the project. Important to note is that these contracts are not suitable for integrated contracts that include the financing of the project, like DBFMO projects.

AVA 2013 and ALIB 2007

General Terms and Conditions for Contracting 2013, or AVA 2013, are a revision of the AVA 1992. It functions as a framework for the general conditions for buildings for private construction works that are more suitable for home and business premises and not as suitable for utility buildings like schools. Moreover, General Terms and Conditions for Installing Companies 2007 (ALIB 2007) is tailored to the installations for new buildings and renovations or maintenance issues (Adriaanssen et al., 2017).

2.7 Determining Project Success Factors

Traditionally a PDM was chosen based only on cost estimations, this changed due to clients seeking better collaboration and integration. Other project success factors were starting to be considered (Ahmed & El-Sayegh, 2020). Gransberg and Villarreal-Buitrago (2002) suggest that choosing the most suitable PDM is influence by the importance of a client's characteristics, experience, and risk tolerance, they suggest that these factors significantly influence the decision on what is the most suitable PDM for a client. The modern frameworks for evaluating PDMs and construction projects encompass both the more traditional- cost, time, and quality metrics and the newer- environmental, social, and economic aspects. These project success factors will be discussed separately in the following parts.

2.7.1 Cost, Time, Quality, and Value

Cost evaluation has typically been a crucial factor in assessing the efficiency of a PDM. Several vital metrics provide insight into budget management and financial performance. These include original and final construction costs, and the growth of these costs. The growth metrics function as a way to determine how much costs have changed compared to initial estimates. A combination of these metrics, including the total costs, gives a comprehensive view of the budget and how it has changed over time (Carpenter & Bausman, 2016; W. T. Chen et al., 2010). Additional cost-related metrics like unit cost per area or cost per user are essential for standardizing values for different projects. These metrics help to understand and compare the differences between buildings and their functionality (Carpenter & Bausman, 2016; El-Sayegh, 2008). Some projects are selected solely on cost performance estimates, called low-bid procurement. This approach can compromise the quality of a project, as the contractor might cut corners to maintain a profit (Hardie & Saha, 2012). Therefore, while cost metrics are vital, it is clear that they can be balanced with considerations on schedule and quality.

Time performance metrics for construction projects can focus on several phases of the overall construction process. These metrics include planned versus actual construction and project days, and therefore also growth metrics. These growth metrics help compare different projects based on what percentage the project was delayed compared to the original planning (W. T. Chen et al., 2010; El-Sayegh, 2008). Time efficiency can also be measured in metrics like construction or project intensity, which evaluates the amount of work completed per day, in square meters or cost (Mesa et al., 2016). Time performance metrics in construction projects focus on the duration of various project phases and the overall timeline. These include planned versus actual construction days and project days and growth in these durations. Metrics like construction growth and project growth percentages help identify delays and their extent, with high construction growth percentages indicating significant delays beyond the planned schedule (W. T. Chen et al., 2010; El-Sayegh, 2008).

Quality metrics are often less clear due to their inherent subjectivity. These metrics assess the product (the delivered building) and the service during the project management and execution. Owner satisfaction surveys often evaluate this quality where the building's interior, exterior, environmental, and overall performance is rated (El-Sayegh, 2008; Hardie & Saha, 2012). The aforementioned service quality is often measured by the effectiveness of communication, collaboration, and cooperation among all parties within the project and their ability to manage costs and schedule (Carpenter & Bausman, 2016). Metrics like readiness, such as the time to complete punch list items after delivery and the number of warranty and callback issues, provide additional insights into a project's service quality. The severity and cost of these issues are often also weighted (Carpenter & Bausman, 2016).

Value

The combination of the cost, time, and quality metrics is seen as value. Because value is a combination of the most important metrics, it is considered the overarching metric to assess overall project success. This metric is complex but can help determine whether the project has met its intended goals and expectations (Chan & Chan, 2004). The metric can be visualized with the 'value triangle' by Hardie and Saha (2012) (Figure 2.9), which illustrates the three elements of cost, time, and quality, how they influence each other, and how they are balanced to create 'value'. In recent years, stakeholders in the construction industry have increasingly realised that costs should not be the only parameter used to select a PDM, and other metrics are equally important.

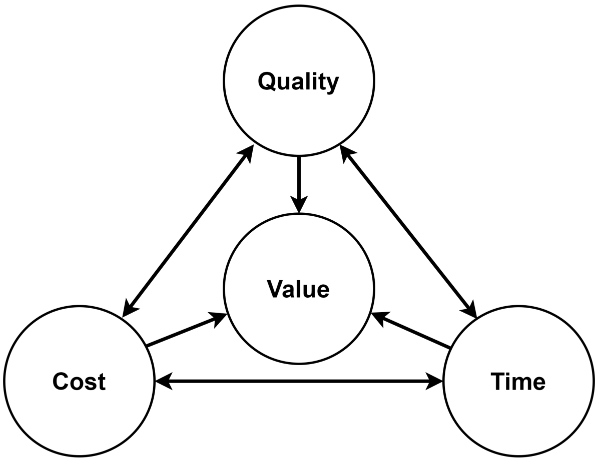


Figure 2.9: The 'Cost, Time, Quality' triangle by Hardie and Saha (2012)

2.7.2 Additional Metrics

Besides cost, time, and quality, other metrics can be collected and compared to better understand project performance. These metrics range from general project characteristics, environmental performance, and innovation to user comfort. As highlighted by Shoesmith (1996), project characteristics also encompass context, size, complexity, and intensity. Additionally, environmental performance and sustainability are also deemed an increasingly crucial segment of the evaluation of buildings, and part of this is the choice of environmentally friendly materials and processes, which is becoming more important. Innovation metrics for both product and progress are deemed valuable for evaluating building processes (Eriksson & Westerberg, 2011).

The post-occupancy comfort and user satisfaction are also vital metrics discussed by Leitner et al. (2020). These metrics include thermal comfort, personal thermal control, internal air quality, visual and acoustic comfort, spatial comfort, and connection to the external environment. Ahmed and El-Sayegh (2020) identify more social metrics like owner involvement, project management characteristics, contractor abilities and experience, and communication quality. Besides the discussed cost, time, and quality, their research also covers market competitiveness, sustainability goals, innovations, risk, and complexity.

While cost and time metrics can be measured at delivery, quality, sustainability, user comfort, and other metrics gathered through POE can only be collected after project delivery and during the buildings' operational period. The evolution of construction projects through different metrics involves an extensive analysis of not only cost, time, and quality but also environmental, innovation, and comfort factors. Together, these provide a more complete view of the project's success and allow projects to be compared.

2.8 Current Expectations of PDMs

Different PDMs have varying expectations, often based on personal experience or a status quo of expectations (Sullivan et al., 2017). This is why it is crucial to understand what the literature says about the difference in expectations of the effect of a PDM on its project success. Adriaanssen et al. (2017) notes a few general conclusions from the client's perspective on the most commonly used PDMs. They state that a traditional method has strengths regarding the client's control over the project and their ability to manage financial risks. Potential downsides include extended project duration, coordination challenges, and accountability issues. In contrast, according to Adriaanssen, integrated projects can lead to improved collaboration and integration between parties, using risk-sharing benefits and performance improvements. They are deemed more complex to set up and offer limited control over the project. Lastly, management contracts are expected to be more flexible and responsive and have a higher level of expertise utilization, according to Adriaanssen. However, this could lead to higher costs and more potential conflicts between parties.

Al-Enezi and Sabah (2023) found that DB projects performed better in terms of schedule and cost efficiency when compared to traditional projects, especially for larger projects, while for smaller projects, the traditional method performed better. Concluding by stating that DB was preferable by most parties, considering its construction speed. Perkins (2009) reported fewer cost overruns and additional costs for DB projects compared to traditional projects. This was attributed to reducing design errors in DB projects. Sullivan et al. (2017) highlighted that DB projects performed better for cost growth metrics at 2,8%, whereas CMR and traditional methods had worse metrics at 5,8% and 5,1% respectively. They emphasized the good cost growth for DB projects, which is most likely because the award amount for this method is typically determined much earlier in the design phase, resulting in better cost predictability. CMR and DB performed best for schedule growth with 10.2% and 10.7% respectively, while traditional methods had the worst schedule growth at 18.4%.

According to Q. Chen et al. (2016), the DB method provides relatively good time performance, with more than 75% of DB projects completed on or before schedule. However, with more than 50% of DB projects experiencing cost overruns, they say that the advantage of cost savings with the DB method remains uncertain. El-Sayegh (2008) indicates that DB methods are more effective in meeting most project objectives, followed by construction management at risk, and lastly, the traditional DBB. DB is relatively more effective in ensuring the shortest project duration than CMR. At the same time, the traditional delivery methods are deemed the least effective in ensuring the shortest duration. CMR is the most effective in ensuring staying within budget. The results also show that the traditional methods provide the greatest flexibility to incorporate changes during the design and construction of the project, although this may come at a higher cost. DB is better suited to handle changes and ensure the highest quality. Additionally, the literature review by Salcedo Rahola (2015) highlights the suitability of integrated PDMs for more sustainability-focused projects. This is due to its emphasis on collaboration. Similarly, Tang et al. (2019) also showed that integrated PDMs had the most significant impact on sustainable building success.

Mollaoğlu-Korkmaz et al. (2013) emphasizes that the early involvement of building contractors is crucial for achieving high integration and project success. They noted that while DB and CMR have better chances of facilitating integration, traditional methods also have the potential to provide high levels of integration if the building contractor is involved early enough. According to them, high levels of integration lead to exceptional projects that outperform intended targets regarding sustainability, cost, schedule, quality, and owner perceptions of post-occupancy performance. This level of integration is possible for all PDMs.

Oladirin et al. (2013) ranked DB highest in cost efficiency, while management contracting ranked lowest in this metric. DB performed best in terms of cost, while management contracting scored highest in client satisfaction and quality assurance and lowest in quality sacrifice. Similarly, Carpenter and Bausman (2016) found traditional methods superior to CMR in all cost metrics for the construction of public schools. However, CMR was deemed better by them in terms of quality performance when compared to the traditional method. The service quality of CMR was also deemed significantly superior to the traditional method. Studies comparing CMR with other PDMs, like DBB and DB, show mixed results. While some research indicates that CMR can perform better in terms of cost control and reduced claims Williams (2003), other studies suggest that traditional methods perform better in controlling cost growth (Konchar & Sanvido, 1998; Rojas & Kell, 2008). Specifically, Konchar and Sanvido (1998) found that DBB outperformed CMR by at least 7.8% in cost efficiency, and DB outperformed CMR by 12.6%. However, Reinisch (2011) found a lesser extent of difference, with DB outperforming CMR by 3.2%.

2.8.1 Summary of Expectations

As indicated above, sources are often divided on the exact impact that the choice of a PDM has on the project. Some general metrics can be agreed upon. While sources are very divided on the effectiveness of different PDMs on different metrics, some general expectations exist.

A traditional approach has strengths in terms of the client's control over the project and their ability to manage financial risks (Adriaanssen et al., 2017). Carpenter and Bausman (2016) found traditional methods superior to CMR in all cost metrics for the construction of public schools. Other studies suggest that traditional methods perform better in controlling cost growth (Konchar & Sanvido, 1998; Rojas & Kell, 2008). This is presumable at the cost of a comparatively bad schedule growth (Sullivan et al., 2017), and more mistakes in the design phase (Perkins, 2009).

According to Adriaanssen et al. (2017), integrated projects can lead to improved collaboration and integration between parties and risk-sharing benefits. Most sources agree that integrated methods like DB have a high likelihood of being cost-effective (Al-Enezi & Sabah, 2023; Oladirin et al., 2013; Perkins, 2009). Additionally, integrated methods are deemed more suited for sustainability-focused projects (Salcedo Rahola, 2015; Tang et al., 2019). Integrated methods give the client less control over the project once the contract has been signed; this brings risks in case the specification is interpreted differently, or the client wants to change something (Adriaanssen et al., 2017).

Management contracts, like CMR and RPM, offer more flexibility and responsiveness, leveraging the expertise of the management contractor. These methods effectively ensure projects stay within budget and often achieve superior quality and client satisfaction (Adriaanssen et al., 2017). However, they are associated with higher costs (Carpenter & Bausman, 2016). Carpenter and Bausman (2016) states that CMR performs better in terms of quality performance and service quality. Other research claims CMR performs better in cost control (Williams, 2003).

Chapter 3

Methodology

The Methodology first elaborates on the goals and methodologies used to answer the subquestions in Section 3.1. The methodology used to answer these subquestions determined the research approach discussed in Section 3.3. This section expands on the quantitative and qualitative methodologies used in this thesis, and on how the results of these methodologies are synthesized in Section 4.3.

3.1 Elaboration of Subquestions

This research consists of one main research question (MRQ) *`What is the relationship between the chosen PDM for primary school buildings, and project success factors?'*. However, This is too large of a question to answer without dividing it into multiple subquestions. These subquestions range from methodology-based questions (SQM 1-3) to knowledge-based questions (SQK 1-7), which have all been introduced in the first chapter. It is essential to plan how to address each of these questions, look at potential approaches, be aware of the strengths and weaknesses of these approaches, and foresee how to address and utilize these strengths and weaknesses. This prevents issues intervening with the quality of the research.

3.1.1 Methodology-based Research Questions

As mentioned, three subquestions are about setting up the research methodology (SQM). Therefore, these are answered in Section 3.2 before setting up the rest of the methodology in Section 3.3.1 onwards. These three subquestions will be answered through exploratory conversations with experts and the extensive literature research performed in Chapter 2.

SQM 1: What are the useable methodologies to compare construction projects and PDMs?

This question aims to identify established frameworks and methodologies for comparing buildings that could also be applied to primary school buildings. Findings of this framework are done by referring to the comprehensive review of academic articles, case studies, and reports on building assessment performed in Chapter 2. These findings are also discussed with experts within the chosen consultancy firm, who discuss their experiences, challenges, and successful strategies when comparing buildings and discussing possible pitfalls.

SQM 2: How can data on primary school building projects be gathered and formatted in such a way that they can be compared effectively?

When comparing buildings on project success factors, it is essential to know that the right things are measured and compared. Therefore, identifying possible methodologies for comparing primary school projects is critical. This is answered with academic studies and industry reports in Section 2.2, and additional literature.

It is essential to understand what data is available on primary school buildings and how this data can be collected, while also creating an understanding of how to effectively format different building metrics so that they and their construction can be compared. Exploratory conversations with professionals within the chosen consultancy firm are performed during which the available data, what locations this data is stored, and the tools that are used to store this data are explored. While simultaneously looking at the academic articles, case studies, and reports discussed in Chapter 2 and how these studies approached this problem.

With the use of the theoretical framework created in Chapter 2 and consulting firm experts on project management, these subquestions are answered, allowing for the creation of a framework for the rest of the methodology of this research from Section 3.3.1 onwards. These methods have their separate strengths and weaknesses, which should be considered when conducting the research. Extensive literature research has the benefit of providing a broad understanding of the existing knowledge and simultaneously being credible and structured. However, it has the downside of being very time-consuming or not being specific enough for the research context. Additionally, the research might not apply to the exact situation concerning the available data. At the same time, conversations with experts provide practical insights into these potential issues. A perspective on current and possibly more modern practices would also allow the research to be more up-to-date. However, this method's limitation is the potential subjectivity and variability of the expert based on the expert's background, expertise, and personal opinions. By combining literature research and conversations with experts, these research questions should be answered in a more balanced and thorough way by leveraging the combination of theoretical foundations and practical insights.

This provides essential information to create the framework for the rest of the research but does not allow for a complete reliance on the results due to the aforementioned weaknesses. This should, however, not be an issue because these questions only serve to create a framework for the rest of the research, hopefully improving the quality of the answers to the "knowledge-based" research questions.

3.1.2 Knowledge-based Research Questions

After determining a framework for the methodology-based research questions, the conclusions of these questions are used to answer the remaining subquestions. These questions are categorized as knowledge-based research questions, which support the main research question 1.2. These 'knowledge-based research questions' and their strengths and weaknesses, their chosen approach, and additional notes are now discussed;

SQK 1: What constitutes project success, and how can it be measured?

First, project success factors must be defined to compare PDMs and project success. These project success factors are determined using the Literature research from Chapter 2 looking at what other research has done and what data can be collected. Answering this research question is essential in quantifying project success during the rest of the study.

SQK 2: What are the current expectations concerning the influence of the chosen PDM on project success?

Before being able to determine what the effects of the choice of a PDM are, it is essential to know what the current decisions are based on. This also aids in understanding what projects can be compared. This research question is answered using the literature (Chapter 2) and exploratory interviews.

SQK 3: Which PDMs are used most often for primary school buildings?

As there is a limited number of projects that can be analysed, both due to the availability of prior primary school project data and the comparability of different projects, not all PDMs can be compared. Therefore, it is crucial to identify the commonly used delivery methods for primary school buildings. A list of prior projects and their respective PDMs is made to answer this question. It is essential to group PDMs accurately, as projects often have minor project-specific aspects to their method.

SQK 4: What are stakeholder expectations on project success factors, and how do these expectations change over the project duration?

The objective of this research question is to gain a deeper understanding of the goals of different stakeholders. What do different parties want to improve in the building process? And how do these priorities change throughout a project? This research question is answered through literature research and interviews with the project manager/advisor from the chosen consultancy firm and a party representing the client.

SQK 5: How do primary school buildings differ in terms of usage, stakeholders, costs, and construction time?

It is also essential to understand how primary school buildings fundamentally differ from each other so that this can be considered when comparing the different buildings. Therefore, this question aims to identify similarities and differences between buildings. This is done by using existing data from prior projects, research of existing case studies and reports, and expert interviews, creating a complete and nuanced answer to the research question.

SQK 6: What are the average project success factors for primary schools, and how do they relate?

This research question aims to create a baseline from empirical data to which all the different primary schools can be compared. From this, it is possible to identify trends for different PDMs. It would also be possible to see how different project success factors relate and interact with each other. Does project cost influence project time, and vice versa? To answer this research question, graphs are made from quantitative data, and qualitative data is used to compare the more complex project success factors.

SQK 7: What is the effect of a PDM on the average project success factors for primary school buildings?

This question aims to analyse the impact of PDMs on project performance and contextualize the empirical data from the gathered data with theoretical insights from literature and interviews. Do projects with the same PDM consistently underperform on a metric compared to the average?

These knowledge-based research questions are answered using literature research, expert opinion of project managers and client representatives, and collecting and analysing empirical data from prior projects within the chosen consultancy firm. All of these methods have their strengths and weaknesses, which are expanded upon in Chapter 6. Combining these three methods aims to create a complete and nuanced view of the subquestions, giving a more complete and comprehensive answer to the research question. As literature and interviews are a tried and true research method, they can also be used to check the validity of the statistical research performed by analysing prior projects. This statistical analysis is tested during the research by comparing them to expectations to see if the results still make sense.

Considering the problem's complexity and the number of factors at work in a construction project is crucial. Not all factors in such a project can be taken into account when comparing PDMs. Giving a conclusive and definitive answer to the research question would be impossible. Therefore, the biggest challenge of this research is to give a conclusive enough answer to the research question so that future project decisions can be made with more of an understanding of the consequences.

3.2 Answering First Research Questions

Three SQM and eight SQK were created to determine the most appropriate way to answer the main research question. The SQM and the first three SQK are answered using the theoretical background of this chapter. The remaining questions are answered in the synthesis section (4.3).

3.2.1 Sub Questions Methodology

SQM 1: What are the useable methodologies to compare construction projects and PDMs?

To compare buildings and assess various PDMs, researchers employ a variety of methodologies, each tailored to gather comprehensive and reliable data from construction projects. These methodologies differ in their conclusions and achieve different goals. To answer SQM 1, the methodologies from other research are discussed, and a preferred methodology for this research is discussed.

Literature Reviews and Meta-Analysis

Literature reviews and meta-analyses are foundational methods for collecting data and synthesizing findings across multiple studies. Ershadi et al. (2021) conducted a literature review followed by a qualitative survey to gather insights from construction professionals in principal contracting firms. Similarly, Leitner et al. (2020) performed a systematic literature review to examine 55 papers on post-occupancy evaluations (POEs), using the 5W1H (Who, What, When, Where, Why, and How) tool to identify key elements of these evaluations. Sullivan et al. (2017) combined quantitative findings from 30 existing studies representing 4,623 projects, analysing metrics such as cost growth, unit cost, schedule growth, delivery speed, and quality to draw more representative conclusions.

Surveys, Questionnaires, and Interviews

Sanoff (2001) employed assessment tools, including surveys, checklists, observation forms, and group discussions, to identify the physical features influencing the learning environment. Their post-occupancy evaluations involved questionnaires, walk-throughs, and interviews with a committee representing the school's organization. Blyth (n.d.) also utilized post-occupancy evaluations through interviews to gather detailed feedback on the performance and user satisfaction of completed projects, thereby offering qualitative insights into the real-world implications of design and construction decisions from the perspective of end-users.

Surveys, questionnaires, and interviews are extensively used to collect data from construction professionals and stakeholders. For instance, Hardie and Saha (2012) initiated their study with a pilot survey targeting builders, property developers, and construction managers and later relied on surveys for a broad quantitative overview of industry perceptions and performance metrics. Oladirin et al. (2013) distributed structured questionnaires to construction professionals in Lagos, Nigeria, receiving 76 suitable responses from 100 distributed questionnaires. Aluko et al. (2020) adopted a survey research approach using a semi-structured questionnaire, forming the basis for descriptive and inferential statistics, to evaluate the relationship between engineering consultants' service quality and client satisfaction.

Love et al. (1998) conducted postal questionnaire surveys of 41 clients and 35 consultants to gather experiences and attitudes towards various procurement methods and the criteria for their selection. Wardani et al. (2006) conducted surveys on 76 DB projects in the US, providing quantitative data on project performance and enabling comparative analysis of different PDMs within a specific context. Mehany et al. (2018) collected data by distributing questionnaires to Departments of Transportation across the transportation sector, analysing the data using descriptive and inferential statistics to reveal insights into the impact of PDMs on various performance factors, including contractor performance and trust. However, no significant impact on claims and dispute performance was found.

El-Sayegh (2008) collected data from 40 experts via questionnaires, obtaining expert opinions and insights into project performance and delivery methods. Mollaoğlu-Korkmaz et al. (2013) used a web-based approach to research the US Green Building Council's database, identifying 12 projects for detailed data collection through telephone and email. Input from owners, designers, and constructors was gathered through 40-50 minute interviews, supplemented by voice recordings and completed survey questionnaires.

Case Studies

Case studies provide in-depth insights and detailed data on specific projects. W. T. Chen et al. (2010) evaluated project control management services in school construction projects in Taiwan by exploring client needs, developing a satisfaction evaluation model, and applying this model across 20 projects. This method allowed researchers to delve deeply into the specifics of each project, gaining comprehensive insights into the factors influencing project outcomes. Similarly, Mollaoğlu-Korkmaz et al. (2013) conducted 12 in-depth case studies, offering detailed insights into specific projects and allowing for an in-depth understanding of the factors that influence project outcomes.

Document Reviews

Directly reviewing project documents is a reliable method for collecting precise cost and schedule information. El-Sayegh (2008) examined actual project documents, such as owner-contractor agreements, architectural agreements, notices to proceed, certificates of substantial completion, and final payment applications, ensuring accuracy based on official records. Carpenter and Bausman (2016) used actual construction documents from 137 southeastern public schools over two years to analyse PDM performance in terms of cost, time, quality, and claims. Additionally, Ireland (1985) collected data from 57 high-rise commercial building projects. This data included detailed project records.

Models

Tang et al. (2019) constructed a system dynamics model based on various variables and criteria. This model includes causal loop diagrams to illustrate the relationships and feedback processes among the variables. Eriksson and Westerberg (2011) developed a conceptual model proposing relationships between procurement procedures, treated as success factors, and project outcomes, treated as success criteria. W. T. Chen et al. (2010) developed a satisfaction evaluation model applied to 19 school projects, with data filled in by directors through five phases of the project life cycle. This model helped assess satisfaction at various stages of project completion. Mesa et al. (2016) employed a General Performance Model to evaluate project performance, allowing for a standardized comparison across different projects.

Simulation and Statistical Analysis

Ireland (1985) collected data from 57 high-rise commercial building projects. This data included direct interviews with project managers to gather first-hand information on managerial practices and project outcomes. The performance of these projects was evaluated based on cost, time, and quality metrics. Cost performance was assessed by comparing project costs to the initial budget. Time performance was measured by comparing the completion time to the planned schedule. These were called 'growth' metrics. Quality performance was evaluated through criteria such as defect rates and client satisfaction. The collected data were analysed using statistical methods to identify significant correlations between specific managerial actions and project performance outcomes. The analysis aimed to pinpoint which actions most substantially impacted if projects were completed within budget, on time, and to the desired quality standards.

Simulation and statistical analysis are used to model and evaluate project performance using various delivery methods. Mesa et al. (2016) applied a simulation method, the General Performance Model, to assess interactions between different project delivery variables, allowing for comparative analysis of potential performance outcomes. Statistical methods also included normalization of costs, hypothesis testing through t-tests and chi-square tests, and analysis of performance metrics (Carpenter & Bausman, 2016; Sullivan et al., 2017).

Combined Methods

Some studies utilize multiple methods to enhance the robustness of their findings. For instance, El-Sayegh (2008) combined an extensive literature review with a two-phase questionnaire survey to collect data on PDMs and selection factors. Similarly, Ershadi et al. (2021) utilized a literature review, qualitative surveys, and thematic analysis to gather and analyse data. This mixed-method approach gave a comprehensive understanding of the factors influencing project performance.

Strengths and Weaknesses

These diverse methodologies, ranging from surveys and interviews to document reviews, simulations, and meta-analyses, provide a comprehensive framework for collecting and analysing data to compare building performance effectively. Various methods have been used to compare different PDMs, and a significant amount of research has been done on the subject. However, most of this research uses surveys, questionnaires, and interviews. Therefore, the subjective opinion of one of the stakeholders involved in the project is that these stakeholders form opinions that are often not based on quantitative results. This means that while this research is often in-depth, its results are still based on subjectivity.

The most promising and airtight method found in the literature research is by El-Sayegh (2008), and Carpenter and Bausman (2016). Both of these studies reviewed data from actual construction projects and compared them between projects. The use of a growth metric in these studies enhances the understanding of how expectations changed compared to a phase earlier in the project. However, because of the use of only two data points per project, it isn't easy to pinpoint the exact reason for the differences between the PDMs and when they originate. Additionally, this method requires better access to often protected documents and more intense research, allowing for a more objective view of the research problem.

Answering SQM 1

Various methods have been used to compare different PDMs, and a significant amount of research has been done on the subject. Most of the research falls into three categories: research of opinion (surveys, questionnaires, interviews), objective research (document reviews), or a combination (models, case studies, simulations). Most of the reviewed literature focused on either research of opinion or a combination of opinion and quantitative metrics. Resulting in the PDMs being graded on how stakeholders viewed the performance of different methods instead of what the performance was. This is logical, as buildings are all very different and, therefore, notoriously difficult to compare.

Reviewing what methodologies apply best for answering the research gap and providing empirical data, it was determined that El-Sayegh (2008) and Carpenter and Bausman (2016) suit the research objective the best. Both use reviewed data from actual construction projects and compare them between projects. The usage of a growth metric also provides an additional layer of information. These strengths resulted in objective and quantitative results. This does not mean, however, that the subjective influence of qualitative studies is not helpful. A subjective methodology considers many different factors about communication and the actual quality of the project that might not be considered in the more quantitative approach used by Carpenter and Bausman (2016) and El-Sayegh (2008). Therefore, research of opinion was also used in this thesis, making it a combined method. Ideally, the conclusions from both methods are individually compared to see where the similarities and the differences lie. During this research, the quantitative and the qualitative research are separated into two parts, after which they are synthesised and a conclusion is made.

SQM 2: How can data on primary school building projects be gathered and formatted in such a way that they can be compared effectively?

Several studies state the difference between 'normal' construction projects and the construction of primary school buildings (Section 2.2). The construction of primary school buildings often entails unique challenges. They differ in having stricter safety and regulatory standards, requiring special facilities, numerous stakeholders, and limitations resulting from financial and regulatory factors (Arnoldussen et al., 2020; W. T. Chen et al., 2010). These economic concerns, in combination with regulatory limitations enforced by municipal, provincial and national organizations, result in a complication of the process and a potential increase of the project risk (Carpenter & Bausman, 2016). These differences are considered key factors in the project success of a primary school building and should, therefore, be considered when comparing these projects.

Within the literature, school buildings were compared using a variety of methodologies, using both a quantitative and qualitative approach. Sanoff (2001) employed assessment tools, including surveys, checklists, observation forms, and group discussions, to identify the physical features influencing the learning environment. Their post-occupancy evaluations involved questionnaires, walk-throughs, and interviews with a committee representing the school's organization. W. T. Chen et al. (2010) developed a satisfaction evaluation model applied to school projects, with data filled in by directors through five phases of the project. This model helped assess satisfaction at various stages of project completion. Rojas and Kell (2008) empirically compares cost growth performance of the CMR and DBB methods for public school projects using records and previous studies. Lastly, Carpenter and Bausman (2016) used actual construction documents from public schools over two years to analyse PDM performance in terms of cost, time, quality, and claims.

School projects are compared using a variety of metrics called project success factors. Within the literature, quantitative data-based methods can gather data on cost and time metrics. While these are relatively simple, these values are entirely objective and can be collected from databases within the chosen consultancy firm, where project documents from completed projects are stored. Combining cost and time metrics and metrics like Gross Floor Area (GFA) and student capacity can lead to more complex metrics like growth and cost per m^2. A combination of these metrics can be used to compare different projects, or an average of these metrics can be made to compare PDMs. Alternatively, qualitative methodologies like surveys or interviews can gather data on more complex or abstract metrics, like project quality, communication quality, sustainability and usability. This leads to a more informed view of different projects. However, it has the downside of being based on opinion. Combining these metrics would provide the most complete framework to compare different PDMs and primary school projects.

3.2.2 Sub-questions Knowledge

SQK 1: What constitutes project success, and how can it be measured?

Project success can be measured through a variety of different metrics called project success factors. These can be compared between different projects to determine the success of a project in different areas. Different project success factors can be prioritized when developing a project. For instance, some buildings may emphasise quality more due to the user group's requirements. In contrast, others might need to adhere to strict timelines, making the completion time critical. Additionally, many projects prioritize cost, particularly those operating within tight budget constraints. The primary project success factors, and the metrics used to measure them, are discussed in Section 2.7. These metrics allow for comparing projects to gauge their success across multiple dimensions. Different success factors may be prioritized when planning a project, depending on the project's specific needs. Project success used to be based solely on cost estimations. The modern frameworks for the evaluation of PDMs and construction projects encompass both the more traditional- cost, time, quality metrics (2.7.1), and the newer- environmental, social, and economic aspects (2.7.2).

Several vital metrics provide insight into budget management and financial performance. These include original and final construction costs and the growth of these costs. These growth metrics function as a way to determine how much costs have changed compared to initial estimates. A combination of these metrics, including the total costs, gives a comprehensive view of the budget and how it has changed over time (Carpenter & Bausman, 2016; W. T. Chen et al., 2010). Additional cost-related metrics like unit cost per area or cost per user are essential for standardizing values for different projects. These metrics help to understand and compare the differences between buildings and their functionality (Carpenter & Bausman, 2016; El-Sayegh, 2008). Some projects are selected solely based on cost performance estimates, known as low-bid procurement. This approach can compromise the quality of a project, as the contractor might cut corners to maintain a profit (Hardie & Saha, 2012). Therefore, while cost metrics are vital, it is clear that they can be balanced with considerations on schedule and quality.

Time performance metrics in construction focus on various phases of the construction process, including planned versus actual construction days and project days, and time growth. These growth metrics help compare projects based on the percentage of delay relative to the original plan (W. T. Chen et al., 2010; El-Sayegh, 2008). Time efficiency can also be measured in metrics like construction or project intensity, which evaluates the amount of work completed per day, in square meters or cost (Mesa et al., 2016). Time performance metrics in construction projects focus on the duration of various project phases and the overall timeline. These metrics include planned versus actual construction days and project days, as well as growth in these durations. Metrics like construction growth and project growth percentages help identify delays and their extent, with high construction growth percentages indicating significant delays beyond the planned schedule (W. T. Chen et al., 2010; El-Sayegh, 2008).

Cost and time metrics can be measured at project delivery, whereas quality metrics are more commonly evaluated post-delivery. While often subjective, they assess the final product and service quality during project management. Quality metrics can either be measured (e.g. maintenance cost, energy cost) or perceived (e.g. user comfort, health) during the operation period of a building (Aluko et al., 2020; Atkinson, 1999; Hardie & Saha, 2012). These metrics are typically gathered through post-occupancy evaluations like owner satisfaction surveys, rating aspects like the building's interior, exterior, environmental performance, and overall performance (El-Sayegh, 2008; Hardie & Saha, 2012). Service quality is often measured by the effectiveness of communication, collaboration, and cooperation among all parties within the project and their ability to manage costs and schedule. Additional insights into service quality come from metrics like readiness, time to complete punch list items, and the number of warranty and callback issues, weighted by severity and cost (Carpenter & Bausman, 2016).

The combination of the cost, time, and quality metrics together is seen as value and the overarching metric to assess overall project success. This metric is complex but can help determine whether the project has met its intended goals and expectations (Chan & Chan, 2004). Beyond cost, time, and quality, other metrics provide a broader understanding of project performance. These include project characteristics, environmental performance, innovation, and user comfort. Project characteristics might include context, size, complexity, and intensity, while environmental performance increasingly emphasizes sustainable materials and processes. Innovation metrics are also becoming important in assessing project success. Post-occupancy comfort and user satisfaction are also vital metrics, as discussed by Leitner et al. (2020). These metrics include thermal comfort, personal thermal control, internal air quality, visual and acoustic comfort, spatial comfort, and connection to the external environment. Ahmed and El-Sayegh (2020) identifies additional social metrics like owner involvement, project management characteristics, contractor abilities and experience, and communication quality. Their research also covers market competitiveness, sustainability goals, innovations, risk, and complexity, with various methods available for measuring these metrics.

The evolution of construction projects through different metrics involves an extensive analysis of cost, time, quality, environmental, innovation, and comfort factors. These provide a more complete view of the project's success while also allowing projects to be compared. These can be measured with various metrics, from simple metrics like total cost to more complex metrics like air quality. A combination of these project success factors and what weight a client gives them determines a project's success. This can then be used to assist in future decisions.

SQK 2: What are the current expectations concerning the influence of the chosen PDM on project success?

As discussed in answering SQK 1 (Section 1.2), several different metrics are used to determine a project's success. The expectation/consensus is that this project's success can differ based on decisions made during the various phases of a project's development. One of these essential decisions is the decision on in what manner, and thus, the project should be developed using what PDM. The current expectations on the influence of a PDM on project success differ slightly. However, general expectations on the performance of PDMs are generally agreed upon. These expectations are discussed to a larger extent in Sections 2.3 and 2.8.

Traditional methods provide robust client control over the project and financial risk management. Its segmented approach allows clients to settle obligations per phase, limiting financial risks, especially for organizations with complex decision-making structures. Clients retain significant influence over the project even after the design phase, allowing for easier adjustments and development of specified requirements. Another advantage is preventing additional costs by directly managing each party involved, avoiding extra charges for coordination tasks. Additionally, formats where a single tender is issued for a combination of parties simplify the process and ensure clearer communication and accountability (Adriaanssen et al., 2017). However, traditional methods often face delays because construction begins only after the design is finalized and the tendering process is completed. This can be critical for time-sensitive projects. Integration difficulties between parties could lead to inefficiencies and higher maintenance costs, as contractors and maintenance parties are typically involved later, making it hard to incorporate practical insights from all stakeholders. Determining responsibility for mistakes can also be challenging and lead to disputes. The traditional method also requires extensive management and coordination skills from the client (Adriaanssen et al., 2017). Designers and contractors often work toward their goals, leading to inefficiencies, project delays, and higher costs (Mehany et al., 2018; Perkins, 2009).

Integrated methods improve collaboration and integration among parties, leveraging risk-sharing benefits and enhancing overall performance. By focusing design and construction responsibilities on a single party, the risk of errors and miscommunications is significantly reduced, resulting in higher project quality and increased client satisfaction. Having one communication point simplifies decision-making and coordination, leading to more efficiently executed projects (Adriaanssen et al., 2017). The intrinsic overlap of the design and construction phases allows a project to be completed in a shorter time than traditional methods (El-Sayegh, 2008; Mehany et al., 2018). The simultaneous progression of phases enhances collaboration between designers and constructors, reducing the likelihood of disputes and litigation (Ndekugri & Turner, 1994). Additionally, methods like DBM, DBMO, and DBFMO optimize the realization and maintenance phases by integrating them with prior phases, ensuring one responsible party for mistakes and facilitating smoother project management (Adriaanssen et al., 2017). However, clients may have less control over design details once the contract is signed, making modifications costly and complex (Adriaanssen et al., 2017; Davis et al., 2008; El-Sayegh, 2008). Selecting and contracting with a single party for multiple phases could result in significant transaction costs, potentially counteracting efficiency gains. The main client influence is often limited to the design phase, making changes difficult once construction begins and reducing adaptability to unforeseen needs. DBMO and DBFMO methods further limit organizational flexibility, making them less suitable for projects requiring a high degree of adaptability (Adriaanssen et al., 2017).

Management contracting offers significant advantages in terms of collaboration, integrated planning, and risk management (Carpenter & Bausman, 2016). These methods are particularly beneficial for complex projects that require a high degree of coordination and quality of service. A key advantage is the responsibility assigned to a single party for pre-construction and construction services, providing a central point of contact. Hiring the general contractor early in the design phase allows the contract manager to act as an advisor, offering insights into cost estimates, schedules, design changes, and risk identification (Cantirino & Fodor, 1999; Farnsworth et al., 2016; Mehany et al., 2018). This integrated approach improves collaboration and significantly reduces the number of change orders, a major cause of claims and disputes (Farnsworth et al., 2016). Performance guarantees offered by the contract manager enhance project reliability and quality (Adriaanssen et al., 2017). CMR is especially beneficial for public school constructions, where collaborative properties lead to higher product and service quality (Carpenter & Bausman, 2016). However, CMR and RPM have several drawbacks. Reduced costs do not always benefit the client fully, and the complex collaborative approach can lead to higher construction costs compared to traditional methods (Carpenter & Bausman, 2016). The complexity of detailed agreements covering various project aspects can result in extensive contracts that are challenging to manage and enforce. Additionally, risks covering different project phases may create uncertainties and potential disputes about responsibility, particularly when issues are not traceable to a single phase or party (Adriaanssen et al., 2017).

Overall, while sources vary on the exact impact of PDM choice on project outcomes, general expectations from the literature indicate that each method has its strengths and weaknesses. The consensus is that traditional methods excel in control and cost management, integrated methods enhance collaboration and speed, and management contracting offers flexibility and expertise but may incur higher costs.

SQK 3: Which PDMs are used most often for primary school buildings?

The literature specifies four different groups of PDMs; traditional, integrated, management contracting, and supply-driven. All the different PDMs can be divided under these four categories. Little information is available in the literature about supply-driven PDMs being used to construct primary school buildings. Therefore, this method is disregarded for this research. Five different sources discuss the relationship between PDMs and specifically primary schools (Carpenter & Bausman, 2016; W. T. Chen et al., 2010; Jacobs et al., 2024; Reinisch, 2011; Rojas & Kell, 2008). They state that the construction of primary school buildings frequently utilizes several PDMs, DBB, DB, and CMR. Each method has specific characteristics that influence its selection based on project needs and goals.

DBB is the most widely used method for constructing primary schools. It is favoured for its segmented approach, which allows clients to make financial commitments phase-by-phase, thereby limiting financial risks. This method also offers high client control over the project, particularly during the design phase, enabling adjustments and specification developments to be made more easily. This is favourable for complex projects like primary schools (Mehany et al., 2018; Perkins, 2009).

The DB method combines the design and construction responsibilities under a single contract, which can lead to significant time savings and improved cost predictability. The overlap of design and construction phases allows for faster project completion, making DB an attractive choice for time-sensitive school construction projects (El-Sayegh, 2008; Mehany et al., 2018). Additionally, DB reduces the risks of errors and miscommunications, potentially leading to higher quality outcomes and increased client satisfaction. Despite these benefits, DB can limit the client's control over the project once the contract is signed, making it more challenging to implement changes or adjustments later in the process. This necessitates a well-defined and high-quality project outline in the definition phase to ensure success (Davis et al., 2008; El-Sayegh, 2008).

CMR is another common PDM used for school construction, particularly for complex projects that require significant coordination and quality control. This method involves the early hiring of a construction manager who provides pre-construction services such as cost estimates, scheduling, and risk management (Cantirino & Fodor, 1999; Mehany et al., 2018). This early involvement often leads to improved collaboration, fewer change orders, and better overall project performance in terms of quality and schedule. However, the costs associated with CMR can be higher than those for DBB due to the added complexity and the need for detailed agreements covering various aspects of the project (Carpenter & Bausman, 2016).

Choosing PDMs to compare should depend on the number of projects available with that method. The more projects are compared, the more significant the results are. Therefore, choosing PDMs to compare should not depend on the literature. Instead, determining the best methods to compare was done by looking at the data and exploratory conversations with experts referenced in the case selection 3.3.1 in the next section.

3.3 Method and Research Approach

To determine the methodology for the research, it is essential to define the research problem sufficiently (Wieringa, 2014). When defining the research problem, it is essential to understand what kind of question is being asked. The research question, in this case, 'What is the relationship between the chosen PDM for primary school buildings and project success factors?' can be classified as a knowledge question. It does not call for a change in the world but asks for knowledge about the world as it is. When answering a knowledge question, it is assumed that there is only one answer. Wieringa (2014) states that Rational discourse implies the assumption of a single truth but must be combined with the assumption of fallibilism: we can never be sure we have found the answer to an empirical knowledge question.

The research is divided into four phases: the theoretical framework phase, the quantitative analysis phase, the qualitative analysis phase, and the conclusion/discussion (Figure 3.1). The split into these four phases allowed for intermediate conclusions and synthesis of collected information, ultimately gaining a better understanding of the research problem. These phases use different methods to gain the necessary knowledge for that sub-phase. These different methods are literature research, data analysis, and expert opinion. With the combination of these different methods, the aim is to understand the research problem and support the intermediate conclusions.

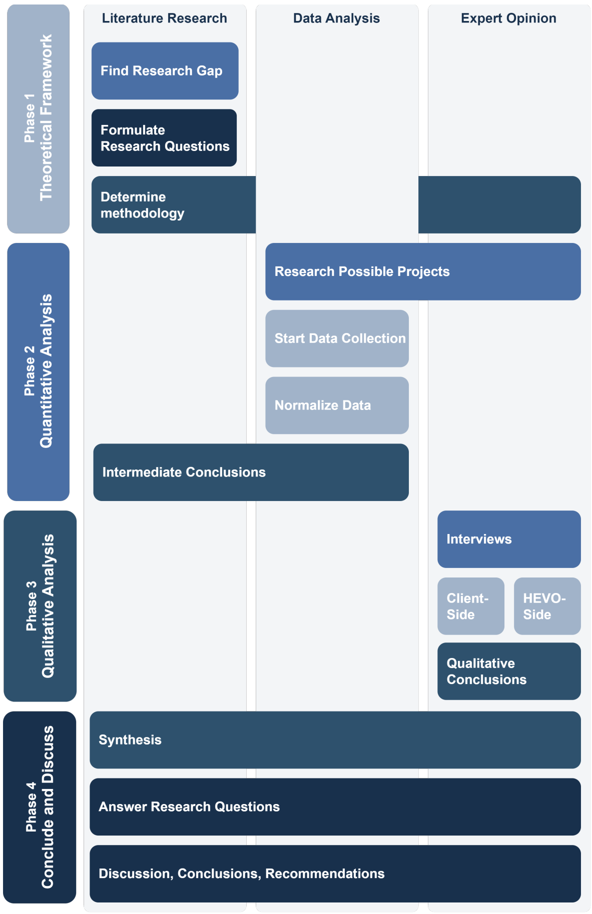


Figure 3.1: The Research approach

The theoretical framework phase has three sub-phases: finding a research gap, formulating research questions, and determining the methodology. In the first sub-phase, a research gap has to be determined. For this, a background literature review was performed that looks at the current expectations of PDMs, what methodology was used to perform this research, and what the recommendations for further research were in the papers. After this background literature is reviewed, a research question is formed. This research question, however, cannot be answered without the help of subquestions. After these have been formed, a methodology is set up. This is again aided by literature research to determine the methodologies used to perform similar research and to see what results they yielded. Additionally, use is made of expert opinion within the chosen consultancy firm, where conversations are conducted with several company experts on approaching the research question and discussing what data could be available within the company. A combination of these two approaches results in a research methodology that tackles the research problem and has a track record of effectiveness.

The first subquestions are answered after the theoretical framework is complete and the methodology has been decided. After this, the next step is the quantitative analysis, which has four different sub-phases. Firstly, research is performed on what projects have enough data to perform an accurate analysis. The selection of projects is made by discussing with internal experts within the consultancy firm what projects could be suitable for this research and what PDM was used for that project, followed up by validation on the availability of the necessary information to create the analysis. After a sufficient selection of projects has been made, the data is collected manually from the different available databases and other sources. When all the necessary information has been collected, the data is transformed into additional metrics and normalized to compare the different projects more effectively. After all the data is transformed and normalized, the data is formed into graphs, averaged out per PDM, or compared individually. This allowed for intermediate conclusions on the similarities and differences with the literature, or based solely on the quantitative data.

These intermediate conclusions serve as the basis for the third phase of the research, the qualitative analysis. This phase consists of creating interview questions based on the previous findings and literature research and selecting possible interview candidates. When possible, for every interview with a project manager within the chosen consultancy firm, a counterpart interview was had with a representative from the client side who was also involved with the project to create a balanced picture of the process. After the interviews,

Lastly, the research is concluded with phase four. A synthesis of the new information and the intermediate conclusions was made. In this synthesis, the differences between the two phases are discussed, and a comparison between the literature, data analysis, and interviews is discussed. The research questions were answered using this synthesis, creating a framework for answering the main research question. After this was answered and advice for different stakeholders was given, a discussion was written about the implications and limitations of the research, the unexpected results, a comparison to other literature, how the results can be applied, the consequences of the research, and a justification of the importance of the findings. Lastly, recommendations for future research are suggested and supported based on the conclusions of the research and the limitations discussed.

3.3.1 Quantitative

The quantitative methodology is split into several parts. Starting with the case selection, where the criteria for the selection of projects to analyse is discussed. Followed by an explanation of the data structure and formatting. The interpolation of missing data and cost distribution is discussed. An explanation of the cost normalization follows this. After this, the remaining methodology for the comparison and intermediate conclusion is discussed.

PDM Selection

As discussed in Section 2.3, PDMs can be grouped into four different categories: traditional, integrated, supply-driven, and management contracting (Adriaanssen et al., 2017). However, according to Carpenter and Bausman (2016), the most commonly used PDMs for school buildings are DBB or the traditional method, DB for integrated, and CMR for management contracting. Therefore, this research only focuses on the three categories more commonly used for school buildings and leaves out the supply-driven PDMs. The categories contain other specific PDMs that have slight variations in structure and responsibility. Most of the traditional projects analysed were 'Hoofdaanneming', and integrated projects either EB, DB, or DBM. However, to increase the effectiveness of the comparison, only the larger categories are compared for traditional and integrated projects, increasing the sample size of each category. Contrarily, all management contracting projects that were analysed used the RPM method, allowing for a more specific comparison.

Case Selection

Before data collection could start, a selection of possible projects was made. This was done with the help of exploratory research of the available data and exploratory conversations, resulting in a selection of projects that is visualized in Figure 3.2. Out of the entire construction sector, only a part of the projects are related to the construction of 'primary school buildings.' Within the Dutch construction sector, only a small part of this is worked by the chosen consultancy firm. The overlap between the built 'primary school buildings' and the projects worked by the 'consultancy firm' are deemed 'suitable projects', lined in red. Not all suitable projects have enough data available, and some are unsuitable for other reasons. This leads to the final selection of projects to be analysed. As discussed in Section 2.3, projects can have subtle differences that lead to the choice of many different PDMs. To ensure that the data groups were sufficiently large for meaningful comparisons of averages, the different PDMs were grouped into the three most common methods: traditional, integrated, and management contracting.

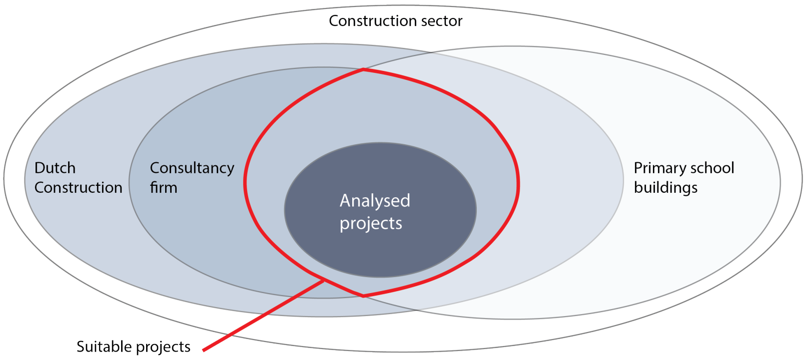


Figure 3.2: Project selection

Data Collection Structure and Formatting

For the quantitative component of the research approach, data collection was performed using various sources to gain this information and ensure that the data is as complete as possible to provide a comprehensive and accurate analysis. The data is structured by dividing the data between the three PDMs; traditional, integrated, and Risk-carrying Project Management (RPM). These are then divided into the projects using that PDM. After which, these projects are split into five different project phases: the PoR, VO, DO, TO, and realisation. After completing these phases, different metrics can be collected from intermediate project documents, which are then transformed into additional metrics. This data structure is visualised in Figure 3.3.

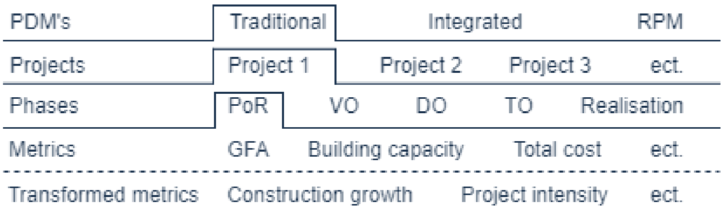


Figure 3.3: Quantitative data collection structure

The primary sources of information are the company databases, DigiOffice, and SharePoint, as well as the private storage of project managers who have worked on these projects. Some information, like student capacity, comes from outside public sources or conversations with users. These sources provide the data that was necessary to perform the quantitative analysis. The collected data encompasses several different file types. These different file types often store various kinds of information in different contexts. The main file types are listed below;

- Excel files, containing detailed project metrics, planning, and financial data. Such as internal budget reports detailing the financial planning and expenditure tracking of the projects from within the consultancy firm.
- Email correspondences, providing communication records and additional planning data.
- Phase reports, documenting the progression during the different design, and sometimes PoRs, project stages. These are often in PDF or Microsoft Word format.
- MS Project files, outlining detailed project schedules and completed phases.

Out of these different file types, comparable data needs to be extracted. This means that the data needs to be collected in a standardized manner, or the data needs to be formatted so that it can become standardized. Therefore, it is essential to collect data according to the following units of measurement:

- Euro, for all financial data.
- Date, for recording specific points in time.
- Days, (including holidays and weekends) to measure the duration of activities and project phases.
- Percentage, for proportional data such as growth rates and budget divisions.
- Square meter, for quantifying project sizes and areas.

The different projects are systematically analysed through the five design phases discussed in the literature review. This method was inspired by W. T. Chen et al. (2010). The end of these phases serves to function as a set data collection moment to ensure that the compared projects are at a similar stage of development and are the national standard when dividing up different phases in a construction project, an example of how the data is structured in these phases can be found in Appendix B.1. The different phases are the definition phase, usually signified by the completion of a PoR, Preliminary design (VO), Definitive design (DO), Technical design (TO), and Realisation. The end of the phase is chosen as a reference point because intermediate progression reports are usually delivered to the client at the end of a phase, allowing the client to track the project's progression. The structure in different phases functions visualised in Figure 3.4 also functions as a framework for the quantitative data collection and research scope.

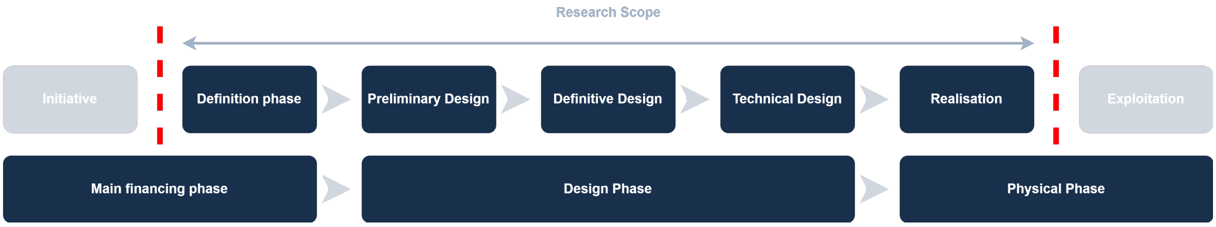


Figure 3.4: Phases for quantitative data collection and research scope

The end of each of these phases marks a moment when these data points are collected. It is crucial to remember that for four of the five phases, most of the collected data is the expected value at the end of the project unless those costs have already been made or the data is on phases that have already happened. This means that unless otherwise specified, all the data is an expected value at that point in time. The data points collected for each phase are as follows;

- Gross Floor Area (GFA) (m^2)
- Building capacity (in number of students).
- Construction costs (€).
- Furnishing costs (€).
- Professional fees (€).
- Additional costs (€).
- Unforeseen expenses (€).
- Total costs (€).
- Start date definition phase.
- (Planned) Start date preliminary design phase.
- (Planned) Start date definitive design phase.
- (Planned) Start date technical design phase.
- (Planned) Start date realization phase.
- (Planned) End date realization phase.
- (Planned) Project delivery date.

The date on the phase report was chosen as the reference point for the conclusion of that phase and, therefore, the beginning of the next phase. In this report, the main takeaways and developments are discussed. Any cost-related metrics always exclude tax, as the value without tax is always available. This ensures accurate comparisons between different projects. Additionally, if the phase has already been completed, the actual start date of the phase is written down. The expected start date is written down if the phase is only planned. The way this data was structured and transformed can be found in Appendix B.

Some of the collected data points are then normalized and combined into additional data points that provide a more complete picture of the projects. These data points and normalization were inspired by Carpenter and Bausman (2016). This step aims to provide more points to compare different projects on, compare different phases within a project to each other, and compare projects of various sizes more effectively. The additional data points are;

$$\text{Construction costs (\%)} = \frac{\text{Construction costs}}{\text{Total costs}} \quad 100 \tag{3.1}$$

$$\text{Furnishing costs (\%)} = \frac{\text{Installation costs}}{\text{Total costs}} \quad 100 \tag{3.2}$$

$$\text{Professional fees (\%)} = \frac{\text{Professional fees}}{\text{Total costs}} \quad 100 \tag{3.3}$$

$$\text{Additional costs (\%)} = \frac{\text{Additional costs}}{\text{Total costs}} \quad 100 \tag{3.4}$$

$$\text{Unforeseen expenses (\%)} = \frac{\text{Unforeseen expenses}}{\text{Total costs}} \quad 100 \tag{3.5}$$

$$\text{Duration } (A)(\Delta t) = \text{Start Date B} \quad \text{Start Date A} \tag{3.6}$$

$$\text{Construction Duration Growth} = \frac{\text{Construction } (\Delta t) \quad \text{Construction } (\Delta t)\ (PoR)}{\text{Construction } (\Delta t)\ (PoR)} \quad 100 \tag{3.7}$$

$$\text{Project Duration Growth} = \frac{\text{Project } (\Delta t) \quad \text{Project } (\Delta t)\ (PoR)}{\text{Project } (\Delta t)\ (PoR)} \quad 100 \tag{3.8}$$

$$\text{Project intensity } (\text{m}^2) = \frac{\text{Gross floor area}}{\text{Total project } (\Delta t)} \tag{3.9}$$

$$\text{Project intensity } (\text{€}) = \frac{\text{Total costs}}{\text{Total project } (\Delta t)} \tag{3.10}$$

$$\text{Construction cost Growth} = \frac{\text{Construction cost} \quad \text{Construction cost (PoR)}}{\text{Construction cost (PoR)}} \quad 100 \tag{3.11}$$

$$\text{Project cost Growth} = \frac{\text{Project cost} \quad \text{Project cost (PoR)}}{\text{Project cost (PoR)}} \quad 100 \tag{3.12}$$

$$\text{Cost per square meter} = \frac{\text{Total costs}}{\text{GFA}} \tag{3.13}$$

$$\text{Cost per student} = \frac{\text{Total costs}}{\text{Building capacity}} \tag{3.14}$$

$$\text{Phase } (\Delta t)\ Growth = \frac{\text{Phase } (\Delta t)}{\text{Phase } (\Delta t)\ (PoR)} \quad 100 \tag{3.15}$$

Data Interpolation

When a data point was unknown or unavailable, it was assumed that the expectations on that metric had not changed. Consequently, the most recent prediction was taken as still being the expected value at that point in time. This approach minimizes inaccuracies in the research by assuming that if any significant changes happened, they would have been recorded, and the changes in the metric would be reported. This is, therefore, the most pragmatic solution to dealing with missing values.

Additionally, integrated contracts had a limited amount of information on cost available. Therefore, instead of taking the total contract value as only construction cost, the final value for the design phases was taken as a constant 'professional fee'. This redistribution was needed to keep the cost correction and cost distribution metrics as accurate as possible.

Cost Normalization

When analysing cost-related metrics, a few things must be considered. As mentioned, all cost-related metrics exclude their Value Added Tax (VAT), as this number is always available in all documents. Considering this when collecting the data ensures a more accurate comparison between different projects. Uncorrected costs provided a preliminary insight into the expenses associated with each project phase under different PDMs. Different projects were built at different times. Throughout time the value of similar projects has changed dramatically, this is due to changes in material costs, changes in wages, and inflation. This means that to compare different projects effectively, a cost correction needs to be performed on the collected data.

The corrected costs adjust for these external factors, thus providing a more standardized and accurate comparison across the different PDMs. This adjustment ensures that the data reflects a true comparison by normalizing the cost metrics to a common baseline, thereby eliminating external biases. The corrected costs help identify true cost drivers within each PDM by eliminating noise from external factors, and were calculated using the following formula;

$$\text{Normalized cost} = \frac{\text{Cost}}{\text{Cost relative to 2023 (\%)}} \quad 100 \tag{3.16}$$

The normalization of each cost-related metric considers the estimated start of each construction phase as the moment that costs are made, as project budgets generally consider the change in costs between initiation and construction start. Cost normalization was done using a cost index from CBS (2024). The cost index used contained data on the construction of new homes from 1995 up until 2023. All cost metrics were converted to the reference year (2023), which was converted to the reference year to keep the data more comparable and relatable to current prices. This table can be found in Appendix C.1. It contains three columns: total construction cost, wage component, and material component. All expenses were corrected using the general construction costs index, except for the professional fees for consultants. These were calculated using the wage component index only. This means that to calculate the total cost, the two separate corrections were added together to create a new total.

Comparing PDMs and Intermediate Conclusions

After this, the collected data was grouped per PDM and averaged out to better understand the general performance of a PDM. These averaged metrics can then be compared to each other and singular projects. The comparison between the different projects is then used to make a general intermediate conclusion, while the comparison between a singular project and these averages are

Additional literature research was performed before the qualitative research is conducted. This was to compare the literature to the intermediate conclusions made after the quantitative research so that fitting questions could be created for the interviews. This comparison aimed to find what questions could be asked throughout the interview, based on the quantitative research findings and the lack of information on the delivered quality of the different PDMs. This information was then used in preparation for the interviews in the qualitative stage.

3.3.2 Qualitative

After this quantitative research, general conclusions are made. While these conclusions are very objective, they could lack important context about the delivered quality of the projects or possible costs and complications after the latest collected data point (the delivery of the project).

It was essential to collect additional qualitative data on the projects to validate or contextualize the data. This qualitative data was also used to detect patterns not found through the literature or the qualitative analysis.

The qualitative analysis consists of creating interview questions based on the results of the intermediate conclusions at the end of the Quantitative section. Stakeholders from both the client side and the project management side of the quantitative research were approached for an interview about their experience and opinion of the project. The clients were also asked questions on their experience with the building post-delivery. The objective was to interview two sides of a project and, therefore, create a complete picture of the project. After the interviews, the new information from the qualitative research and the old conclusions from the quantitative research are synthesised. In this synthesis, the differences between the PDMs are discussed, and a comparison between the literature, data analysis, and the interviews is discussed.

Interviews

The interviews focused on two groups: project managers within the chosen consultancy firm and client representatives from different sectors representing the client and user, including school board directors, municipalities, and housing associations. The main goal of the interviews is to obtain qualitative information on some of the quantitatively analysed projects, like post-delivery project quality. And be able to reveal characteristics of PDMs that were not uncovered through the literature or quantitative analysis.

The qualitative analysis started with the selection of interviewees. Project managers were chosen based on their involvement in the consultancy firm, ensuring they had significant experience with the projects under review. Client representatives were selected from various organizations responsible for the projects, depending on who was deemed more suitable or most involved. The objectives of the interviews were clear, and while mostly similar, the interviews with the project manager and client representatives had slight differences depending on the interviewee's role within the project. The project manager interviews generally focused on their experience with the project delivery method, challenges faced during the project, and their perspective on the project success factors. The interviews with the client representatives focused more on understanding their satisfaction with the project, the quality of the finished building, post-completion issues, and their view on the effectiveness of the chosen PDM on this project.

The interviews were semi-structured according to a framework (Appendix D.1), and lasted approximately 45 minutes per project. Due to geographical and availability constraints, face-to-face, telephone, and video call methods were employed. Questions were asked about general topics, but if something important arose, additional conversation was had about the subject. These questions concerned various aspects of the project, including planning, quality, and general PDM preference and satisfaction. After giving a brief introduction of the results, the interviewees were asked their first impressions of the project and how they thought it succeeded, both during and post-delivery. This was followed by asking the interviewee why a certain PDM was chosen and what factors led to this choice. After this, their experience with the PDM during that project and its influence on the project was discussed. This was then compared to the collected data from that singular project and the averages per project delivery method. Outliers of this comparison and possible reasons for the existence of these outliers were explored. The interviews were concluded by asking the interviewees whether they had additional comments about the project.

3.3.3 Synthesis Methodology

After the qualitative research was completed and separate discoveries discussed, they were compared to the intermediate conclusions from the quantitative research. This synthesis was performed to validate results and identify discrepancies or additional insights, providing a more complete picture of the research problem. This synthesis allowed for the remaining subquestions and the main research question, to be answered.

Chapter 4

Data Collection and Results

The following section elaborates on the data that was collected using the methodology discussed in Section 3.3.1 and 3.3.2. The resulting information gathered from this data are then is discussed with the use of tables and graphs. As the methodology was split into two distinctive parts, the quantitative data collection and results are discussed first, followed by the qualitative data collection and results. This section concludes with a synthesis of these two parts.

4.1 Quantitative

The quantitative research contains several steps. Before the research could be performed, a selection of possible projects was made; this was followed by the collection and subsequent formatting of data. After this, all cost-related metrics were normalized. Finally, a comparison between the different PDMs was made, concluded by making intermediate conclusions. The results of these phases will now be discussed.

4.1.1 Data Collection

The methodology for data collection was discussed extensively in Section 3.3.1. After selecting possible projects, the data was collected for 25 different primary schools. Additional data was collected for two middle schools to compare effectiveness and see if the research could be expanded also to compare middle schools. These projects were chosen based on the available data's completeness and the PDM chosen for the project. Out of the 25 projects, 8 used a traditional method, 7 used an integrated method, and 10 used a management contracting method. The PDM of the two remaining projects was irrelevant as these were only used to explore potential future research possibilities.

The 27 projects' data were collected, with an estimated 261 data points per project, leading to a total of 7047 data points. Of these 7047 data points, 2160 were collected from existing documents like project plans and phase reports, and 4914 were transformed from this collected data.

An overview of the analysed projects and indicative rounded data can be found in Figure 4.1. In this table, all numeric values have been rounded to preserve confidentiality. GFA values are rounded to the nearest thousand square meters, capacities are rounded to the nearest hundred students, and total costs are rounded to the nearest million euros. The same project acronyms are used in Section 4.2

Table 4.1: Project Details

Project Acronym	PDM	Delivery	GFA	Capacity	Total Cost
T1	Traditional	2020	2000	300	€ 8.000.000
T2	Traditional	2021	2000	300	€ 6.000.000
T3	Traditional	2021	1000	300	€ 5.000.000
T4	Traditional	2020	2000	200	€ 5.000.000
T5	Traditional	2019	7000	600	€ 21.000.000
T6	Traditional	2018	6000	800	€ 13.000.000
T7	Traditional	2023	3000	300	€ 8.000.000
T8	Traditional	2013	1000	300	€ 3.000.000
I1	Integrated (DB)	2012	3000	500	€ 7.000.000
I2	Integrated (EB)	2018	3000	400	€ 6.000.000
I3	Integrated (EB)	2015	3000	500	€ 5.000.000
I4	Integrated (DBM)	2022	2000	400	€ 6.000.000
I5	Integrated (DBM)	2016	3000	400	€ 7.000.000
I6	Integrated (EB)	2021	2000	300	€ 5.000.000
I7	Integrated (EB)	2021	2000	300	€ 5.000.000
R1	RPM	2014	2000	600	€ 5.000.000
R2	RPM	2017	3000	400	€ 7.000.000
R3	RPM	2015	3000	400	€ 6.000.000
R4	RPM	2019	2000	100	€ 5.000.000
R5	RPM	2016	5000	1000	€ 8.000.000
R6	RPM	2014	2000	300	€ 5.000.000
R7	RPM	2015	2000	300	€ 4.000.000
R8	RPM	2017	4000	500	€ 8.000.000
R9	RPM	2019	3000	500	€ 6.000.000
R10	RPM	2019	2000	300	€ 4.000.000

4.1.2 Cost Normalization

The effect of the cost correction is visualized in Figures 4.1 and 4.2, and additional context on the effect of the cost correction can be found in Appendix C.1. In these figures, the effect of the cost correction is visible. After applying the cost corrections, the disparities between the different PDMs have reduced significantly. This standardization has brought the cost figures of Traditional, RPM, and Integrated PDMs relatively closer to each other. The cost correction has a logical result, as the cost correction is correlated to the delivery date, and RPM projects have the earliest average delivery date. Whereas traditional projects have the latest average delivery date (Figure 4.3). An example of the use of this correction is the notable increase in costs after the completion of the VO that is now visible after the correction. That could point to specific inefficiencies or challenges inherent to that method, which were masked in the uncorrected data. These could be explained by optimistic estimations of the start date of the realisation phase, as the correction is based on this metric.

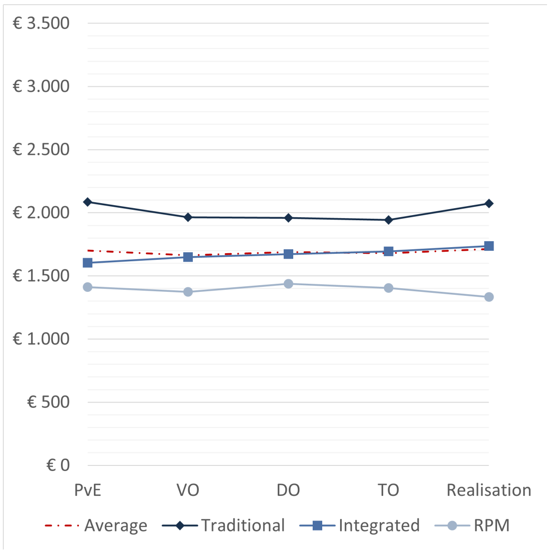


Figure 4.1: Expected Project Costs per m^2 (€) (uncorrected)

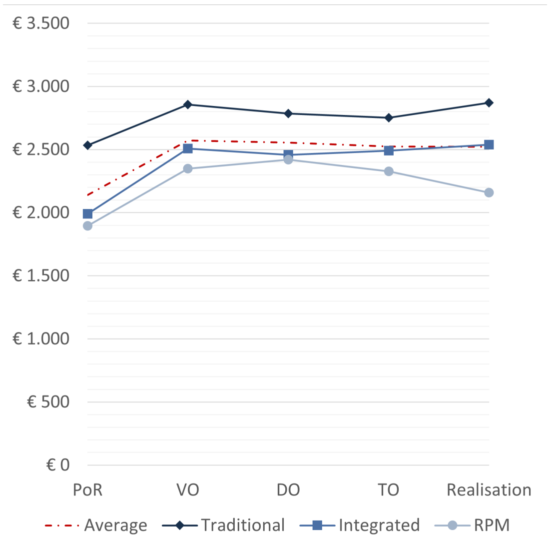


Figure 4.2: Expected Project Cost per m^2 (€) (corrected)

4.1.3 Quantitative Results

The three PDMs are compared using the metrics reviewed in Section 3.3.1. They are discussed with a particular focus on time and cost performance. Each method's effectiveness is assessed to determine trends and efficiencies in managing construction projects. The results provide insights into cost efficiency, time management, and overall project execution, quantitatively highlighting each PDMs strengths and weaknesses. Important metrics are also represented with box plots showing the variance of the metric on delivery (e.g. Figure 4.3, 4.4).

4.1.4 General Results

The analysed projects were build during different times and were of various sizes; taking this into account when comparing different PDMs could be essential. In Figures 4.3 and 4.4, the 'Project delivery dates' and 'Gross Floor Area (GFA) (m^2)' of the different projects are visualized. This shows that of the analysed projects, traditional projects were delivered the most recently, while also having a large spread between larger and smaller projects. Integrated projects were delivered in a large spread ranging from recent to 2012, and tended to be smaller. Finally, the RPM projects analysed were not as recent and were delivered between 2013 and 2019 while also being small to medium-sized projects.

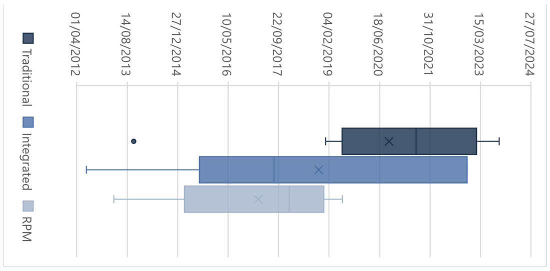


Figure 4.3: Project delivery date

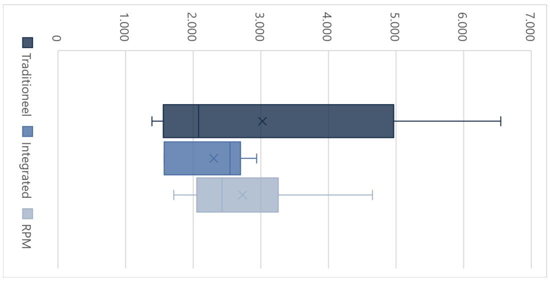


Figure 4.4: Gross Floor Area (GFA) (m^2)

4.1.5 Cost

In Figure 4.5 the “Expected Project Cost per m^2 (€)” are visualized. The graph shows that the analysed traditional projects consistently incur a higher cost per square meter, reaching its peak at the end with €2.870. The integrated method performs almost exactly along the average while also seeming the most stable, as it consistently performs close to its estimations after the VO phase (€2.539). RPM methods seem to create the lowest cost per m^2, ending up around €2.160. There seems to be a peak after the DO phase, which cut down during the TO and realisation phases. Figure 4.7 shows that RPM projects not only performed excellent on average on this metric, but also seem the most consistent compared to the other methods. The highest cost of RPM projects was around €2.500/m^2. This is still significantly lower than the averages of the other PDMs. Overall, the traditional method performs worst, integrated projects perform average and are stable, and RPM projects cut back costs in later phases to end up with the lowest cost per m^2

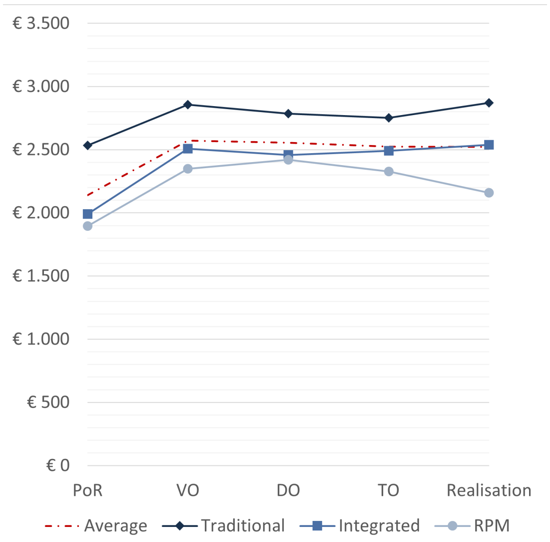


Figure 4.5: Expected Project Cost per m^2 (€)

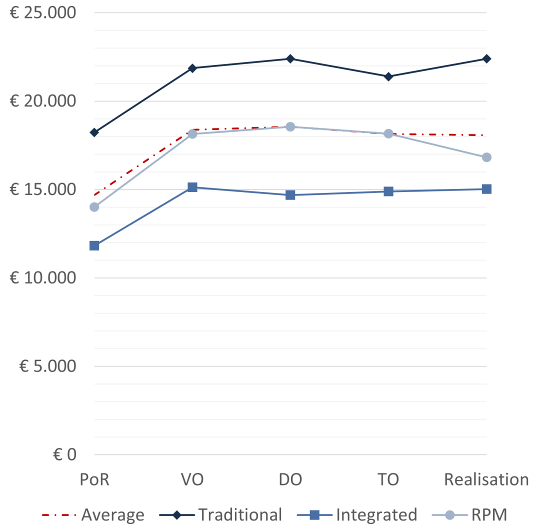


Figure 4.6: Expected Cost per Student (€)

Figure 4.6 shows the “Expected Cost per Student (€)”, which seems to have a larger spread between PDMs. Again, traditional projects seem to perform the worst, as the cost per student rose to €22.393. Integrated methods perform very consistent again from the VO onwards, while also being the cheapest per student (€15.023). RPM projects performed almost exactly around

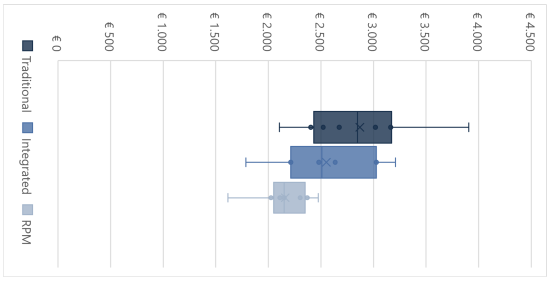


Figure 4.7: Cost per m^2 (€)

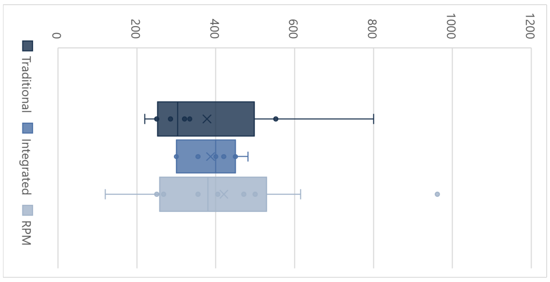


Figure 4.8: Student Capacity

average until the final phase, where it dropped to €16.817 per student. This again indicates cost-cutting during the latter phases. Significant differences indicate a possibility of traditional projects being more likely to develop projects with additional functionality like libraries or sports halls, and the opposite for integrated projects. However, these extra functionalities can not be excluded from the data for reasons explained in the Limitations (Section 5.1). Overall, this metric is less applicable for comparison than 'Cost per m^2' due to the inclusion of extra functionalities for some projects. The difference between these metrics does indicate that integrated methods are less likely to contain expensive extra functionalities, as integrated methods emerge as the most cost-efficient per student. As opposed to the performance of the traditional projects, which seem most expensive by a large margin, and therefore indicate extra functionalities. RPM projects, when compared to Figure **??**, indicate that these methods probably contain extra functions. Interestingly, 'cost per student' does not seem to be influenced by 'student capacity' (Figure 4.8), as integrated projects are average in average student capacity.

The “Construction Cost Fraction (%)” of the different PDMs are visualized in Figure 4.9. A few things stand out when looking at how much of a project's budget was estimated to be spent on the construction of the projects. Traditional methods start at the lowest percentage (76%), but quickly rise to 83% in the final phase. The integrated projects show a constant rise in the fraction of the budget spent on construction, with a rise to 82%. RPM methods seem to spend the lowest fraction of the budget on construction, at 78% in the Realisation phase. This indicates an accurate approach to cost allocation throughout the different project phases, as well as an accurate cost estimate. In general, the traditional and integrated methods show significant increases in the allocation of the construction budget, with both methods rising up to above 82%. RPM project's budget allocation for construction costs seems the most stable, indicating a balanced approach.

Figure 4.10 shows the “Expected Project Cost Growth (€)” averages of different PDMs. This metric indicates the expected costs compared to the PoR using the growth metric, which is why all start at 0%. Traditional methods seem to perform fairly stable after its initial hike to 22% after the VO phase, decreasing and increasing again before delivery. The significantly larger average size of analysed traditional projects represented in Figure 4.11 means that traditional projects are less comparable in a cost growth metric, as a small percentage increase will still be a significant amount of money. The cost growth spread in Figure 4.12 shows that traditional projects do have the potential to be significantly below budget, and do not have any projects with a cost growth higher than 42%, these could be benefits from the additional bidding moment compared to integrated methods. Integrated projects also seem stable after their larger increase to 29%, after the PoR integrated projects seem to stay very constant on this metric. They are more comparable in average project cost to RPM projects but show a significantly higher cost growth. No integrated projects were below a -4% cost growth, this is most likely because this was deemed a profit by the building contractor. Almost none of the analysed integrated projects were delivered below budget. RPM projects show the largest peak, at 36%. After the completion of the DO phase, RPM projects seem to tone it down effectively, ending up at the

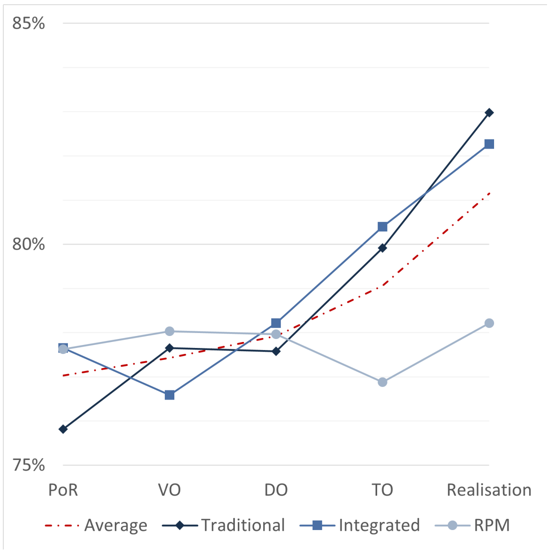


Figure 4.9: Construction Cost Fraction (%)

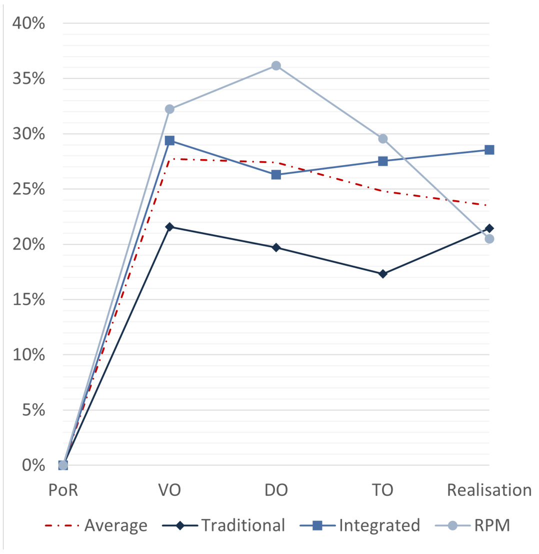


Figure 4.10: Expected Project Cost Growth (€)

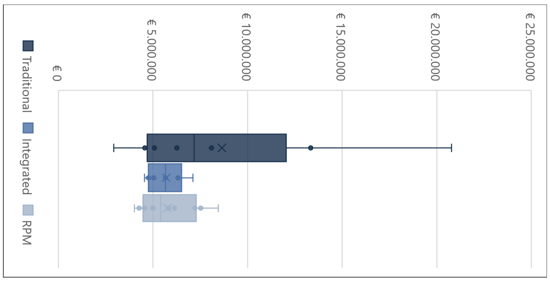


Figure 4.11: Project Cost (€)

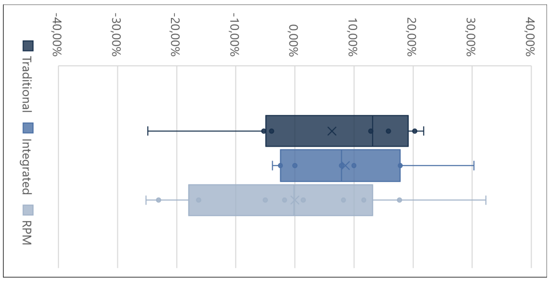


Figure 4.12: Cost Growth (%)

smallest cost growth with 20%. This effective cost-cutting was also visible in Figures 4.5 and 4.6. All PDMs show a large cost hike between the completion of the PoR and VO phases; this could be due to a combination of factors. The cost correction depends on the expected date of starting realisation, large delays in this expectation can be large between the completion of the PoR, and the start of the VO phase. Secondly, without the cost correction, there is still an increase for all PDMs. This could be due to a tendency to underestimate project cost during the PoR phase, which is generally finished before the procurement process and thus the bidding. Overall, both traditional and integrated projects perform stable after the initial hike. Important to note is that integrated projects perform significantly worse. RPM projects generally start with a very large estimated cost growth, and manage to reduce it to the best performing PDM in this metric, traditional projects a very close second.

4.1.6 Time

Figure 4.13 exhibits the “Expected Total Project Duration after Phase (days)”, which visualises the expected project duration throughout the project. Traditional projects start with an expected duration of 968 days and have a notable increase in the later stages of a project, rising to 1093 days as an average final duration. As opposed to integrated projects, which have the most significant rise in expected duration in the earlier phases of the project but then stable out in the later phases. Integrated PDMs also seems to have the lowest project duration out of the three, ending up around 1042 days. The worst performing PDM on total project duration is the RPM method; this is already visible after the PoR phase (1007 days). This increased rapidly throughout the design process, ending up around 1346 days.

Figure 4.13: Expected Total Project Duration after Phase (days)

Figure 4.14: Expected Project Duration Growth (%)

This rise compared to the first estimation is even more visible in Figure 4.14. This figure describes \Expected Project Duration Growth (%)" and gives an idea of the expected total project duration's growth. This graph shows that traditional projects know the least growth (14%), with most of the increase in the later stages. While integrated projects experience most of its growth until the completion of the DO phase, ending up around a 31% increase. While RPM projects already start with the highest estimated project duration, they also experience the most growth until the realisation phase, where the method ends up at 36%.

When looking at both figures, it can be seen that all projects take significantly longer than first expected. However, when comparing the different PDMs, traditional projects have the most accurate project duration expectation. Integrated and RPM methods experience difficulties in this regard. Especially RPM projects know a large growth when considering its already comparatively long project duration. It is important to note that even with the integrated method's large growth, it still produces the shortest average project duration.

Figure 4.15 shows the \Actual Project Duration after each phase (days)", meaning what the average time was that each PDM took to finish that phase. This graph is assisted by the bar chart in Figure 4.16, which shows \Actual Phase Duration (days)". Traditional projects starts with the shortest duration after the PoR phase, while RPM takes significantly longer with 270 days. In the two stages afterwards, all PDMs rise fairly comparatively, until the TO phase where integrated projects take significantly shorter than average, and RPM projects take much longer (324 days). Within the realisation phase, traditional projects take significantly longer. This means that integrated projects end up taking the shortest time on average (1031 days), traditional projects take on average 1084 days, and RPM projects take the longest with 1339 days. RPM projects have a considerably longer time for the PoR phase. This is logical, as a significant amount of time is needed for the client and management contractor to agree on a contract first. Only after this is complete, the first phase of procurement can start.

The distribution of project durations represented in 4.17 shows that both traditional and integrated perform similarly on total project duration, while also showing similar distributions. The distribution of project duration times for RPM projects shows that not all RPM projects have a long delivery time, showing that they are not consistently slower. Interestingly, the construction duration depicted in Figure 4.18 shows that traditional projects consistently perform

Figure 4.15: Actual Project Duration after each phase (days)

Figure 4.16: Actual Phase Duration (days)

Figure 4.17: Project duration (days)

Figure 4.18: Construction duration (days)

the worst in this metric. Integrated projects perform the best on average but show by far the largest spread out of the analysed PDMs, an undesirable factor. RPM projects have a slightly longer construction duration, but also show a slightly more consistent duration.

In total, it can be seen that traditional projects manage the early phases the quickest, but this slows down in the later phases, which could suggest communication issues or early mistakes. Integrated projects take the least amount of time on average, while also taking the least time during the realisation phase, this is important as time is worth the most in this phase because of the larger payroll. Furthermore, RPM performs the worst on this metric out of the three methods. It takes the most time in nearly all design phases, possibly because of the time it takes to cut costs, which was discussed earlier in this section. Important to note is that this does not translate into an increased realisation time.

Figure 4.19 shows the \Expected Project Intensity (m^2/day)", while Figure 4.21 shows the final project intensity spread per PDM. These give insight into how fast the project is built compared to its size and how consistently a PDM performs with a certain intensity. Both of these figures should be considered with GFA and project duration in mind (Figures 4.4 and 4.17). These figures show that traditional projects are often much bigger, while RPM projects take longer. Traditional projects tend to perform the best on this metric, finishing the projects with an average of 2,8 m^2/day. Important to note is the optimistic peak after the DO phase, which only lasts shortly. It also seems to perform closest to its original expectation, which could have to do with traditional methods experiencing the least project duration growth (Figure 4.14). Another notable statistic is the large spread of project intensity shown in Figure 4.21. As traditional projects have the most extensive spread of project GFAs, it is logical to assume that project intensity and GFA are primarily correlated. Integrated projects experience a significant drop during the VO and DO phases, after which it stabilizes; this ensures that before the construction starts, the client can be reasonably sure it will deliver in time. These projects are consistent in their project intensities, with the thinnest spread of this metric. This is consistent because integrated projects also have the most consistent project duration and GFAs. RPM projects follow a similar path, although the decline is slower, but continues throughout the TO phase. Both integrated and RPM projects end around 2.3 m^2/day. Notable is that RPM projects show a considerably larger spread than integrated projects. Overall, traditional projects perform best on this metric, performing significantly better than the integrated and RPM metrics.

Figure 4.19: Expected Project Intensity (m^2/day)

Figure 4.20: Expected Construction Duration Growth (%)

Figure 4.21: Project Intensity (m^2/day)

Figure 4.22: Construction Intensity (m^2/day)

Lastly, Figure 4.20 shows the \Expected Construction Time Growth (%)" which visualizes how much the expected construction duration has changed since the original prediction in the PoR phase. It is accompanied by a box plot of construction intensity in Figure 4.22, which shows the consistency of the construction intensity. The two metrics show the effectiveness and predictability of the construction phase and, therefore, are essential metrics for analysing the construction phase, which is generally the most expensive and valuable phase of a project (Carpenter & Bausman, 2016). Traditional projects perform very close to average on the metric, with the most significant increase in the realisation phase, growing by 11% (18% to 29%). Similar to the total project intensity, traditional projects seem to have the largest variation of intensities. This could also be attributed to the more extensive range of GFAs. Notable is that while traditional projects experience the highest project intensity (m^2/day), they also know the lowest average construction intensity. Suggesting inefficiencies compared to the much faster design phases. Furthermore, integrated methods perform the worst on this metric. Even though the final realisation phase performs best out of all PDMs (Figure 4.16), the duration of construction still grew up to 37% after the realisation phase when compared to the PoR. The results of integrated projects on construction intensities are interesting, as the one outlier achieved a construction intensity of 14,5 m^2/day. RPM projects seem to perform best on construction duration growth, giving clients the most assurance on construction duration. However, the decrease in expected construction duration in the VO phase followed by the increase in later phases suggests that the optimism in this phase is misguided.

Between the different PDMs, there are significant differences in expected project duration, and combining this with Figure 4.16 results in a clearer understanding of the situation. Traditional projects perform the worst in actual construction time, partly because of their optimistic first expectation, and could be prevented by more effective time management. Integrated projects perform the best in actual construction time but the worst in construction growth. Estimating the construction time more accurately could give the client more certainty. RPM projects perform very well on both the intensity and duration growth metrics, with some optimism after the VO phase. Overall, all projects show a large variety in construction intensities, which is probably very dependent on other factors outside the choice of PDM.

4.1.7 Intermediate Conclusion

The quantitative research indicates several strong relationships between PDMs and project success factors. The Intermediate Conclusions are made considering that these relationships do not mean causality. An additional explanation of the difference between relationships and causality can be found in Section 5.1.

Traditional projects tend to have been delivered more recently (Figure 4.3) and involve larger GFAs (Figure 4.4). It performs poorly in terms of cost per square meter and cost per student, indicating inefficiencies in cost management. It maintains an average construction cost fraction and shows comparatively good cost growth, suggesting some control over escalating costs. Traditional PDMs demonstrate good overall project duration and the best project duration growth, indicating some certainty for the client when it comes to time performance, although there is still a rise in duration in the later stages. The largest construction time is a significant weakness despite having the lowest construction time until the realisation phase, which implies inefficiencies in the later stages of construction. This could be caused by communication issues or a lack of integration between different phases. The highest project intensity complies with the fact that these projects might be larger in scale. Still, the bad construction time growth indicates challenges in maintaining efficiency as the project progresses.

Integrated projects have a wide range of delivery dates and generally lower GFAs. It is average in cost per meter but excels with the lowest cost per student by far, highlighting its cost efficiency in terms of educational space. While the construction cost fraction is the largest, the stability in project cost growth is a strength despite being the worst in overall cost growth. Integrated PDMs slightly achieve the best project duration and exhibit good realisation duration. However, there is a significant increase in duration growth, which is a weakness. The bad project intensity might be attributed to the smaller project sizes. The very bad construction growth contrasts with the good realisation duration, indicating potential issues in phase management versus actual construction efficiency. This suggests that while the first expected construction duration might be very optimistic, the actual project duration is still very competitive. Except for this growth in construction duration, in general, integrated projects seem to have a lot of stability after the DO phase on many metrics (expected total project duration, project duration growth, and cost metrics).

RPM projects, on average, have the earliest delivery dates and mostly lower GFAs, with a few medium-sized projects. They achieve the lowest cost per square meter and below-average cost per student, indicating strong cost efficiency. The construction cost fraction is the lowest and most stable, reflecting consistent cost management. RPM projects exhibit the lowest cost growth with efficient cost-cutting measures implemented after the DO phase. However, they suffer from the highest project duration and significant duration growth, highlighting inefficiencies in maintaining timelines. This could be caused by increased focus on cost-cutting during the later design phases. While the phase duration for all design phases is very high, the construction phase duration is relatively low, a positive aspect that is not negatively impacted by cost-cutting. RPM projects have low project intensity, possibly caused by the lower GFA projects combined with the longer design phases. RPM projects also know the lowest construction time growth, suggesting effective management in the construction phase despite challenges in the design phases.

All projects across the three PDMs exhibit a spike in cost per square meter during the VO phase, indicating a common challenge in accurately predicting the costs effectively during this phase. This is also reflected in the considerable cost growth spike during the VO phase. Additionally, all projects experience a significant increase in project duration during the VO phase, highlighting that cost and scheduling are often very optimistic in the PoR phase. These common trends suggest that the VO phase is particularly challenging across all PDMs and requires focused attention to improve cost and duration management.

When comparing the three PDMs, Integrated PDM stands out for its cost efficiency per student and stable metrics after the do phase, especially for cost metrics and expected project duration. However, it struggles with project intensity and construction time growth. Traditional PDM demonstrates strengths in project duration growth and project intensity but faces challenges with cost management and construction time. RPM PDMs excel in cost efficiency and stable construction cost management, likely at the cost of a severely prolonged project duration, especially during the design phases. These different strengths highlight that a PDM should be chosen according to the priorities of the stakeholders, specifically the client.

4.1.8 Comparing Intermediate Results with Literature

In answering SQK 2 (Section 3.2.2), a few general expectations of PDMs on project success were discussed. This was followed by a quantitative analysis of the performance of a subset of PDMs on the performance of primary school projects. The conclusions of these, expected, do not entirely overlap. Before starting the interviews, it was essential to know where these differences lie and what the cause of these differences might be.

The literature's findings on the performance of traditional PDMs strong client control and integration difficulties align with the quantitative results. The instability of different metrics in the later stages suggests changes late in the process and integration difficulties. The literature's expectations with higher project cost per unit are also represented, even more extreme, in the quantitative data. However, the quantitative findings show that the traditional method generally achieves good project duration and cost growth. This contrasts with the literature's emphasis on frequent delays and financial risk management.

According to the literature and the quantitative results, the integrated PDMs provide stability after the early design phases. It also offers cost-efficient projects, especially in the cost-per-student metric. Both also expect a higher transaction cost, which is visible in the relatively large cost growth compared to the first prediction. While both agree on the shorter project duration, the quantitative findings contrast with the literature on duration growth and project intensity. This could potentially be due to project size differences.

The literature and the quantitative findings agree that challenges are associated with the RPM method. This is evidenced by the expected prolonged design phases and significant duration growth. However, the quantitative findings on RPM projects reveal a strong performance on cost efficiency and effective construction management, this stands completely opposed to the literature which suggests higher cost due to complexity. Less noted in the literature is the ability RPM to cut costs effectively after the DO phase, proving the effectiveness of an experienced project manager with performance guarantees for the client. Important to note here is that the literature mainly reviewed other management contracting methods, as RPM is more recent and less common. At the same time, the quantitative research only focused on RPM projects.

In general, while the literature and the quantitative analysis agree on many expectations, the quantitative research led to different conclusions. These differences are an important topic during the following qualitative research in Section 4.2.2.

4.2 Qualitative

After completing the quantitative research, the qualitative research was started, which consisted of interviews with stakeholders involved with the analysed projects. For these interviews, several project managers and client representatives were approached for interviews about their experience with the projects, their opinions of the chosen PDM, their PDM preferences, and a discussion about how the project they were involved in performed in the quantitative research. The questions in these interviews were based on the analysis of Section 4.1.8.

4.2.1 Data Collection

Of the 27 available projects analysed in the quantitative analysis, project managers within the consultancy firm and the corresponding client representatives of 12 projects were approached for an interview. The result of this request is displayed in Table 4.2. In total, 18 interviews were conducted, of which 12 were with project managers within the consultancy firm, and six were conducted with the corresponding client representatives.

The 11 distinct projects were categorized into three groups based on their delivery methods: three traditional projects (T1, T2, T3), five integrated projects (I1, I2, I3, I4, I5), and four RPM projects (R1, R2, R3, R4). Two client representatives were available for an interview for the traditional projects. Three client representatives were available for integrated projects, and none were available for RPM projects. The client representatives that were approached either didn't work there anymore, had retired, or were unavailable due to personal reasons. It is important to note that nobody refused to conduct an interview.

4.2.2 Results

Firstly, the results are discussed by reviewing the interviews per PDM, drawing general conclusions. With the information gathered from the interviews about these projects, some general strengths and weaknesses of the PDMs are discussed. After this, subjects that do not overlap with all interviewees or projects will be highlighted. When all the three PDMs have been discussed, the general conclusions will be compared.

Table 4.2: Interviews grouped per PDM

Group	Project	Project Manager	Client Representative
Traditional	T1	X	X
	T2	X	X
	T3	X	
Integrated	I1	X	X
	I2	X	
	I3	X	X
	I4	X	X
	I5	X	X
RPM	R1	X	
	R2	X	
	R3	X	
	R4	X	

Project Managers and Client Representatives

Interviews with project managers and client representatives often had a different focus because of the different experiences and expertise of the interviewees. During interviews with project managers, different projects were more easily compared, as project managers had often done many more primary school projects with various organizations. Interviews with client representatives usually focussed on long-term quality and user comfort. This meant that while there was sometimes a slight difference of opinion between a client representative and a project manager of the same project, there were no significant contradicting experiences between them.

Interviews Traditional Projects

According to the interviewees, the traditional projects have strengths in quality and sustainability, client control and availability, predictability, and innovation possibilities. While some weaknesses in cost overruns and budget issues, time delays, communication issues, and client risk are also apparent.

The quality and sustainability of traditional projects was an important topic during the interviews, as all projects achieved high-quality outcomes with significant attention and success on sustainability aspects. This was emphasised by projects T1 and T3, which focused on the innovative use of sustainable materials. Another strength of traditional projects seems to be the ability for clients to have more control over the project during all phases and, therefore, be more involved throughout the design process. This involvement was emphasised as essential for user-focused projects like primary schools, as it helps make adjustments during the design to meet user quality requirements. The eventual quality is more predictable because the client remains in charge of the project.

The strengths of traditional projects are opposed by weaknesses in cost overruns and budget issues. This was apparent as all interviewees mentioned significant cost growth during the design and construction phases. T1 and T3 faced higher-than-expected costs on materials, while T2 needed substantial budget cuts during the design that reduced the quality but were needed to stay within budget. Time delays were also a common issue for the traditional projects; these were often caused by third-party dependency and changes by the client later in the project scope. T1 and T3 experienced significant delays due to municipal processes and material price increases. Additionally, communication issues between project phases were an issue, this was seen in T2 where client instability and absence in meetings enlarged the problem leading to instability and delays. The largest disadvantage of traditional projects is the risk that the client carries. This means that the client needs to be comfortable in making decisions and be able to take financial setbacks. Project T3 shows this, where the client bore much higher costs than anticipated.

The interviewees were divided on the profitability of traditional methods. While T1 turned a profit after delivery, T2 and T3 faced financial issues due to cost overruns and budget constraints. Interestingly, interviewees expected that traditional projects would be cheaper due to the additional market forces of the additional bidding moment. This did not coincide with the quantitative results. The highly valued flexibility of traditional methods was also questioned by T2, as excessive changes by the client during the design phase led to instability and delays. In general, traditional methods were seen as suitable for complex projects on the condition that the client is very involved and experienced throughout the project. This was managed for projects T1 and T3, but a significant issue for T2. A consensus about traditional projects seems to be that because the client carries more financial risk, the municipality might need to step in with financial aid. In these cases, where a financial setback can be covered, the quality of the project can be warranted.

Traditional PDMs can deliver high-quality and sustainable projects, especially for user-focused projects like primary schools. They allow for high client involvement and control, which results in a more predictable project quality. However, it faces challenges in cost management, time delays, and communication issues. These issues are emphasised if the client is less experienced. The traditional method seems most suitable if the school's municipality is willing to cover large financial setbacks.

Interviews Integrated Projects

The interviewees indicated the biggest strengths of the integrated projects were time efficiency, low financial risk, and early price and time guarantees. The time efficiency of integrated projects was evident in projects I1 and I3. Both projects had a low project duration and a low project growth after the VO phase. Additionally, considering its budget, I3 was completed in a very short timeframe. This budget control of integrated projects results in low-cost growth, low cost per student, and low cost per square meter. Because the designers and the building contractor worked together in a team, some projects found implementing innovation through prefabrication and standardization easier. This was visible in I2, where prefabrication helped maintain efficiency and manage tight construction timelines.

According to the interviewees, the most considerable weakness of integrated projects is guaranteeing long-term quality in a project. Projects like I1 faced ongoing maintenance issues because during construction often the cheapest option was chosen, when this stopped working the replacements cost more than it would otherwise have cost. This quality was also an issue in Project I5, where the building contractor wanted to save costs on quality if expectations were not explicitly discussed. The replacement of lacking installations also leads to additional costs post-delivery. This was especially visible in I1, which was over budget due to additional expenses incurred after the project's delivery, primarily due to maintenance and long-term quality issues. While the price and time guarantees can be a big strength, they also mean that the client does not have a big influence later in the project. I2 faced significant issues because a client wanted to make changes late in the project, creating substantial conflicts with the build partner. The client's inability to make changes later in the project also means that some projects struggle with meeting user needs adequately. I1 had these issues, which led to user dissatisfaction and long-term quality issues. Managing integrated projects seems to take considerable effort and extra costs, this was visible in I2, where guiding the project was very time-intensive and costly.

Moreover, there was a clear divide in opinions about the suitability of integrated projects for complex user-focused buildings like primary schools. While client representatives of I4 and I5 advocated strongly for integrated projects, others, such as those involved in I1 and I2, preferred traditional methods due to concerns about quality and flexibility.

A few key factors seem to lead to the success of integrated projects. The first essential factor appears to be an involved client with clear communication early in the design process and functioning as a control factor later; projects like I4 and I5 attributed a large part of their success to this. Secondly, the client representative needs sufficient experience within the construction industry. This allows clients to convey their goals early in the design process and enables them to participate actively. Projects like I3 and I4 did this successfully, while I1 did not succeed due to a lack of experience and engagement. Thirdly, good relationships and communication are deemed essential. Successfully integrated projects, like I4, highlighted that stakeholders work together for a large portion of the project, which increases the importance of good communication and collaboration among all parties. Lastly, client representatives and project managers of I1, I4, and I5 emphasized that the inclusion of a maintenance factor (e.g., DBM, DBMO) in integrated projects is essential for a project's success. This ensured that building contractors would implement the best long-term quality options instead of the short-term path, resulting in much higher quality for the client.

Integrated PDMs for primary school demonstrated clear strengths in achieving faster construction times and effective budget control. Projects were more successful if an experienced representative had strong client involvement, good communication and relationships between parties, and a maintenance format was implemented. These projects' effectiveness was highly dependent on these factors, risking challenges in long-term quality, post-completion cost overruns, and conflicts between client and contractor.

Interviews RPM Projects

The interviewees for RPM projects mention that these projects benefit from a high building quality. R1 and R2 both reported very good quality due to the RPM method, which facilitated continuous collaboration between all parties involved, even with the limited availability of the client. Using prefabricated and standardized parts, which benefitted projects R1 and R4, contributed to time and cost management. Innovation with techniques like this is made possible by the experience of a managing contractor. Managing contractors function as a single point of contact, which was also highly effective in R2, where it helped manage communication and coordination with a fragmented municipality. This facilitates long-term collaborative relationships between stakeholders, as mentioned by the interviewee of R1, where the project's success led to continued cooperation on subsequent projects. While the intense management of the RPM method was deemed the leading cause of the bad time performance during the quantitative analysis, this intense management was generally considered necessary to keep cost and quality up to standard. In these cases, the time performance of the projects was deemed less important than the other project success factors, and thus the delays were intentional.

The RPM also showed that for some projects intense management was needed by the managing contractor to keep the project within schedule and budget, this was especially visible in R4. Divisive aspects that came up during the interviews were the involvement and control of the client. While the client can stay involved more than in the integrated methods, they are often not making the final decisions. This can lead to unhappiness with the end product and, thus, a lower quality for the client.

RPM projects demonstrated strength in management aspects and high building quality by fostering collaborative relationships. However, they also faced challenges coordinating with municipalities, profitability, and dependency on external factors. The success of RPM projects was not guaranteed, as some projects succeeded more than others. According to the interviewees, the RPM method is excellent for clients who cannot carry the risks but still want to stay involved while developing the projects. They mention that taking the responsibility of the project from the client is its greatest strength.

Table 4.3: Performance of Different Projects According to Interviews

Factor	T1	T2	T3	I1	I2	I3	I4	I5	R1	R2	R3	R4
Quality Focus	+	+	+	-	-	+	+	+	+	+	+	/
Time Management	-	0	-	+	-	+	+	+	+	+	0	-
Client Involvement	+	+	+	0	0	+	+	+	0	0	0	/
Cost Management	-	-	-	-	0	+	+	-	+	0	0	/
Communication & Coordination	0	-	0	0	-	0	+	+	+	0	+	-
Project Speed	-	0	-	+	+	+	+	+	+	+	0	+
Flexibility & Changes	+	+	+	-	-	0	-	-	/	0	/	/
Risk Management	-	-	-	0	0	+	+	+	+	+	+	+
Profitability	0	-	-	-	0	0	+	0	+	0	-	0
Maintenance & Long-term Quality	0	0	0	-	-	0	+	-	+	+	/	0

Qualitative Conclusion

The interviews reveal strengths and weaknesses of the different PDMs. These are visualized in Table 4.3, ('+' indicates a good performance, '0' an average performance, '-' a lacking performance, and '/' a lack of information on the topic). Traditional methods seem to ensure a higher quality, partly because of the extensive involvement of the client. This same client involvement has the risk of causing cost and time management challenges due to late changes requested by the client. Communication issues between stakeholders can also lead to additional cost and time challenges. Integrated projects often offer more efficiency and performance guarantees earlier in development, reducing risks. If the client is not experienced in the construction industry or does not know what they want, this method runs the risk of low user satisfaction because of the limited flexibility for the client. Additionally, most interviewees recommend the inclusion of a maintenance element to the contract, as this tends to improve the delivered quality of the building. RPM methods excel in managing different stakeholders by being a singular point of communication, enhancing collaboration and innovation options. They give the client a guarantee early in the process while still allowing them to affect the design process, which can lead to time delays. These time delays can also be caused by intense management, which often prevents cost- and quality-related oversights before construction commences.

Summarized, different PDMs seem to thrive in different contexts. Traditional methods are suitable for projects requiring high client involvement and where municipal support is available to cover financial setbacks. Integrated methods are best for projects needing quick delivery and clear initial planning, with experienced clients and good stakeholder relationships. RPM methods are ideal for clients who prefer reduced risk responsibility and benefit from an experienced management contractor.

4.3 Synthesis

After finishing both the quantitative analysis in Section 4.1.3 and the qualitative part of this research in Section 4.2.2, a synthesis can be made of the intermediate conclusion and the results of the interviews. This synthesis includes the answers to the unanswered subquestions SQK 4-7, following this the main research question can be answered. This section is concluded by applying the synthesis findings into recommendations for different stakeholders.

4.3.1 Answering Remaining Subquestions

SQK 4: What are stakeholder expectations on project success factors, and how do these expectations change over the project duration?

At the start of a construction phase, stakeholders establish their goals, ambitions, and wishes for a project and write these in a PoR (Section 2.1), outlining initial expectations. These estimations are often optimistic, assuming things happen according to plan. Over time, these expectations change until after the delivery of a project.

The first main transition of expectations happens after the bidding phases (2.6). A critical phase of a project where stakeholder expectations shift significantly based on the received bids, and according to both the quantitative and qualitative research, also depends on the project's chosen PDM. For traditional PDMs, this bidding process occurs twice, once after the definition phase and once after the design phase. The quantitative research (e.g. Figure 4.10) indicates that expectations change significantly after these bidding phases. According to the interviews, costs are more volatile and often rise because the bidding was less successful than expected, and additional risks arose between phases. Integrated projects only facilitate one bidding moment, according to the interviews. This stabilizes the prize and time performance, which is visible in the quantitative analysis. Interviews indicate that long-term quality can suffer if maintenance responsibilities are not included, as the contractor will try to shave costs wherever they can after the contract is signed. Typically, there are two bidding moments in RPM projects; however, this is not the rule. While the expected delivery time of RPM projects is often much later than expected, the RPM method tends to maintain accurate construction time predictions. According to quantitative research, the RPM method performs closest to the first estimation in the definition phase in cost-related metrics. This could be due to the performance guarantee in the contract between the client and the managing contractor.

Notable from the quantitative data is that all projects seem to have a large hike in cost estimations between the PoR and VO phases, especially visible in the cost growth metric. The cause of this increase is partly due to delayed construction starts, inflation, and rising material prices. Still, it could also be because of a constant underestimation of costs by clients in the beginning stages of a project. During the later stages of a project, the estimations on cost and time performance continue to change. Some examples of this are that RPM projects seem very cost-efficient after the DO phase, and the expected project duration rises significantly for both integrated and RPM projects. Generally, expectations become more conservative throughout the design process as costs and duration metrics rise throughout the design phases. The construction phase is where traditional projects see a large rise in expected construction time and cost according to the quantitative data, this indicates inefficiencies between the different phases, the interviews show that this could be due to communication issues between different stakeholders. Both traditional and integrated projects take significantly longer for the construction phase when compared to the original expectation from the PoR. In comparison, RPM projects perform significantly better, with only a slight increase. The interviews also show that quality expectations can sometimes be outperformed, especially on sustainability metrics. Considering the budget, the interviewees explained that if the bidding is successful and martial prices are beneficial, much more is possible than expected. However, quality expectations can also be under-performed, especially for integrated projects, when a maintenance element is not included in the contract. The qualitative data shows that including this in the contract will improve quality assurance significantly.

Stakeholder expectations evolve significantly throughout a project's different phases. These changes are influenced by the chosen PDM, the bidding process, market prices, and the stakeholders' competencies. The quantitative and qualitative research indicates that initial optimism often makes way for more conservative expectations. However, they also show that careful management and extra attention to different aspects can improve the accuracy of these expectations. This is dependent on the chosen PDM and the stakeholders involved in the project.

SQK 5: How do primary school buildings differ in terms of usage, stakeholders, costs, and construction time?

The analysed projects show the many differences that primary schools can have. These differences range from different usage philosophies to higher budgets. Understanding these differences in detail is essential to comparing these buildings effectively.

Primary schools differ in their functions; this difference is caused by different design philosophies, target users, available budgets, etc. Additional functions included in a primary school building could be libraries, gymnasiums, and daycare facilities. These extra functionalities can incur extra costs and add GFA to the analysed building. This became very clear during the data collection and quantitative analysis. Many of the analysed projects included at least one of these extra functions. These were often not budgeted separately, so they were chosen to be included in the analysis.

Primary school buildings also differ in stakeholder involvement; the projects vary in neighbourhoods and have different clients with different needs. Sometimes, multiple schools will operate within the same buildings, which will also impact the number of stakeholders influencing the project. These stakeholders all affect the decisions made during the project, impacting the predictability of the project. These different circumstances create the need for different buildings. Examples of this are the size of the analysed schools, which range from 1.390 m^2 to 6.550 m^2 (Figure 4.4), and a capacity ranging from 120 to 800 students (Figure 4.8). The difference in stakeholders, budget, and functions will also lead to buildings with different geometries, like extra floors or increased playground areas. The interviews also show that this difference in stakeholder involvement will lead to different sustainability goals for a new project.

Additionally, the analyses show a difference in project cost and budget between different projects. This financial difference is very apparent when comparing the quantitative data; this is most apparent in the total cost of these projects, which ranges from ¿ 2.924.749 to ¿ 20.782.439. The quantitative research corrects this difference in project budget and size with cost normalization formulas like Formula 3.3.1, resulting in a more contextualized difference in cost per meter of ¿ 1.691 to ¿ 3.263 A part of the financial success that a project had was derived using the cost growth metric in the quantitative research, this ranged from 74,83% to 132,31%

of the original predicted cost.

Another aspect in which primary school building projects differ significantly is the timeframes of the projects. The most apparent difference is the range of delivery dates from the analysed projects; these range from Q3 of 2012 to Q4 of 2023. This delivery date significantly impacts the project's cost due to inflation and fluctuations in material price. The cost correction model is used in Section 3.3.1 to correct this difference. Total project duration is another metric that significantly differs between the projects, ranging from 779 to 2077 days. This total project duration can often be misleading, as projects can be put on hold or experience little time pressure. Other significant metrics include construction duration (175 to 638 days) and construction intensity (2,51 to 13,26 m^2/day). These metrics are an essential difference between construction projects, as quick construction often indicates efficient design and fewer communication errors.

When comparing primary school projects, the differences in usage, stakeholders, costs, and construction time are significant, and it is important to consider and fully understand them. This is especially important when analysing the quantitative data because this quantitative method forgoes much of the context of a construction project.

SQK 6: What are the average project success factors for primary schools, and how do they relate?

The relationships between different project success factors are essential to understanding the project's successes and shortcomings. Understanding these interrelations can function as a comparative baseline for analysis. Their interrelations can explain key trend differences between PDMs and a project's success. The averages of the different project success factors also function as a way to compare the different PDMs to each other, especially when determining the strength of one PDM compared to the others. Key cost-related project success factors that emerged from the research are cost per m^2, cost per student, construction cost per m^2, construction cost fraction, and project cost growth. Time-related project success factors are project duration, project duration growth, final duration per phase, project intensity (m^2), construction time, and construction time growth.

Cost has always been one of the most important factors in determining project success. The most effective way to compare the costs of buildings of different shapes and sizes is to normalize these metrics. The quantitative research resulted in an average project cost of €2.526 per square meter and €18.092 per student capacity. As the average construction cost fraction of these projects was 83%, the average construction cost per square meter was €2.185. Additionally, between the definition phase and the delivery, the projects experienced an average cost growth of 24%.

The quantitative research also collected data on several essential time factors. The analysed projects shared an average project duration of 1160 days, experiencing a 27% project growth compared to their first expectation. This duration consisted of an average of 194 days for the definition phase, 157 days for the VO, 157 days for the DO, 226 days for the TO, 418 days for realisation, and eight days until the project was delivered with a project intensity of 2.45 meters built per day. The construction phase is the most costly, so performance on this metric should be emphasised. On average, projects took 23% longer to construct than previously expected.

These different project success factors can also significantly influence each other. Some of these are self-evident. An increase in total project cost will probably also increase the other cost factors. However, less plain influence between project success factors should also be considered. An increase in construction time will probably also influence the cost metrics of the project, as the construction phase of a project is very cost-intensive; it could also lead to an increase in the construction cost fraction of the project. A delay in one of the design phases might need to be made up during one of the other phases, especially if there is a project deadline, this could lead to a decrease in construction time, or an increase in cost metrics. A longer overall project duration can lead to a lower construction cost fraction; if more resources are put into the project's design phases, the design process will generally be more expensive, while a detailed design could also prevent mistakes during the construction, keeping costs low.

The interviews showed that these metrics can also influence the project's delivered quality. Additional functions could be included in the building; a project could have a larger budget for sustainability, or different materials could be used to increase the building's longevity. A higher budget could mean more sustainable materials are chosen, more complex functions could mean the design phase takes longer, etc.

SQK 7: What is the effect of a PDM on the average project success factors for primary school buildings?

The effect of a PDM on average project success factors is essential to answering the main research question. By combining the quantitative and qualitative research, a few prognoses can already be made on the effect of different PDMs. However, it is essential to consider the difference between causation and correlation when answering this sub-question. A more complex project might lead to higher project duration, higher cost and lower intensity, but the complexity suits one PDM more than the other. This problem will be discussed extensively in Section 5.1.

Traditional projects exhibit mixed performance on key project success factors. The quantitative data indicates that these projects often struggle with cost. This is evidenced by the significantly higher cost per meter and cost per student metrics. The higher costs are unexpected, as interviews indicated the expectation that traditional projects have better cost performance due to the additional market forces. According to the interviewees, this could be caused by the larger scale of traditional projects. While construction cost factions are average, traditional methods often face cost escalation in the later phases of a project. This indicates issues with cost control, unforeseen expenses, and communication issues between phases. Another challenge of traditional PDMs is time management. Despite having a very low project duration until the construction phase, a large construction time growth often leads to large delays and the longest construction time of all PDMs. While traditional projects frequently struggle with cost and time management according to the quantitative data, the qualitative analysis exhibits that traditional PDMs, on average, perform well on quality metrics like user satisfaction. According to the interviewees, this is because of the client's large control over the projects' duration.

Integrated PDMs demonstrate strong cost efficiency. This is visible in the quantitative results, where it performs best on cost per student. This efficiency could also be caused by the lack of additional functions typical for integrated projects, as they perform on average for cost per square meter. Integrated projects typically provide significant stability, as after the VO phase, most project success factors remain very stable, except for constant construction time growth. Despite this stability, the integrated projects, on average, still know the worst cost growth out of all PDM because of the large rise between the PoR and VO phases. Integrated projects show good realization durations, indicating fast construction. This is despite a very large construction duration growth, indicating that its initial construction duration prediction might generally be very optimistic. The interviews show that often integrated project performance on long-term quality is variable. This is dependent on whether a maintenance element is included in the contract. Additionally, integrated projects perform better on all quality metrics if the client clearly knows what they want and can put this into the PoR. Careful quality control is essential during the project duration to ensure that the building contractor is not shaving quality to save on costs.

RPM projects perform well on cost metrics, especially cost per square meter. The construction cost fraction is also the most stable of the different PDMs, indicating stability and cost management. Cost management performance is evident in cost growth performance, where a big spike during the middle of the design phase is corrected during project development. This indicates very effective cost-reduction measures. Project duration is a significant issue for RPM projects, as these projects take significantly longer to complete, while also experiencing considerable duration growth during the design phases. However, the construction duration and duration growth performance are very good, indicating adequate construction preparation during the design phases. Interestingly, quality does not seem to drop due to the cost-cutting during the design phases, as the interviews show that RPM methods generally deliver high-quality projects. They indicate that this could be explained by the effective use of innovative techniques like prefabrication, or by overall effective cost and quality management.

Each PDM shows clear trends in its performance on different project success factors compared to the average. Traditional projects struggle with cost but perform well on quality. Integrated projects perform well on cost while struggling with quality. RPM projects have very long project durations but perform well on both cost and quality.

4.3.2 Answering Main Research Question

Main Research Question: What is the relationship between the chosen PDM for primary school buildings, and project success factors?

The relationship between a chosen PDM and the project success factors for primary schools is complex and influenced by various factors. These include the different goals and stakeholders within the project, the difference in budgets, and the amount of risk a client can take. These differences have been discussed extensively in answering SQK 5. The analysis of different PDMs reveals distinct strengths and weaknesses in project success factors per PDM.

Traditional PDMs tend to struggle with both cost and time management. The quantitative analysis indicates that these projects experience a higher average and more variable cost per square meter and student, with significant cost escalation during the construction phase of the projects. The answer to SQK 7 suggests that traditional projects could be prone to cost overruns due to the larger average project scale and higher complexity of these projects. In contrast, the literature and the interviews suggest the reason could be a downside of high client influence, changes late in the design process, and communication issues. This will potentially result in the longest average construction times out of all analysed PDMs, which results from large construction duration growth in the realization phase. According to the interviews, the challenges in cost and time factors are balanced with the traditional methods' performance in quality. They reveal that client control during the project is a key factor in creating high-quality and high-user-satisfaction buildings.

Integrated PDMs demonstrate strong cost efficiency metrics, especially in buildings without additional functions, evidenced by the lowest cost per student according to the quantitative research. Integrated projects stabilize after the early design phases, which leads to more predictable cost and duration metrics. This stability is emphasized by the low variance on most cost and time metrics, visible in the box plots in Section 4.1.3, except for construction duration (Figure 4.18). Important to note is that the expected cost growth during the VO phase indicates that the expected cost in the PoR phase is often overly optimistic. The most significant benefit of integrated projects is the performance on project duration metrics, as integrated projects have the lowest average project duration, while also having the lowest variance on this metric. This is despite challenges on construction time growth, which are discussed in SQK 6. The interviews also highlight that this time efficiency is a notable benefit of the integrated PDM. However, quality outcomes often vary for integrated projects, especially long-term quality. The analysis of the interviews suggests that adding a maintenance aspect in the integrated format is essential for preserving the long-term quality of these projects. Additionally, sufficient experience and a clear PoR are needed for high user satisfaction, as a considerable downside of integrated projects is the lack of client control after the project's initial phase.

RPM projects perform best on quantitative cost metrics as they achieve by far the lowest cost per square meter, the lowest project cost growth, and maintain a stable construction cost fraction. This is made possible by efficient cost management during the later design phases, resulting in solid cost control without compromising quality. According to the interviews, RPM projects deliver high-quality outcomes with strong client satisfaction and the possibility of innovative techniques. The project manager's planning and communication experience benefits quality, even with solid cost management. While RPM projects seem to perform well on cost and quality, the quantitative analysis shows significant challenges in time management. This is evident by the longest average project duration, high duration variability, and very high duration growth. The interviews also indicate that RPM projects often experience longer project durations to preserve cost and quality. However, the construction phase does not experience this struggle with time management. Together with integrated projects RPM knows the lowest average construction time and highest construction intensity. Indicating that the extended duration of the design phases prevented issues during the realisation of the projects.

The relationship between a PDM and a primary school project success factor is often characterized by trade-offs between these factors. Different PDMs prioritize different project success factors. This emphasizes the need for a client to choose a PDM that fits the goals of the project and the involved stakeholders. The choice of a PDM seems to significantly influence the project success factors of a primary school.

4.3.3 Recommendations for Stakeholders

Using the answer to the main research question and the additional knowledge gathered throughout this study, stakeholders involved in the construction of (primary school) buildings can be advised. The recommendations are based on both the results of this thesis and the strengths of the methodology in showing the development of expectations on metrics throughout phases and their variance.

The priority of traditional projects is quality, and they are best utilized when the client has sufficient financial stability or support from others to manage the risks of the method. Clients can expect high cost and quality, but be wary of communication issues between phases. Building contractors should consider these potential communication issues and expect a potential increase in cost and time during construction. This means that end-users can expect a potential delay during the realisation phase, which will, in turn, delay delivery and the usability of the building.

Integrated projects seem best suited for an experienced client with a clear vision of the project's goals. Projects where time is an issue also suit this method, as project intensity (m^2) is a significant strength. If a client is experienced in this method, long-term quality issues common for these projects can be prevented. Design- and construction contractors should prioritize communication with the client throughout a project, which could help user satisfaction. End-users should plead for a maintenance element in the contract, as this prevents maintenance issues during occupancy.

RPM projects are best suited for projects where cost control can not get in the way of high quality, and time is not a big issue. They are highly effective for complex projects where clients want to offload risks while maintaining influence. Additionally, inexperienced clients, or clients who do not expect time pressure, should consider the RPM method. Design phase stakeholders can expect to work on successful, high-quality projects that might encounter challenges in cost reduction while preserving quality in the later design phases. Building contracts can expect high construction intensity and effective communications. End-users can expect a high-quality product that might take a significant amount of time to realise due to the large project duration and duration growth.

Chapter 5

Discussion

This thesis asked the question What is the relationship between the chosen PDM for primary school buildings, and project success factors”? This question was answered by systemically exploring the relationships between different PDMs and their influence on project success factors. By analysing these quantitative and qualitative methods, the study reveals specific relationships and how they influence project outcomes. The research provided evidence of clear relationships and also offered practical insights into which PDMs are most effective for different projects. Therefore, the research answers the original research question about the relationship between PDMs and project success factors and provides a framework for more informed decision-making in future projects. An important factor to consider is that this study finds a relationship between a PDM and project success factors, a relationship does not necessarily indicate causality. The impact and limitations are further elaborated in Section 5.1.

Complementary findings: A substantial part of the research findings align with existing literature on the effect of PDMs on project success factors discussed in Section 2.8. The research and existing literature consistently indicate that traditional PDMs encounter significant challenges in time management and communication issues (Perkins, 2009). They also state the client's great control during the project and the tenancy to deliver high-quality projects (Adriaanssen et al., 2017). Similarly, it matches the literature on the expectation that integrated PDMs provide better cost efficiency and time management due to the early determination of project cost and the integration of phases (Al-Enezi & Sabah, 2023; Oladirin et al., 2013; Perkins, 2009). Both the literature and this study recognize the strength of management contracting in strong cost control (Williams, 2003) and the ability to deliver high-quality projects (Carpenter & Bausman, 2016). This is attributable to the effective planning and expertise of experienced project managers.

Diverging findings: However, some research conclusions introduce differences that extend and diverge from the literature. One of these differences emerges in the notable variability of quality outcomes in integrated projects found by this thesis. At the same time, the existing literature focuses on the strengths of integrated methods through collaboration. It does not comment on potential long-term quality issues, particularly in the context of complex primary school projects. Additionally, while the literature highlights the cost-effectiveness of management contracts (Al-Enezi & Sabah, 2023; Oladirin et al., 2013; Perkins, 2009), this research highlights how and during what phase this cost management happens. The literature emphasises the effectiveness of RPM in financial management and quality (Carpenter & Bausman, 2016; Williams, 2003), while this thesis adds that this can come at the expense of project timelines.

Contradictory findings: One of the most considerable differences between the literature and the results is the emphasis the literature puts on the frequent delays of traditional projects

(Sullivan et al., 2017). The quantitative research shows that total project duration growth of traditional projects performs the best on average of the analysed projects. At the same time, the duration growth is most apparent during the construction phase, which could explain the literature. Another large discrepancy between the literature and this research is the literature's expectation of higher absolute cost of RPM projects due to complexity (Carpenter & Bausman, 2016). In contrast, this research suggests that RPM is highly effective in managing cost, indicated by the lowest cost growth and lowest cost per m^2.

Innovative findings: The most important contribution of this research is the innovative findings that provide unprecedented insights into how project success factors develop throughout different project phases. Existing literature at most considers two different phases of expected value (Carpenter & Bausman, 2016; El-Sayegh, 2008), the five phases considered in this thesis provide unique insight into how project success factors develop throughout a project. These innovative findings allowed for recommendations to be made to several different stakeholders in Section 4.3.3 using newly acquired information on the relationship between PDMs and project success factors.

5.1 Limitations

Each phase of this research came paired with some limitations. This is because of the sheer scope of the research and the inherent problem of comparing different buildings. This research covered numerous projects that differed in all kinds of ways. For example, buildings were of various sizes, had different budgets, were built in different areas, and were built at different times.

Literature: A significant limitation of the literature research is the age of the sources used, as some of the sources used date back to 1985. These sources function as a backbone of the structure of PDMs but cannot be relied upon for up-to-date information or its applicability to modern research practices. Moreover, a significant amount of research is based on international projects from the USA, Nigeria, or different parts of Asia. These countries have distinct rules and regulations that impact using different PDMs. Furthermore, the management contracting PDMs analysed in these papers is often about the CM/GC or CMR methods instead of the RPM method analysed in this thesis. Resulting in findings that might not completely apply to this slightly differing method.

HEVO: As all data came from the same company, different biases could affect the result. For instance, HEVO and its employees could function better on RPM projects as they specialize in this specific method, leading to more efficient projects. Another firm could specialise in a different PDM, leading to better results for that PDM. Increasing the sample size from different companies with different specialities would increase the applicability of the results for the public.

General Methodology: This thesis's qualitative and quantitative research aspects deal with some of the same limitations. The limited sample size of both methods also restricted the accuracy of the results. Some of these inaccuracies are caused by the fact that no buildings are exactly alike; buildings are built in different areas and times and have different stakeholders, budgets, goals, etc. An increase in sample size would allow these differences to be averaged out to a more accurate level. This also allows the PDMs to be grouped in more specific groups, allowing for more different PDMs to be compared. These larger groups can obscure the nuanced differences that PDMs within the same group have. For example, a higher sample size could have allowed integrated projects with a maintenance aspect to be separated from those without it, to see the effect of this maintenance aspect on different factors. The sample size could also be increased by gathering data from a different firm.

Quantitative research: The limitations specific to the quantitative research part relate mainly to how data is collected and compared. A considerable limitation to this part of the research is that the different volumes of buildings were not considered, and building a square meter on the second floor is generally more expensive than on the ground floor. Additionally, some buildings had additional functions like a gymnasium, a library, or a daycare. These aspects were lost in the quantitative analysis, as the costs for these extra functions were not specified separately from the project. This made metrics like `Cost per Student' significantly less applicable. A second limitation is the limited data availability for integrated and traditional projects. The consultancy firm was often only in an advisory role in these projects, so the complete data was not always available. Additionally, some projects lacked a clear structure or didn't comply with the usual phases of the design process, sometimes passing over the DO or TO phases. These issues resulted from the data interpolation discussed in Section 3.3.1, which reduced the accuracy of changes between phases. Additionally, using this methodology, qualitative metrics can often only be managed after a project's delivery (e.g. maintenance cost, energy cost, comfort, health). This means that qualitative metrics could not be effectively analysed through the quantitative part of this study. Furthermore, these data points lack context; for example, cost increases might be due to more budget becoming available, indicating more space for quality instead of inefficiency. Moreover, the registered end date of a phase was taken as the start of the new phase. Realistically, a delay could have happened between the ending of one phase and the beginning of another. Lastly, as discussed in answering SQK 7, the difference between causation and correlation is not apparent in the quantitative research. A traditional project might be more suited for complex projects, which generally have higher costs; this does not mean that a traditional project is, per definition, more expensive.

Qualitative research: Personal factors play a significant role in qualitative research, as the interviewees could perform differently depending on experience and environment. This leads to very subjective opinions given by the interviewees. Part of this confirms the problem definition from Chapter 1. However, this also reduces the dependability on the results of the qualitative research. Additionally, the availability of client representatives of RPM projects due to retirement or other personal factors greatly impacted the ability to compare the user quality of these projects with the other PDMs. Moreover, because some of these projects were relatively old, the interviewees' ability to recollect the exact issues during the project's development was negatively impacted.

Synthesis and Causality: Synthesizing the qualitative and quantitative findings came with additional limitations. The relationship between both parts was often presumed, and no definitive proof could be given on causal relationships. Additionally, comments from the interviewees sometimes did not align with the conclusions drawn from the quantitative graphs discussed during the project. This leads to questions about the accuracy of the gathered data and a complication of the synthesis, making it more challenging to draw definitive conclusions. Essential to realise is that this study found relationships between PDMs and project success factors, and that these relationships do not prove causality. More expensive projects could be more likely to be organised in a traditional way, and RPM projects might be developed with less time pressure causing its longer durations.

However, during the research, each of the limitations was taken into account, and the effects of the limitations were minimized through various methods. Corrections were made for quantitative inconsistencies. Recent literature was prioritized for detailed information, whereas older or less applicable literature was only used fundamentally. A considerable number of projects were analysed to keep the sample size as high as possible, considering the time and data accessibility limitations of this research. Data interpolation was done to correct for projects missing a consistent structure. Interviews were used to correct for the lack of context within the quantitative research. While the subjectivity of the interviews was corrected by the quantitative data.

5.2 Implications of Research

This research addresses the growing complexity of primary school construction projects due to regulatory demands and sustainability goals. The findings of this research emphasize the critical need to base organizational decisions beyond experience-based decision-making and towards a more informed approach. This is achieved by analysing how metrics develop through different project phases, providing a level of understanding not yet available in the literature. The variance shown in the qualitative results also provides more certainty on the performance of different project success factors to varying phases during a project. This challenges the reliance on static and one-dimensional expectations of PDMs, allowing for a theoretical understanding of during what phases the PDMs are most effective, where the pitfalls are, and how PDMs affect development throughout a project. The results also fill a gap in the empirical understanding of the relationship between PDMs and project success factors by providing less-explored quantitative evidence in this field, allowing for a more robust foundation in selecting a PDM for a project.

With the use of previously unavailable quantitative data and unprecedented data on project expectations between phases, a client's decision-making process is enriched significantly. It benefits clients overwhelmed by the complexity of modern construction projects and their organisation. Using more empirical evidence could lead to more predictable and successful project outcomes, potentially reducing risk and increasing user satisfaction. Providing an analysis of how project success factors are influenced by PDMs throughout a project equips the clients with information to make informed and data-driven decisions. Clients can avoid pitfalls with an increased understanding of the development of a project throughout its phases, consultants can provide more accurate guidance, and building contractors can predict design issues. While, end users could predict maintenance issues later in occupancy.

This additional information reduces the risk of uninformed decisions that could impact overall project success. It highlights the need for the selection of a PDM that aligns with the needs of the project and its context and allows all stakeholders involved in a project to foresee upcoming pitfalls that are characteristic of a certain PDM.

5.3 Future Research

After performing this study, a few recommendations for future research can be made. These recommendations range from indicating the importance of different metrics to suggesting additional research. Additionally, a few improvements could be made in correcting the limitations discussed in Section 5.1.

When replicating or improving this research, a suggestion is to prioritize important quantitative metrics, such as cost per square meter and all growth-related metrics. Additionally, the identification of potential quantitative quality metrics would significantly improve this part of the study and is therefore highly recommended. Metrics that could be used for this include post-occupancy energy performance, maintenance cost, or embodied carbon metrics. Furthermore, data could be collected from different (consultancy) firms to remove inaccuracies due to experience or specializations. Implementing an efficient data collection framework could also make it easier to collect data from different companies on projects significantly more efficient, allowing for more projects or PDMs to be compared.

Outliers could be removed before analysing the project to see if this improves the results. The accuracy of the cost correction could also be improved by using existing tools to calculate expected costs based on neighbourhood or municipality and building function. These building functions could also be considered in further detail by either removing them from the quantitative data or comparing buildings with different functionalities.

As the relative value of a project is made up of Cost, Time, and Quality (Hardie & Saha, 2012), all the different results could be quantified and put into a formula calculating the total value that the project had. Different weights could be given to these project success factors reflecting the priority a stakeholder places on that metric. This would allow stakeholders to easily compare PDMs, and decide which suits them best. Future research could attempt to create such a formula using the data gathered in the quantitative analysis and quantify the data gathered from qualitative research so that this can also be used in such a 'value formula' (Formula 5.1).

$$\text{Cost} \quad \text{Time} \quad \text{Quality} = \text{Value} \tag{5.1}$$

Lastly, exploratory research during the quantitative phase was also performed on middle school projects. These schools generally have different functionality, budgets, and size when compared to primary schools. Adding these projects would drastically improve the number of possible projects to analyse, while also generalizing the results to fit a larger subsection of construction projects. The exploratory research showed promising results due to the effective normalization of metrics. Middle schools were comparable in metrics like cost per meter, cost per student, project intensity, and all growth-related metrics. Future research could research the effect of PDMs on middle schools or on school buildings in general.

Chapter 6

Conclusions

This study aimed to answer the question, "What is the relationship between the chosen PDM for primary school buildings, and project success factors?" It answers this question by systematically analysing different PDMs for primary school projects. This study reveals clear relationships between these PDMs and project success factors, thus providing a framework for informed decision-making in future projects.

Quantitative and qualitative methods were used during this research. Both methods challenged the static expectations of PDMs by quantitatively analysing project success factors across different project phases and synthesizing these results with qualitative information obtained through interviews. Both methods identify distinct strengths and weaknesses of various PDMs. Traditional PDMs excelled in quality but faced significant cost and construction time management challenges. Integrated PDMs showed strong cost efficiency and time management, but long-term quality varied. RPM projects performed well in cost management and quality but struggled with extended project timelines. This thesis provides valuable insights into the research subject and has shown promising results for applicability to other projects, provided that the limitations resulting from sample size, variability of project characteristics, and reliance on data from a single source are taken into account.

The findings of this thesis help clients and other stakeholders of these projects make data-driven decisions in the growing complexity of these projects. The empirical evidence of the influence of PDMs throughout different phases equips clients with unprecedented tools for strategic decision-making, reducing risk, and potentially enhancing project outcomes. It also helps stakeholders prepare for common pitfalls and downsides of PDMs at each project stage.

Several avenues for future research are recommended based on this research's strengths, possibilities, and limitations. Future research could combine different project success factors into one value formula that quantifies overall project success. Additional research could be done to see if this analysis is also possible for other kinds of buildings, with exploratory research on middle schools already showing promising results. The robustness of the study could be improved by increasing the sample size, collecting data from multiple sources, or decreasing the diversity of projects. This diversity of projects could also be researched by further addressing the effect of variations in building functions and correcting for these factors. Lastly, when interpreting the results, it is important that they indicate relationships and do not prove causality.

In conclusion, this research answers the research question with unprecedented quantitative analysis of PDMs throughout project phases and qualitative research complementing the findings. It contributes significantly to understanding the relationship between PDMs and the success of project success factors throughout different phases, while also opening up new questions and areas for additional exploration in future research.

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Appendix A

Literature

A.1 PDM Structure

Depicted below are the different PDMs discussed during the literature research. For additional context on the PDMs read Section 2.3.

Figure A.1: 'Hoofdaanneming' diagram adapted from Adriaanssen et al. (2017)

Figure A.2: 'Nevenaanneming' diagram adapted from Adriaanssen et al. (2017)

Figure A.3: Early Contractor Involvement diagram adapted from Adriaanssen et al. (2017)

Figure A.4: Design and Build diagram adapted from Adriaanssen et al. (2017)

Figure A.5: Engineer and Build diagram adapted from Adriaanssen et al. (2017)

Figure A.6: Build and Maintain diagram adapted from Adriaanssen et al. (2017)

Figure A.7: Design, Build, and Maintain diagram adapted from Adriaanssen et al. (2017)

Figure A.8: Design, Build, Maintain, and Operate diagram adapted from Adriaanssen et al. (2017)

Figure A.9: Design, Build, Finance, Maintain, and Operate diagram adapted from Adriaanssen et al. (2017)

Figure A.10: Construction Manager (at) Risk diagram adapted from Adriaanssen et al. (2017)

Figure A.11: Risk-carrying Project Management diagram adapted from Adriaanssen et al. (2017)

Figure A.12: Conceptual building diagram adapted from Adriaanssen et al. (2017)

Figure A.13: Turn-key diagram adapted from Adriaanssen et al. (2017)

Appendix B

Data Collection and Structure

The following information provides more details about this thesis's data collection and structure. It assists the explanation in the methodology and results chapter 3. Project-specific details are left out of the appendix due to confidentiality issues.

B.1 Methodology

Figure B.1 illustrates the data collection and organization structure within the quantitative research component. The data is collected in a central Microsoft Excel file, containing all the analysed projects. All the data for one project is collected in a project specific Microsoft Excel tab. Which is then further categorized by the different project phases: Programme of Requirements (PoR), Preliminary Design (VO), Definitive Design (DO), Technical Design (TO), and Realization.

Figure B.1: Data structure

The structure of the collected data per project per phase is visualized in figure B.2 Within each project and phase, key metrics are collected and analysed. These metrics include general project information such as Gross Floor Area (GFA) and Student Capacity. Additional performance metrics discussed in formula 3.1-3.15 are also calculated. The data for each project phase is recorded in raw values (e.g., costs in euros) and percentages.

Figure B.2: Data structure per phase

B.2 Data Collection

The 27 projects' data were collected, with an estimated 261 data points per project, for a total of 7047 data points. Of these 7047 data points, 2160 were collected by reading existing documents like project plans and phase reports, and 4914 were transformed from this collected data. An overview of analysed projects and indicative rounded data can be found in figure 4.1. In this table, all numeric values have been rounded to preserve confidentiality. GFA values are rounded to the nearest thousand square meters, capacities are rounded to the nearest hundred students, and total costs are rounded to the nearest million euros.

Table B.1: Project Details

Project Acronym	PDM	Delivery	GFA	Capacity	Total Cost
T1	Traditional	2020	2000	300	¿ 8.000.000
T2	Traditional	2021	2000	300	¿ 6.000.000
T3	Traditional	2021	1000	300	¿ 5.000.000
T4	Traditional	2020	2000	200	¿ 5.000.000
T5	Traditional	2019	7000	600	¿ 21.000.000
T6	Traditional	2018	6000	800	¿ 13.000.000
T7	Traditional	2023	3000	300	¿ 8.000.000
T8	Traditional	2013	1000	300	¿ 3.000.000
I1	Integrated (DB)	2012	3000	500	¿ 7.000.000
I2	Integrated (EB)	2018	3000	400	¿ 6.000.000
I3	Integrated (EB)	2015	3000	500	¿ 5.000.000
I4	Integrated (DB)	2022	2000	400	¿ 6.000.000
I5	Integrated (DB)	2016	3000	400	¿ 7.000.000
I6	Integrated (EB)	2021	2000	300	¿ 5.000.000
I7	Integrated (EB)	2021	2000	300	¿ 5.000.000
R1	RPM	2014	2000	600	¿ 5.000.000
R2	RPM	2017	3000	400	¿ 7.000.000
R3	RPM	2015	3000	400	¿ 6.000.000
R4	RPM	2019	2000	100	¿ 5.000.000
R5	RPM	2016	5000	1000	¿ 8.000.000
R6	RPM	2014	2000	300	¿ 5.000.000
R7	RPM	2015	2000	300	¿ 4.000.000
R8	RPM	2017	4000	500	¿ 8.000.000
R9	RPM	2019	3000	500	¿ 6.000.000
R10	RPM	2019	2000	300	¿ 4.000.000

Appendix C

Result tables and graphs

C.1 Cost Correction

Table C.1 shows the values used to correct the cost during the quantitative research. An Excel command took an original value, after which the corresponding expected construction start date was referred to. This date was then used to look up the respective value compared to 2023. The original cost was then corrected to its 2023 levels. The cost estimate for realisation was corrected using the total construction cost index, while all other cost were corrected using only the wage component.

The effect of the cost correction on different metrics is shown in the following graphs and tables, some of these have already been used in the report but are repeated here for clarity reasons. If applicable, an additional box plot of the spread of the results is added.

Table C.1: Construction Costs and Components Indexes (year 2023 = 100%)

Period	Total Construction Costs Index	Wage Component Index	Material Component Index
1990	.	.	41.1
1991	.	.	41.8
1992	.	.	42.6
1993	.	.	43.7
1994	.	.	44.6
1995	47.6	48.3	46.1
1996	48.0	49.5	46.0
1997	48.9	50.6	46.6
1998	50.2	52.6	47.4
1999	51.0	54.2	47.7
2000	52.9	55.5	49.9
2001	55.6	58.7	52.2
2002	57.8	62.0	53.5
2003	59.0	64.1	54.0
2004	60.1	65.2	55.1
2005	61.3	66.3	56.3
2006	63.1	66.9	58.7
2007	65.6	67.7	62.1
2008	68.6	70.3	65.2
2009	68.7	72.9	64.1
2010	69.2	74.3	64.0
2011	70.5	75.4	65.4
2012	71.8	77.3	66.3
2013	71.9	78.7	65.8
2014	72.6	80.4	65.9
2015	73.9	81.1	67.5
2016	75.4	82.4	69.0
2017	77.2	84.1	71.4
2018	79.1	86.1	73.3
2019	81.3	88.4	75.5
2020	83.1	92.0	75.8
2021	86.9	93.1	81.7
2022	94.7	95.8	93.8
2023	100.0	100.0	100.0

C.1.1 Expected Project Costs per m^2 (¿)

Figure C.1: Expected Project Costs per m^2 (¿) (uncorrected)

Figure C.2: Expected Project Cost per m^2 (¿) (corrected)

Table C.2: Expected Project Costs per m^2 (¿) (uncorrected)

	PoR	VO	DO	TO	RE
Trad	2,086	1,965	1,959	1,943	2,072
Int	1,604	1,648	1,671	1,693	1,735
RPM	1,412	1,373	1,437	1,405	1,332
Avg	1,701	1,662	1,689	1,680	1,713

Table C.3: Expected Project Costs per m^2 (¿) (corrected)

	PoR	VO	DO	TO	RE
Trad	2,534	2,857	2,786	2,753	2,870
Int	1,991	2,508	2,457	2,491	2,539
RPM	1,896	2,349	2,419	2,327	2,160
Avg	2,140	2,571	2,554	2,524	2,523

Figure C.3: Cost per m^2 (¿) (uncorrected)

Figure C.4: Cost per m^2 (¿) (corrected)

C.1.2 Expected Project Costs Student (¿)

Figure C.5: Expected Cost per Student (¿) (uncorrected)

Figure C.6: Expected Cost per Student (¿) (corrected)

Table C.4: Expected Cost per Student (¿) (uncorrected)

	PoR	VO	DO	TO	RE
Trad	14,976	15,159	15,848	15,212	16,311
Int	9,468	9,779	9,818	9,931	10,113
RPM	10,474	10,749	11,149	11,082	10,536
Avg	11,639	11,896	12,272	12,075	12,320

Table C.5: Expected Cost per Student (¿) (corrected)

	PoR	VO	DO	TO	RE
Trad	18,227	21,861	22,393	21,387	22,393
Int	11,817	15,124	14,690	14,882	15,023
RPM	14,009	18,136	18,557	18,161	16,817
Avg	14,685	18,374	18,546	18,143	18,077

Figure C.7: Cost per Student (¿) (uncorrected)

Figure C.8: Cost per Student (¿) (corrected)

C.1.3 Expected Project Costs (¿)

Figure C.9: Project Costs (¿) (uncorrected)

Figure C.10: Project Costs (¿) (corrected)

Table C.6: Project Costs (¿) (uncorrected)

	PoR	VO	DO	TO	RE
Trad	5.954.825	5.658.617	6.012.469	5.774.959	6.166.849
Int	3.626.984	3.740.135	3.764.761	3.794.381	3.833.312
RPM	3.632.746	3.798.451	3.961.313	3.743.150	3.570.947
Avg	4.404.852	4.399.068	4.579.514	4.437.497	4.523.703

Table C.7: Project Costs (¿) (corrected)

	PoR	VO	DO	TO	RE
Trad	7.321.648	8.272.450	8.600.089	8.266.573	8.645.458
Int	4.572.435	5.895.339	5.759.374	5.812.494	5.793.583
RPM	4.868.933	6.462.267	6.621.025	6.163.795	5.766.964
Avg	5.587.672	6.876.685	6.993.496	6.747.621	6.735.335

Figure C.11: Project Costs (¿) (uncorrected)

Figure C.12: Project Costs (¿) (corrected)

C.1.4 Project Cost Growth (%)

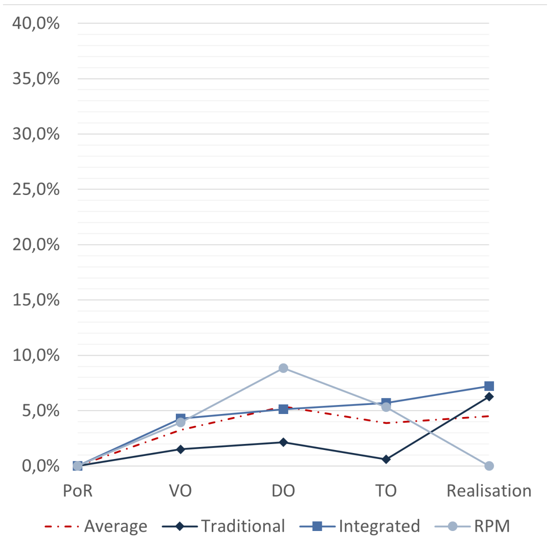


Figure C.13: Project Cost Growth (%) (uncorrected)

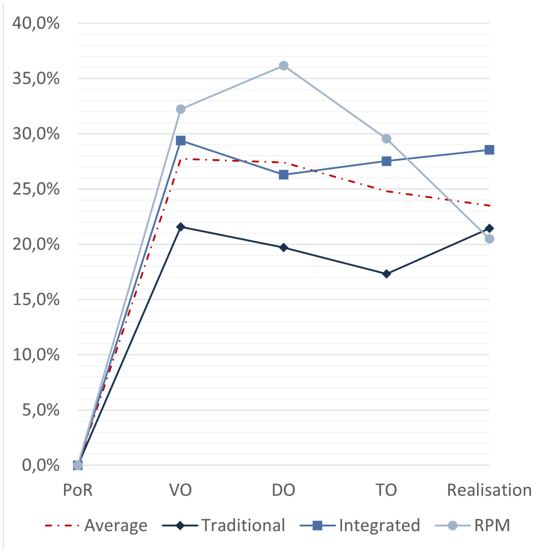


Figure C.14: Project Cost Growth (%) (corrected)

Table C.8: Project Cost Growth (%) (uncorrected)

	PoR	VO	DO	TO	RE
Trad	0,0%	1,5%	2,1%	0,6%	6,3%
Int	0,0%	4,3%	5,1%	5,7%	7,2%
RPM	0,0%	3,9%	8,8%	5,3%	0,0%
Avg	0,0%	3,2%	5,4%	3,9%	4,5%

Table C.9: Project Cost Growth (%) (corrected)

	PoR	VO	DO	TO	RE
Trad	0,0%	21,6%	19,7%	17,3%	21,4%
Int	0,0%	29,4%	26,3%	27,5%	28,5%
RPM	0,0%	32,2%	36,2%	29,5%	20,5%
Avg	0,0%	27,7%	27,4%	24,8%	23,5%

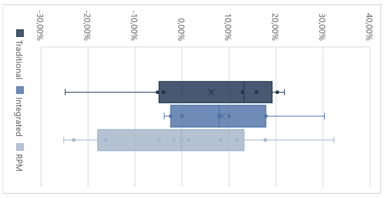


Figure C.15: Project Cost Growth (%) (uncorrected)

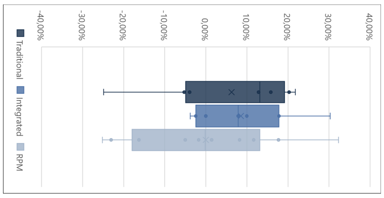


Figure C.16: Project Cost Growth (%) (corrected)

C.1.5 Construction Cost (€)

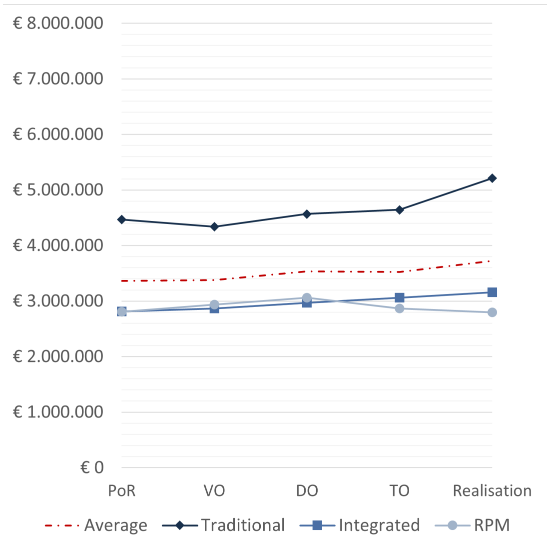


Figure C.17: Construction Cost (€) (uncorrected)

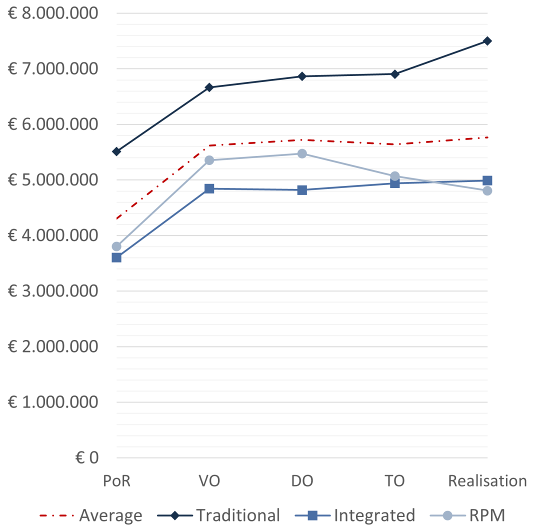


Figure C.18: Construction Cost (€) (corrected)

Table C.10: Construction Cost (€) (uncorrected)

	PoR	VO	DO	TO	RE
Trad	4.466.313	4.336.764	4.567.135	4.642.337	5.213.662
Int	2.812.983	2.866.551	2.970.986	3.058.090	3.158.037
RPM	2.807.532	2.937.124	3.061.286	2.866.704	2.796.340
Avg	3.362.276	3.380.147	3.533.136	3.522.377	3.722.680

Table C.11: Construction Cost (€) (corrected)

	PoR	VO	DO	TO	RE
Trad	5.509.817	6.664.160	6.866.848	6.905.419	7.499.123
Int	3.603.431	4.844.916	4.819.043	4.942.744	4.990.692
RPM	3.803.632	5.354.521	5.475.480	5.068.854	4.808.310
Avg	4.305.627	5.621.199	5.720.457	5.639.006	5.766.042

C.1.6 Project Intensity (€/day)

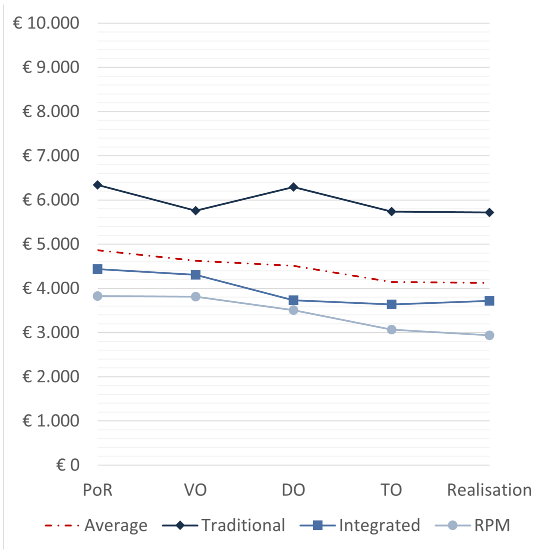


Figure C.19: Project Intensity (€/day) (uncorrected)

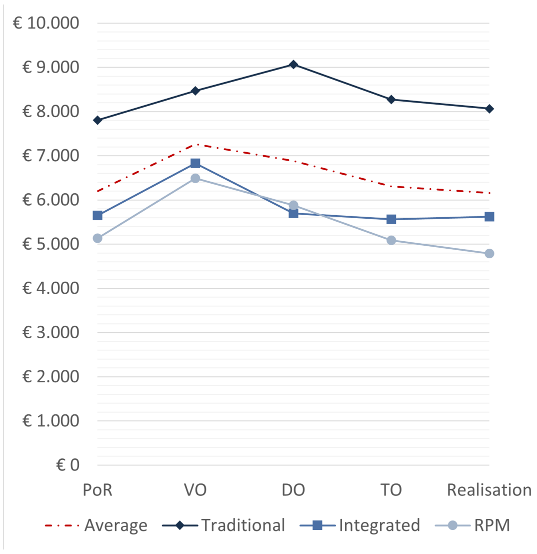


Figure C.20: Project Intensity (€/day) (corrected)

Table C.12: Project Intensity (€/day) (uncorrected)

	PoR	VO	DO	TO	RE
Trad	6.340	5.757	6.294	5.739	5.720
RPM	3.827	3.811	3.505	3.065	2.937
Int	4.434	4.308	3.730	3.636	3.719
Avg	4.867	4.625	4.510	4.147	4.125

Table C.13: Project Intensity (€/day) (corrected)

	PoR	VO	DO	TO	RE
Trad	7.804	8.467	9.063	8.274	8.066
RPM	5.132	6.488	5.880	5.084	4.787
Int	5.652	6.831	5.694	5.563	5.622
Avg	6.196	7.262	6.879	6.307	6.158

C.2 Results

The following section highlights the graphs that have not been discussed in the previous section. Again, certain graphs have already been used during the quantitative section of this thesis, but are also added in this section for clarity reasons.

C.2.1 Project/Construction Intensity (m^2/day)

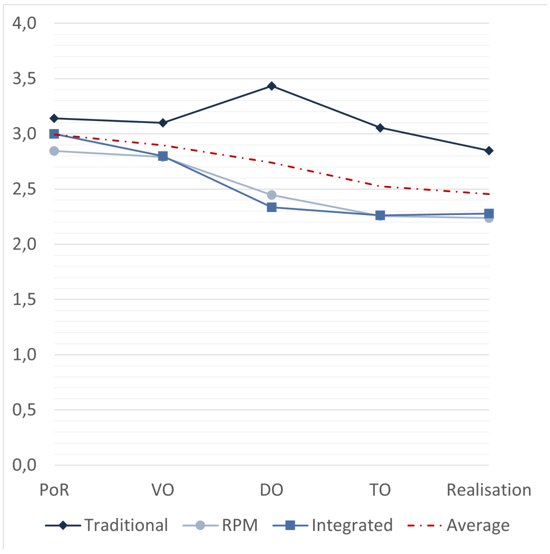


Figure C.21: Project Intensity (m^2/day)

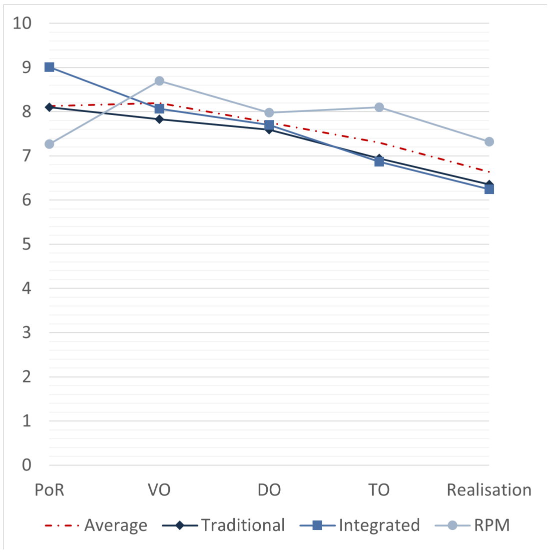


Figure C.22: Construction Intensity (m^2/day)

Table C.14: Project Intensity (m^2/day)

	PoR	VO	DO	TO	RE
Traditional	3,14	3,10	3,43	3,05	2,85
RPM	2,85	2,79	2,45	2,26	2,24
Integrated	3,00	2,80	2,34	2,26	2,28
Average	2,99	2,90	2,74	2,52	2,45

Table C.15: Construction Intensity (m^2/day)

	PoR	VO	DO	TO	RE
Traditional	8,10	7,83	7,59	6,94	6,35
RPM	7,27	8,70	7,98	8,10	7,32
Integrated	9,01	8,07	7,70	6,86	6,24
Average	8,13	8,20	7,76	7,30	6,64

Figure C.23: Project Intensity (m^2/day)

Figure C.24: Construction Intensity (m^2/day)

C.2.2 Project duration

Figure C.25: Actual Project Duration after each phase (days)

Figure C.26: Actual Phase Duration (days)

Table C.16: Actual Project Duration after each phase (days)

	PoR	VO	DO	TO	RE
Trad	123	147	113	225	477
Int	189	128	197	131	387
RPM	270	196	161	324	389
Avg	194	157	157	226	418

Table C.17: Actual Phase Duration (days)

	PoR	VO	DO	TO	RE
Trad	123	270	382	607	1084
Int	189	316	513	644	1031
RPM	270	466	626	950	1339
Avg	194	351	507	733	1151

Figure C.27: Project duration (days)

Figure C.28: Construction duration (days)

C.2.3 Duration Growth (%)

Figure C.29: Expected Total Project Duration after Phase (days)

Figure C.30: Expected Project Duration Growth (%)

Table C.18: Expected Total Project Duration after Phase (days)

	PoR	VO	DO	TO	RE
Trad	968	1010	971	1036	1093
Int	842	892	1011	1047	1042
RPM	1007	1055	1210	1350	1346
Avg	939	986	1064	1144	1160

Table C.19: Expected Project Duration Growth (%)

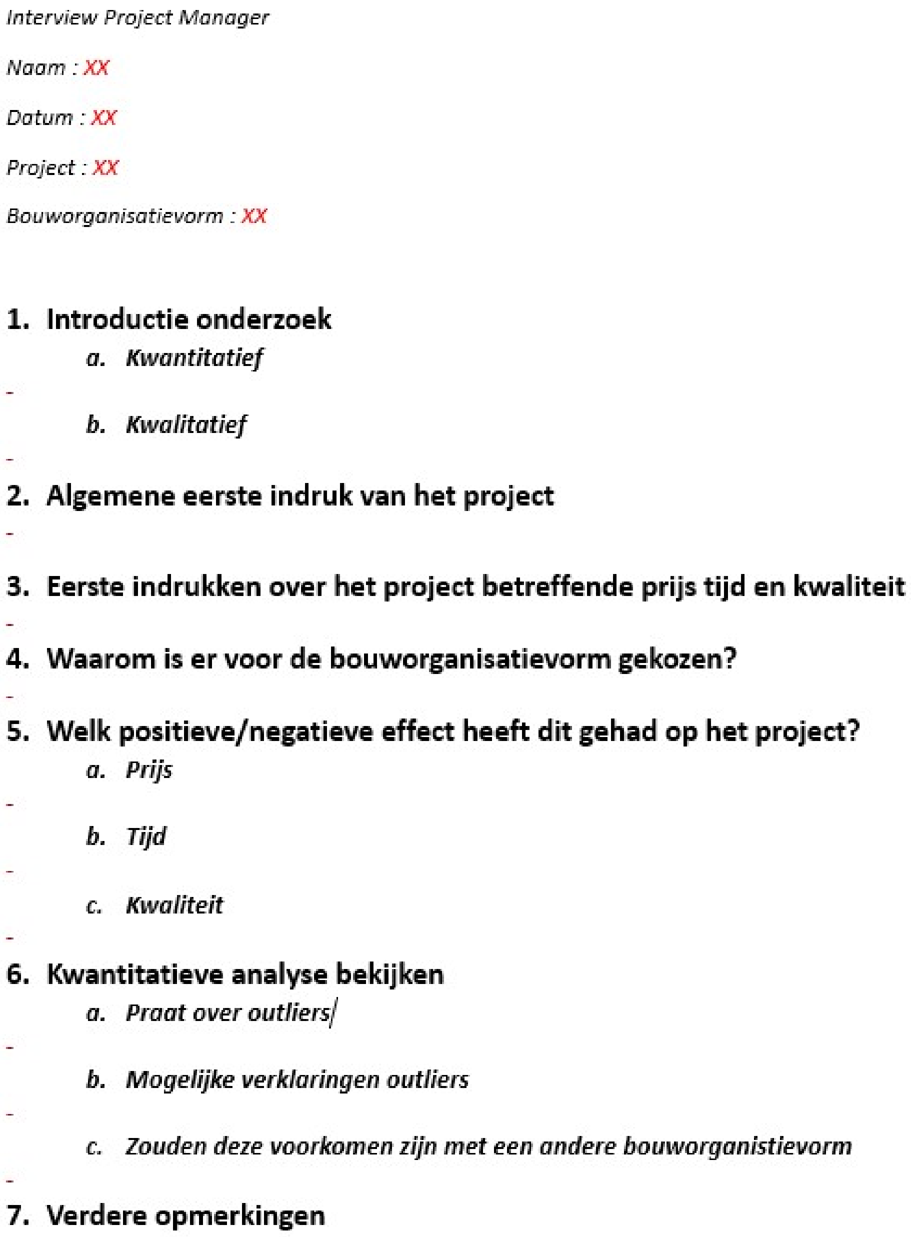
	PoR	VO	DO	TO	RE
Trad	0%	5%	1%	7%	14%
Int	0%	8%	27%	32%	31%
RPM	0%	8%	23%	36%	36%
Avg	0%	7%	17%	25%	27%

Appendix D

Interviews

D.1 Interview Framework

Figure D.1 depicts the general framework used for both the interviews with the client representatives and the project managers. Figure D.2 shows the translated framework, as all the interviews were originally performed in Dutch. Only the framework could be added to this appendix, as no project-specific information can be made available. For additional information, read Section 3.3.2.



Interview Project Manager

Naam : XX

Datum : XX

Project : XX

Bouworganisatievorm : XX

1. **Introductie onderzoek**
    a. ***Kwantitatief***
-
    b. ***Kwalitatief***
-

2. **Algemene eerste indruk van het project**
-

3. **Eerste indrukken over het project betreffende prijs tijd en kwaliteit**
-

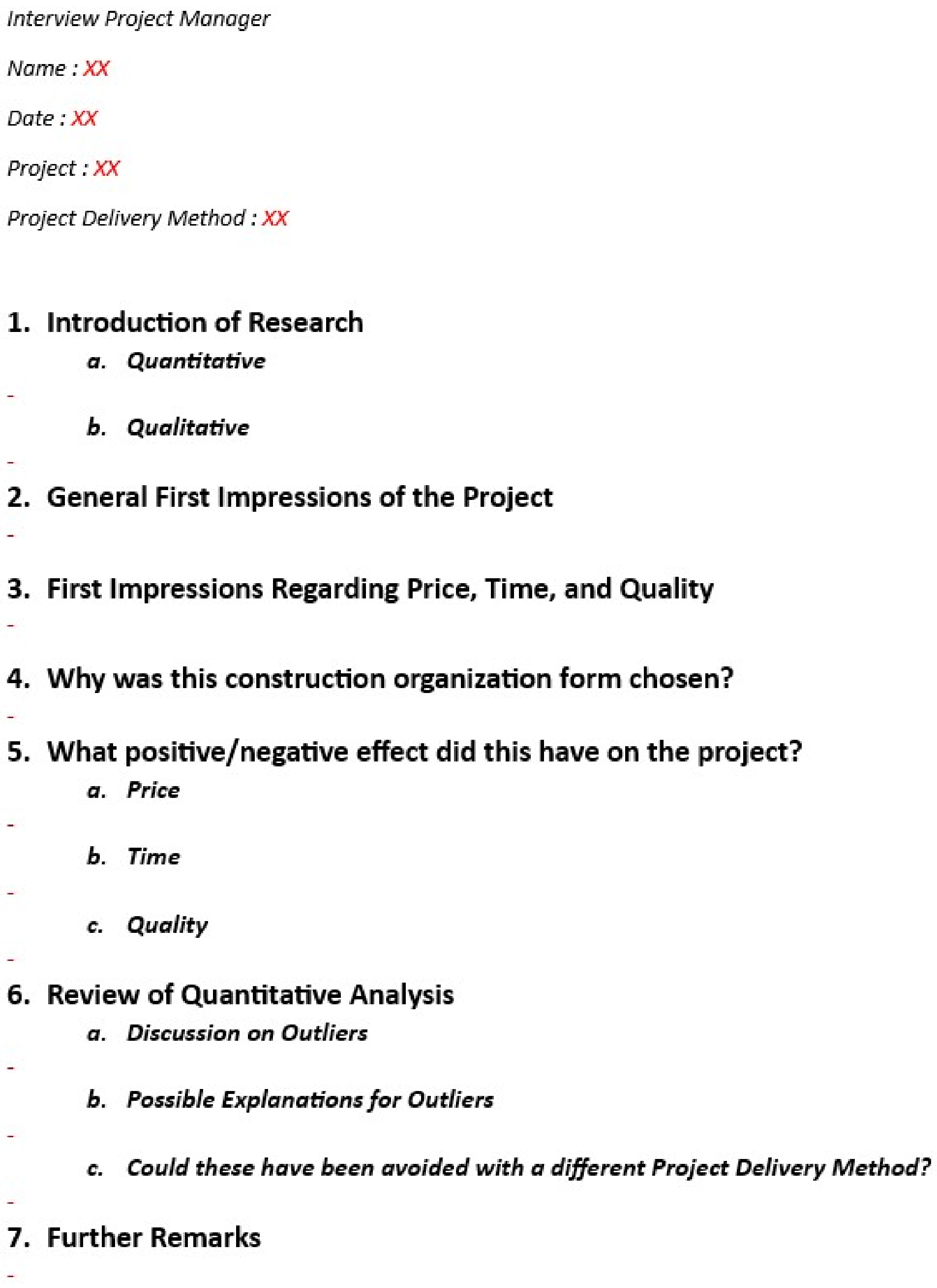
4. **Waarom is er voor de bouworganisatievorm gekozen?**
-

5. **Welk positieve/negatieve effect heeft dit gehad op het project?**
    a. ***Prijs***
-
    b. ***Tijd***
-
    c. ***Kwaliteit***
-

6. **Kwantitatieve analyse bekijken**
    a. ***Praat over outliers***
-
    b. ***Mogelijke verklaringen outliers***
-
    c. ***Zouden deze voorkomen zijn met een andere bouworganistievorm***
-

7. **Verdere opmerkingen**

Figure D.1: Original Framework interviews



Interview Project Manager

Name : XX

Date : XX

Project : XX

Project Delivery Method : XX

1. **Introduction of Research**
    a. ***Quantitative***

-

    b. ***Qualitative***

-

2. **General First Impressions of the Project**

-

3. **First Impressions Regarding Price, Time, and Quality**

-

4. **Why was this construction organization form chosen?**

-

5. **What positive/negative effect did this have on the project?**
    a. ***Price***

-

    b. ***Time***

-

    c. ***Quality***

-

6. **Review of Quantitative Analysis**
    a. ***Discussion on Outliers***

-

    b. ***Possible Explanations for Outliers***

-

    c. ***Could these have been avoided with a different Project Delivery Method?***

-

7. **Further Remarks**

-

Figure D.2: Translated Framework interviews