Segmented Contracting

Segmentation, a solution for complex infrastructure projects?

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Colophon

The following colophon provides detailed information about this master thesis, including the author, contact information, graduation committee, and the company.

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Abstract

This research has explored the potential of segmentation and segmented contracting as a solution for managing the complexities of infrastructure projects in the Netherlands. As the country's civil infrastructure ages, innovative approaches are required to address the extensive challenges of renewal and renovation that lie ahead. This study has examined the benefits, challenges, and key considerations of segmented contracting, providing a comprehensive understanding for clients and contractors. The research has begun by reviewing various project delivery methods, including traditional, integrated, and co-contracting approaches, to establish a theoretical foundation. It has then analysed how segmentation is applied in current and recent projects, identifying its impact on project complexity and potential solutions. A segmentation framework has been developed to guide the application of segmented contracting. The framework demonstrates the impact of horizontal and vertical segmentation on project complexity elements. Additionally, a typology of segmented project delivery methods has been introduced, categorising approaches such as the segmented traditional project delivery method, the segmented integrated project delivery method, the segmented design team (2.0) project delivery method, and the segmented two-phase project delivery method. Expert insights have been incorporated to validate the findings and provide strategic approaches for effective implementation of segmented contracting. Segmentation, segmented project delivery methods, and segmented contracting offer several solutions to address complexity elements in complex infrastructure projects. By breaking down projects into smaller, manageable segments, clients and contractors can allocate resources and expertise more effectively, tailor risk management strategies, and maintain better control over budgets and schedules. This approach facilitates specialised focus on specific tasks, enhances project manageability, and improves the predictability of project outcomes. However, segmentation also introduces significant challenges, requiring robust coordination, communication, and integration efforts. Without these, projects may face inefficiencies, increased risks, and potential delays. Ultimately, this research has aimed to enhance industry practices, improve market competition, and support the civil engineering sector in addressing the significant infrastructure renewal and renovation challenges ahead. The findings have offered both practical and theoretical insights, promoting better management and fostering a more resilient and adaptive built environment.

Summary (EN)

Introduction

The Netherlands is facing a significant challenge in renewing its aging civil infrastructure over the coming decades. Roads, bridges, viaducts, locks, weirs, quays, and sewage systems are reaching the end of their technical lifespans. The intensive usage of these structures, often exceeding original expectations, underscores the critical need for replacement and renovation to maintain the nation's safety, liveability, and accessibility. This infrastructure renewal is a substantial undertaking, affecting the local environment and the accessibility of roadways and waterways.

In addition to the need for renewal, there is a pressing demand for implementing these measures in a climate-neutral and circular manner. The Dutch government has set ambitious targets, including a 55% reduction in CO2 emissions by 2030 and achieving a fully circular economy by 2050. Rijkswaterstaat, the Ministry of Infrastructure and Water Management, and other market participants face evolving tasks and dynamics, including sustainability objectives, limited social acceptance of disruptions, and the need for advanced project management strategies. These challenges are particularly acute for large and complex projects, which often exhibit the characteristics of an imperfect market, with Rijkswaterstaat being the sole recurring client for significant projects.

The renovation of the Van Brienenoordbrug, initiated in 2022, exemplifies these challenges. The project highlights the urgent need for infrastructure renewal, aligning with sustainability and circularity principles. However, it also reflects the limited contractor interest in such complex projects, with prominent contractors opting out due to perceived disproportionate risks. This situation has spurred a crucial debate co effectiveness of existing tender processes and the need for innovative contracting strategies focusing on collaborative contract management.

Problem description

The abrupt halt of the Van Brienenoordbrug project tender process in 2024 underscores the inherent complexity and constraints of managing large-scale, high-risk infrastructure projects. This development highlights the critical need for balanced risk sharing between clients and contractors. The failure of this tender process serves as a learning opportunity, emphasising the need for clients and contractors to re-evaluate and potentially overhaul how risks are shared and managed in future projects. Innovative, adaptable contracting strategies are essential for attracting capable contractors and ensuring the successful realisation of critical infrastructure projects.

The current market dynamics and approaches to risk, especially in large and complex projects, highlight an urgent need for changes to encourage healthy competition. Contractors struggle to price risks adequately, particularly when new design solutions and techniques are involved. This difficulty is compounded by varying abilities among bidders to identify and mitigate risks. The trend of low bidding practices, driven by the demand for innovative and cost-effective designs, has led to fewer contractors willing to participate in high-risk tenders due to the associated financial and operational risks.

Project complexity is a critical factor influencing market behaviour. Complexity in infrastructure projects arises from technical, organisational, and external factors, such as scope uncertainties, multidisciplinary collaboration, and diverse stakeholder involvement. Addressing both inherent and perceived complexity is key to developing adaptive contracting strategies that better align with the demands of large infrastructure projects.

One proposed solution is segmenting large projects into smaller subprojects. This approach could isolate risks, reduce scale, and potentially improve pricing accuracy, resource allocation, and contractor

engagement. However, its feasibility and effectiveness require careful evaluation to ensure it truly enhances outcomes in the Dutch civil engineering sector.

Definitions

"Segmentation"
The process of dividing, or segmenting, the scope of a project into smaller, more manageable subprojects, or segments.

"Vertical segmentation"
Vertical segmentation divides a project into segments based on technical discipline, also known as functional segmentation.

"Horizontal segmentation"
Horizontal segmentation divides a project into segments based on geographic location, also known as geographical segmentation.

"Segmented project delivery method"
An umbrella term for various segmented project delivery methods that result from the application of segmentation to a project delivery method.

"Segmented contracting"
The comprehensive approach to implementing segmentation and a segmented project delivery method in a project, where each segment is individually legally contracted by the client to a contractor.

Note. The definitions of segmentation, vertical segmentation, horizontal segmentation, segmented project delivery methods, and segmented contracting presented in this thesis are self-defined by the writer to provide a clear and specific framework for the research.

Segmentation involves dividing a project into smaller, more manageable subprojects or segments to address specific elements of complexity. This method consistently leads to a "physical cut" in the project, creating distinct segments with inherently connected interfaces. Segmentation is categorised into two principal types: vertical and horizontal. Vertical segmentation organises a project based on the technical discipline of contractors within the same geographic location. Horizontal segmentation divides a project according to geographic location, with co-contractors operating in distinct geographic areas. In the realm of construction, the organisation of tasks and responsibilities is referred to as a project delivery method (known as "bouworganisatievorm" in Dutch), which outlines how tasks are distributed among the various participants in the construction process. By applying the principles of segmentation to a project delivery method, a segmented project delivery method is achieved. This concept serves as an umbrella term for various project delivery methods that incorporate segmentation principles. In this thesis, segmented contracting is defined as the comprehensive approach to implementing segmentation and segmented project delivery methods in a project, where each segment is individually legally contracted by the client to a contractor or a consortium of contractors. It is important to note that segmented contracting should not be confused with merely the legal contracting of segments. Instead, it refers to a holistic strategy that includes planning, coordination, integration, overall management, and implementation of segmentation and segmented project delivery methods to effectively address the complexities inherent in complex infrastructure projects. Segmented contracting (often) results in co-contractors working on different segments of the project, whether these segments are divided by horizontal or vertical segmentation. However, it is important to note that segmented contracting is not limited to engaging multiple contractors because

each segment can also be awarded to the same contractor. In this research, a consortium of contractors is treated as a single contractor unless explicitly stated otherwise.

As segmented contracting often involves co-contractors, it is crucial to understand the concept of co-contracting and the co-contracting project delivery method. The definition of co-contractors is consistent across various segmented project delivery methods, making it a fundamental aspect of segmented contracting. In the co-contracting project delivery method, each contractor is responsible for a specific part of the project scope. These contractors, working alongside each other on different parts of the project scope, are referred to as ‘nevenaannemers’ or co-contractors. The co-contractors typically do not have a contractual relationship with each other, but only with the client. However, their work is often closely interlinked, with one contractor’s output frequently building upon another’s.

Understanding the difference between segmented contracting and tendering with lots is crucial, as both involve breaking down projects into smaller parts but differ fundamentally in approach and implications. Segmented contracting breaks a project into smaller subprojects or segments, each with its own tender process, often distributed over time, and requires high interrelatedness, coordination, and integration due to the "physical cut" between segments. Conversely, tendering with lots involves a single tender process for all lots simultaneously, with no "physical cut," leading to lower interrelatedness and coordination requirements.

Rationale for research

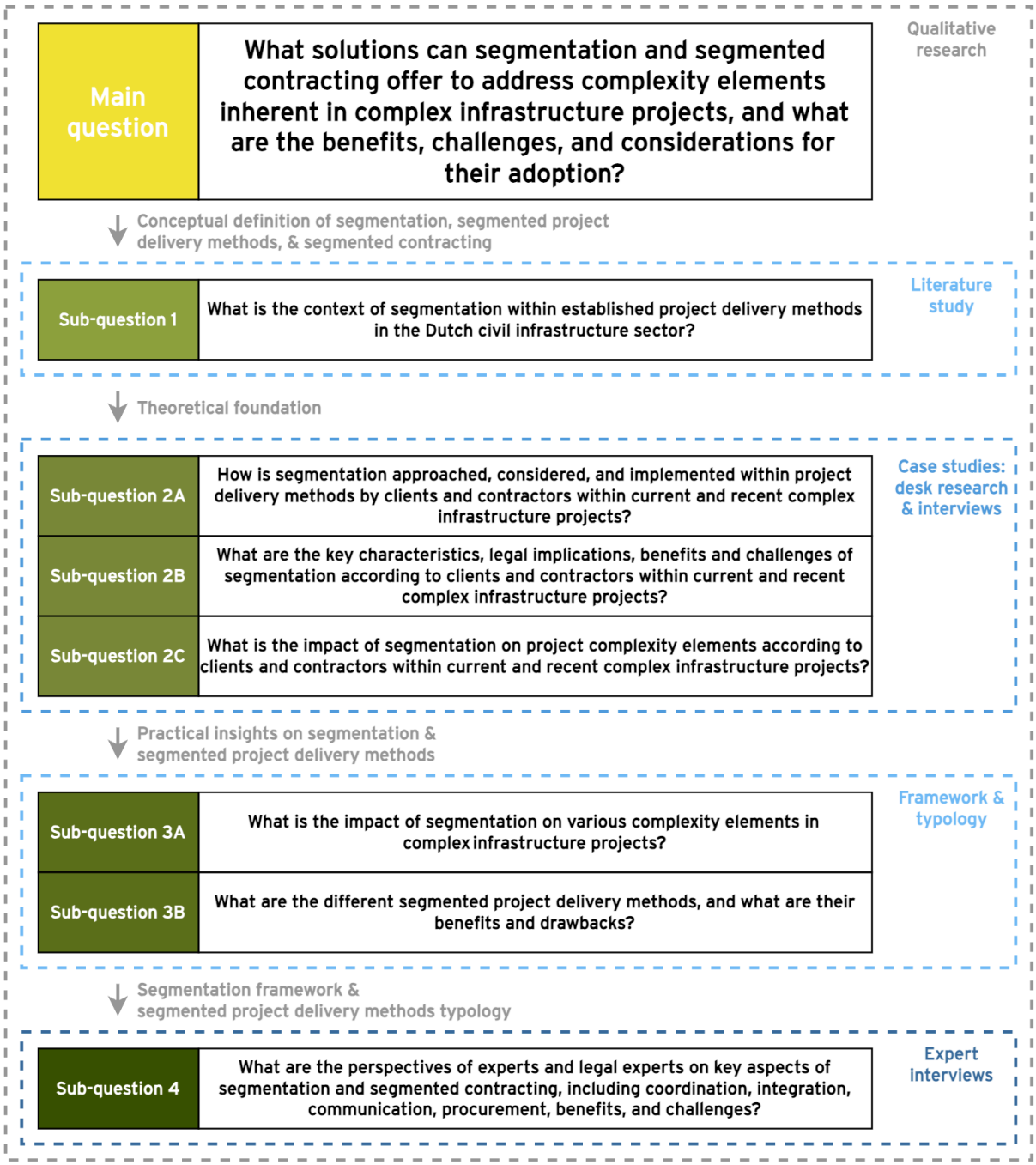
The significance of well-developed infrastructure for societal well-being, economic growth, and quality of life underscores the need for this study. The challenges of aging infrastructure in the Netherlands and the shift from traditional contracts to more integrated forms highlight the importance of developing effective contracting strategies. Segmented contracting can optimise infrastructure development, ensuring it meets future demands and supports the continued growth of modern societies.

Research scope and goal

This research aims to enhance the understanding of segmented contracting among professionals managing and realising complex infrastructure projects (in the Netherlands). By providing a thorough and empirically backed examination of segmentation and segmented contracting, this effort extends beyond academic contributions. It seeks to influence industry practices by improving the comprehension of segmented contracting among clients, contractors, and consultants in the civil engineering sector. Additionally, the study examines how segmentation can address the complexities inherent in these projects, thereby promoting better management, enhancing market competition, and improving risk-reward dynamics. By dissecting these aspects, the study aims to offer practical and theoretical insights on strategic segmentation, ultimately enabling the sector to effectively tackle the massive upcoming replacement and renovation challenges.

Methodology

The research adopts an exploratory mixed methods design, incorporating a literature study, case studies, and expert interviews. The literature study establishes the context of segmentation within various project delivery methods. The case studies of five major Dutch infrastructure projects provide practical insights into the implementation and impacts of segmentation strategies. The development of a framework and typology for segmented project delivery methods offers a structured analysis of the impacts of segmentation. Expert interviews enrich the understanding of segmented contracting by capturing the perspectives of industry professionals.



Findings and conclusion

Sub-question 1	What is the context of segmentation within established project delivery methods in the Dutch civil infrastructure sector?

The literature study (3.6 Conclusion literature study) established that segmentation could operate within various project delivery methods, each presenting unique challenges and benefits related to coordination, risk management, and resource allocation. Traditional methods struggle with managing complexity due to the separation of design and construction phases, while integrated methods streamline these phases but place more risk on contractors. The design team method fosters early contractor involvement, improving project feasibility. The two-phase method enhances risk

management by separating design and construction phases, and co-contracting offers direct control over segments but demands robust coordination.

Sub-question 2A	How is segmentation approached, considered, and implemented within project delivery methods by clients and contractors within current and recent complex infrastructure projects?

Case studies (4.6 Conclusion of the case study) revealed that segmentation is approached strategically to manage project complexities. Clients and contractors divide projects into manageable segments based on specific technical and geographic challenges, facilitating better control, enhanced risk management, and precise budgeting. However, segmentation also presents challenges, such as ensuring seamless integration across interfaces, managing and coordinating multiple contractors, and addressing increased organisational complexities.

Sub-question 2B	What are the key characteristics, legal implications, benefits, and challenges of segmentation according to clients and contractors within current and recent complex infrastructure projects?

Segmentation enables specialised focus, improved risk management, and better control over project components. Legal implications involve the need for detailed contractual provisions to manage roles, responsibilities, and integration of segments. Benefits include enhanced efficiency, targeted risk management, and precise budgeting. Challenges include the need for robust coordination mechanisms, clear communication channels, and effective integration strategies to mitigate inefficiencies and delays.

Sub-question 2C	What is the impact of segmentation on project complexity elements according to clients and contractors within current and recent complex infrastructure projects?

Segmentation impacts project complexity elements in nuanced ways. While it reduces technical complexities by enabling focused management and specialised expertise, it increases organisational complexities due to the need for extensive coordination and integration efforts. For example, the Noord/Zuidlijn project demonstrated effective complexity management through segmentation but highlighted the necessity for stronger central oversight and clearer communication channels. The Schiphol-Amsterdam-Almere and Zuidasdok projects showed that segmentation enhances efficiency and focus but requires meticulous planning and robust project management to address coordination challenges. The Oranje Loper and Stadsdijken Zwolle projects further illustrated how segmentation improves project manageability and risk management.

Sub-question 3A	What is the impact of segmentation on various complexity elements in complex infrastructure projects?

The framework analysis (5.1 Segmentation) revealed that both horizontal and vertical segmentation offer unique advantages and challenges in managing complex infrastructure projects. Horizontal segmentation generally reduces complexity by allowing specific focus on geographic segments, leading to clearer strategies and execution plans. However, it introduces dependencies at segment interfaces, requiring meticulous coordination. Vertical segmentation leverages specialised expertise within functional areas, ensuring high standards and effective management of innovative technologies. However, it requires careful alignment of functions managed by different co-contractors, necessitating robust coordination mechanisms. The following framework highlights the most important elements, showcasing an important part of the overall framework.

	Complexity element	Type of segmentation	Impact of segmentation on complexity element	Remarks
T Technical complexity	High number of project goals	Horizontal segmentation	Generally reduces complexity by allowing the client and contractors to focus more specifically on the goals within each geographic segment. This focused management approach typically leads to clearer strategies and execution plans, thereby reducing the overall project complexity.	The Noord/Zuidlijn, SAA, and Zuidasdok projects were characterised by many goals addressing a wide range of development objectives, significantly contributing to their complexities. Segmentation allowed for clearer focus on specific goals within each segment and facilitated more focused management of each segment's objectives, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly, vertical segmentation often reduces complexity by allowing each co-contractor to concentrate on achieving specific functional goals. This separation enables each segment to work towards its objectives more effectively, decreasing the project's overall complexity.	
	Uncertainties in scope	Horizontal segmentation	Typically decreases complexity by enabling the client and contractors to manage uncertainties within each geographic segment. This approach allows for adjustments and changes to be confined to specific segments, improving overall project adaptability.	Projects like Noord/Zuidlijn, SAA, Zuidasdok, and Oranje Loper often encountered significant scope uncertainties, contributing to their compelxities. Segmentation helped manage these uncertainties by confining changes to specific segments, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly reduces complexity by allowing co-contractors to manage uncertainties within their specific functional areas. This targeted approach ensures that scope changes are handled within each segment, reducing the project's overall complexity.	
	Project duration	Horizontal segmentation	Can often reduce the overall project duration by enabling multiple segments to progress concurrently. The client and contractors benefit from parallel advancements, although this requires effective coordination to ensure alignment across segments. The net effect is typically a decrease in project complexity.	The extended timelines of the Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle projects introduced significant complexities. Segmentation enabled phased initiation and parallel progress in multiple segments, which helped reduce the overall project duration by allowing some segments to begin while others were still being planned or executed. This effectively decreased the contribution to the project's complexity.
		Vertical segmentation	Frequently streamlines timelines within functional segments by allowing co-contractors to advance independently. This approach mitigates delays caused by interdependencies, although it demands careful coordination, potentially adding some complexity.	
	Size in CAPEX	Horizontal segmentation	Often increases complexity due to the need to manage multiple budgets and contracts, leading to higher transaction costs. However, it also enhances financial control by breaking down large investments into smaller, more manageable segments. This allows the client to track expenses more accurately and allocate resources efficiently, reducing risk exposure.	Projects like Noord/Zuidlijn, SAA, and Zuidasdok involved substantial capital expenditures, contributing significantly to their complexities. While segmentation increased transaction costs due to managing multiple budgets and contracts, it also enhanced financial manageability by dealing with smaller budgets per segment, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly increases complexity by necessitating multiple budget allocations and contract management, also resulting in higher transaction costs. However, it improves financial oversight within each functional segment, making it easier for the client and co-contractors to control costs and manage financial risks.	
	High number of tasks	Horizontal segmentation	Often reduces complexity by distributing tasks across multiple geographic segments, improving manageability. Each contractor can handle a specific set of tasks, which reduces the overall workload on any single team and allows for more effective task management.	A multitude of tasks, as seen in Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle, contributed significantly to project complexity. Segmentation did not directly reduce the number of tasks but allowed for their division among multiple contractors, making management more effective and decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly reduces complexity by dividing tasks among specialised technical teams. Each co-contractor can focus on tasks related to their functional area, enhancing efficiency and reducing the potential for task overload.	

T Technical complexity	Dependencies between tasks	Horizontal segmentation	Generally results in fewer dependencies within each geographic segment, allowing for more straightforward management of tasks by the client and contractors. However, it increases the complexity at the interfaces between segments, as coordination is required to ensure seamless integration between geographic areas. This means while tasks within a segment are less dependent on each other, the dependency shifts to managing the boundaries between segments, often complicating the overall project.	Managing interdependencies between tasks added significant complexity to projects like Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle. Horizontal segmentation reduced dependencies within segments but increased complexity at interfaces. Vertical segmentation increased dependencies at interfaces with horizontally segmented segments, maintaining a high contribution to the project's complexity.
		Vertical segmentation	Often increases complexity by requiring alignment of functions managed by different co-contractors. Each functional segment depends on the others to progress effectively, meaning careful coordination is necessary to align their work. This frequently results in increased interdependencies and potential for misalignment, thereby increasing the project's overall complexity.	
	Technical risks	Horizontal segmentation	Typically decreases complexity by containing risks within geographic segments, allowing for targeted risk management strategies. However, it introduces interface complexities that need careful management to ensure overall project safety.	Technical risks, such as structural impacts and unforeseen conditions, were significant in projects like Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle. Segmentation allowed for specialised contractors to manage these risks more effectively. However, it also introduced additional complexities at interfaces, maintaining a high contribution to the project's complexity.
		Vertical segmentation	Often reduces complexity within functional segments by leveraging specialised expertise to manage technical risks. However, it increases interface risks between horizontally segmented areas, requiring careful coordination to mitigate these risks.	
O Organisational complexity	Interfaces between different disciplines	Horizontal segmentation	Generally increases complexity due to enhanced coordination and integration needs across geographic segments. Ensuring seamless integration across segments requires meticulous planning and management by the client and contractors, increasing the project's organisational complexity.	Managing interfaces between different technical and organisational disciplines was crucial and complex, contributing substantially to the project's complexity. Segmentation significantly increased the complexity of managing these interfaces due to the need for heightened coordination and integration across segments. This was particularly evident in projects like SAA and Zuidasdok, where ensuring cohesive integration across different construction activities added a layer of complexity, thereby increasing the contribution to the project's complexity.
		Vertical segmentation	Also increases complexity by requiring careful management of interfaces between technical disciplines. Coordination and integration across functional segments is crucial to ensure that all components integrate smoothly, adding to the project's complexity.	
	Number of contracts	Horizontal segmentation	Typically increases complexity by necessitating multiple contracts for each geographic segment. This adds administrative overhead and requires careful management to ensure all contracts align with the overall project objectives.	Segmentation invariably resulted in an increase in the number of contracts, as the project was divided into smaller, more manageable segments, each requiring its own contractual arrangement. This led to an increase in the contribution to the project's complexity across all cases, such as Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle, due to the higher transaction costs and administrative burdens associated with managing multiple contracts.
		Vertical segmentation	Often has a similar impact, increasing the number of contracts for each functional segment. This requires detailed contract management to ensure that all segments meet their specific requirements while aligning with the broader project goals.	
	Type of contract	Horizontal segmentation	Horizontal segmentation often results in a variety of contract types, as different geographic locations require distinct contractual approaches. This variety increases the contribution to the project's complexity due to the need for coordinating different contractual terms and ensuring compliance across all segments	Segmentation resulted in a variety of contract types being used in projects, ranging from traditional contracts to more integrated Design and Construct contracts. This variety necessitated distinct management approaches for each contract type, increasing the contribution to the project's complexity.
		Vertical segmentation	Vertical segmentation often results in a variety of contract types, as different functions require distinct contractual approaches. This variety	

O Organisational complexity			increases the contribution to the project's complexity due to the need for coordinating different contractual terms and ensuring compliance across all segments	
	Organisational risks	Horizontal segmentation	Often increases complexity due to the need for alignment across multiple geographic segments. Ensuring all segments work towards the overall project goals requires careful coordination, integration, and management by the client and contractors, adding to the project's organisational risks	The client faced significant organisational risks in managing and coordinating mega infrastructure projects, contributing very much to the project's complexity. Segmentation often complicated the management of these projects due to the increased number of segments, interfaces, and contractors involved. This was particularly challenging in projects like Noord/Zuidlijn, SAA, Zuidasdok, and Oranje Loper, where the added complexity of managing multiple segments and their interdependencies increased the contribution to the project's complexity. However, in some cases like Stadsdijken Zwolle, segmentation helped streamline coordination and improve financial planning and control, thereby aiding in more effective management of budget allocation and cost control, thus slightly decreasing organisational risks.
		Vertical segmentation	Generally increases complexity similarly by requiring coordination and integration across functional segments. Managing the interdependencies between segments is crucial to maintaining project cohesion and success, increasing the project's organisational risks.	
E External complexity	Lack of resource & skills availability	Horizontal segmentation	Generally decreases complexity by allowing for the specialised allocation of resources and skills within each geographic segment. This enables more effective utilisation of available resources and reduces the project's overall complexity.	There was often a deficiency in the availability of required skills and resources, particularly in specialised areas critical to the project's success, significantly contributing to the project's complexity. Segmentation allowed for more precise allocation of necessary resources and skills within specific segments, thus decreasing the contribution to the project's complexity. This was notably beneficial in projects like Noord/Zuidlijn and Oranje Loper, where specialised contractors could focus on their areas of expertise.
		Vertical segmentation	Often decreases complexity similarly by concentrating specialised resources and skills within functional segments. This allows for more efficient resource management and reduces the project's overall complexity.	
	Dependencies on external stakeholders	Horizontal segmentation	Often decreases complexity by allowing specific stakeholder interactions within geographic segments. This simplifies stakeholder management for the client and contractors and reduces the range of concerns and negotiations needed at any one time.	Dependencies on various external stakeholders, including governmental bodies for subsidies and approvals, contractors for construction, and the public for support and feedback, contributed very much to the project's complexity in projects like Noord/Zuidlijn, SAA, and Zuidasdok. Segmentation did not change the dependencies on stakeholders but allowed for more effective management by dealing with stakeholders on a per-segment basis. This approach helped in managing these dependencies more effectively, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Typically decreases complexity similarly by aligning stakeholder management with functional segments. This allows for more focused and effective interactions with external stakeholders, reducing the project's overall complexity.	
	Number of external stakeholders	Horizontal segmentation	Often decreases complexity by aligning specific stakeholder groups with relevant geographic segments. This simplifies the management of external stakeholders by reducing the number of interactions required for each segment.	Interacting with a wide array of external stakeholders, such as city residents, businesses, commuters, local government agencies, and environmental groups, added significant complexity to projects like Noord/Zuidlijn, SAA, and Zuidasdok. Segmentation did not reduce the number of external stakeholders but allowed for more focused attention within each segment. This approach simplified stakeholder management, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly reduces complexity by aligning stakeholder groups with functional segments. This targeted approach to stakeholder management simplifies interactions and reduces the project's overall complexity.	

Sub-question 3B	What are the different segmented project delivery methods, and what are their benefits and drawbacks?

The typology of segmented project delivery methods (5.2 Segmented project delivery methods) includes segmented traditional, integrated, design team, and two-phase project delivery methods. Each model offers distinct approaches to managing complexities, with specific benefits and challenges. The segmented traditional method allows direct control over segments but demands robust coordination. The segmented integrated method streamlines phases but places more risk on the

contractor. The segmented design team method fosters early contractor involvement, improving feasibility. The segmented two-phase method separates design and construction phases, enhancing risk management. However, all segmented project delivery methods present challenges such as the need for effective coordination, communication, and integration.

Note: Segmented design team 2.0 project delivery method excluded for figure clarity. The segmented traditional project delivery method illustrates segmentation during both the procurement and realisation phases. However, segmentation can also occur during the design phase, depending on project needs. Similarly, the segmented design team project delivery method demonstrates segmentation during the realisation phase but can also be applied during the procurement and design team phases based on project requirements.

Sub-question 4	What are the perspectives of experts and legal experts on key aspects of segmentation and segmented contracting, including coordination, integration, communication, procurement, benefits, and challenges?

Expert interviews (6.1.9 Conclusion expert interviews and 6.2.5 Conclusion legal expert interviews) highlighted the importance of early and strategic planning, robust coordination mechanisms, transparent communication, and flexible legal frameworks for effective segmentation. Experts emphasised the need for seamless integration and coordination across segments to prevent inefficiencies and delays. They also underscored the importance of well-defined coordination agreements and detailed contractual provisions. Legal experts stressed the necessity of comprehensive coordination agreements, clear communication protocols, and robust risk allocation strategies. Both groups recognised the benefits of segmentation in improving manageability and efficiency but cautioned about the risks to collaborative partnerships and the need for meticulous planning and strategic management.

Main question	What solutions can segmentation and segmented contracting offer to address complexity elements inherent in complex infrastructure projects, and what are the benefits, challenges, and considerations for their adoption?

Segmentation, segmented project delivery methods, and segmented contracting offer several solutions to address complexity elements in complex infrastructure projects. By breaking down projects into smaller, manageable segments, clients and contractors can allocate resources and expertise more effectively, tailor risk management strategies, and maintain better control over budgets and schedules. This approach facilitates specialised focus on specific tasks, enhances project manageability, and improves the predictability of project outcomes. Segmentation enables targeted attention on specific project components, allowing teams to apply specialised expertise where it is most needed. By isolating risks within specific segments, clients and contractors can develop tailored mitigation strategies and enhance overall project stability. Additionally, segmentation facilitates better financial oversight and resource allocation, helping to keep projects within budgetary constraints. This method allows for the segmentation of projects to adapt more easily to changes and unforeseen circumstances, ensuring timely completion and high-quality outcomes.

However, segmentation also presents significant challenges. Ensuring seamless integration across segments requires robust coordination mechanisms and clear communication protocols. Without these, projects can face inefficiencies, increased risks, and potential delays. The segmentation introduces additional administrative overhead and transaction costs, necessitating strict planning and strategic management. Moreover, segmentation might disrupt the natural synergies that arise from teamwork and shared responsibilities, potentially leading to an "every man for himself" mentality. This shift may necessitate a different approach from contractors, who could become co-contractors in a segmented project, requiring them to adapt their collaboration strategies to achieve successful outcomes. Detailed contractual provisions are necessary to manage roles, responsibilities, and integration of segments. Adjustments to standard contracts are often required to accommodate the specific demands of segmented projects. For the adoption of segmentation, early and thorough planning is crucial to define clear segments based on functionality or geography. Comprehensive coordination agreements that outline roles, responsibilities, procedures for coordination failure, and conflict resolution mechanisms are essential. Clear communication agreements detailing update frequency, communication channels, and responsibilities are vital for optimising collaboration. Adjustments to standard contracts and the inclusion of supplementary agreements are necessary to support the dynamic needs of segmented projects. Strong central oversight and clear communication channels are vital to handle dependencies and interactions between segments effectively.

In conclusion, segmentation, segmented project delivery methods, and segmented contracting provide valuable solutions for managing the complexities inherent in complex infrastructure projects. By adopting these strategies and addressing the associated challenges through strict planning, robust coordination, and flexible legal frameworks, clients and contractors can enhance project manageability, improve efficiency, and achieve successful outcomes in complex infrastructure projects.

Summary (NL)

Introductie

Nederland staat voor een grote uitdaging in het vernieuwen van zijn verouderde civiele infrastructuur in de komende decennia. Wegen, bruggen, viaducten, sluizen, stuwen, kades en rioleringssystemen bereiken het einde van hun technische levensduur. Het intensieve gebruik van deze structuren, vaak meer dan oorspronkelijk verwacht, onderstreept de dringende noodzaak van vervaning en renovatie om de veiligheid, leefbaarheid en toegankelijkheid van het land te waarborgen. Deze infrastructuurvernieuwing is een omvangrijke onderneming die de lokale omgeving en de toegankelijkheid van wegen en waterwegen beïnvloedt.

Naast de noodzaak van vernieuwing is er een dringende vraag naar het uitvoeren van deze maatregelen op een klimaatneutrale en circulaire manier. De Nederlandse regering heeft ambitieuze doelen gesteld, zoals een CO2-reductie van 55% in 2030 en het bereiken van een volledig circulaire economie in 2050. Rijkswaterstaat, het Ministerie van Infrastructuur en Waterstaat en andere marktdeelnemers staan voor evoluerende taken en dynamieken, zoals duurzaamheidsdoelstellingen, beperkte maatschappelijke acceptatie van verstoringen en de behoefte aan geavanceerde projectmanagementstrategieën. Deze uitdagingen zijn vooral groot voor grote en complexe projecten, die vaak kenmerken van een imperfecte markt vertonen, waarbij Rijkswaterstaat de enige terugkerende opdrachtgever is voor belangrijke projecten.

De renovatie van de Van Brienenoordbrug, gestart in 2022, is een voorbeeld van deze uitdagingen. Het project benadrukt de dringende noodzaak van infrastructuurvernieuwing, in lijn met duurzaamheid- en circulariteitsprincipes. Het weerspiegelt echter ook de beperkte interesse van aannemers in dergelijke complexe projecten, waarbij prominente aannemers zich terugtrekken vanwege waargenomen onevenredige risico's. Deze situatie heeft een cruciaal debat aangewakkerd over de effectiviteit van bestaande aanbestedingsprocessen en de noodzaak van innovatieve contracteringsstrategieën die gericht zijn op samenwerkingsgericht contractmanagement.

Probleemanalyse

Het abrupte stopzetten van het aanbestedingsproces van het Van Brienenoordbrug-project in 2024 onderstreept de inherente complexiteit en beperkingen van het beheren van grootschalige, risicovolle infrastructuurprojecten. Deze ontwikkeling benadrukt de kritieke noodzaak van een evenwichtige risicodeling tussen opdrachtgevers en aannemers. Het falen van dit aanbestedingsproces dient als een leermoment en benadrukt de noodzaak voor opdrachtgevers en aannemers om de manier waarop risico's worden gedeeld en beheerd in toekomstige projecten te herzien. Innovatieve, aanpasbare contracteringsstrategieën zijn essentieel voor het aantrekken van capabele aannemers en het verzekeren van de succesvolle realisatie van cruciale infrastructuurprojecten.

De huidige marktdynamiek en benaderingen van risico's, vooral in grote en complexe projecten, benadrukken een dringende behoefte aan veranderingen om gezonde concurrentie aan te moedigen. Aannemers hebben moeite om risico's adequaat te prijzen, vooral wanneer nieuwe ontwerpoplossingen en technieken betrokken zijn. Deze moeilijkheid wordt verergerd door de variërende capaciteiten van bieders om risico's te identificeren en te beperken. De trend van lage biedpraktijken, gedreven door de vraag naar innovatieve en kosteneffectieve ontwerpen, heeft geleid tot minder aannemers die bereid zijn deel te nemen aan risicovolle aanbestedingen vanwege de bijbehorende financiële en operationele risico's.

Projectcomplexiteit is een cruciale factor die het marktgedrag beïnvloedt. De complexiteit van infrastructuurprojecten ontstaat door technische, organisatorische en externe factoren, zoals

onzekerheden in de scope, multidisciplinaire samenwerking en de betrokkenheid van diverse belanghebbenden. Het adresseren van zowel de inherente als de waargenomen complexiteit is essentieel voor het ontwikkelen van adaptieve contractstrategieën die beter aansluiten bij de eisen van grootschalige infrastructuurprojecten.

Een voorgestelde oplossing is het opdelen van grote projecten in kleinere subprojecten. Deze aanpak kan helpen om risico's te isoleren, de schaal te verkleinen en mogelijk de nauwkeurigheid van prijsbepaling, resourceallocatie en betrokkenheid van aannemers te verbeteren. De haalbaarheid en effectiviteit hiervan moeten echter zorgvuldig worden beoordeeld om te waarborgen dat het daadwerkelijk leidt tot betere resultaten in de Nederlandse civiele techniekssector.

Definities

"Segmenteren"
Het proces waarbij de scope van een project wordt opgedeeld, of gesegmenteerd, in kleinere, beter beheersbare subprojecten, of segmenten.

"Verticale segmentatie"
Verticale segmentatie verdeelt een project in segmenten op basis van technische discipline, ook wel functionele segmentatie genoemd.

"Horizontale segmentatie"
Horizontale segmentatie verdeelt een project in segmenten op basis van geografische locatie, ook wel geografische segmentatie genoemd.

"Gesegmenteerde bouworganisatievorm"
Een overkoepelende term voor verschillende gesegmenteerde bouworganisatievormen die voortvloeien uit de toepassing van segmentatie op een bouworganisatievorm.

"Gesegmenteerd contracteren"
De uitgebreide aanpak voor de implementatie van segmentatie en een gesegmenteerde bouworganisatievorm in een project, waarbij elk segment individueel juridisch wordt gecontracteerd door de opdrachtgever aan een aannemer of een consortium van aannemers.

Noot: De definities van segmenteren, verticale segmentatie, horizontale segmentatie, gesegmenteerde bouworganisatievormen en gesegmenteerd contracteren die in deze scriptie worden gepresenteerd, zijn zelf gedefinieerd door de auteur om een duidelijk en specifiek kader voor het onderzoek te bieden.

Segmenteren houdt in dat een project wordt opgedeeld in kleinere, beter beheersbare subprojecten of segmenten om specifieke elementen van complexiteit aan te pakken. Deze methode leidt consistent tot een "fysieke knip" in het project, waarbij duidelijke segmenten met inherent verbonden interfaces ontstaan. Segmentatie wordt ingedeeld in twee hoofdcategorieën: verticaal en horizontaal. Verticale segmentatie organiseert een project op basis van de technische discipline van aannemers binnen dezelfde geografische locatie. Horizontale segmentatie verdeelt een project op basis van geografische locatie, waarbij nevenaannemers in verschillende geografische gebieden opereren.

In de bouwsector wordt de organisatie van taken en verantwoordelijkheden aangeduid als een bouworganisatievorm, die beschrijft hoe taken worden verdeeld onder de verschillende deelnemers aan het bouwproces. Door de principes van segmentatie toe te passen op een bouworganisatievorm,

ontstaat een gesegmenteerde bouworganisatievorm. Dit concept fungeert als een overkoepelende term voor verschillende bouworganisatievormen die segmentatieprincipes integreren.

In deze scriptie wordt gesegmenteerd contracteren gedefinieerd als de uitgebreide aanpak voor de implementatie van segmentatie en gesegmenteerde bouworganisatievormen in een project, waarbij elk segment individueel juridisch wordt gecontracteerd door de opdrachtgever aan een aannemer of een consortium van aannemers. Het is belangrijk op te merken dat gesegmenteerd contracteren niet moet worden verward met enkel het juridisch contracteren van segmenten. In plaats daarvan verwijst het naar een holistische strategie die planning, coördinatie, integratie, algemeen management en implementatie van segmentatie en gesegmenteerde bouworganisatievormen omvat om de complexiteit inherent aan complexe infrastructuurprojecten effectief aan te pakken. Gesegmenteerd contracteren resulteert vaak in nevenaannemers die aan verschillende segmenten van het project werken, of deze segmenten nu horizontaal of verticaal zijn verdeeld. Het is echter belangrijk op te merken dat gesegmenteerd contracteren niet beperkt is tot het betrekken van meerdere aannemers, aangezien elk segment ook aan dezelfde aannemer kan worden gegund. In dit onderzoek wordt een consortium van aannemers behandeld als een enkele aannemer, tenzij expliciet anders vermeld.

Relevantie

Het belang van goed ontwikkelde infrastructuur voor het welzijn van de samenleving, economische groei en de kwaliteit van leven onderstreept de noodzaak van deze studie. De uitdagingen van verouderde infrastructuur in Nederland en de verschuiving van traditionele contracten naar meer geïntegreerde vormen benadrukken het belang van het ontwikkelen van effectieve contractstrategieën. Gesegmenteerd contracteren kan de ontwikkeling van infrastructuur optimaliseren, zodat deze voldoet aan toekomstige eisen en de voortdurende groei van moderne samenlevingen ondersteunt.

Afbakening en doelstelling

Dit onderzoek heeft tot doel het begrip van gesegmenteerd contracteren te vergroten onder professionals die complexe infrastructuurprojecten in Nederland beheren en realiseren. Door een grondige en empirisch onderbouwde studie van segmentatie en gesegmenteerd contracteren te bieden, reikt deze inspanning verder dan academische bijdragen. Het beoogt de praktijk in de sector te beïnvloeden door het begrip van gesegmenteerd contracteren te verbeteren bij opdrachtgevers, aannemers en consultants in de civiele techniek. Daarnaast onderzoekt de studie hoe segmentatie kan helpen bij het aanpakken van de complexiteit die inherent is aan deze projecten, waardoor beter beheer, verbetering van de marktconcurrentie en een betere balans tussen risico en beloning wordt bevorderd. Door deze aspecten te analyseren, streeft de studie ernaar praktische en theoretische inzichten te bieden over strategische segmentatie, zodat de sector effectief de enorme uitdagingen van aankomende vervangings- en renovatieprojecten kan aanpakken.

Methodologie

Het onderzoek maakt gebruik van een verkennend “mixed-methods” ontwerp, waarbij een literatuurstudie, casestudy’s en expertinterviews worden gecombineerd. De literatuurstudie schetst de context van segmentatie binnen verschillende bouworganisatievormen. De casestudy’s van vijf grote Nederlandse infrastructuurprojecten bieden praktische inzichten in de implementatie en effecten van segmentatiestrategieën. De ontwikkeling van een raamwerk en typologie voor gesegmenteerde bouworganisatievormen biedt een gestructureerde analyse van de effecten van segmentatie. Expertinterviews verrijken het begrip van gesegmenteerd contracteren door de perspectieven van professionals uit de sector vast te leggen.

Bevindingen en conclusie

Deelvraag 1	Wat is de context van segmenteren binnen de gevestigde bouworganisatievormen in de Nederlandse civiele infrastructuursector?

Uit de literatuurstudie (3.6 Conclusie literatuurstudie) bleek dat segmenteren kan worden toegepast binnen verschillende bouworganisatievormen, waarbij elke vorm unieke uitdagingen en voordelen biedt met betrekking tot coördinatie, risicomanagement en toewijzing van middelen. Traditionele methoden hebben moeite met het beheren van complexiteit door de scheiding van ontwerp- en bouwfasen, terwijl geïntegreerde methoden deze fasen stroomlijnen maar meer risico's bij aannemers leggen. De bouwteam methode bevordert vroege betrokkenheid van de aannemer, wat de haalbaarheid van het project verbetert. De twee-fasen methode verbetert risicomanagement door

ontwerp- en bouwfasen te scheiden, en nevenaanneming biedt directe controle over segmenten maar vereist robuuste coördinatie.

Deelvraag 2A	**Hoe wordt segmenteren benaderd, overwogen en geimplementeerd binnen bouworganisatievormen door opdrachtgevers en aannemers in huidige en recente complexe infrastructuurprojecten?**

Uit de casestudy's (4.6 Conclusie van de casestudy) bleek dat segmenteren strategisch wordt benaderd om projectcomplexiteiten te beheren. Opdrachtgevers en aannemers verdelen projecten in beheersbare segmenten op basis van specifieke technische en geografische uitdagingen, wat leidt tot betere controle, verbeterd risicomanagement en nauwkeurige budgettering. Echter, segmenteren brengt ook uitdagingen met zich mee, zoals het waarborgen van naadloze integratie over interfaces, het beheren en coördineren van meerdere aannemers, en het aanpakken van toegenomen organisatorische complexiteiten.

Deelvraag 2B	**Wat zijn de belangrijkste kenmerken, juridische implicaties, voordelen en uitdagingen van segmenteren volgens opdrachtgevers en aannemers in huidige en recente complexe infrastructuurprojecten?**

Segmenteren stelt in staat tot gespecialiseerde focus, verbeterd risicomanagement en betere controle over projectonderdelen. Juridische implicaties omvatten de noodzaak van gedetailleerde contractuele bepalingen om rollen, verantwoordelijkheden en integratie van segmenten te beheren. Voordelen zijn onder andere verbeterde efficiëntie, gericht risicomanagement en nauwkeurige budgettering. Uitdagingen omvatten de noodzaak voor robuuste coördinatiemechanismen, duidelijke communicatiekanalen en effectieve integratiestrategieën om inefficiënties en vertragingen te verminderen.

Deelvraag 2C	**Wat is de impact van segmenteren op projectcomplexiteitselementen volgens opdrachtgevers en aannemers in huidige en recente complexe infrastructuurprojecten?**

Segmenteren heeft op genuanceerde wijze invloed op projectcomplexiteitselementen. Hoewel het technische complexiteiten vermindert door gerichte beheersing en gespecialiseerde expertise mogelijk te maken, verhoogt het organisatorische complexiteiten door de behoefte aan uitgebreide coördinatie- en integratie-inspanningen. Bijvoorbeeld, het Noord/Zuidlijn project toonde effectief complexiteitsbeheer door segmenteren, maar benadrukte de noodzaak voor sterkere centrale supervisie en duidelijkere communicatiekanalen. De projecten Schiphol-Amsterdam-Almere en Zuidasdok lieten zien dat segmenteren efficiëntie en focus verhoogt, maar vereisen zorgvuldige planning en robuust projectmanagement om coördinatie-uitdagingen aan te pakken. De projecten Oranje Loper en Stadsdijken Zwolle illustreerden verder hoe segmenteren de beheersbaarheid en het risicomanagement van projecten verbetert.

Deelvraag 3A	**Wat is de impact van segmenteren op verschillende complexiteitselementen in complexe infrastructuurprojecten?**

Uit de raamwerkanalyse (5.1 Segmenteren) bleek dat zowel horizontaal als verticaal segmenteren unieke voordelen en uitdagingen biedt bij het beheren van complexe infrastructuurprojecten. Horizontaal segmenteren vermindert over het algemeen complexiteit door specifieke focus op geografische segmenten mogelijk te maken, wat leidt tot duidelijkere strategieën en uitvoeringsplannen. Echter, het introduceert afhankelijkheden bij segmentinterfaces, wat nauwkeurige coördinatie vereist. Verticaal segmenteren benut gespecialiseerde expertise binnen functionele gebieden, wat zorgt voor hoge standaarden en effectief beheer van innovatieve technologieën. Echter,

het vereist zorgvuldige afstemming van functies die door verschillende nevenaannemers worden beheerd, wat robuuste coördinatiemechanismen noodzakelijk maakt. Het volgende raamwerk benadrukt de belangrijkste elementen, wat een belangrijk deel van het totale raamwerk toont.

	Complexiteitselement	Type segmentatie	Impact van segmentatie op complexiteit	Opmerkingen
T Technische complexiteit	Hoog aantal projectdoelen	Horizontale segmentatie	Vermindert over het algemeen de complexiteit door de opdrachtgever en aannemers in staat te stellen zich meer te concentreren op de doelen binnen elk geografisch segment. Deze gefocuste beheers benadering leidt meestal tot duidelijkere strategieën en uitvoeringsplannen, waardoor de algehele projectcomplexiteit afneemt.	De projecten Noord/Zuidlijn, SAA, en Zuidasdok werden gekenmerkt door veel doelen die een breed scala aan ontwikkelingsdoelstellingen aanspraken, wat significant bijdroeg aan de complexiteit van de projecten. Segmentatie zorgde voor een duidelijkere focus op specifieke doelen binnen elk segment en maakte meer gerichte beheersing van de doelen mogelijk, waardoor de bijdrage aan de complexiteit van het project afnam.
		Verticale segmentatie	Vermindert op vergelijkbare wijze vaak de complexiteit door elke nevenaannemer in staat te stellen zich te concentreren op het bereiken van specifieke functionele doelen. Deze scheiding maakt het voor elk segment mogelijk om effectiever naar zijn doelen te werken, waardoor de algehele projectcomplexiteit afneemt.	
	Onzekerheden in scope	Horizontale segmentatie	Vermindert typisch de complexiteit door de opdrachtgever en aannemers in staat te stellen onzekerheden binnen elk geografisch segment te beheren. Deze aanpak maakt aanpassingen en veranderingen mogelijk die beperkt blijven tot specifieke segmenten, waardoor het algehele projectaanpassingsvermogen verbetert.	Projecten zoals Noord/Zuidlijn, SAA, Zuidasdok, en Oranje Loper hadden vaak te maken met aanzienlijke onzekerheden in de scope, wat bijdroeg aan hun complexiteit. Segmentatie hielp deze onzekerheden te beheersen door wijzigingen te beperken tot specifieke segmenten, waardoor de bijdrage aan de projectcomplexiteit afnam.
		Verticale segmentatie	Vermindert op vergelijkbare wijze de complexiteit door nevenaannemers in staat te stellen onzekerheden binnen hun specifieke functionele gebieden te beheren. Deze gerichte aanpak zorgt ervoor dat scope-wijzigingen binnen elk segment worden afgehandeld, waardoor de algehele projectcomplexiteit afneemt.	
	Projectduur	Horizontale segmentatie	Kan vaak de totale projectduur verminderen door meerdere segmenten gelijktijdig te laten verlopen. De opdrachtgever en aannemers profiteren van parallelle voortgang, hoewel dit effectieve coördinatie vereist om afstemming over segmenten heen te waarborgen. Het netto-effect is meestal een vermindering van de projectcomplexiteit.	De lange tijdlijnen van de projecten Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, en Stadsdijken Zwolle introduceerden aanzienlijke complexiteiten. Segmentatie maakte gefaseerde initiatie en parallelle voortgang in meerdere segmenten mogelijk, wat hielp om de totale projectduur te verkorten door sommige segmenten te laten beginnen terwijl andere nog werden gepland of uitgevoerd. Dit verminderde effectief de bijdrage aan de complexiteit van het project.
		Verticale segmentatie	Vereenvoudigt vaak tijdlijnen binnen functionele segmenten door nevenaannemers onafhankelijk te laten voortschrijden. Deze aanpak vermindert vertragingen veroorzaakt door onderlinge afhankelijkheden, hoewel zorgvuldige coördinatie vereist is, wat enige complexiteit kan toevoegen.	
	Omvang in CAPEX	Horizontale segmentatie	Verhoogt vaak de complexiteit vanwege de noodzaak om meerdere budgetten en contracten te beheren, wat leidt tot hogere transactiekosten. Het verbetert echter ook de financiële controle door grote investeringen op te splitsen in kleinere, beter beheersbare segmenten. Dit stelt de opdrachtgever in staat om uitgaven nauwkeuriger te volgen en middelen efficiënt toe te wijzen, waardoor het risico wordt verminderd.	Projecten zoals Noord/Zuidlijn, SAA, en Zuidasdok omvatten aanzienlijke kapitaaluitgaven, wat aanzienlijk bijdroeg aan hun complexiteit. Hoewel segmentatie de transactiekosten verhoogde door het beheren van meerdere budgetten en contracten, verbeterde het ook de financiële beheersbaarheid door met kleinere budgetten per segment om te gaan, waardoor de bijdrage aan de complexiteit van het project afnam.
		Verticale segmentatie	Vergroot op vergelijkbare wijze de complexiteit door de noodzaak van meerdere budgettoewijzingen en contractbeheer, wat ook resulteert in hogere transactiekosten. Het verbetert echter het financieel overzicht	

T Technische complexiteit			binnen elk functioneel segment, waardoor het voor de opdrachtgever en nevenaannemers gemakkelijker wordt om kosten te beheersen en financiële risico's te beheren.	
	Hoog aantal taken	Horizontale segmentatie	Vermindert vaak de complexiteit door taken over meerdere geografische segmenten te verdelen, wat de beheersbaarheid verbetert. Elke aannemer kan een specifiek takenpakket afhandelen, wat de algehele werkdruk op elk team vermindert en effectiever taakbeheer mogelijk maakt.	Een groot aantal taken, zoals te zien in de projecten Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, en Stadsdijken Zwolle, droeg aanzienlijk bij aan de projectcomplexiteit. Segmentatie verminderde niet direct het aantal taken, maar maakte hun verdeling onder meerdere aannemers mogelijk, wat het beheer effectiever maakte en de bijdrage aan de complexiteit van het project verminderde.
		Verticale segmentatie	Vermindert op vergelijkbare wijze de complexiteit door taken te verdelen onder gespecialiseerde technische teams. Elke nevenaannemer kan zich richten op taken binnen hun functioneel gebied, wat de efficiëntie verhoogt en de kans op taakoverbelasting vermindert.	
	Afhankelijkheden tussen taken	Horizontale segmentatie	Leidt over het algemeen tot minder afhankelijkheden binnen elk geografisch segment, waardoor eenvoudiger taakbeheer door de opdrachtgever en aannemers mogelijk is. Het verhoogt echter de complexiteit bij de interfaces tussen segmenten, omdat coördinatie vereist is om naadloze integratie tussen geografische gebieden te waarborgen. Dit betekent dat terwijl taken binnen een segment minder afhankelijk van elkaar zijn, de afhankelijkheid verschuift naar het beheren van de grenzen tussen segmenten, wat vaak de algehele projectcomplexiteit compliceert.	Het beheren van onderlinge afhankelijkheden tussen taken voegde aanzienlijke complexiteit toe aan projecten zoals Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, en Stadsdijken Zwolle. Horizontale segmentatie verminderde afhankelijkheden binnen segmenten maar verhoogde de complexiteit bij de interfaces. Verticale segmentatie verhoogde afhankelijkheden bij interfaces met horizontaal gesegmenteerde segmenten, waardoor de bijdrage aan de projectcomplexiteit hoog bleef.
		Verticale segmentatie	Verhoogt vaak de complexiteit door de afstemming van functies beheerd door verschillende nevenaannemers te vereisen. Elk functioneel segment is afhankelijk van de anderen om effectief voortgang te boeken, wat zorgvuldige coördinatie vereist om hun werk af te stemmen. Dit resulteert vaak in verhoogde onderlinge afhankelijkheden en de kans op misalignment, waardoor de algehele projectcomplexiteit toeneemt.	
	Technische risico's	Horizontale segmentatie	Vermindert typisch de complexiteit door risico's binnen geografische segmenten te beheersen, wat gerichte risicobeheerstrategieën mogelijk maakt. Het introduceert echter interface-complexiteiten die zorgvuldig moeten worden beheerd om de algehele projectveiligheid te waarborgen.	Technische risico's, zoals structurele invloeden en onvoorziene omstandigheden, waren significant in projecten zoals Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, en Stadsdijken Zwolle. Segmentatie maakte het mogelijk voor gespecialiseerde aannemers om deze risico's effectiever te beheren. Het introduceerde echter ook extra complexiteiten bij interfaces, waardoor de bijdrage aan de complexiteit van het project hoog bleef.
		Verticale segmentatie	Vermindert vaak de complexiteit binnen functionele segmenten door gebruik te maken van gespecialiseerde expertise om technische risico's te beheren. Het verhoogt echter de interface-risico's tussen horizontaal gesegmenteerde gebieden, wat zorgvuldige coördinatie vereist om deze risico's te mitigeren.	
O Organisatorische complexiteit	**Interfaces tussen disciplines**	Horizontale segmentatie	Verhoogt over het algemeen de complexiteit vanwege de verhoogde coördinatie- en integratiebehoeften over geografische segmenten heen. Het waarborgen van naadloze integratie over segmenten vereist nauwgezette planning en beheer door de opdrachtgever en aannemers, wat de organisatorische complexiteit van het project verhoogt.	Het beheren van interfaces tussen verschillende technische en organisatorische disciplines was cruciaal en complex, wat aanzienlijk bijdroeg aan de projectcomplexiteit. Segmentatie verhoogde de complexiteit van het beheren van deze interfaces aanzienlijk vanwege de noodzaak voor verhoogde coördinatie en integratie over segmenten heen. Dit was vooral duidelijk in projecten zoals SAA en Zuidasdok, waar het waarborgen van samenhangende integratie over verschillende bouwactiviteiten een extra laag complexiteit toevoegde, waardoor de bijdrage aan de projectcomplexiteit toenam.
		Verticale segmentatie	Verhoogt ook de complexiteit door zorgvuldig beheer van interfaces tussen technische disciplines te vereisen. Coördinatie en integratie over functionele segmenten heen is cruciaal om ervoor te zorgen dat alle	

O Organisatorische complexiteit			componenten soepel integreren, wat bijdraagt aan de complexiteit van het project.	
	Aantal contracten	Horizontale segmentatie	Verhoogt typisch de complexiteit door de noodzaak van meerdere contracten voor elk geografisch segment. Dit voegt administratieve overhead toe en vereist zorgvuldig beheer om ervoor te zorgen dat alle contracten in lijn zijn met de algemene projectdoelen.	Segmentatie resulteerde onvermijdelijk in een toename van het aantal contracten, aangezien het project werd opgedeeld in kleinere, beter beheersbare segmenten, die elk hun eigen contractuele regeling vereisten. Dit leidde tot een toename van de bijdrage aan de projectcomplexiteit in alle gevallen, zoals Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, en Stadsdijken Zwolle, vanwege de hogere transactiekosten en administratieve lasten die gepaard gaan met het beheren van meerdere contracten.
		Verticale segmentatie	Heeft vaak een vergelijkbaar effect door het aantal contracten voor elk functioneel segment te verhogen. Dit vereist gedetailleerd contractbeheer om ervoor te zorgen dat alle segmenten aan hun specifieke eisen voldoen terwijl ze in lijn blijven met de bredere projectdoelen.	
	Type contract	Horizontale segmentatie	Leidt vaak tot een verscheidenheid aan contracttypen, omdat verschillende geografische locaties verschillende contractuele benaderingen vereisen. Deze verscheidenheid verhoogt de bijdrage aan de complexiteit van het project vanwege de noodzaak om verschillende contractuele voorwaarden te coördineren en naleving over alle segmenten te waarborgen.	Segmentatie resulteerde in een verscheidenheid aan contracttypen die in projecten werden gebruikt, variërend van traditionele contracten tot meer geïntegreerde Design and Construct-contracten. Deze verscheidenheid vereiste verschillende beheerbenaderingen voor elk contracttype, wat de bijdrage aan de complexiteit van het project verhoogde
		Verticale segmentatie	Leidt vaak tot een verscheidenheid aan contracttypen, omdat verschillende functies verschillende contractuele benaderingen vereisen. Deze verscheidenheid verhoogt de bijdrage aan de complexiteit van het project vanwege de noodzaak om verschillende contractuele voorwaarden te coördineren en naleving over alle segmenten te waarborgen.	
	Organisatorische risico's	Horizontale segmentatie	Verhoogt vaak de complexiteit vanwege de noodzaak van afstemming over meerdere geografische segmenten. Het waarborgen dat alle segmenten werken aan de algemene projectdoelen vereist zorgvuldige coördinatie, integratie en beheer door de opdrachtgever en aannemers, wat bijdraagt aan de organisatorische risico's van het project.	De opdrachtgever staat vaak voor aanzienlijke organisatorische risico's bij het beheren en coördineren van mega infrastructuurprojecten, wat veel bijdraagt aan de projectcomplexiteit. Segmentatie bemoeilijkte vaak het beheer van deze projecten vanwege het verhoogde aantal segmenten, interfaces en betrokken aannemers. Dit was vooral uitdagend in projecten zoals Noord/Zuidlijn, SAA, Zuidasdok, en Oranje Loper, waar de toegevoegde complexiteit van het beheren van meerdere segmenten en hun onderlinge afhankelijkheden de bijdrage aan de projectcomplexiteit verhoogde. In sommige gevallen, zoals Stadsdijken Zwolle, hielp segmentatie echter de coördinatie te stroomlijnen en de financiële planning en controle te verbeteren, wat bijdroeg aan een effectiever beheer van budgettoewijzing en kostenbeheersing, waardoor de organisatorische risico's enigszins afnamen.
		Verticale segmentatie	Verhoogt over het algemeen de complexiteit op vergelijkbare wijze door coördinatie en integratie over functionele segmenten te vereisen. Het beheren van de onderlinge afhankelijkheden tussen segmenten is cruciaal om projectcohesie en succes te behouden, wat de organisatorische risico's van het project verhoogt.	
E Externe complexiteit	**Beschikbaarheid van middelen en vaardigheden**	Horizontale segmentatie	Vermindert over het algemeen de complexiteit door de gespecialiseerde toewijzing van middelen en vaardigheden binnen elk geografisch segment mogelijk te maken. Dit stelt een effectievere benutting van beschikbare middelen mogelijk en vermindert de algehele complexiteit van het project.	Er was vaak een tekort aan de beschikbaarheid van vereiste vaardigheden en middelen, vooral in gespecialiseerde gebieden die cruciaal waren voor het succes van het project, wat aanzienlijk bijdroeg aan de projectcomplexiteit. Segmentatie maakte een nauwkeurigere toewijzing van benodigde middelen en vaardigheden binnen specifieke segmenten mogelijk, waardoor de bijdrage aan de projectcomplexiteit afnam. Dit was vooral gunstig in projecten zoals Noord/Zuidlijn en Oranje Loper, waar gespecialiseerde aannemers zich konden richten op hun expertisegebieden.
		Verticale segmentatie	Vermindert vaak op vergelijkbare wijze de complexiteit door gespecialiseerde middelen en vaardigheden binnen functionele segmenten te concentreren. Dit zorgt voor efficiënter middelenbeheer en vermindert de algehele complexiteit van het project.	

E Externe complexiteit	**Afhankelijkheden van externe belanghebbenden**	Horizontale segmentatie	Vermindert vaak de complexiteit door specifieke belanghebbende interacties binnen geografische segmenten mogelijk te maken. Dit vereenvoudigt het belanghebbende management voor de opdrachtgever en aannemers en vermindert het aantal zorgen en onderhandelingen die op enig moment nodig zijn.	Afhankelijkheden van verschillende externe belanghebbenden, waaronder overheidsinstanties voor subsidies en goedkeuringen, aannemers voor de bouw, en het publiek voor steun en feedback, droegen veel bij aan de projectcomplexiteit in projecten zoals Noord/Zuidlijn, SAA, en Zuidasdok. Segmentatie veranderde de afhankelijkheden van belanghebbenden niet, maar maakte een effectiever beheer mogelijk door met belanghebbenden per segment om te gaan. Deze aanpak hielp bij het effectiever beheren van deze afhankelijkheden, waardoor de bijdrage aan de projectcomplexiteit afnam.
		Verticale segmentatie	Vermindert typisch de complexiteit op vergelijkbare wijze door het belanghebbende management op functionele segmenten af te stemmen. Dit stelt gerichte en effectieve interacties met externe belanghebbenden mogelijk, wat de algehele complexiteit van het project vermindert.	
	Aantal externe belanghebbenden	Horizontale segmentatie	Vermindert vaak de complexiteit door specifieke belanghebbende groepen op relevante geografische segmenten af te stemmen. Dit vereenvoudigt het beheer van externe belanghebbenden door het aantal interacties dat voor elk segment nodig is te verminderen.	Afhankelijkheden van verschillende externe belanghebbenden, waaronder overheidsinstanties voor subsidies en goedkeuringen, aannemers voor de bouw, en het publiek voor steun en feedback, droegen veel bij aan de projectcomplexiteit in projecten zoals Noord/Zuidlijn, SAA, en Zuidasdok. Segmentatie veranderde de afhankelijkheden van belanghebbenden niet, maar maakte een effectiever beheer mogelijk door met belanghebbenden per segment om te gaan. Deze aanpak hielp bij het effectiever beheren van deze afhankelijkheden, waardoor de bijdrage aan de projectcomplexiteit afnam.
		Verticale segmentatie	Vermindert op vergelijkbare wijze de complexiteit door belanghebbende groepen op functionele segmenten af te stemmen. Deze gerichte aanpak van belanghebbende management vereenvoudigt interacties en vermindert de algehele complexiteit van het project.	

Deelvraag 3B	Wat zijn de verschillende gesegmenteerde bouworganisatievormen en wat zijn hun voordelen en nadelen?

De typologie van gesegmenteerde bouworganisatievormen (5.2 Gesegmenteerde bouworganisatievormen) omvat gesegmenteerde traditionele, geïntegreerde, bouwteam (2.0) en twee-fasen bouworganisatievormen. Elk model biedt verschillende benaderingen voor het beheren van complexiteiten, met specifieke voordelen en nadelen. De gesegmenteerde traditionele methode biedt directe controle over segmenten maar vereist robuuste coördinatie. De gesegmenteerde geïntegreerde methode stroomlijnt fasen maar legt meer risico bij de aannemer. De gesegmenteerde bouwteam methode bevordert vroege betrokkenheid van de aannemer, wat de haalbaarheid van het project verbetert. De gesegmenteerde twee-fasen methode scheidt ontwerp- en bouwfasen, wat het risicomanagement verbetert. Echter, alle gesegmenteerde bouworganisatievormen presenteren uitdagingen zoals de behoefte aan effectieve coördinatie, communicatie en integratie.

Noot: Voor de duidelijkheid van de figuur is de segmenteerde bouwteam bouworganisatievorm 2.0 uitgesloten. De gesegmenteerde traditionele bouworganisatievorm illustreert segmentatie tijdens zowel de aanbestedings- als realisatiefase. Echter, segmentatie kan ook plaatsvinden tijdens de ontwerpfase, afhankelijk van de projectbehoeften. Evenzo toont de gesegmenteerde bouwteam bouworganisatievorm segmentatie tijdens de realisatiefase, maar kan ook worden toegepast tijdens de aanbestedings- en bouwteamfase, afhankelijk van de projectvereisten.

Deelvraag 4	Wat zijn de perspectieven van experts en juridische experts op belangrijke aspecten van segmenteren en gesegmenteerd contracteren, inclusief coördinatie, integratie, communicatie, inkoop, voordelen en uitdagingen?

De interviews met experts (6.1.9 Conclusie interviews met experts, 6.2.5 Conclusie interviews met juridische experts) benadrukten het belang van vroege en strategische planning, robuuste coördinatiemechanismen, transparante communicatie en flexibele juridische kaders voor effectief segmenteren. Experts legden de nadruk op de noodzaak van naadloze integratie en coördinatie tussen

segmenten om inefficiënties en vertragingen te voorkomen. Ze onderstreepten ook het belang van goed gedefinieerde coördinatieafspraken en gedetailleerde contractuele bepalingen. Juridische experts benadrukten de noodzaak van uitgebreide coördinatieafspraken, duidelijke communicatieprotocollen en robuuste strategieën voor risicoverdeling. Beide groepen erkenden de voordelen van segmenteren bij het verbeteren van de beheersbaarheid en efficiëntie, maar waarschuwden voor de risico's voor samenwerkingsverbanden en de noodzaak van zorgvuldige planning en strategisch management.

Hoofdvraag	**Welke oplossingen kunnen segmenteren en gesegmenteerd contracteren bieden voor de complexiteitselementen inherent aan complexe infrastructuurprojecten, en wat zijn de voordelen, uitdagingen en overwegingen voor hun adoptie?**

Segmenteren, gesegmenteerde bouworganisatievormen en gesegmenteerd contracteren bieden verschillende oplossingen om de complexiteitselementen in complexe infrastructuurprojecten aan te pakken. Door projecten op te delen in kleinere, beheersbare segmenten, kunnen opdrachtgevers en aannemers middelen en expertise effectiever toewijzen, risicomanagementstrategieën op maat maken en betere controle houden over budgetten en planningen. Deze aanpak faciliteert gespecialiseerde focus op specifieke taken, verbetert de beheersbaarheid van projecten en verhoogt de voorspelbaarheid van projectresultaten.

Segmenteren maakt gerichte aandacht voor specifieke projectonderdelen mogelijk, waardoor teams gespecialiseerde expertise kunnen toepassen waar dat het meest nodig is. Door risico's binnen specifieke segmenten te isoleren, kunnen opdrachtgevers en aannemers op maat gemaakte mitigatiestrategieën ontwikkelen en de algehele stabiliteit van het project verbeteren. Bovendien faciliteert segmenteren een betere financiële controle en toewijzing van middelen, waardoor projecten binnen budgettaire beperkingen blijven. Deze methode maakt het mogelijk om projecten flexibeler aan te passen aan veranderingen en onverwachte omstandigheden, wat zorgt voor tijdige voltooiing en hoogwaardige resultaten.

Echter, segmenteren brengt echter ook aanzienlijke uitdagingen met zich mee. Voor een naadloze integratie tussen segmenten zijn robuuste coördinatiemechanismen en duidelijke communicatieprotocollen essentieel. Zonder deze kunnen projecten te maken krijgen met inefficiënties, verhoogde risico's en mogelijke vertragingen. Segmentatie zorgt voor extra administratieve lasten en transactiekosten, wat een strikte planning en strategisch management vereist. Bovendien kan segmentatie de natuurlijke synergiën verstoren die ontstaan door samenwerken en gedeelde verantwoordelijkheden, wat mogelijk leidt tot een "ieder voor zich" mentaliteit. Deze verschuiving kan een andere benadering van aannemers vereisen, die als nevenaannemers in een gesegmenteerd project zouden kunnen werken en hun samenwerkingsstrategieën moeten aanpassen om succesvolle resultaten te behalen. Gedetailleerde contractuele bepalingen zijn noodzakelijk om rollen, verantwoordelijkheden en integratie van segmenten te beheren. Aanpassingen aan standaardcontracten zijn vaak nodig om te voldoen aan de specifieke eisen van gesegmenteerde projecten

Voor de adoptie van segmenteren is vroege en grondige planning cruciaal om duidelijke segmenten te definiëren op basis van functionaliteit of geografie. Uitgebreide coördinatieafspraken die rollen, verantwoordelijkheden, procedures bij coördinatie tekortkomingen en conflictmechanismen beschrijven, zijn essentieel. Duidelijke communicatieafspraken die de frequentie van updates, communicatiekanalen en verantwoordelijkheden detailleren, zijn van vitaal belang voor het optimaliseren van samenwerking. Aanpassingen aan standaardcontracten en de opname van

aanvullende overeenkomsten zijn noodzakelijk om de dynamische behoeften van gesegmenteerde projecten te ondersteunen. Sterk centraal toezicht en duidelijke communicatiekanalen zijn essentieel om afhankelijkheden en interacties tussen segmenten effectief te beheren.

Samenvattend bieden segmenteren, gesegmenteerde bouworganisatievormen en gesegmenteerd contracteren waardevolle oplossingen voor het beheersen van de complexiteiten inherent aan complexe infrastructuurprojecten. Door deze strategieën te adopteren en de bijbehorende uitdagingen aan te pakken via strikte planning, robuuste coördinatie en flexibele juridische kaders, kunnen opdrachtgevers en aannemers de beheersbaarheid van projecten verbeteren, de efficiëntie verhogen en succesvolle resultaten behalen in complexe infrastructuurprojecten.

Table of contents

Colophon **2**

Acknowledgements **3**

Abstract **4**

Summary (EN) **5**

Summary (NL) **16**

List of figures **32**

List of tables **33**

Glossary **34**

1. Introduction **36**

1.1 Context *36*

1.2 Problem description *37*

1.3 Definition *40*
1.4.1 Segmentation 40
1.4.2 Segmented project delivery method 41
1.4.2 Segmented contracting 42
1.4.3 Segmented contracting and co-contracting 42
1.4.4 Segmented contracting and tender with lots 43

1.4 Rationale for research *44*

1.5 Knowledge gap *45*

1.6 Research scope and goal *48*

1.7 Research questions *49*

1.8 Structure of the thesis *50*

2. Research methodology **52**

2.1 Research approach *52*

2.2 Research strategy *53*

2.3 Literature study *55*
2.3.1 Selection criteria 56
2.3.2 Search strategy 56
2.3.3 Analysis strategy 57

2.4 Case studies *57*
2.4.1 Interviews 57
2.4.2 Desk research 58
2.4.3 Selection criteria 58
2.4.4 Search strategy 60
2.4.5 Analysis strategy 60

2.5 Expert interviews *61*
2.5.1 Selection criteria 61
2.5.2 Interview setup 61
2.5.3 Analysis strategy 62

2.6 Ethical considerations *62*

3. Literature study **63**

3.1 Background *63*

3.2 Traditional project delivery method *63*

3.3 Integrated project delivery method *64*

3.3 Design team project delivery method *65*

3.4 Two-phase project delivery method *67*

3.5 Co-contracting project delivery method *68*
3.5.1 Coordination 69
3.5.2 Key characteristics of co-contracting 70
3.5.3 Challenges and benefits 71
3.6 Conclusion literature study 72

4. Case study 73

4.1 Noord/Zuidlijn *74*
4.1.1 Complexities of Noord/Zuidlijn 74
4.1.2 The tender phases of Noord/Zuidlijn 76
4.1.3 Understanding segmentation in Noord/Zuidlijn 80
4.1.4 Key characteristics of segmentation in Noord/Zuidlijn 81
4.1.5 Legal aspects of segmentation in Noord/Zuidlijn 82
4.1.6 Challenges and benefits of segmentation in Noord/Zuidlijn 83
4.1.7 The results of segmentation in Noord/Zuidlijn 83

4.2 Schiphol-Amsterdam-Almere *87*
4.2.1 Complexities of Schiphol-Amsterdam-Almere 87
4.2.2 Segmentation in Schiphol-Amsterdam-Almere 89
4.2.3 Segmented project delivery method in Schiphol-Amsterdam-Almere 91
4.2.3 Key characteristics of segmentation in Schiphol-Amsterdam-Almere 92
4.2.4 Legal aspects of segmentation in Schiphol-Amsterdam-Almere 93
4.2.5 Challenges and benefits of segmentation in Schiphol-Amsterdam-Almere 95
4.2.6 The results of segmentation in Schiphol-Amsterdam-Almere 95

4.3 Zuidasdok *98*
4.3.1 Complexities of Zuidasdok 99
4.3.2 Segmentation in Zuidasdok 100
4.3.2 Segmented project delivery method in Zuidasdok 103
4.3.3 Key characteristics of segmentation in Zuidasdok 104
4.3.4 Legal aspects of segmentation in Zuidasdok 105
4.3.5 Challenges and benefits of segmentation in Zuidasdok 106
4.3.6 The results of segmentation in Zuidasdok 107

4.4 Oranje Loper *110*
4.4.1 Complexities of Oranje Loper 110
4.4.2 Segmentation in Oranje Loper 112
4.4.2 Segmented project delivery method in Oranje Loper 114
4.4.3 Key characteristics of segmentation in Oranje Loper 115
4.4.4 Legal aspects of segmentation in Oranje Loper 117
4.4.5 Challenges and benefits of segmentation in Oranje Loper 118
4.4.6 The results of segmentation in Oranje Loper 119

4.5 Stadsdijken Zwolle *121*
4.5.1 Complexities of Stadsdijken Zwolle 122
4.5.2 Segmentation in Stadsdijken Zwolle 124
4.5.3 Segmented project delivery method in Stadsdijken Zwolle 126
4.5.3 Key characteristics of segmentation in Stadsdijken Zwolle 127
4.5.4 Legal aspects of segmentation in Stadsdijken Zwolle 129
4.5.5 Challenges and benefits of segmentation in Stadsdijken Zwolle 129
4.5.6 The results of segmentation in Stadsdijken Zwolle 130

4.6 Conclusion of the case study *133*

5. Framework and typology 135

5.1 Segmentation framework *135*

5.2 Segmented project delivery methods typology *141*
5.2.1 Segmented traditional project delivery method 141
5.2.2 Segmented integrated project delivery method 143
5.2.3 Segmented design team project delivery method 144
5.2.5 Segmented two-phase project delivery method 146

5.4 Conclusion on framework and typology *148*

6. (Legal) Expert interviews **149**

6.1 Insights of experts *149*
6.1.1 Segmentation 149
6.1.2 Co-contracting 152
6.1.3 Market consultation 154
6.1.4 Coordination and integration 155
6.1.5 Risk management 158
6.1.6 Project delivery methods and contract forms 159
6.1.7 Finance and budget 160
6.1.8 Partnerships 161
6.1.9 Conclusion expert interviews 162

6.2 Insights of legal experts *163*
6.2.1 Segmentation 163
6.2.2 Coordination in segmented project delivery methods 164
6.2.3 Communication and information provision in segmented project delivery methods 167
6.2.4 Integration in segmented project delivery methods 169
6.2.5 Procurement of segmented project delivery methods 171
6.2.5 Conclusion legal expert interviews 173

7. Discussion **175**

7.1 Interpretation *175*

7.2 Reflection *175*

7.3 Limitations *176*

7.4 Implications *176*

7.5 Contribution to knowledge *177*

8. Conclusion **179**

9. Recommendations **184**

9.1 Recommendations for clients *184*

9.2 Recommendations for contractors *185*

9.3 Recommendations for policymakers *186*

9.4 Recommendations for researchers *187*

References **189**

Appendices **194**

Appendix A. Data management plan *194*

Appendix B. Informed consent form (NL) *198*

Appendix C. Case study: interview questions for the client (EN) *200*

Appendix D. Case study: interview questions for the client (NL) *202*

Appendix E. Case study: interview questions for a contractor (EN) *204*

Appendix F. Case study: interview questions for a contractor (NL) *206*

Appendix P. Expert interview questions (EN) *208*

Appendix Q. Expert interview questions (NL) *210*

Appendix R. Legal expert interview questions (EN) *212*
Appendix S. Legal expert interview questions (NL) *214*

List of figures

Figure 1. Conceptual definition of segmentation, segmented project delivery methods, and segmented contracting 40
Figure 2. Definition of vertical and horizontal segmentation 41
Figure 3. Example of a project delivery method 41
Figure 4. Example of a segmented project delivery method 42
Figure 5. Research questions 50
Figure 6. Research strategy 53
Figure 7. Overview of the research strategy 55
Figure 8. Scope of a project 59
Figure 9. Selection criteria for the case study 59
Figure 10. Schematic representation of the relationships in the traditional project delivery method 63
Figure 11. Schematic representation of the traditional project delivery method 64
Figure 12. Schematic representation of the relationships in the integrated project delivery method 65
Figure 13. Schematic representation of the integrated project delivery method 65
Figure 14. Schematic representation of the relationships in the design team project delivery method 66
Figure 15. Schematic representation of the design team project delivery method 66
Figure 16. Schematic representation of the two-phase project delivery method 67
Figure 17. Schematic representation of the relationships in the co-contracting project delivery method 68
Figure 18. Schematic representation of the co-contracting project delivery method 69
Figure 19. The selected cases for the case study 73
Figure 20. Schematic representation of the segmented PDM for the Noord/Zuidlijn (first tender phase) 77
Figure 21. Schematic representation of the segmented PDM for the Noord/Zuidlijn (second tender phase) 79
Figure 22. Schematic representation of the segmented PDM for Schiphol-Amsterdam-Almere 92
Figure 23. Schematic representation of the segmented PDM for Zuidasdok 104
Figure 24. Schematic representation of the segmented PDM for Oranje Loper 115
Figure 25. Schematic representation of the segmented PDM for Stadsdijken Zwolle 127
Figure 26. Schematic representation of the segmented traditional project delivery method 142
Figure 27. Schematic representation of the segmented integrated project delivery method 143
Figure 28. Schematic representation of the segmented design team (traditional) project delivery method 144
Figure 29. Schematic representation of the segmented design team (2.0) project delivery method 145
Figure 30. Schematic representation of the segmented two-phase project delivery method 146
Figure 31. Segmented contracting 148
Figure 32. Segmented project delivery methods 181

List of tables

Table 1. Similarities and differences between segmented contracting and tender with lots 44
Table 2. TOE Framework analysis of the project complexities in Noord/Zuidlijn 75
Table 3. Overview of segmentation in the scope and agreements for Noord/Zuidlijn (first tender phase) 77
Table 4. Overview of segmentation in the scope and agreements for Noord/Zuidlijn (second tender phase) 78
Table 5. TOE Framework analysis of segmentation impact on the project complexities in Noord/Zuidlijn 84
Table 6. TOE Framework analysis of the project complexities in SAA 88
Table 7. Overview of segmentation in the scope and agreements for SAA 90
Table 8. TOE Framework analysis of segmentation impact on the project complexities in SAA 96
Table 9. TOE Framework analysis of the project complexities in Zuidasdok 100
Table 10. Overview of segmentation in the scope and agreements for Zuidasdok 102
Table 11. TOE Framework analysis of segmentation impact on the project complexities in Zuidasdok 108
Table 12. TOE Framework analysis of the project complexities in Oranje Loper 112
Table 13. Overview of segmentation in the scope and agreements for Oranje Loper 113
Table 14. TOE Framework analysis of segmentation impact on the project complexities in Oranje Loper 120
Table 15. TOE Framework analysis of the project complexities in Stadsdijken Zwolle 123
Table 16. Overview of segmentation in the scope and agreements for Stadsdijken Zwolle 125
Table 17. TOE Framework analysis of segmentation impact on the project complexities in Stadsdijken Zwolle 132
Table 18. The impact of horizontal and vertical segmentation on complexity elements 135

Glossary

	English term	Dutch term	Definition
C	**Client**	**Opdrachtgever**	The client, also known as the owner or principal, is the party that commissions the work.
	Co-contractor	**Nevenaannemer**	Contractors, working alongside each other on different aspects of the same project, are referred to as co-contractors. Co-contractors have a direct contractual relationship with the client.
	Consortium	**Consortium**	A consortium is a temporary collaboration between different parties. Typically, it is an association, but it can also be a contractual partnership. The consortium is formed to achieve a specific goal. It is a situational combination. If the goal is not achieved, the consortium disbands.
	Contract form	**Contractvorm**	A contract form refers to the legal documentation of the contractual agreements made between those participants, given the chosen project delivery method.
	Contractor	**Aannemer**	The contractor is the party hired by the client to perform the work specified in the contract.
P	**Project delivery method**	**Bouworganisatievorm**	In the realm of construction, the organisation of tasks and responsibilities is referred to as a project delivery method, which outlines how tasks are distributed among the various participants in the construction process.
S	**Segmentation**	**Segmenteren**	The process of dividing the scope of a project into smaller, more manageable subprojects or segments. It is important to acknowledge that segmentation consistently leads to a "physical cut" in the project, resulting in the creation of distinct segments with interfaces that are inherently connected.
	Segmented contracting	**Gesegmenteerd contracteren**	The comprehensive approach to implementing segmentation and segmented project delivery methods in a project, where each segment is individually legally contracted by the client to a contractor or a consortium of contractors.
	Segmented project delivery method	**Gesegmenteerde bouworganisatievorm**	An umbrella term for various segmented project delivery methods that result from the application of segmentation to a project delivery method.
	Sub-contractor	**Onderaannemer**	A subcontractor is a type of contractor that is hired by a main contractor to perform a specific portion or task within a project. Subcontractors have a direct contractual relationship with the primary contractor, not with the client.
T	**Tender in lots**	**Aanbesteden in percelen**	Tendering with lots involves bringing different parts of a large project to market simultaneously. This means that all lots are put out for tender at the same time.

			Unlike segmentation, tendering with lots does not involve a "physical cut" in the project.
U	**UAC 2012**	**UAV 2012**	The 'Uniform Administrative Conditions 2012' is a standard set of terms and conditions used in the Netherlands for the realisation of construction contracts. This framework provides guidelines for the rights and obligations of the parties involved, including the client and the contractor. In this thesis, the framework and responsibilities set out by the UAC 2012 are often referred to as a Design-Bid-Build contract.
	UAC-IC 2005	**UAV-GC 2005**	The 'Uniform Administrative Conditions for Integrated Contracts 2005' is another standard set of terms and conditions used in the Netherlands, specifically designed for integrated contracts. This framework is tailored for projects where the design and realisation phases are combined into a single contract. In this thesis, the framework and responsibilities set out by the UAC-IC 2005 are often referred to as a Design & Build contract.

1. Introduction

1.1 Context

The Netherlands' civil infrastructure is aging, and in the forthcoming decades, there is a substantial challenge ahead for the nation to renew this infrastructure (Bleijenberg, 2021). Numerous roads, bridges, viaducts, locks, weirs, quays, and sewage systems are growing old and approaching the end of their technical lifespan (Rasker er atl., 2023). These civil engineering works are used heavily, often more so than originally expected when they were built. This intensive usage highlights the importance of replacement and renovation of the structures. For the Netherlands, having dependable, safe, and adequately available infrastructure is indispensable (Rasker et al., 2023; see also Lijesen et al., 2007). It's critical for maintaining the safety, liveability, and accessibility of the country (Rasker et al., 2023). Renewal initiatives, including replacement and renovation, are substantial undertakings for this infrastructure. Rarely undertaken during the technical lifetime, these actions signal the commencement of a fresh lifecycle. Furthermore, these interventions profoundly affect the local environment and the accessibility of the intricate network of roadways and waterways (Rasker et al., 2023; Rijkswaterstaat, n.d., 2019).

Alongside the expected task of civil infrastructure replacement and renovation, there is the added challenge of implementing these measures in a manner that is as climate-neutral and circular as possible (Pörtner et al., 2022; Rasker et al., 2023). At the forefront are societal demands for sustainability (Pörtner. The Rutte-III government agreement translated the commitments of the Paris Climate Agreement into specific targets for the Netherlands, aiming for a 55% reduction in CO2 emissions by 2030 compared to 1990 (Rijksoverheid, 2023). The Ministry of Infrastructure and Water Management is steadfast in its goal to achieve carbon neutrality by 2030 (Ministry of Infrastructure and Water Management, 2023). Looking further ahead, the Netherlands is committed to developing a fully circular economy by 2050 (Rijksoverheid, 2023; Rijkswaterstaat, 2023b). This ambitious plan entails ensuring that the environmental impact of using raw materials for Dutch production and consumption will be within 'planetary boundaries'. Rijkswaterstaat has established ambitious internal goals for circularity, striving to operate entirely in a circular fashion by 2030 and to eliminate waste production altogether by 2050. These objectives are intended to be comprehensive, encompassing the entire spectrum of activities linked to Rijkswaterstaat projects (Rijkswaterstaat, 2019). Furthermore, societal expenses associated with navigational and traffic disturbances are rising, and there is less tolerance for delays (both in time and money) in significant projects that cause inconvenience and traffic disruptions (Rijkswaterstaat, 2019).

Rijkswaterstaat and market participants face obstacles as the sector's tasks and dynamics evolve. The changing nature of work, sustainability objectives, limited social acceptance of disruptions, time and expense delays, and future needs for infrastructure functionalities all present issues for the civil engineering sector (Rijkswaterstaat, 2019; see also Rijksoverheid, 2023). These issues come not just from their nature, but also because the industry, particularly for large and complex projects, has the characteristics of an imperfect market. Rijkswaterstaat is the sole recurring client for significant projects, with a small number of contractors (Rijkswaterstaat, 2019).

This scenario demands that clients, such as Rijkswaterstaat, Dutch Water Authorities, ProRail and contractors not only revise their market strategy and risk distribution, but also place a greater focus on sophisticated project management (Rasker et al., 2023). The aim is to maintain a competitive and financially stable Dutch civil engineering sector (Rijkswaterstaat, 2019). This is crucial, particularly as numerous large contractors are increasingly avoiding complex and high-risk projects, a trend highlighted in reports by Financieel Dagblad (2023) and Rijkswaterstaat (2019). Enhanced contract management will be key in this environment, ensuring projects are efficiently handled and risks are

effectively allocated. Contractors must also become more adaptable in introducing new features, and significantly improve in the proactive identification, allocation, and management of risks (Rijkswaterstaat, 2019).

The renovation of the Van Brienenoordbrug, initiated in 2022, stands as a prominent example of the ongoing challenges within the Dutch civil engineering sector. This pivotal mega project highlights the urgent need for the renewal of aging infrastructure, aligning with the latest principles of sustainability and circularity (Rijkswaterstaat, 2022). It symbolises the intricate challenges and innovative solutions being pursued in the sector to ensure the infrastructure meets both current and future needs while adhering to environmental sustainability goals.

This project also highlights the significant challenge of the limited interest from contractors in such complex projects, which Rijkswaterstaat anticipated according to their report “Toekomstige opgave Rijkswaterstaat” (2019). This foresight highlights the inherent challenges in garnering sufficient contractor interest for such ambitious projects (Financieel Dagblad, 2023). A key point of contention has been the contract form, a design-and-construct contract, which was deemed by many builders as carrying risks disproportionate to the potential benefits (Van Belzen & Du Saar, 2023). Prominent contractors, including Ballast Nedam, BAM, and VolkerWessels, had opted out even before the tender officially began. Proposals for alternative contract forms, emphasising collaboration and equitable risk distribution, were raised during market consultations by Rijkswaterstaat but ultimately not pursued. This situation, combined with specific construction method requirements, led to a phenomenon described by some experts as a 'builders' boycott' (Van Belzen & Du Saar, 2023).

The project reflects the broader complexities and challenges that clients and contractors face in the Dutch civil engineering sector, particularly when it comes to managing large-scale, high-risk projects within the current market dynamics (Rijkswaterstaat, 2019) and environmental regulations (Rijksoverheid, 2023). The Van Brienenoordbrug project thus signifies not just progress in infrastructure renewal, but also underscores the importance of adaptive strategies and enhanced contract management. It accentuates the necessity for collaborative efforts to navigate the evolving challenges within the civil engineering sector effectively.

1.2 Problem description

In a notable turn of events in the Dutch civil engineering sector, Rijkswaterstaat had announced that the tender process for the Van Brienenoordbrug project has come to an abrupt halt (Klumpenaar, 2024). This unexpected but somewhat predictable termination of the procurement process serves as a sharp reminder of the inherent complexity and constraints connected with carrying out large-scale and high-risk infrastructure projects. This development exposes the deep-rooted challenges Rijkswaterstaat faces in managing complex infrastructure projects but also emphasises the critical need for balanced risk sharing between clients, including Rijkswaterstaat, and contractors (Van Staveren, 2023).

The recent failure in the tender process of the Van Brienenoordbrug project has ignited a crucial debate on the effectiveness of existing tender processes and underscored the urgent need for innovative, adaptable contracting strategies that focus on collaborative contract management for complex infrastructure projects. This situation, highlighted by the Minister of Infrastructure and Water Management (Harbers, 2024) in his letter to the House of Representatives, is rare for Rijkswaterstaat, but it serves as an essential learning opportunity. There is a clear need for clients and contractors to re-evaluate and potentially overhaul how risks are shared and managed in future projects (Rijkswaterstaat, 2019; Van Staveren, 2023). New, flexible contracting strategies are vital for attracting

capable contractors and ensuring the successful realisation of critical infrastructure renovations and developments.

This analysis of the challenges faced by clients and contractors in the Dutch civil engineering sector, particularly regarding the tendering process and risk management, is primarily informed by insights from Rijkswaterstaat (2019). The current market dynamics and approaches to risk, especially in large and complex projects, highlight an urgent need for changes to encourage healthy competition. Contractors currently struggle to adequately price risks, a critical factor in the tendering process. This difficulty is compounded by varying abilities among bidders to identify and mitigate risks, an issue particularly pronounced when new design solutions and techniques are involved (Rijkswaterstaat, 2019). Rijkswaterstaat acknowledges the challenge in accurately assessing risk evaluations submitted by bidders. The trend of under-pricing risks, as identified by contractors, began with the shift from traditional RAW contracts to integrated contract forms like D&C, DBFM, and DBM. This transition has seen construction companies failing to adjust their pricing and bidding strategies sufficiently to accommodate the increased tender costs and the transfer of risks to market parties. This has led to a trend of low bidding practices, which, while increasing the chances of winning tenders, also escalates the risk profiles and potential strains on collaborative relationships (Rijkswaterstaat, 2019). Despite Rijkswaterstaat's efforts to prevent price from being the dominant factor in tenders, their measures have inadvertently increased the risk profiles for contractors, especially in the context of complex projects. There is a general perception among market parties that Rijkswaterstaat tenders tend to favour the lowest bid, thereby reducing the effectiveness of qualitative award criteria. Nevertheless, Rijkswaterstaat’s analysis indicates that the Best Price-Quality Ratio (BPKV) scores can be a decisive factor in D&C contracts. For large projects that use DBFM contracts, there has been an observable reluctance among contractors to engage in high-risk complex projects. This trend of low bidding, driven by the demand for innovative and cost-effective designs, has led to fewer contractors being willing to participate in high-risk tenders due to the associated financial and operational risks, as outlined by Rijkswaterstaat (2019).

This backdrop sets the stage for a deeper exploration into the inherent complexities of such projects. It prompts the questions: What makes projects complex, and why does this lead to an imperfect market? The term "complexity" is commonly used in the construction sector. However, there is no universal definition of complexity that can be used to characterise each project (Kermanshachi et al., 2016). Schlindwein and Ison (2005) argue that there are two main scientific approaches of complexity. The first approach, descriptive complexity, views complexity as an inherent characteristic of systems, which motivated scientists to attempt measuring or quantifying complexity. An instance of this perspective can be found in Baccarini's (1996) work. Baccarini (1996) argues that complexity consist of organisational complexity and technological complexity and articulates project complexity through two fundamental dimensions: differentiation and interdependency. Differentiation encompasses the variety of elements within a project, including tasks, specialists, and materials, while interdependency emphasises how these elements interact and depend on one another. The second approach, which is referred to as the area of perceived complexity, views complexity as subjective (Vidal & Marle, 2008). This approach acknowledges that individuals in the same organisation, working on the same projects and in similar roles, can have vastly different perceptions of what constitutes complexity (Bosch-Rekveldt et al., 2014). Vidal and Marle (2008) link the different perspectives of complexity, acknowledging the relevance of both descriptive and perceived complexities in the management of projects. They define project complexity as the characteristic that complicates the understanding, prediction, and control of a project's overall behaviour, even with comprehensive information. This complexity is driven by the project's size, diversity, interdependencies, and environmental context, highlighting the multifaceted challenges in grasping and managing a project's full scope and impact. Baccarini (1996) and Vidal and Marle (2008) both recognise that while large-scale projects are often complex, their complexity extends beyond mere size. Industry insights, particularly from Rijkswaterstaat (2019), support this view, showing that the size of a project does not inherently

determine its complexity. This distinction underscores that project complexity is not solely determined by the project's scale but emerges from the dynamic interactions and relationships among various project components (Vidal & Marle, 2008). Bosch-Rekveldt et al. (2018) identified the factors significantly contributing to project complexity in the construction and infrastructure sector, categorising these elements into technical, organisational, and external categories. This classification provides a comprehensive framework to understand and address the multifaceted challenges encountered within this sector. Technically, the main complexities arise from scope uncertainties, task interdependencies, multidisciplinary technical involvement, and misaligned objectives. Organisationally, challenges include tight scheduling, resource and skill deficits, inter-disciplinary interfaces, and logistical hurdles. Externally, complexity is heightened by diverse stakeholder viewpoints, interactions with existing infrastructure, political factors, stakeholder multitude, and geographical remoteness. This detailed categorisation aids in comprehensively understanding and strategically addressing the complex nature of these projects. Moreover, the concept of perceived complexity adds a layer of depth to these elements, acknowledging that individuals' experiences and roles within a project influence their perception of its complexity (Bosch-Rekveldt et al., 2014). The intricate discussion on project complexity, highlighting both its inherent and perceived dimensions, sets the stage for understanding its impact on market dynamics. The complexity of a project, encompassing organisational, technological, external, differentiation, and interdependency aspects, along with the subjective interpretations of those involved, fundamentally challenges traditional market mechanisms. This complexity not only hampers the predictability and manageability of projects but also influences the willingness of contractors to engage with high-risk projects (Financieel Dagblad, 2023; see also Van Staveren, 2023). The observed trend of contractors increasingly hesitating to engage in risky ventures (Financieel Dagblad, 2023) or demanding high costs for risk mitigation (Rijkswaterstaat, 2019, 2024), coupled with the current labour market's scarcity (Rijkswaterstaat, 2024) forcing companies to strategically allocate their limited capacity, underscores a significant market inefficiency: the inability to effectively allocate resources to highly demanding projects. Such a scenario, accentuated by reports from Financieel Dagblad (2023) and Rijkswaterstaat (2019, 2024), necessitates a shift towards innovative contracting methods, to navigate and mitigate the market imperfections spawned by project complexity. This bridge connects the theoretical exploration of complexity with the practical implications it has on market behaviour and contracting strategies, highlighting the urgency for adaptive approaches in the face of evolving project demands.

While re-evaluating the current tender procedure of the Van Brienenoordbrug, the Minister of Infrastructure and Water Management (Harbers, 2024) underscores Rijkswaterstaat's commitment to integrating key insights and lessons learned to substantially enhance subsequent phases. This focus on refinement and progression in the tender process is geared towards achieving more effective and efficient outcomes for complex projects. A crucial aspect of this evaluation is the consideration of dividing the project into smaller subprojects. However, this raises several questions: Is this a good idea? How should it be implemented, and what potential benefits can be achieved? Additionally, what are the possible drawbacks?

To address these questions, this research specifically focuses on segmentation and segmented contracting as a strategic approach to enhancing the management of complex infrastructure projects within the Dutch civil engineering sector. By delving into the nuances of segmentation, segmented project delivery methods, and segmented contracting, the study aims to deepen the understanding of this approach, examining its potential benefits and challenges. This exploration is underpinned by an initiative aimed at reducing project complexity, mitigating risks, and positively influencing market forces, thereby addressing critical areas of concern in the management of complex infrastructure projects. The subsequent chapter will provide a detailed explanation of the definitions of segmentation and segmented contracting

1.3 Definition

Following the context and problem statement, this chapter aims to establish a clear foundation for the research by defining the key concepts of "segmentation", "segmented project delivery methods", and "segmented contracting" as they apply to the management of complex civil infrastructure projects. As understanding these conceptual definitions is essential for readers of this research, it is strategically chosen to explain the definitions in an early chapter of the thesis. This initial clarification sets the stage for a more detailed exploration throughout the research study. Additionally, this chapter will elucidate the relationship between segmented contracting and co-contracting, as well as the differences between segmented contracting and tendering with lots, further enhancing the understanding of segmentation, segmented project delivery methods, and segmented contracting. Figure 1 offers a comprehensive explanation of the conceptual definitions of segmentation, segmented project delivery methods, and segmented contracting. The following sections will provide further context and elaborate on each definition in detail.

"Segmentation"

The process of dividing, or segmenting, the scope of a project into smaller, more manageable subprojects, or segments.

"Segmented project delivery method"

An umbrella term for various segmented project delivery methods that result from the application of segmentation to a project delivery method.

"Segmented contracting"

The comprehensive approach to implementing segmentation and a segmented project delivery method in a project, where each segment is individually legally contracted by the client to a contractor.

Figure 1. Conceptual definition of segmentation, segmented project delivery methods, and segmented contracting

Note. The definitions of segmentation, segmented project delivery methods, and segmented contracting presented in this thesis are self-defined by the writer to provide a clear and specific framework for the research.

1.4.1 Segmentation

Segmentation is defined as the process of dividing, or segmenting, the scope of a project into smaller, more manageable subprojects, or segments. This method aims to address specific elements of complexity by breaking the project into manageable parts, potentially facilitating focused management and realisation. It is important to acknowledge that segmentation consistently leads to a "physical cut" in the project, resulting in the creation of distinct segments with interfaces that are inherently connected. In this research, segmentation is categorised into two principal types: vertical and horizontal. Vertical segmentation organises a project based on the technical discipline of contractors, resulting in co-contractors (known as 'nevenaannemers' in Dutch) working within the same geographical location on different aspects of the project. Horizontal segmentation, on the other hand, divides a project according to geographical location, leading to co-contractors operating in distinct geographic areas. Figure 2 provides a comprehensive overview of both definitions. The notes of the figure also include an example to illustrate the concepts of vertical and horizontal segmentation.

"Vertical segmentation"

Vertical segmentation divides a project into segments based on technical discipline, also defined as functional segmentation.

"Horizontal segmentation"

Horizontal segmentation divides a project into segments based on geographic location, also defined as geographical segmentation.

Figure 2. Definition of vertical and horizontal segmentation

Note. The definitions of vertical and horizontal segmentation presented in this thesis are self-defined by the writer to provide a clear and specific framework for the research.

Example. To illustrate the concepts of vertical and horizontal segmentation, the Van Brienenoordbrug can be used as an example, although the scope is somewhat exaggerated for clarity. For this example, the scope includes renovating and replacing both the bridge and the A16 highway. In terms of vertical segmentation, the Van Brienenoordbrug can be divided into different technical disciplines, all within the same geographic location of the bridge. For instance, one contractor is tasked with the structural steel elements of the bridge, another manages the technical installations and the bridge valve, and a third is responsible for constructing the roadway on the bridge. Each contractor focuses on their specific technical area, allowing for specialised expertise in the realisation of the project. For horizontal segmentation, the project scope may be divided geographically, with one segment focusing on renovating and replacing the Van Brienenoordbrug and two other segments dedicated to renovating the A16 highway north and south of the bridge in the densely populated urban area of Rotterdam. This geographic division allows each contractor to address the specific environmental and regulatory challenges unique to their respective segments.

1.4.2 Segmented project delivery method

In the realm of construction, the organisation of tasks and responsibilities is referred to as a project delivery method (known as "bouworganisatievorm" in Dutch), which outlines how tasks are distributed among the various participants in the construction process. By applying the principles of segmentation to a project delivery method, a segmented project delivery method is achieved. This concept serves as an umbrella term for various project delivery methods that incorporate segmentation principles. A visual example of this concept is provided by the segmentation of the traditional project delivery method, resulting in a segmented project delivery method. Figure 3 provides a schematic representation of the traditional project delivery method, as described by Chao-Duivis et al. (2018), as an example of a project delivery method. Figure 4 visually conceptualises an example of a segmented project delivery method. Segmentation and the formation of distinct project segments can be observed in this visualisation of the segmented project delivery method.

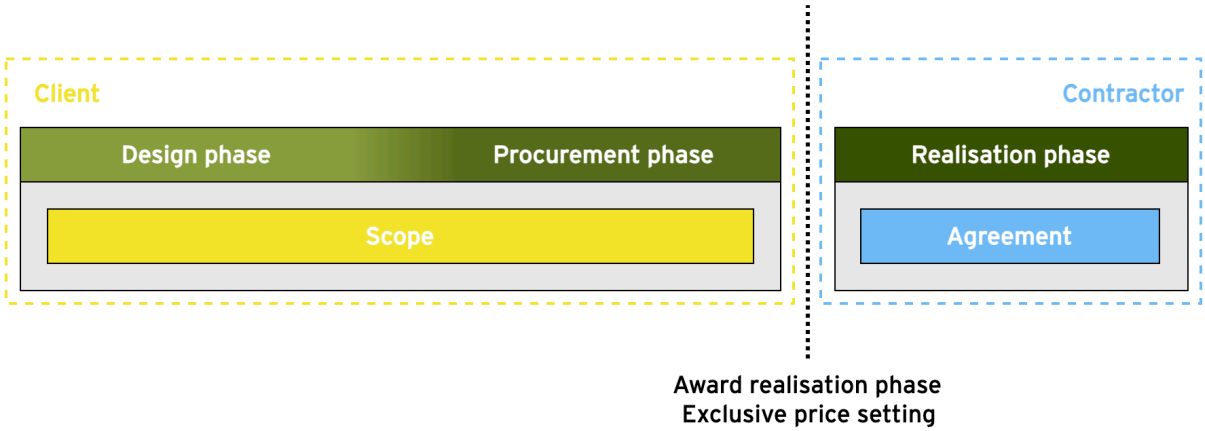


Figure 3. Example of a project delivery method

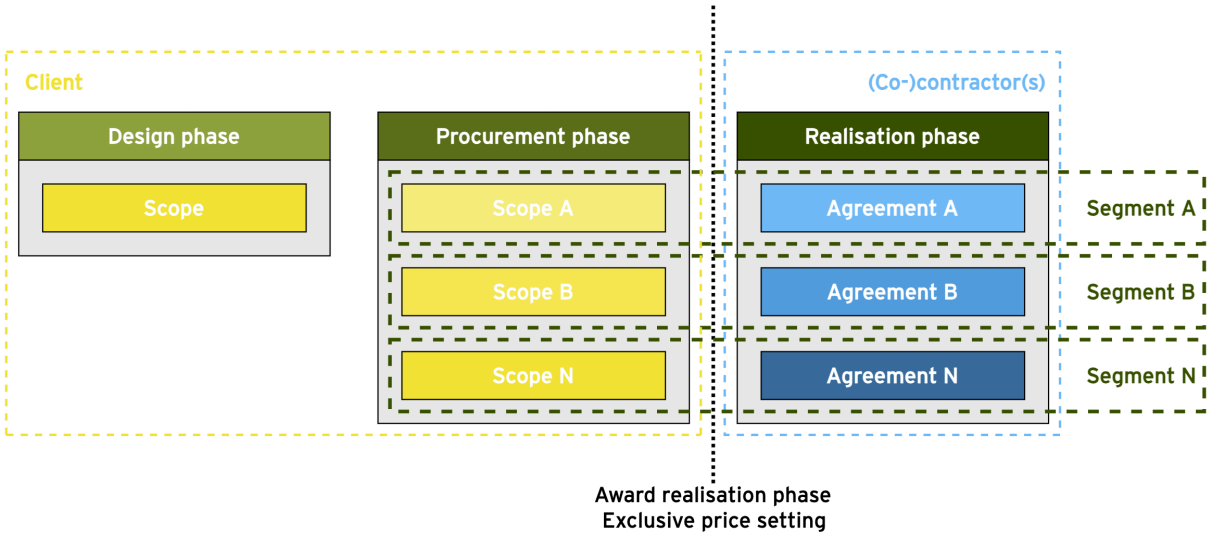


Figure 4. Example of a segmented project delivery method

1.4.2 Segmented contracting

In this thesis, segmented contracting is defined as the comprehensive approach to implementing segmentation and segmented project delivery methods in a project, where each segment is individually legally contracted by the client to a contractor or a consortium of contractors. It is important to note that segmented contracting should not be confused with merely the legal contracting of segments. Instead, it refers to a holistic strategy that includes planning, coordination, integration, overall management, and implementation of segmentation and segmented project delivery methods to effectively address the complexities inherent in complex infrastructure projects. This self-defined definition reflects the perspective of the writer of this research. Segmented contracting (often) results in co-contractors working on different segments of the project, whether these segments are divided by horizontal or vertical segmentation. However, it is important to note that segmented contracting is not limited to engaging multiple contractors because each segment can also be awarded to the same contractor. In this research, a consortium of contractors is treated as a single contractor unless explicitly stated otherwise.

1.4.3 Segmented contracting and co-contracting

As segmented contracting often leads to the involvement of co-contractors, it is important to understand the concept of co-contracting and the co-contracting project delivery method. Co-contracting, which involves a client dividing a construction project into multiple segments and assigning each segment to different contractors, is the most fundamental segmented project delivery method within segmented contracting. However, this research has identified additional segmented project delivery methods that build upon this basic framework. For the sake of clarity, the definition of co-contractors is borrowed as this definition holds up even when applied in segmented project delivery methods. Understanding co-contracting provides a solid foundation for exploring the more integrated segmented project delivery methods identified in this research.

In the co-contracting project delivery method, each contractor is responsible for a specific part of the project scope. These contractors, working alongside each other on different parts of the project scope, are referred to as ‘nevenaannemers’ or co-contractors. The contractors typically do not have a contractual relationship with each other, but only with the client. However, their work is often closely interlinked, with one contractor’s output frequently building upon another’s (Van Gulijk & Muller, 2011). Chapter “3.5 Co-contracting project delivery method” will dive deeper into co-contracting, offering a more comprehensive understanding of its mechanisms.

1.4.4 Segmented contracting and tender with lots

Understanding the difference between segmented contracting and tendering with lots (known as “aanbesteden in percelen” in Dutch) is also crucial, as both approaches are closely related and can easily be confused. To clarify these distinctions, discussions were held with two legal experts in the field of complex infrastructure projects (Appendix V.1 Segmented contracting and tender with lots). These discussions helped sharpen the definition of segmented contracting and highlight the unique characteristics of this approach. As understanding the difference between these methods is essential for readers of this research, it is strategically chosen to explain the definitions in an early chapter of the thesis.

Segmented contracting and tendering with lots both involve breaking down the scope of a project into smaller segments or lots, but they do so in fundamentally different ways, each carrying its own legal and practical implications. This chapter will explore these differences in detail to provide a clear understanding of how each method operates and when each should be applied.

As explained in chapter “1.4.2 Segmented contracting”, segmented contracting involves applying segmentation to the project delivery method and contractual arrangements of a project, where each segment is contracted individually. This approach is often used when projects are too large or too complex to be executed as a single contract, making it necessary to split the project into manageable segments (Appendix V.1 Segmented contracting and tender with lots). Two legal experts emphasised that, while legally permissible, it is essential to ensure that this segmentation is not unnecessary or artificial, aimed at circumventing certain procurement thresholds. Legally, the segmentation of a project must be justified by the scope and complexity of the work involved (Appendix V.1 Segmented contracting and tender with lots). For instance, in the Zuidasdok project, a large and complex initiative, the segmented contracting approach was applied. This was not seen as an unnecessary division but as a necessary measure due to the project's enormous scope (chapter “4.3 Zuidasdok”). Each segment of the project remained substantial and presented significant challenges, justifying that each part be treated as a separate tender (Appendix V.1 Segmented contracting and tender with lots). In practice, this means that a separate tendering procedure is organised for each segment, with each segment's tendering process (often) being completed before the next one begins (Appendix V.1 Segmented contracting and tender with lots). The realisation of segments is often distributed over time for the same reasons as the tendering process. This allows clients to focus entirely on each specific part without being overwhelmed by the complexity of the entire project. Different contractors (co-contractors) can be assigned to different segments, leading to specialised attention and expertise for each subproject (segment) (Appendix V.1 Segmented contracting and tender with lots).

Tendering with lots, on the other hand, involves bringing different parts of a large project to market simultaneously (Appendix V.1 Segmented contracting and tender with lots). This means that all lots (or segments) are put out for tender at the same time. Unlike segmentation, tendering with lots does not involve a "physical cut" in the project. This method allows contractors to bid on multiple lots simultaneously, potentially enabling a single contractor to win multiple lots. This can be advantageous for project coordination if one contractor is responsible for multiple related tasks, but it can also lead to less competition, as larger contractors may dominate multiple lots (Appendix V.1 Segmented contracting and tender with lots).

The approach of tendering with lots is particularly suitable for projects where the different lots are interrelated but can also be executed independently without affecting the overall project progress (Appendix V.1 Segmented contracting and tender with lots). This method requires less intensive coordination compared to segmented contracting, as each lot is treated as a separate entity without a

“physical cut” between them. This allows different parts of the project to be developed in parallel, which can potentially lead to faster completion of the entire project (Appendix V.1 Segmented contracting and tender with lots). In contrast, segmented contracting requires deep integration and coordination between the different project segments, as segmentation consistently leads to a "physical cut" in the project. This approach is often used when projects are too complex to be tendered as a whole and close cooperation between segments is necessary for the project's success (Appendix V.1 Segmented contracting and tender with lots). Moreover, the criteria for determining whether a project qualifies as segmented, and thus adopting the strategy of segmented contracting, are discussed in chapter “2.4.3 Selection criteria”. The following table (Table 1) provides a detailed comparison of the relative similarities and differences between segmented contracting and tendering with lots, highlighting key aspects gathered from the comprehensive research conducted for this thesis.

Table 1. Similarities and differences between segmented contracting and tender with lots

Note: This comparison highlights the aspects relative to each other, based on insights gathered throughout the entire research of this thesis.

Segmented contracting
Dividing the scope of a project into smaller subprojects, or segments
Multiple tenders often distributed over time
“Physical cut”
High interrelatedness
High coordination and integration
Realisation of segments often distributed over time
Tender with lots
Dividing the scope of a project into smaller subprojects, or lots
Single tender
No “physical cut”
Low interrelatedness
Low coordination and integration
Realisation of lots rarely distributed over time

1.4 Rationale for research

As this research delves into the rationale behind focusing on segmented contracting, it’s essential to understand how this approach aligns with broader objectives in both scientific and societal realms. Segmented contracting, characterised by the segmentation of extensive contracts into multiple, distinct agreements, offers a multifaceted perspective that intersects with scientific inquiry, societal impact, and practical application in the field of civil engineering and beyond. The following justification underscores the relevance and significance of this research focus from these three critical viewpoints.

Civil infrastructure projects hold significant sway over societal well-being, impacting economic growth, public safety, and overall quality of life (Ossokina & Brouwers, 2016). The policy letter by Ossokina and Brouwers (2016) underscores that well-developed infrastructure is a key contributor to the quality of

life and economic efficiency in a society. This understanding reinforces the view that civil infrastructure is not just a physical asset, but a fundamental pillar supporting the functioning and growth of modern societies (Ossokina & Brouwers, 2016). The significance of civil infrastructure projects (Ossokina & Brouwers, 2016) and the challenges facing the Netherlands' aging infrastructure (Rasker et al., 2023) both underscore the need for a focused study on a segmented contracting. Given the substantial tasks ahead in renewing numerous roads, bridges, and other infrastructure (Rasket er atl., 2023), which are crucial for maintaining the country's safety, liveability, and accessibility (Ossokina & Brouwers, 2016), researching segmented contracting can provide vital insights. These insights could benefit the optimisation of the development and renovation of infrastructure, ensuring its adequacy for future demands and the continued growth of modern societies.

In addressing the complexity inherent in civil infrastructure projects, it's pivotal to consider innovative contracting strategies like segmented contracting. This approach, by breaking down large projects into smaller, manageable segments, directly tackles the multifaceted nature of project complexity. Such complexity, defined by a combination of complexity elements (Bosch-Rekveldt et al., 2018), interdependencies (Vidal & Marle, 2008), and varying perceptions of complexity (Bosch-Rekveldt et al., 2014), poses significant challenges in project management, risk allocation, and market dynamics (Rijkswaterstaat, 2019). Segmented contracting thus emerges as a strategic response, potentially enhancing flexibility, risk management, and the adaptability of contracting practices to the intricate demands of modern infrastructure development.

The report “Toekomstige Opgave Rijkswaterstaat: Perspectief op de uitdagingen en verbeter-mogelijkheden in de GWW-sector” by Rijkswaterstaat (2019) also provides a compelling rationale for focusing research on segmented contracting, especially in the context of large and complex infrastructure projects. This report underscores the critical need for change in the current market dynamics, highlighting the challenges contractors face in effectively pricing risks, an issue magnified in the shift from traditional Design-bid-Build contracts to more integrated forms like Design & Build. The inability to appropriately price risks not only impact the quality of infrastructure projects but also poses significant questions about risk management and market competition. Additionally, the report sheds light on the ongoing tension between quality and price in tender decisions, suggesting the necessity of a balanced approach (Rijkswaterstaat, 2019). Thus, investigating segmented contracting emerges as a practical and relevant area of study, aimed at developing more effective contracting strategies that align with current market dynamics and complexities, and ensuring that quality in infrastructure development is not compromised by cost considerations.

In an era where the construction industry is increasingly faced with complex and dynamic challenges, the necessity for flexible contracting models is more evident than ever. Segmentation and segmented contracting could offer a potential contracting solution to navigate these evolving landscapes, providing a tailored approach to effectively address the specific demands and uncertainties of civil infrastructure projects.

1.5 Knowledge gap

This chapter serves as a pivotal component of this research, aiming to explore and analyse existing scientific works and reports related to segmentation and segmented contracting. It aims to bridge the gap in our current knowledge by systematically examining existing literature and identifying practices that either align with or diverge from the principles of these concepts as they are conventionally understood.

In this evolving landscape, Rijkswaterstaat's recent endeavours offer a relevant case study. The organisation is currently assessing the tendering process for the renewal of the Van Brienenoordbrug,

with the intention of applying lessons learned to future projects (Harbers, 2024). A focal point of this evaluation is the division of the contract into multiple parts, a strategy prompted by the recognition that managing the bridge's renewal and renovation as a unified project presents excessive complexity and risk, thereby inflating costs (Rijkswaterstaat, 2024). This shift towards segmented contracting by Rijkswaterstaat signifies the novelty of the strategy within the realm of complex infrastructure projects, showcasing a strategic pivot towards minimising project risks and complexities (Harbers, 2024). This chapter will examine how Rijkswaterstaat's approach to segmented contracting mirrors broader trends and insights in the field, thereby enriching our understanding of segmented contracting's potential to enhance the management of complex infrastructure projects. The review will begin by examining Rijkswaterstaat's vision for the future, given Rijkswaterstaat's stature as a principal client in the infrastructure sector (Rijkswaterstaat, 2019; see also Du Saar & Adamse, 2023), delving into both the known and unknown strategies to pinpoint the gaps in segmented contracting. This exploration aims to uncover the scope of segmented contracting's potential and its implications for evolving contract management practices.

The analysis of the report "Toekomstige Opgave Rijkswaterstaat: Perspectief op de uitdagingen en verbeter-mogelijkheden in de GWW-sector" by Rijkswaterstaat (2019) lays foundational principles for the civil engineering sector (GWW-sector) in the Netherlands and identifies critical developments necessitating a transition within the sector. As highlighted in Chapter 2 of the report and as mentioned prior in the problem statement, there is a risk that, if the trend of reduced bidding on large and complex works continues, there could be few or even no bidders for significant projects. The report outlines four concrete measures that Rijkswaterstaat can initiate to catalyse this transition, aiming for a financially healthier, more competitive, innovative, cost-effective, and sustainable Dutch GWW sector. These measures include reducing selective risks by setting construction phase prices at a later project stage, introducing a portfolio approach, improving preconditions across Rijkswaterstaat's projects, and encouraging the participation and collaboration of more technology-oriented parties. The focus is drawn specifically to the third measure highlighted in the report, which centres on the reduction of project complexity. While the strategy resembles segmented contracting in its approach to breaking down larger projects into more manageable segments, it is not explicitly mentioned as such. This method implies a strategy similar to segmented contracting, aiming to enhance project manageability and reduce the necessity for consortium formation by simplifying the complexities associated with interface and overlap management. This nuanced approach suggests an implicit application of segmented contracting principles, even if not directly named, reflecting a strategic move towards more flexible and adaptable contract management practices within the infrastructure sector.

Both of the preceding paragraphs underscore an approach that closely resembles segmented contracting, highlighted as a potential solution for managing the complexities inherent in large-scale and high-risk infrastructure projects (Harbers, 2024; Rijkswaterstaat, 2019). These sections collectively illuminate Rijkswaterstaat's strategic shift towards breaking down projects into more manageable segments, an initiative aimed at reducing project complexity, risks, and the propensity for consortium formation (Harbers, 2024; Rijkswaterstaat, 2019). While this strategy is implicitly aligned with the principles of segmented contracting, it is noteworthy that both discussions underscore a significant knowledge gap: there is a lack of explicit recognition and detailed understanding of segmented contracting as a defined strategy within these contexts. This omission points to an unexplored territory in the realm of segmented contracting, suggesting that, despite its potential benefits and alignment with current needs, there is still much to learn about how segmented contracting can be systematically applied and optimised within the sector. This gap underscores the necessity for further exploration and documentation of segmented contracting strategies, to fully comprehend their implications, effectiveness, and potential to revolutionise project management practices in the civil engineering sector.

So, what do we know regarding segmented contracting? The concept of segmented contracting, while implicitly present in the strategies discussed, remains an area ripe for exploration within the civil engineering sector. The article "Het belang van coördinatie bij nevenaanneming" by Van Gulijk & Muller (2011) sheds light on segmented contracting, particularly in its traditional approach, by emphasising the critical role of coordination in co-contracting practices. It discusses the operational and financial advantages of dividing large projects into smaller, more manageable segments, each handled by different co-contractors. This strategy is recognised for its potential to streamline project execution and mitigate risks, provided there is effective coordination and communication among all parties involved. The insights from this paper contribute to our understanding of segmented contracting, highlighting the importance of meticulous planning and collaboration to leverage its benefits fully. However, this article also highlights a gap in knowledge concerning its adaptation and effectiveness in more contemporary or integrated contract models.

A real-time example of complex infrastructure projects where the segmented contracting strategy was used is the Noord-Zuidlijn project in Amsterdam. The article by Ten Heuvelhof and Van der Heijden (2010) describes aspects of segmented contracting as observed in the Noord-Zuidlijn Amsterdam project. During the second tendering phase, the municipality opted for a strategic redirection, choosing to segment the large-scale project into smaller, distinct segments under a Design-bid-Build contract framework. This restructuring was aimed at enhancing the project's overall manageability and attracting specialised subcontractors by reducing the scale and complexity of the tenders. This segmentation, although strategic, also introduced the need for intricate coordination and interface management, underscoring a critical facet of segmented contracting in practice. This case also highlights the nuanced use of segmented contracting strategies within the boundaries of conventional contracting frameworks.

The Zuidasdok project, another ambitious infrastructure undertaking, applied an approach like segmented contracting (Rijkswaterstaat, 2023a, 2023b). As noted in the 'halfjaarlijkse rapportage Zuidasdok,' by Programmaorganisatie Zuidasdok (2020) this strategy involved dividing the project into work packages as a risk mitigation measure due to its complexity. However, this division necessitated more robust interface management and system integration, areas which faced challenges post-segmentation. The partitioning increased the role and potential risks for the client, especially regarding the need for precise coordination across various work packages, schedules, and contractors. This situation underscores the critical balance between reducing project risks through segmentation and the increased responsibility it places on project management to ensure seamless integration and coordination.

The consideration of segmented contracting comes at a pivotal moment in the evolution of project management within the civil engineering sector. As Chao-Duivis (2019) pointed out in her farewell address, Rijkswaterstaat's "Toekomstige Opgave" represents a firm and proper step towards revolutionising our approach to construction projects, and she advocates for the development and continuation of this transformative path. While segmented contracting is cautiously suggested as part of this innovative pathway, comprehensive knowledge about the application of segmentation and segmented contracting remains largely unknown, underscoring a significant gap in the current literature and practice. This lack of detailed understanding strengthens the call for a thorough exploration into segmented contracting and its potential to address the complexities of large-scale projects. Chao-Duivis also signals the pressing need to modernise the Design-bid-Build and Design & Build project delivery methods, highlighting a move towards redefining legal and organisational structures in contarctor contracting to meet current demands. This shift indicates an industry on the brink of significant changes in contract management. However, it is noted that the application of segmentation and segmented contracting, remains largely unexplored. This gap suggests a critical area for development, with the potential to revolutionise how contracts are managed in the face of evolving project complexities.

This chapter has explored the realm of segmentation and segmented contracting within civil engineering, delving into both its theoretical foundation and practical applications. Through the examination of Rijkswaterstaat's projects, like the Van Brienenoordbrug and Zuidasdok, and scholarly insights from "Het belang van coördinatie bij nevenaanneming," this review has illuminated the nuanced strategies related to segmented contracting. Despite these insights, a significant knowledge gap persists, particularly in the application of segmentation and segmented contracting. This gap highlights the industry's need for a deeper understanding of segmentation and segmented contracting's potential to tackle complex project challenges. As we stand in the midst of a paradigm shift in project management, prompted by evolving project complexities and the call for innovation by eminent figures such as Chao-Duivis, the burning question remains: What possible solutions could segmentation and segmented contracting offer to complex projects? This pivotal question forms the core of this research, steering the study into the subsequent stages with a focus on revealing how segmentation and segmented contracting could revolutionise the approach to managing complex infrastructure projects in today's dynamic construction landscape.

1.6 Research scope and goal

The primary goal of this research has been to explore the potential solutions that segmentation, and consequently segmented contracting, might offer for managing the complexity of complex infrastructure projects. The study has aimed to examine the considerations, benefits, and challenges of segmentation and segmented contracting, thereby deepening the understanding of this strategy for both clients and contractors. By providing the civil engineering sector with a comprehensive understanding of this strategy, the research has aimed to elucidate the benefits, drawbacks, and important considerations for adopting segmentation and segmented contracting in future (complex infrastructure) projects.

The first objective has been to explore the context of segmented contracting and segmentation within the diverse project delivery methods employed in the Dutch civil infrastructure sector. This has necessitated a thorough review of various project delivery methods, from traditional to more integrated models like the design-team approach. Special attention has been given to the co-contracting project delivery method and the underlying mechanics of co-contracting. Additionally, the arrangement of coordination within each project delivery method has been thoroughly researched. Establishing a theoretical foundation by identifying the prevalent project delivery methods in the sector has been essential. This initial step has been important for understanding the environments in which segmentation might occur, setting the stage for comprehensive research on segmented contracting.

The second objective has examined how segmentation is approached, considered, and implemented (within project delivery methods) by clients and contractors in current and recent complex infrastructure projects, aiming to understand the key characteristics, legal implications, benefits, and challenges of segmentation according to clients and contractors. It has also aimed to identify the impact of segmentation on project complexity elements to determine the potential solutions that segmented contracting could offer for the management of complex infrastructure projects.

The third goal has been to assess the impact of segmentation on various complexity elements, highlighting the practical effects of segmentation. Additionally, it has sought to identify and evaluate different segmented project delivery methods, presenting the benefits and drawbacks of each model. This goal has aimed to provide a comprehensive understanding of segmented contracting, detailing how segmentation and segmented project delivery methods can be strategically applied to manage complexities in infrastructure projects.

The final objective has been to validate segmentation and segmented contracting by incorporating insights from experts and legal authorities in the field of complex infrastructure projects. This has involved examining their perspectives on key aspects of segmented contracting, segmentation, and segmented project delivery methods, such as coordination and integration. These expert insights have offered a comprehensive understanding of the strategic approaches required for successfully managing and realising segmented complex infrastructure projects, emphasising the critical factors and best practices that drive project success.

Ultimately, this study aims to enhance the understanding of segmented contracting among professionals managing and realising complex infrastructure projects (in the Netherlands). By providing a thorough and empirically backed examination of segmentation and segmented contracting, this effort extends beyond academic contributions. It seeks to influence industry practices by improving the comprehension of segmented contracting among clients, contractors, and consultants in the civil engineering sector. Additionally, the study examines how segmentation can address the complexities inherent in these projects, thereby promoting better management, enhancing market competition, and improving risk-reward dynamics. By dissecting these aspects, the study aims to offer practical and theoretical insights on strategic segmentation, ultimately enabling the sector to effectively tackle the massive upcoming replacement and renovation challenges.

1.7 Research questions

In the pursuit of advancing our understanding of segmentation and segmented contracting within the realm of civil engineering and infrastructure development, this chapter has laid out a series of focused research questions. These questions have guided the research in uncovering the nuances, challenges, and potential solutions offered by segmentation and segmented contracting in the context of Dutch civil infrastructure projects.

The main research question has delved into the central theme of this study: "What solutions can segmentation and segmented contracting offer to address complexity elements inherent in complex infrastructure projects, and what are the benefits, challenges, and considerations for their adoption?" This question has formed the foundation for a thorough exploration into the potential solutions that segmented contracting could provide for complex infrastructure projects. To support the main research question, the research has delved into several sub-questions. It has examined the context of segmentation within various established project delivery methods in the Dutch civil infrastructure sector, with special attention to co-contracting and coordination arrangements. The study has evaluated how segmentation is approached, considered, and implemented by clients and contractors in current and recent projects, investigating the key characteristics, legal implications, benefits, and challenges of this approach. Additionally, the research has sought to understand the impact of segmentation on project complexity elements and has identified different segmented project delivery methods, presenting their benefits and drawbacks. The study has been supplemented by expert interviews to validate segmentation and segmented contracting, capturing the practical perspectives of industry experts on the benefits, challenges, and considerations of segmentation, segmented project delivery methods, and segmented contracting. Figure 5 provides an overview of the research questions. Through these research questions, the study has intended to explore the potential solutions that segmentation and segmented contracting might offer for complex infrastructure projects.

Main question	**What solutions can segmentation and segmented contracting offer to address complexity elements inherent in complex infrastructure projects, and what are the benefits, challenges, and considerations for their adoption?**
Sub-question 1	What is the context of segmentation within established project delivery methods in the Dutch civil infrastructure sector?
Sub-question 2A	How is segmentation approached, considered, and implemented within project delivery methods by clients and contractors within current and recent complex infrastructure projects?
Sub-question 2B	What are the key characteristics, legal implications, benefits and challenges of segmentation according to clients and contractors within current and recent complex infrastructure projects?
Sub-question 2C	What is the impact of segmentation on project complexity elements according to clients and contractors within current and recent complex infrastructure projects?
Sub-question 3A	What is the impact of segmentation on various complexity elements in complex infrastructure projects?
Sub-question 3B	What are the different segmented project delivery methods, and what are their benefits and drawbacks?
Sub-question 4	What are the perspectives of experts and legal experts on key aspects of segmentation and segmented contracting, including coordination, integration, communication, procurement, benefits, and challenges?

Figure 5. Research questions

1.8 Structure of the thesis

This thesis is structured to systematically explore and address the research questions related to segmentation, segmented project delivery methods, and segmented contracting within the Dutch civil infrastructure sector. Each chapter builds upon the preceding one, creating a cohesive and comprehensive narrative that guides the reader through the study's context, methodology, findings, and conclusions. By following this structured approach, the thesis aims to provide a thorough and well-rounded understanding of how the concepts of segmentation, segmented project delivery methods, and segmented contracting can enhance the management of complex infrastructure projects in the Dutch civil engineering sector

Chapter 2. Research methodology

This chapter outlines the research methodology designed to explore segmentation, segmented project delivery methods, and segmented contracting. It details the specific research approach, strategies, and analytical techniques employed. The chapter is divided into sections corresponding to different research methods: literature study, case studies, and expert interviews. Each method concludes with its own findings, providing insights that contribute to the overall understanding of the research questions. The methodology also includes a discussion on ethical considerations, ensuring that the research adheres to the highest standards of academic integrity.

Chapter 3. Literature study

In this chapter, a thorough examination of the most prominent project delivery methods used in the construction industry is presented. It lays the groundwork by identifying common project delivery

methods and their relevance to segmentation. This foundational step is essential for understanding the operational context of segmentation and segmented project delivery methods. The chapter concludes with key insights from the literature, which inform the subsequent stages of the research.

Chapter 4. Case studies

This chapter presents detailed case studies of five major Dutch infrastructure projects: Noord/Zuidlijn, Schiphol-Amsterdam-Almere, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle. Each case study explores the application and outcomes of segmentation strategies, providing comprehensive insights into their implementation and impact. The chapter highlights both the benefits and challenges of segmentation, concluding with lessons learned from each project.

Chapter 5. Framework and typology

In this chapter, a comprehensive analysis of the impact of horizontal and vertical segmentation on various complexity elements is presented. It introduces different segmented project delivery methods gathered from the case studies and organises them into a typology. The framework and typology provide a structured understanding of segmented contracting, showcasing the benefits and challenges of each model. The chapter concludes with a synthesis of the findings, offering valuable guidance for managing complex infrastructure projects.

Chapter 6. (Legal) Expert interviews

This chapter presents insights from experts on segmentation in complex infrastructure projects. The expert interviews reveal a nuanced understanding of the benefits and challenges associated with segmentation. Key aspects such as coordination, integration, communication, and procurement are discussed. The chapter concludes with a comprehensive understanding of the critical factors and best practices for managing segmented projects, as highlighted by the experts.

Chapter 7. Discussion

The discussion chapter interprets the findings of the research, reflecting on the insights gained from the literature study, case studies, and expert interviews. It emphasises the importance of strategic planning, robust coordination, and flexible legal frameworks for effective segmentation. The chapter also discusses the limitations of the research and the implications of the findings for practitioners and policymakers. It concludes by highlighting the contributions of the research to the field of infrastructure project management.

Chapter 8. Conclusion

The final chapter synthesises the conclusions from each section of the methodology, providing a holistic answer to the main research question. It summarises the solutions that segmentation and segmented contracting offer for addressing complexity elements in complex infrastructure projects. The chapter highlights the benefits, challenges, and considerations for adopting these strategies, offering a comprehensive conclusion that integrates the insights from the entire study.

Chapter 9. Recommendations

Based on the findings and conclusions of this research, several key recommendations are proposed to optimise the implementation of segmentation, segmented project delivery methods, and segmented contracting in complex infrastructure projects for clients, contractors, policymakers, and researchers.

2. Research methodology

This chapter outlines the research methodology designed to explore segmentation and segmented contracting. It details the specific research approach, strategies, and analytical techniques employed, which have been carefully chosen to align with the unique requirements of the study's main and sub-questions.

The methodology was carefully selected to correspond with the research objectives and the specific nature of the data involved. This chapter provides a breakdown of the methods used to investigate the context of segmentation within established project delivery methods in the Dutch civil infrastructure sector, how segmentation has been approached, considered, and implemented within project delivery methods by clients and contractors in current and recent complex infrastructure projects, the key characteristics, legal implications, benefits, and challenges of segmentation according to clients and contractors within these projects, the impact of segmentation on project complexity elements according to clients and contractors, the impact of segmentation on various complexity elements in complex infrastructure projects, the different segmented project delivery methods, and their benefits and drawbacks, and the perspectives of experts and legal authorities on key aspects of segmentation and segmented contracting.

Furthermore, the chapter delves into the ethical considerations pivotal to the research process. This includes addressing issues of data confidentiality, informed consent, and the maintenance of academic integrity. The emphasis is on ensuring that the research adheres to the highest ethical standards, respecting both the subjects involved and the broader academic community. This methodological framework is designed not only to guide the study effectively but also to ensure that it contributes valuable and ethically sound insights into the application of segmented contracting in the field of civil engineering.

2.1 Research approach

Given the research questions' focus on segmentation and segmented contracting, a qualitative research approach is considered most suitable (Creswell & Clark, 2017). This approach is beneficial for generating in-depth, contextualised insights into the characteristics of segmentation and segmented contracting in complex infrastructure projects (Amaratunga et al., 2002; Fossey et al., 2002). The exploratory and flexible nature of qualitative research is instrumental in uncovering factors and experiences that might be overlooked by quantitative methods, thereby providing a comprehensive understanding of the subject matter (Hennink et al., 2020, see also Creswell, 2009). While quantitative research has its advantages, it may not fully capture the complexities of this study, which is less about quantifying variables and more about understanding the nuanced relationships among segmented contracting, contract management, and complex infrastructure projects (Amaratunga et al., 2002). Overall, this qualitative research approach aims to offer thorough insights into the understanding of segmented contracting.

2.2 Research strategy

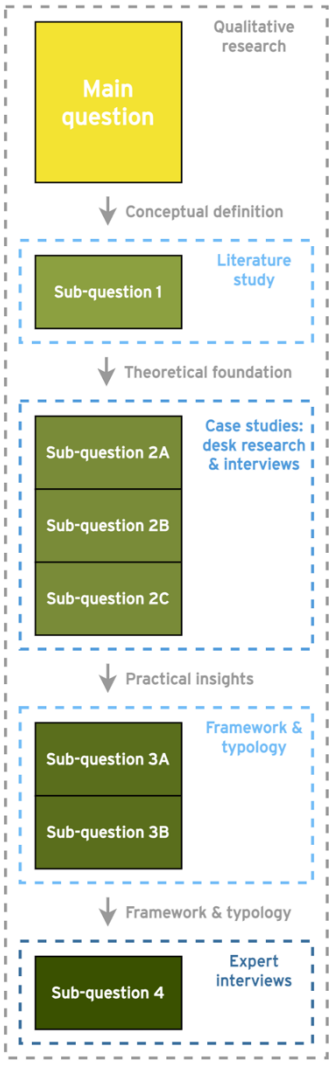


Figure 1. Research strategy

The research strategy for this study is designed to comprehensively address the challenges and potentials of segmented contracting for complex civil infrastructure projects, guided by the main research question: " What solutions can segmentation and segmented contracting offer to address complexity elements inherent in complex infrastructure projects, and what are the benefits, challenges, and considerations for their adoption?". This strategy incorporates an exploratory mixed methods design (Creswell, 2009; Creswell & Clark, 2017) consisting of a literature study, case studies, and interviews, each method specifically chosen to align with the unique aspects of each sub-questions (see Figure 6). This triad of qualitative research methods is chosen for their complementary strengths in providing rich, in-depth insights (Creswell & Clark, 2017) into segmentation and segmented contracting. The exploratory mixed methods design relies on qualitative data as the primary source of information and is particularly suitable for investigating phenomena without established frameworks or theories, or where specific measures or instruments are not readily available (Almeida, 2018, Creswell, 2009). By combining these methods, the study aims to provide a detailed understanding of segmented, while adhering to the ethical guidelines set out by Hennink et al. (2020) and the Delft University of Technology ethics committee. (see chapter “2.6 Ethical considerations”).

The conceptual definition of segmentation and segmented contracting (chapter 1.3) functions as input for the first sub-question. For the initial sub-question (1), "What is the context of segmentation within established project delivery methods in the Dutch civil infrastructure sector?", a literature study approach will be employed. This will involve an extensive review of existing academic and grey literature to establish a clear theoretical definition of the context of segmentation within established project delivery methods that are utilised in the Dutch civil engineering industry. Chapter “2.3 Literature study” will go over the selection criteria, search strategy, and analysis strategy of the literature study in greater detail. The findings from this literature study will establish a robust theoretical foundation, which will then serve as a basis for the subsequent stage of the research strategy.

To address the second set of sub-questions (2A, 2B, and 2C) "How is segmentation approached, considered, and implemented within project delivery methods by clients and contractors within current and recent complex infrastructure projects?", "What are the key characteristics, legal implications, benefits and challenges of segmentation according to clients and contractors within current and recent complex infrastructure projects?", and "What is the impact of segmentation on project complexity elements according to clients and contractors within current and recent complex infrastructure projects?" the research will undertake case studies, consisting of desk research and interviews. These case studies will be pivotal in exploring the different types of segmented project delivery methods, aiming to develop a typology that captures the diversity of segmentation approaches. Additionally, the case study seeks to explore how segmentation is approached, considered, and implemented within project delivery methods, what the key characteristics, legal implications, benefits, and challenges are of segmentation, and what the impact is of segmentation on project complexity elements. The approach of the case study allows for a nuanced understanding of the concept of segmentation by grouping cases based on shared characteristics (Stapley et al., 2022).

By examining various, current and recent, complex projects within the Dutch civil infrastructure sector, the study will discern how clients and contractors are practically approaching segmenting strategies, which will illuminate the characteristics of segmentation in real-world scenarios. In chapter 2.4 Case studies, the case study's selection criteria, search strategy, and analysis strategy will be discussed in more detail.

The framework showcasing the impact of segmentation on complexity elements and the typology of segmented project delivery methods provides the foundation for answering the third set of sub-questions (3A and 3B), "What is the impact of segmentation on various complexity elements in complex infrastructure projects?" and "What are the different segmented project delivery methods, and what are their benefits and drawbacks?". During this phase, the impact of segmentation on complexity elements will be systematically framed, and the various types of segmented project delivery methods identified in the case study will be conceptualised to develop generic models. This step primarily leverages the insights gained from the case study regarding the impact of segmentation on complexity elements and project delivery methods, supplemented by information from the literature review. This approach ensures that the results are broadly applicable and not limited to specific cases.

To address the final sub-questions (4), " What are the perspectives of experts and legal experts on key aspects of segmentation and segmented contracting, including coordination, integration, communication, procurement, benefits, and challenges?", the study will conduct in-depth interviews with industry leading (legal) experts. These interviews will supplement the analysis of segmentation, segmented project delivery methods, and segmented contracting by capturing the practical perspectives of industry and legal experts on the benefits, challenges, and considerations of these approaches.

The exploratory mixed methods design allows for a comprehensive exploration of segmentation and segmented contracting. Figure 7 provides an overview of the adopted strategy and the research questions for this study. The subsequent sub-chapters will delve into each method in detail, respectively.

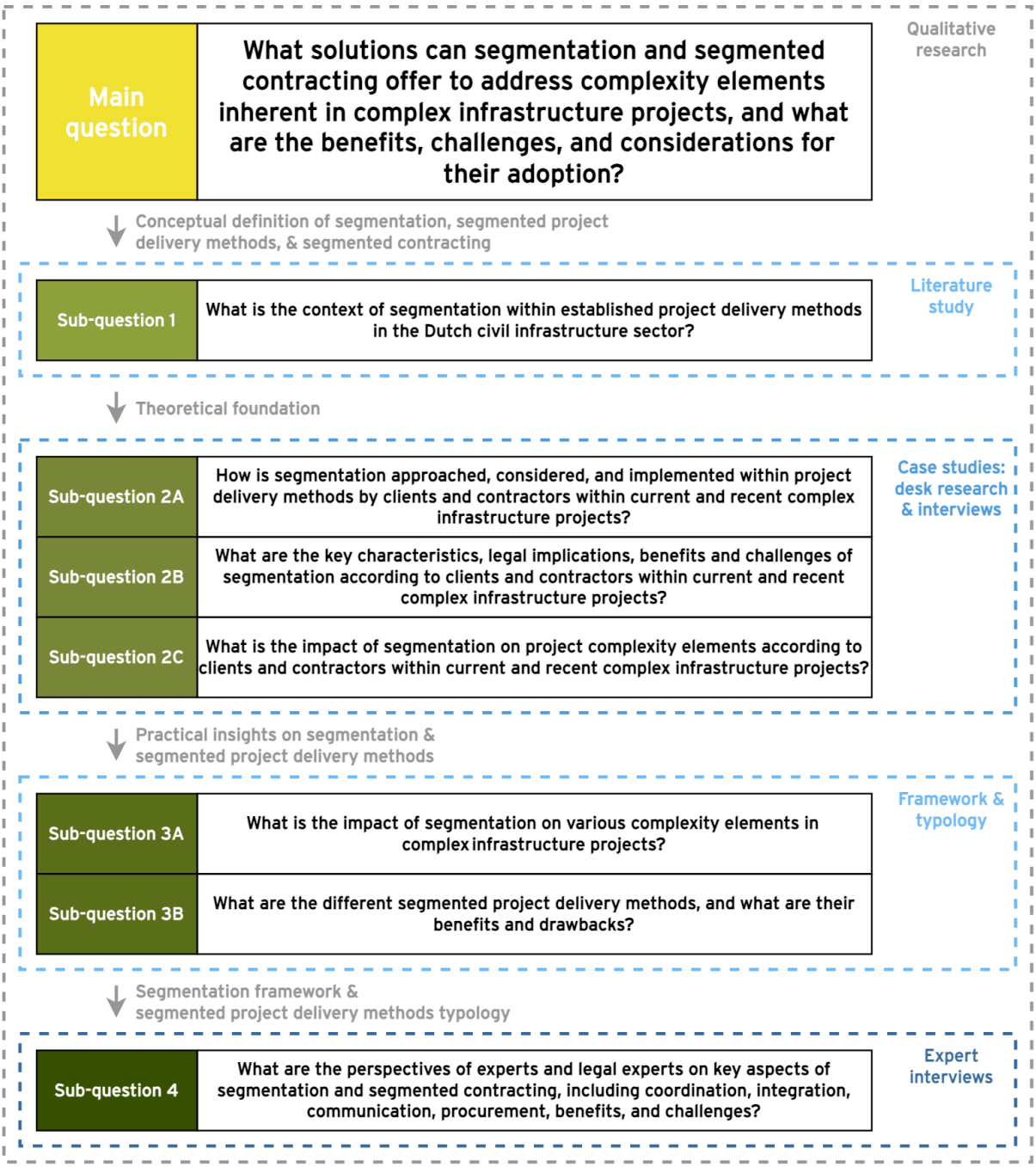


Figure 7. Overview of the research strategy

2.3 Literature study

The literature study will answer the first sub-questions (1) " What is the context of segmentation within established project delivery methods in the Dutch civil infrastructure sector?". In undertaking this research study, devising a search plan for information gathering is important. A well-structured search plan prompts a detailed consideration of the specific information needs, guiding what to look for and where to find it. This plan is instrumental in facilitating an efficient search process, ensuring the acquisition of the most relevant and highest quality information for the research questions (Technische Universiteit Delft, n.d.-b). As part of this strategy, the literature will be selected based on defined criteria, emphasising the separation of academic literature and case studies to streamline the search process tailored to segmented contracting. This involves segregating empirical findings from theoretical frameworks to ensure a comprehensive review. Selection of databases will be guided by the type of

information required, employing precise search syntax and semantics, including carefully chosen keywords pivotal to segmented contracting themes (TU Delft, n.d.-d). Advanced search strategies utilising Boolean operators and other techniques will enhance the search breadth and depth, ensuring a focused and relevant compilation of literature (De Bruijne & Elmohr, 2023).

2.3.1 Selection criteria

This section discusses the criteria used to discover relevant literature for the research. These criteria have been carefully designed to guarantee that both academic and grey literature are included, which greatly contributes to the understanding of segmenting and segmented contracting. The emphasis is placed on sourcing literature that aligns with the research themes and stands out for its credibility and applicability to the nuanced aspects of the topic. The selection criteria are assessed using two essential dimensions: relevance and reliability (TU Delft, n.d.-a). This dual-focus strategy guarantees that selected sources are not only relevant to the research objectives, but also meet the highest levels of academic rigour and integrity.

The relevance of the chosen literature to the research topic is critical (Onwuegbuzie, 2012; Creswell, 2009), a source may be academically accurate and brilliantly written, but it may not assist the research's aims if its subject matter deviates from the desired focus. To determine the relevance of search results, several main factors are examined (TU Delft, n.d.-a; see also Creswell, 2009): the title of the work, which provides an initial indication of its applicability, the keywords, which offer insights into the thematic focus and can signal alignment with the research themes, the abstract or summary (in the case of articles), which presents a concise overview of the study’s aims, methods, and findings, the year of publication, ensuring the information is current and reflective of recent advancements in the field, and the source, with preference given to reputable journals and conference proceedings known for their scholarly integrity. This multifaceted approach ensures that only literature closely aligned with the research questions and objectives is selected for review (Onwuegbuzie, 2012).

The reliability of information gathered during the research process is critical to maintaining the study's integrity and validity. Reliability refers to the trustworthiness of information, whether it is supported by scientific research or just represents personal opinion (TU Delft, n.d.-a). To determine a search result's reliability, it is vital to examine key elements. The first step involves scrutinising the author(s)' background information to assess their expertise, credentials, and contributions to the field, which signals the reliability of their work. Next, considering the intended audience is important. Materials meant for scholarly audiences, like academics or industry professionals, are generally seen as more reliable than those targeting the general public. Finally, analysing the purpose behind the information's creation helps differentiate between sources aimed at informing and educating through rigorous research and those potentially biased or persuasive. This careful assessment ensures that the literature incorporated into the research is not only relevant but also reliable, contributing to the overall rigor and credibility of the study.

2.3.2 Search strategy

This section describes the literature search strategy, which includes a variety of scholarly search engines including Google Scholar as well as comprehensive databases like Scopus, Web of Science, ScienceDirect, ResearchGate, and IBR Tracker. The search strings are created with exact keywords and Boolean operators such as "AND", "OR", and wildcards. Keywords include search terms such as "project delivery method," "bouworganisatievorm," "nevenaanneming," "co-contracting,", "coordination", and contracting.” This structured and systematic search approach has helped explore the literature with broad coverage and efficiency, ensuring a thorough and rigorous investigation.

2.3.3 Analysis strategy

The analysis strategy for the literature study will encompass a robust approach to evaluate and synthesise the collected literature. This process begins by determining the available time for reading and analysis, ensuring a realistic and efficient use of resources. A strategic scanning strategy will be utilised to quickly assess the material's significance. This method will focus on crucial elements that have been carefully picked for their ability to expose the work's relevance and credibility, in accordance with the selection criteria stated in chapter 2.3.1 Selection criteria. Note-taking is crucial, with emphasis on understanding and summarising the content in relation to the established research goals and questions. Additionally, the study employs active reading tactics to deepen engagement with the information, promoting reading with intent and utilising a personalised annotation system for improved comprehension and recall. To ensure full comprehension, the literature might be read several times. This thorough method (TU Delft, n.d.-c) is intended to integrate the findings logically into the larger study narrative.

2.4 Case studies

The case studies will answer the second set of sub-questions (2A, 2B, and 2C) "How is segmentation approached, considered, and implemented within project delivery methods by clients and contractors within current and recent complex infrastructure projects?", "What are the key characteristics, legal implications, benefits and challenges of segmentation according to clients and contractors within current and recent complex infrastructure projects?", and "What is the impact of segmentation on project complexity elements according to clients and contractors within current and recent complex infrastructure projects?". The case study's goal in examining actual projects is to find instances where segmentation strategies, or approaches that are similar to them, have been used, possibly without a full understanding of the concept of segmentation and segmented contracting as a formal strategy. Case studies allow for the development of empirically supported theory (Eisenhardt, 1989), which is closely related to the unique characteristics of segmentation. They add depth by combining various types of data collection and providing a thorough understanding of the dynamics involved (Flyvbjerg, 2006) in segmentation.

2.4.1 Interviews

Within the framework of this comprehensive case study approach, interviews are a critical method for gathering in-depth insights into segmentation strategies within complex infrastructure projects. The research specifically focuses on engaging two key groups of stakeholders: clients, who have a complete overview of the project, and contractors, who are responsible for a segment of the project. This targeted approach aims to capture the nuanced perspectives on the practice and implementation of segmentation directly from those who play pivotal roles in the realisation of projects. The primary goal of the interviews is to explore how segmentation is approached, considered, and implemented within project delivery methods, what the key characteristics, legal implications, benefits, and challenges are of segmentation, and what the impact is of segmentation on project complexity elements. The selection criteria for case study interviews with clients and contractors have been carefully developed to include individuals who have accumulated more than ten years of experience in their respective fields. The emphasis is on individuals who hold prominent positions within the project, ensuring a comprehensive collection of information on segmentation within the project.

The interview will be semi-structured, allowing for both guided questions and the opportunity for participants to share insights beyond the initial scope of inquiry. This approach promotes a rich, conversational exchange in which unexpected topics and insights can emerge, adding value to the research. The questions will cover a variety of topics, such as the segmented project delivery method,

key characteristics, legal aspects, challenges and benefits, project complexity elements, and lessons learned. The specific questions for the interviews can be found in Appendix C. Case study: interview questions for the client (EN) , Appendix D. Case study: interview questions for the client (NL), Appendix E. Case study: interview questions for a contractor (EN), and Appendix F. Case study: interview questions for a contractor (NL). Additionally, an informed consent form, which outlines the ethical considerations and confidentiality commitments of this research, is available in Appendix B. Informed consent form (NL). This ensures that all participants are fully informed and agree to the terms of participation, fostering an environment of trust and openness.

Before the interviews, participants will be informed that references to 'you' in the questions are specific to their role in the project, whether as a client or a contractor. This clarification ensures that the responses are clear and relevant, allowing the research to accurately capture each stakeholder group's unique experiences and insights. The carefully analysed interview data will serve as the foundation for identifying common themes, strategies, challenges, and outcomes associated with segmented contracting. This qualitative analysis, which includes coding the interview transcripts and synthesising the data, aims to uncover patterns and insights critical to understanding segmentation in practice. By combining interview findings with desk research, a comprehensive overview of segmentation practices in the Dutch civil infrastructure sector will be developed.

2.4.2 Desk research

Desk research is an important component of this study, with the goal of gathering, reviewing, and analysing existing data on segmented contracting in complex infrastructure projects. Desk research complements case study interviews by providing a broad context and background, allowing for more focused and informed discussions during the interview. The documents gathered during the desk research phase help to strengthen and facilitate quoting statements from the interviews, ensuring that the findings are based on tangible evidence. This combination of desk research and case study interviews ensures a comprehensive approach, which improves the research findings' depth, accuracy, and reliability.

In addition to publicly available data sources, this study includes a number of specific documents to provide a comprehensive understanding of segmented contracting. These include project overview documents that describe the project's objectives, scope, and expected outcomes, strategic planning documents that detail project realisation and phases, contractual documents that outline the framework within which projects operate, risk management documents that detail identified risks and mitigation strategies, and performance reports that highlight the outcomes and effectiveness of project segmentation.

Gathering these documents enables a comprehensive analysis of how segmentation is used in practice, its impact on project dynamics, and the strategies used to manage segmented contracts. This collection of documents enhances the desk research phase by providing insights into the strategic, operational, and risk management dimensions of segmented contracting, thereby strengthening the study's empirical foundation.

2.4.3 Selection criteria

The projects selected for this case study were identified through an open dialogue with Dura Vermeer, examining their project portfolio to find projects that align with the predefined criteria, which this chapter will go over in detail. First and foremost, the project must be a complex civil infrastructure project in the Netherlands. Note that complexity in construction projects is often described without a universally accepted definition, however, it is widely recognised through its inherent characteristics

and perceived implications. These projects could either be in the procurement, design, or realisation phase, or have already been completed.

The fundamental criterion was that these projects initially possessed a single scope, which was later segmented into multiple parts, with each segment contracted independently, regardless of when the segmentation occurred (whether during the procurement phase or later in the design phase, for example). This segmentation reflects a form of co-contracting within the project delivery method of the project. Additionally, defining a single scope of a project presents challenges. There is a subtle distinction between a large project being considered as a standalone project and when it transitions into a programmatic approach. A large project, initially perceived as a standalone entity, can evolve into what is often termed a program following segmentation. For example, the Zuidasdok project illustrates this transition: initially referred to as a project during the initial tender phase (Rijkswaterstaat, 2015), which failed, it was later categorised as a program during the subsequent tender phase (Programmaorganisatie Zuidasdok, 2022, 2023a).

For the purposes of this research, a project is considered to have one scope when all elements, or in this case, all segments, of the project are interconnected geographically, in terms of decision-making, and through the project's timeline. (see Figure 8).

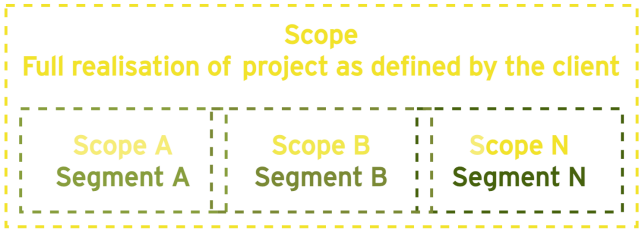


Figure 8. Scope of a project

This distinction is crucial for the research, as many clients and even contractors often have very different views on whether a project should be treated as a standalone project or as part of a broader program. Considering that all segments of a project are connected both geographically and in terms of policy means that changes or causes in one area can have effects on each segment of the project. This interconnectedness would not be present if a project segment is not connected geographically or policy-wise. This framework of selection criteria (Figure 9) allows for a thorough investigation of how segmentation is approached, considered, and implemented within project delivery methods, what the key characteristics, legal implications, benefits, and challenges are of segmentation, and what the impact is of segmentation on project complexity elements.

Type of project	Civil infrastructure project in the Netherlands.
Complexity	The project is characterised by technical, organisational, and external complexity elements.
Project phase	The segments of the project can be in any phase (procurement, design, or realisation), or may have already been completed.
Project scope	Initially, projects should have a single scope that is later segmented into multiple subprojects, with each segment being contracted independently.
Interconnection	Projects are considered to have one scope when all segments are interconnected geographically, in terms of decision-making, and through the project's timeline.
Project delivery method	The projects should reflect segmentation within their project delivery method

Figure 9. Selection criteria for the case study

2.4.4 Search strategy

The search strategy for the case studies, developed in collaboration with Dura Vermeer, aims to identify recent and ongoing complex infrastructure projects that meet the predefined selection criteria. This collaboration takes advantage of Dura Vermeer's extensive project portfolio and deep industry expertise to help identify complex projects. Such a collaborative approach is critical for ensuring that the chosen case studies are relevant and demonstrate tangible examples of segmentation application in practice. This provides the study with concrete examples that are useful in developing a typology, thereby increasing the empirical robustness of the research. Key figures from each case will be approached to gather the necessary information, ensuring a thorough understanding of segmentation.

2.4.5 Analysis strategy

This section outlines a detailed strategy for processing and evaluating the data collected through the case study in order to thoroughly analyse how segmentation is approached, considered, and implemented within project delivery methods, as well as the key characteristics, legal implications, benefits, and challenges of segmentation, and the impact of segmentation on project complexity elements. The primary data will be gathered through semi-structured interviews with key stakeholders, including clients and contractors involved in these projects. After each interview, the conversations will be transcribed to ensure that all details are accurately recorded. To ensure ethical research practices and confidentiality, all interview transcripts will be anonymised in accordance with the Human Research Ethics Committee (HREC) guidelines of the Delft University of Technology.

The structured results will then be organised systematically by topic to facilitate a comprehensive analysis of each aspect of segmentation discussed during the interviews. The categorisation of complexity elements will be based on the TOE (Technical, Organisational, and External) framework classification provided by Bosch-Rekveldt et al. (2018). This method allows for a focused examination of how segmentation is approached, implemented, and perceived within the context of complex project environments.

Additionally, the case study analysis will be supplemented with desk research, which entails reviewing relevant documents shared by the client and/or contractor, such as project reports, tender documents, and contractual agreements. This secondary research will provide a deeper understanding of how segmentation is approached, considered, and implemented, complementing the insights gained from the interviews. Through this dual approach of qualitative interviews and document analysis, the study aims to construct a detailed picture of the segmentation landscape, highlighting its characteristics on project delivery within the Dutch civil infrastructure sector.

2.5 Expert interviews

Expert interviews will enhance the research on segmentation, segmented project delivery methods, and segmented contracting by capturing practical insights from industry and legal experts. These interviews will address the final sub-questions: "What are the perspectives of experts and legal experts on key aspects of segmentation and segmented contracting, including coordination, integration, communication, procurement, benefits, and challenges?" These interviews will provide valuable insights from experts and legal experts in the field of complex infrastructure projects, by investigating their perspectives on key aspects of segmented contracting, segmentation, and segmented project delivery methods. Interviews, as systematic conversations between researchers and participants, allow exploration of individuals' perspectives and wider social phenomena (Knott et al., 2022). They offer the flexibility to adapt questioning based on emerging themes and new insights (Hammer & Wildavsky, 1993). Semi-structured interviews will be conducted to balance structure and flexibility, allowing for a detailed exploration of participants' viewpoints and experiences (Gill et al., 2008; Kvale, 2003) in relation to segmentation and segmented contracting. To ensure comprehensive coverage of the topic, interviews will be conducted with both legal experts and experts in contracting and procurement, providing diverse perspectives on the concepts of segmentation and segmented contracting within the civil engineering sector.

2.5.1 Selection criteria

The selection criteria for expert interviews are meticulously designed to include individuals with over 10 years of experience in their respective fields, focusing on those with significant expertise within the sectors of civil engineering, contracting, and legal aspects relevant to segmented contracting. Some of these experts even have 20 to 30 years of experience, making them prominent players in the sector. This approach ensures that the experts chosen for interviews possess a deep and influential understanding, providing high-quality, informed insights essential for validating the findings from the case studies. By engaging leading legal experts along with seasoned professionals in contracting and procurement, the research benefits from a well-rounded perspective on the practical applications and implications of segmented project delivery methods. This strategic selection of experts is critical for ensuring that the discussions contribute valuable, real-world insights into the challenges and benefits of segmented contracting.

2.5.2 Interview setup

The setup of the expert interviews is designed to ensure that the interviews are both comprehensive and conducive to gathering deep insights. Prior to the interviews, a detailed plan will be formulated, which includes the development of a semi-structured interview guide. This guide will consist of open-ended questions that align with the research objectives, designed to elicit detailed responses on segmented contracting practices, legal considerations, benefits, and challenges. The specific questions for the (legal) expert interviews can be found in Appendix P. Expert interview questions (EN), Appendix Q. Expert interview questions (NL), Appendix R. Legal expert interview questions (EN), and Appendix S. Legal expert interview questions (NL). Each interview will be scheduled to last approximately 60 minutes, conducted either in-person or via a secure online platform (Microsoft Teams), depending on the availability and preference of the interviewees. This flexibility ensures that the interviews are accessible to all participants, regardless of their geographical location. All interviews will be audio-recorded with the informed consent of the participants to ensure accurate capture of the information shared during the sessions. To uphold ethical standards and participant privacy, all recorded data will be stored securely, with access restricted to the research team. Furthermore, all data handling will comply with the privacy regulations outlined by Human Research Ethics Commission (HREC) of Delft University of Technology. This careful setup of expert interviews aims to foster an environment that

encourages open and insightful discussions, ensuring that the collected data is both rich and relevant to the research questions. This approach is pivotal for acquiring a profound understanding of the nuanced aspects of segmentation and segmented contracting as perceived by industry experts.

2.5.3 Analysis strategy

This chapter outlines the approach for processing and analysing the data collected from expert interviews, ensuring a rigorous evaluation of the segmented project delivery methods as per the research's objectives. The data will be collected through semi-structured interviews with legal experts and sector-leading experts in contracting and procurement. These interviews are designed to explore the perceived legal implications, benefits, and challenges of segmented contracting.

Following each interview, the conversations will be carefully transcribed to capture the full breadth of expert insights and perspectives. This transcription process is crucial for preserving the integrity and richness of the data. To adhere to ethical research standards and protect the confidentiality of the participants, all transcripts will be anonymised. This will be done in accordance with the HREC guidelines, ensuring that all personal identifiers are removed from the documentation.

The anonymised transcripts will then be systematically analysed to distil the core themes and insights related to the legal aspects, benefits, and challenges of segmented contracting. This analysis will employ qualitative data analysis techniques, such as thematic coding, to identify and categorise themes consistently and reliably. The coded data will facilitate a structured and detailed examination of the expert opinions, enhancing the understanding of how segmented contracting is viewed and implemented within the industry. This approach ensures a comprehensive and nuanced understanding of the segmented project delivery methods, contributing to the robustness of the research findings and their applicability in improving project management practices in civil engineering.

2.6 Ethical considerations

This research will follow the ethical guidelines proposed by Hennink et al. (2020), 'The Netherlands Code of Conduct for Research Integrity' (KNAW et al., 2018) and the guidelines of the Delft University of Technology Human Research Ethics Committee. This is especially important when employing case studies and interviews, as these methods involve direct interaction with participants and often entail handling sensitive information (Hennink et al., 2020). The study will ensure informed consent by transparently communicating its aims, procedures, potential benefits, and risks, underlining participants' right to voluntary involvement and withdrawal at any time. Maintaining participants' confidentiality and anonymity, if requested, in shared or published work, ensures that their rights and dignity are protected, creating an environment where they feel respected, understood, and safe during the research process. Central to this study is respect for individual autonomy, culture, and values, paired with a commitment to harm prevention. Rigorous, secure, and restricted data handling and storage processes will be put in place to preserve participant confidentiality while bolstering data integrity and contributing to the trustworthiness of the research, thereby enhancing the credibility of findings from these case studies and interviews. The process will be underscored by trustworthiness and transparency, ensuring accurate representation of participants' experiences and perspectives while openly acknowledging any biases or limitations. This approach not only safeguards the participants' rights and promotes their safety but also enriches the depth and quality of the research outcomes by facilitating a more nuanced and respectful understanding of their experiences and perspectives (Hennink et al., 2020).

3. Literature study

To address the first sub-research question, 'What is the context of segmentation within established project delivery methods in the Dutch civil infrastructure sector?', a comprehensive literature study was undertaken. This review establishes the groundwork by identifying the most prominent project delivery methods used in the construction industry, which is crucial for understanding the operational context of segmentation and segmented project delivery methods.

3.1 Background

Before delving deeper into the nuances of segmentation in the later stages of the research, it is critical to lay the groundwork by gathering the most common project delivery methods used in the civil engineering sector. This fundamental step is required for understanding the context in which segmentation occurs. This chapter will first dissect and examine the traditional project process design. Following that, the focus will shift to the more integrated contract approaches. By delving into these contract approaches, this chapter seeks to provide a comprehensive background against which the concept of segmentation can be further understood and evaluated.

3.2 Traditional project delivery method

The traditional project delivery method involves three distinct parties: the client, the architect, and the contractor (Chao-Duivis et al., 2018). This model includes two contract relationships. The first contractual relationship exists between the client and the consultant (which may include roles such as a consultant, architect, or consulting engineer). These parties reach an agreement regarding the creation of a design. The DNR (The New Rules) 2011 is a commonly used set of general conditions that govern this agreement. The second contractual relationship exists between the client and the contractor. The UAC (UAV) 2012 conditions are frequently used in this agreement, which focuses on design execution. There is no contract between the architect and the contractor. Figure 10, based on Chao-Duivis et al.'s (2018) schematic representation of the relationships in traditional project delivery method, depicts the functional relationships between the contractor and the consultant, as well as the contractual relationships between the client and each contractor. In this traditional model, any coordination required to align design or construction activities occurs internally within the firms of the designing and executing parties. As a result, in this model, coordination is not a factor in the design or realisation agreement between the client and the consultant or contractor, as applicable (Strang, 2018).

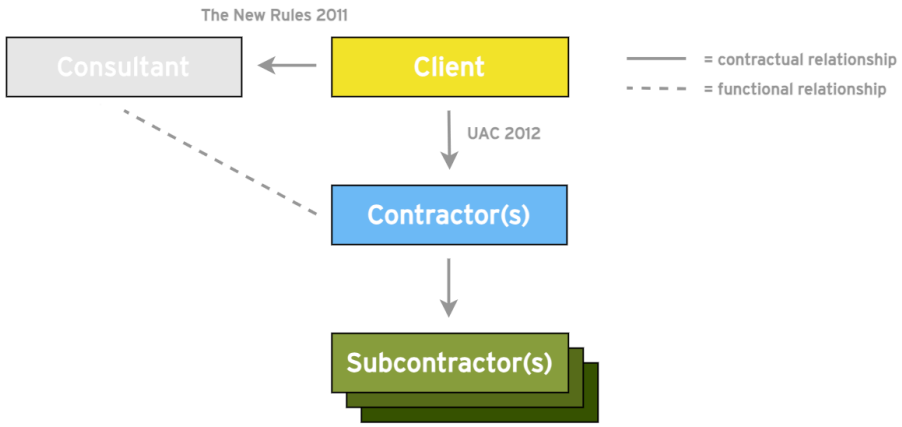


Figure 10. Schematic representation of the relationships in the traditional project delivery method

Figure 11, based on the schematic representation of the traditional project delivery method by Bruggeman and Jansen (n.d.), depicts a schematic overview of the traditional building process,

highlighting the different phases of the construction lifecycle. This illustration emphasises the client's responsibility for the design and procurement phases, while the contractor is in charge of the realisation phase. It also indicates that the client has the flexibility to complete these phases on their own or with the assistance of a consultant (Chao-Duivis et al., 2018). Although no design activities are required during the realisation phase, in some cases the consultant may be involved as the supervising officer (Chao-Duivis et al., 2018).

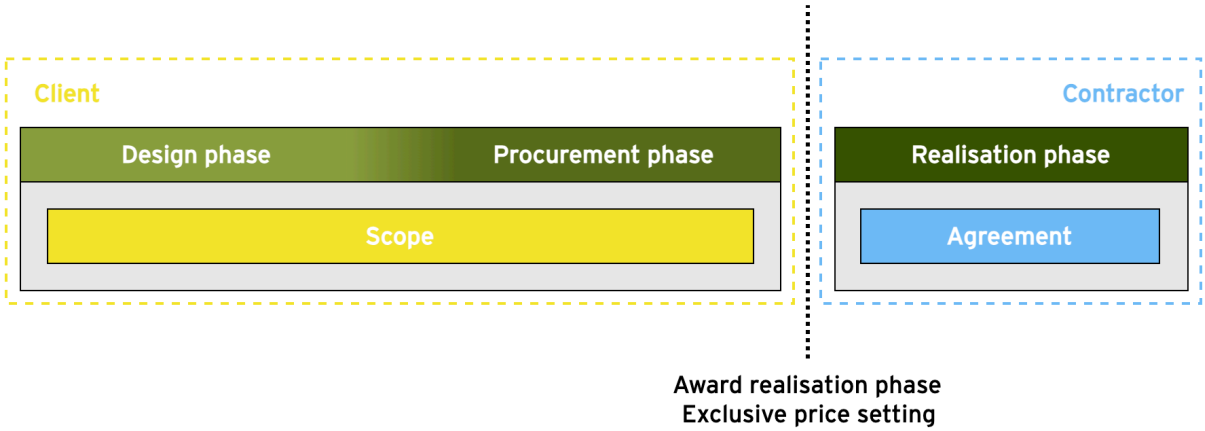


Figure 11. Schematic representation of the traditional project delivery method

In reality, construction projects are frequently too complex to be successfully managed using the traditional model (Strang, 2018), as it is not always possible to maintain a clear distinction between the design and realisation phases. A client may therefore decide to select an integrated contract model in which the client assigns both design and execution tasks to a single contractor (Chao-Duivis et al., 2018).

3.3 Integrated project delivery method

In the integrated collaboration model, the client delegated design and construction responsibilities to a single contractor. In this integrated collaboration model, the UAC-IC (UAV-GC) 2005 is typically used to govern the legal relationship between the client and contractor (Chao-Duivis, 2015; Chao-Duivis et al., 2018). Figure 12, which is based on Chao-Duivis et al. (2018)'s schematic representation of the relationships in the integrated project delivery method, depicts the integrated relationships between the client and the contractor, as well as the contractual relationships between the contractor and the consultant and/or subcontractor. The adoption of this model is motivated by the belief that integrating design and construction tasks will result in a more efficient workflow with better alignment of design and construction activities (Strang, 2018; Van Leeuwen, 2016; see also de Ridder, 2009). Considering only the client-contractor relationship, the assignment's design and construction components are indeed integrated (Strang, 2018). However, this does not imply that an integrated approach is always used when carrying out design and construction tasks, as contractors often use subcontractor(s) and consultants (Chao-Duivis & Wamelink, 2013).

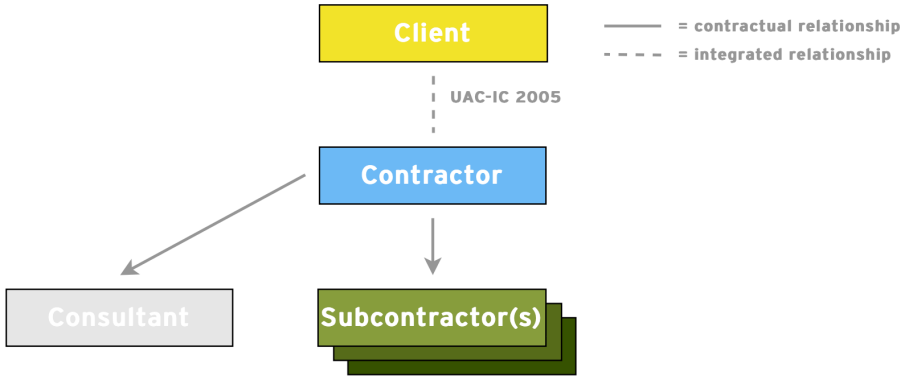


Figure 12. Schematic representation of the relationships in the integrated project delivery method

It is important to note that under the UAC-IC, the contractor bears some of the risk, particularly the design risk. This differs from the UAC 2012, where the client frequently bears a significant portion of the design risk. Furthermore, unlike the UAC 2012, the client's requirements and elaboration are described functionally rather than in detail in the UAC-IC. Here, the client defines the expectations, and the contractor determines how they will be met (Chao-Duivis, 2015). Figure 13, based on the schematic representation of the integrated project delivery method by Bruggeman and Jansen (n.d.), displays a schematic overview of the integrated project delivery method, outlining the stages of the construction process. This figure highlights the client's duty for the procurement phase, whilst the contractor is in charge of the design and realisation phases.

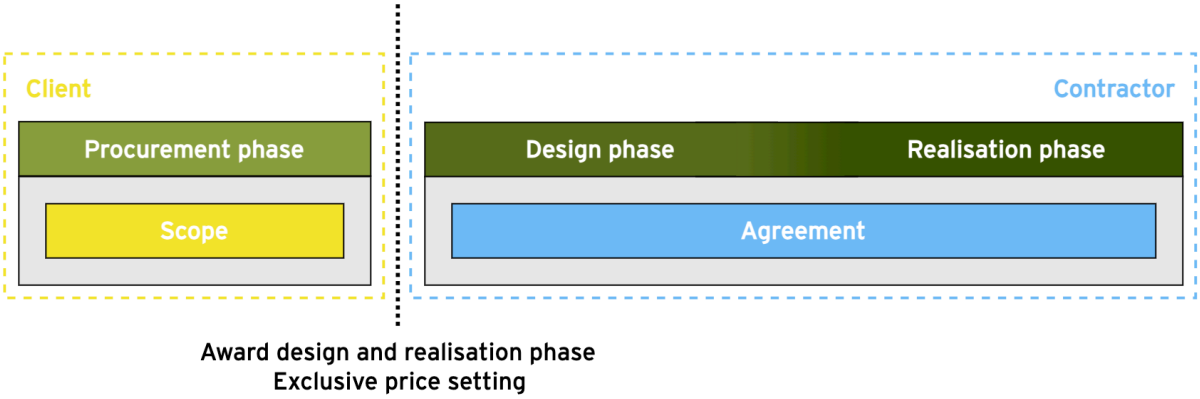


Figure 13. Schematic representation of the integrated project delivery method

The contractor bears primary responsibility for coordination (Strang, 2018). Furthermore, with respect to the client, this contractor oversees both coordination and design. This implies that there may be incentives to create the design in such a way that the interface risks associated with the design during the execution phase are minimised (Chao-Duivis, 2015; De Ridder, 2009).

3.3 Design team project delivery method

The 'early contractor involvement (ECI)' or ‘design team’ (known as “bouwteam” in Dutch) contract model introduces a collaborative approach in which the architect and consulting engineers lead the design process, which differs from the traditional project delivery method (Chao-Duivis et al., 2018). Figure 14, based on Chao-Duivis et al. (2018)'s schematic representation of the relationships in the design team project delivery method, depicts the contractual relationships between the client, the contractor, and the consultants (which may include roles such as a consultant, architect, consulting engineer, coordinators, and cost experts), as well as the contractor-consultant coordination agreement.

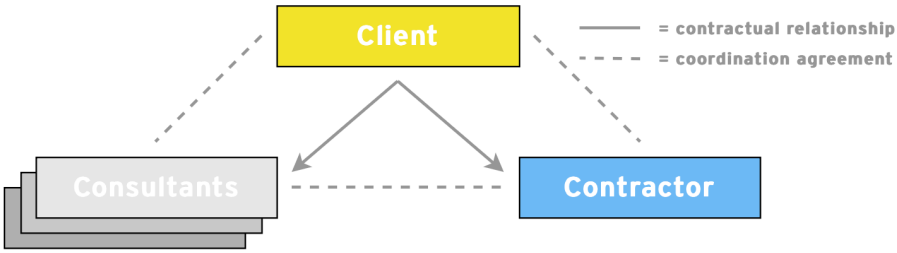


Figure 14. Schematic representation of the relationships in the design team project delivery method

This model modifies the conventional framework by involving the contractor early in the design phase, leveraging their knowledge of cost implications and design execution methodologies (Chao-Duivis et al., 2018; see also De Ridder, 2009). This proactive involvement of the contractor, which differs from the traditional model's later engagement, is critical to incorporating cost-effective and practical insights into the design, thereby increasing project efficiency and feasibility. As the design phase progresses to a sufficient level of detail, the client forms a separate contractual agreement with the contractor, either the one involved from the beginning or a new contractor, for the project's realisation (Chao-Duivis et al., 2018; see also De Ridder, 2009). According to the Model Design Team Contract, the participating bidder in the construction team has the first and only option to make a price offer (Strang, 2018; see also Chao-Duivis et al., 2018). Figure 15, based on the schematic representation of the design team project delivery method by Bruggeman and Jansen (n.d.), depicts a schematic overview of the design team project delivery method. This image emphasises the client's responsibility for the procurement phase, whilst the design team is in charge of the design and the contractor is in charge of the realisation phases,

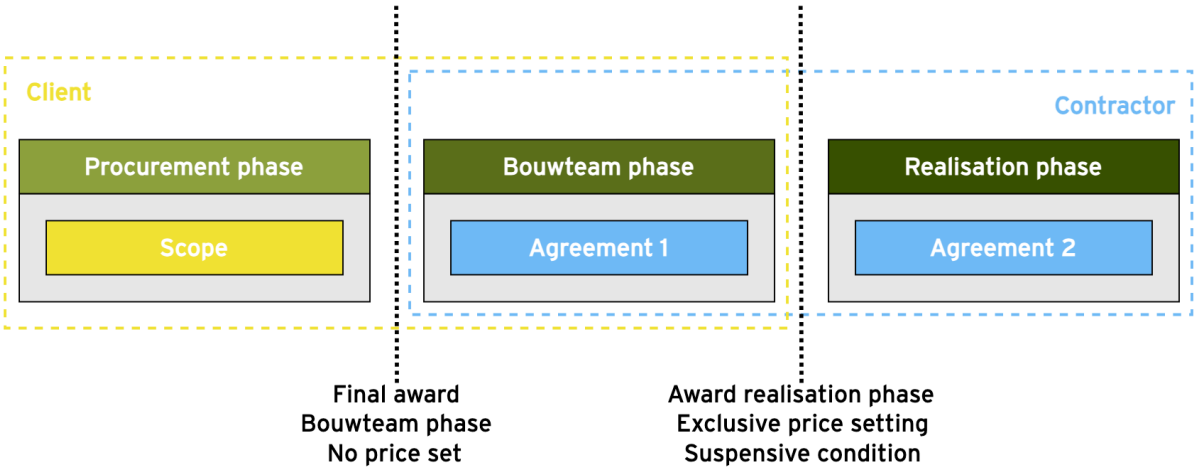


Figure 15. Schematic representation of the design team project delivery method

The design process is organised as follows: it begins by outlining the broad characteristics of the design team, then proceeds on to describe the numerous contracts that the client enters with the design team members, with a particular emphasis on the contract between the client and the contractor who is on the design team (Chao-Duivis et al., 2018). A set of general conditions exists expressly for the design team, which includes contractor participation. This is reflected in the 1992 Model Design Team Contract, issued by VGBouw, designated as Agreement 1 in Figure 15. Consequently, this set of general conditions does not delve into the legal connection between the client and each member of the design team (including the contractor), nor the legal relationships among the various members themselves (Chao-Duivis et al., 2018). Following this initial design phase, Agreement 2 could be based on either the UAC 2012, representing a traditional "Bouwteam," or the UAC-IC 2005, which leads to what is referred to as "Bouwteam 2.0" (Bruggeman & Jansen, n.d.). The choice between UAV 2012 and UAV-GC 2005 for Agreement 2 significantly influences the project's contractual and risk management framework, with UAV-GC 2005 aiming for a more integrated and collaborative approach.

The design team approach places a strong focus on coordinated collaboration. The goal of this coordinated effort is to guarantee that members of the construction team work closely together to ensure that their diverse contributions are well-aligned (Strang, 2018). There is no integration of process functions, therefore each party is accountable for tasks within their respective field. When defining the parameters of the partnership, it is normal practice to reach a coordination agreement among the construction team members. This agreement may include procedures for communication, scheduling, and other aspects of project management (Chao-Duivis et al., 2018; Strang, 2018). The presence of one or more contractors in the design phase raises concerns about how responsibility for the design is distributed among parties. Article 12 of Standard Design Team Contract 1992 states that responsibility for advice and designs rests with the person on the design team whose particular area that advice and those designs relate, provided that the person has accepted and adopted that advice and those designs (Chao-Duivis et al., 2018). The objective for this change in liability is to encourage parties to offer new ideas in another party's territory without fear of liability. The liability clause encourages those who follow the advice to thoroughly review it (Strang, 2018).

3.4 Two-phase project delivery method

In the 2019 report 'Toekomstige Opgave Rijkswaterstaat,' Rijkswaterstaat endorses the two-phase process as an effective strategy for tackling the complexities of infrastructure projects. While the concept of segmented contracting can also trace its origins to this report, gaining a thorough understanding of the two-phase method is imperative, as it establishes one of the ultimate boundaries for the case study. In the two-phase process, the price for the construction phase is determined after the design or engineering phase (Jansen, 2021). At this point, more information is available, resulting in fewer uncertainties and financial risks, providing insight into a better risk distribution (Jansen, 2021; see also Rijkswaterstaat, 2019). The two-phase approach can be executed in various ways, with the variations primarily based on the 'opt-in' and 'opt-out' models (Bruggeman & Jansen, n.d.). Figure 16, informed by Jansen (2021) and Bruggeman and Jansen (n.d.), provides an illustration of the two-phase project delivery method.

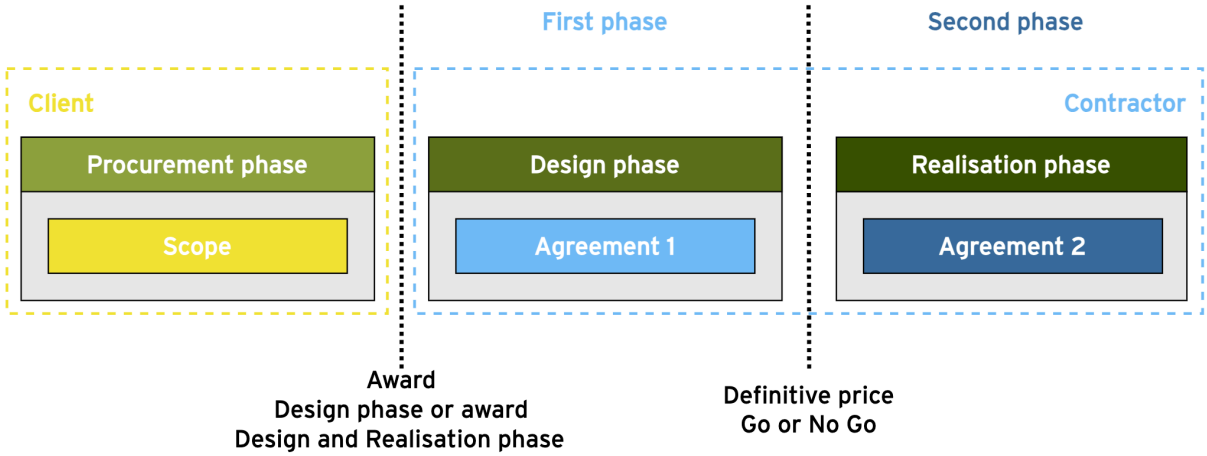


Figure 16. Schematic representation of the two-phase project delivery method

The report by Rijkswaterstaat (2019) discusses several advantages of the two-phase approach. To begin, the implementation of this process is expected to reduce overall risks in the short term, which will benefit both clients and the market parties involved. Over time, the financial position of market participants will improve as a result of productivity gains and innovations. Second, it is expected that market participants' priorities will shift from a "focus on risk" to a "balance of risks and improvements." Third, this approach may result in lower tendering costs for construction companies. Because a broad tender is only organised for the first phase, the design phase, construction companies' participation

efforts are limited. Finally, if a price agreement is reached for the second phase, only the party carrying out the realisation is required to recalculate. In the medium term, this could result in potential savings for the national government, as lower prices may be passed on to customers.

3.5 Co-contracting project delivery method

As detailed in chapter “1.4.3 Segmented contracting and co-contracting”, segmented contracting often involves co-contractors, making it essential to understand the concepts of co-contracting project delivery method and co-contractors in greater detail.

Co-contracting entails a client dividing a construction project into multiple segments and establishing separate contracts with different contractors for each segment (Van den Berg & Van Gulijk, 2022; Van Gulijk & Muller, 2011; see also Strang, 2018). Within such frameworks, at least two contractors are engaged, with each assuming responsibility for a distinct part of the project. These contractors, operating concurrently on various facets of the same project, are termed ‘nevenaannemers’ or co-contractors (Van den Berg & Van Gulijk, 2022; Van Gulijk & Muller, 2011). The client enters into separate agreements for the realisation of the project with each co-contractor, indicating that these contractors usually do not share a contractual relationship amongst themselves. Yet, their work is intricately connected, with the output of one contractor often serving as a foundation for another’s work (Van den Berg & Van Gulijk, 2022). Figure 17, based on Chao-Duivis et al. (2018)'s schematic representation of the relationships in the traditional project delivery method and the description of co-contracting provided by van den Berg and van Gulijk (2022), displays the contractual links between the client and the co-contractors, as well as the functional relationships between the consultant and each individual co-contractor. Furthermore, a co-contractor involved in the project may outsource one or more aspects of their job to subcontractors (Van den Berg & Van Gulijk, 2022). In this arrangement, the initial co-contractor serves as the client for the subsequent subcontractors, who subsequently become co-contractors to one another.

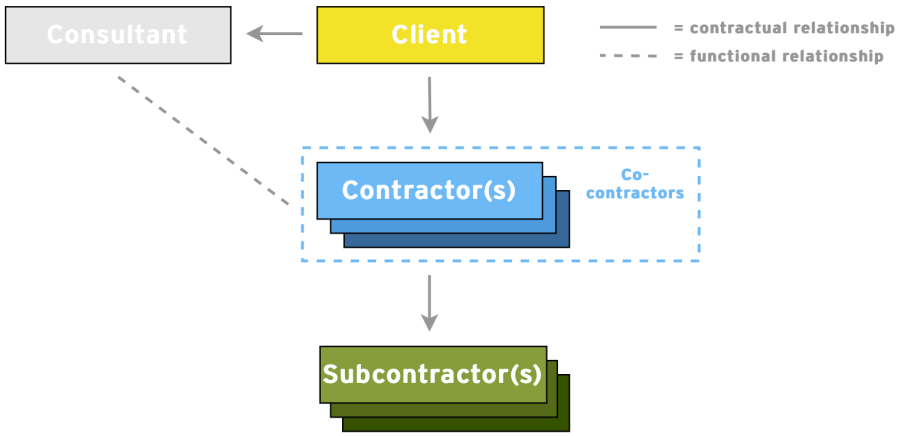


Figure 17. Schematic representation of the relationships in the co-contracting project delivery method

A visual depiction of the co-contracting project delivery method is provided in Figure 18, based on the traditional project delivery method as detailed by Chao-Duivis et al. (2018) and the description of co-contract offered by van den Berg and van Gulijk (2022), this illustration offers a representation of co-contracting in the traditional project delivery method. Specifically, the term "segmenting" denotes the strategic division of a project into smaller, distinct units or segments, as demonstrated in Figure 1, yielding segments identified as A, B, and C.

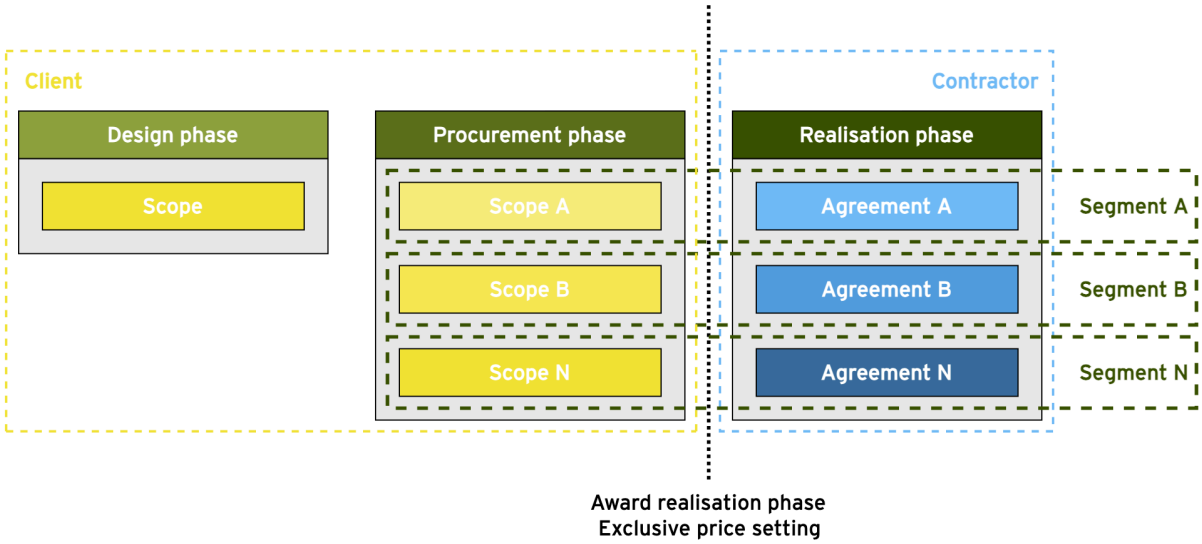


Figure 18. Schematic representation of the co-contracting project delivery method

3.5.1 Coordination

A distinguishing aspect of co-contracting is that each involved co-contractor is assigned a specific segment of the project and has no control over how the other co-contractors carry out their different jobs (Van Gulijk & Muller, 2011). To ensure that each co-contractor can genuinely and adequately accomplish their duty, the co-contractors' activities must be coordinated (Van den Berg & Van Gulijk, 2022; see also Van Gulijk & Muller, 2011). This necessitates the creation of a schedule outlining when each co-contractor should begin their segment, how and in what order they should execute their work, and when they should finish their segment (or a specific aspect of it) (Van den Berg & Van Gulijk, 2022; see also Van Gulijk & Muller, 2011). Furthermore, it is critical to guarantee that all co-contractors follow this timeline. It makes sense for the client to set and oversee such a schedule authoritatively. After all, the client has a contractual relationship with each co-contractor, giving them the legal authority to dictate the workflow, although there is no legal connection between the co-contractors themselves (Van den Berg & Van Gulijk, 2022; see also Van Gulijk & Muller, 2011). As a result, the client is the appropriate entity to coordinate the operations of the co-contractors and bears primary responsibility for their coordination (Van den Berg & Van Gulijk, 2022; see also Van Gulijk & Muller, 2011). The general conditions and case law are consistent with this principle (Strang, 2018; Van den Berg & Van Gulijk, 2022; Van Gulijk & Muller, 2011). The general legal characteristics of co-contracting discussed prior imply that this collaborative approach may automatically involve situations that underpin coordination issues. As a project is divided into segments, the co-contractors' economic interests are initially linked only to these segments, the client, who may be considered non-expert, bears primary responsibility for coordination, and collaboration and decision-making must take place among parties who are not directly contractually connected. Furthermore, the essential properties of this paradigm do not provide intrinsic incentives for participants to participate in collaborative, communication, and (implicit) coordinating activities. These disadvantages can be (somewhat) avoided by using a coordination agreement (Strang, 2018). If such an agreement is reached, the arrangement of coordinating activities in the agreement, as well as how the agreement effects the crucial components of collaboration and communication, become important considerations (Strang, 2018; Van den Berg & Van Gulijk, 2022; Van Gulijk & Muller, 2011).

The client may choose not to handle the coordination duty themselves and instead hire an assistant. However, this only partially addresses the drawback of the client's coordination responsibilities in the co-contracting approach (Van den Berg & Van Gulijk, 2022; Van Gulijk & Muller, 2011). Another way to delegate the coordination responsibility to another construction participant is to allocate it to one of

the co-contractors (Van den Berg & Van Gulijk, 2022). The following paragraph uses insights from the last referenced source to delve more into the effects of this approach.

When one of the co-contractors is allocated the coordination responsibility, the agreement with that co-contractor includes a service obligation. This means that the specified contractor is accountable not only for successfully performing their own task, but also for effectively coordinating the operations of the other co-contractors. The client and the coordinating co-contractor must specifically agree on this coordination duty. According to case law, vague agreements might lead to scenarios in which, in the event of damages originating from the co-contractors' unsatisfactory performance, the client, rather than the coordinating co-contractor, may be held liable for any consequent damages. The co-contractor in charge of coordination must prepare an acceptable work plan in cooperation with the other co-contractors and ensure that it is followed. If a co-contractor falls behind schedule, the coordinating contractor must address the issue immediately and, through conversations with the lagging contractor and others, endeavour to minimise disruption to the overall timetable, possibly by accelerating or relocating other work components. However, the coordinating contractor is expected to make every attempt to fulfil the schedule but is not obligated to do so. Their position is described as a duty of care, not an absolute guarantee of outcome. Designating one of the co-contractors as the coordinator does not relieve the client of all duty for appropriate coordination. However, it reduces the likelihood of disorganisation by utilising the coordinating co-contractor's unique knowledge. In contrast to the subcontracting model, in which the main contractor who has taken on the entire execution of the work bears full responsibility for coordination, the client retains a significant degree of responsibility for coordination in this co-contracting variant, even when the coordination task is assigned to one of the co-contractors. Furthermore, a charge must be paid for the portion of the coordination accepted by the coordinating contractor, which may reduce the financial benefits often associated with co-contracting. Furthermore, the overall organisational benefits of co-contracting (direct client influence over co-contractors and equal status among co-contractors) may be diminished in this variant, as the client employs the coordinating contractor as an intermediary. As a result, while giving the coordination duty to a co-contractor mitigates one of the disadvantages of co-contracting, it also greatly reduces the benefits.

It is also possible to designate all co-contractors jointly for the coordination of realisation activities, with each accepting responsibility for the preparation of a shared work plan, as well as its implementation and monitoring (Van den Berg & Van Gulijk, 2022). While this results in some shared responsibility among the co-contractors for good coordination, it does not entirely shift the burden to them.

3.5.2 Key characteristics of co-contracting

Following the exploration of the co-contracting project delivery method, the characteristics of co-contracting within construction projects are further detailed. Co-contracting, as a structural strategy, involves dividing a construction project into smaller, more manageable parts or segments, each handled by different co-contractors. This division is aimed at enhancing project management efficiency, enabling specialised focus on distinct project aspects, and potentially facilitating the integration of innovative construction techniques and materials specific to each segment (Van den Berg & Van Gulijk, 2022; Van Gulijk & Muller, 2011).

As a project is divided into segments, the economic interests of the co-contractors are initially only tied to these subprojects, adding a layer of complexity to the project's overall management. In some cases, collaboration and decision-making must take place among parties who are not directly contractually linked to one another, presenting unique challenges in aligning project goals and ensuring cohesive progress across all segments (Van den Berg & Van Gulijk, 2022).

The concept of co-contracting inherently involves a significant coordination effort, especially in ensuring that the work of various co-contractors aligns seamlessly to meet the overall project objectives. As previously discussed, coordination challenges can emerge due to the disparate nature of the tasks assigned to each co-contractor and the need for synchronising their outputs. The contractual arrangement underpinning segmenting typically grants the client the pivotal role of orchestrating this coordination, although, as noted, this responsibility can be partly alleviated by designating one of the co-contractors or employing a coordination assistant (Van den Berg & Van Gulijk, 2022).

Effective co-contracting requires meticulous planning and execution oversight to prevent any misalignments or delays that could impact the project timeline or budget. The coordination mechanism, whether managed directly by the client or through a designated co-contractor, needs to be robust enough to handle the complexities introduced by segmenting. This includes managing the interfaces between different project segments, ensuring quality across all segments, and resolving any conflicts or issues that arise due to the interdependencies between segments (Van den Berg & Van Gulijk, 2022; Van Gulijk & Muller, 2011).

Furthermore, the economic and contractual dynamics of co-contracting offer both opportunities and challenges. On one hand, co-contracting can lead to cost savings and enhanced control over the project for the client, as it allows for direct contracting with specialised co-contractors for different segments of the work. On the other hand, the division of the project into segments increases the complexity of coordination and project management, potentially leading to increased risks of miscommunication, delays, and quality issues. As a project is divided into segments, and the economic interests of the co-contractors are initially only tied to these subprojects (Strang, 2018). In some cases, collaboration and decision-making must take place among parties who are not directly contractually linked to one another (Van den Berg & Van Gulijk, 2022).

3.5.3 Challenges and benefits

Dividing a project among co-contractors can result in cost benefits for the client while also providing significant control over the course of the realisation process. However, in the event of co-contracting, the client has primary responsibility for coordinating the operations of the many co-contractors (Van den Berg & Van Gulijk, 2022). When the client assigns the entire project to a single contractor, who then hires subcontractors for specific parts, the overall project price includes the fees owed to those subcontractors, as well as a markup for general expenses, profit, and risk for the main contractor. The client can save money on the markup by directly employing co-contractors for sections that are scheduled to be outsourced (Van Gulijk & Muller, 2011). Additionally, employing co-contractors directly gives the client more control over the progress of the work than subcontracting (Van Gulijk & Muller, 2011). Co-contracting allows the client to maintain a direct contractual contact with each co-contractor, as opposed to sub-subcontracting, which relies on the primary contractor's intermediary. Furthermore, the equal position that co-contractors have relative to one another allows specialised contractors to offer their specific skills more effectively than if they were involved in the task as a sub-subcontractor.

However, the benefit of subcontracting is offset by the fact that the client is responsible for effectively coordinating the activities of the many co-contractors. This responsibility arises from the client's commitment to aid the completion of each party's job. The client may be held accountable for any deficiencies in activity coordination. For example, the client may be required to compensate for the delay damages caused by another co-contractor's lag (Van den Berg & Van Gulijk, 2022). Improper work synchronisation can also result in quality flaws, which the client must pay to correct. In reality, such concerns are addressed by involving the numerous co-contractors in a coordination agreement between the client and the co-contractors (Van den Berg & Van Gulijk, 2022). Co-contracting can lead

to disagreements over which co-contractor's error is to blame for a quality issue found in the job. Because their tasks can intertwine, it may not always be easy to determine where the fault is. This issue would not exist if the client had assigned the entire project to one contractor, who then outsourced portions of it as subcontractor work (Van den Berg & Van Gulijk, 2022). Finally, in the case of co-contracting, it may be unclear who is liable for temporary construction site features that benefit many co-contractors, such as access roads. For example, if the corresponding specifications do not explicitly state which co-contractor is accountable for specific site provisions, this ambiguity may be deemed the client's obligation (Van den Berg & Van Gulijk, 2022; see also Van Gulijk & Muller, 2011).

Overall, co-contracting is a nuanced approach to civil engineering project management, with specific characteristics that demand careful analysis and management of coordination, planning, and contractual agreements. The case study will explore how the principles of segmentation within co-contracting extend to more integrated project delivery methods, aiming to deepen our understanding of segmentation.

3.6 Conclusion literature study

This chapter has provided a thorough examination of the most prominent project delivery methods used in the construction industry. Laying the groundwork by identifying common project delivery methods is essential for understanding the operational context of segmentation and segmented project delivery methods. This foundational step provides the necessary context for researching segmentation in later stages of the research. Segmented contracting is not a standalone concept but operates within the broader frameworks of traditional, integrated, design team, two-phase, and co-contracting project delivery methods. Each method presents unique challenges and benefits related to coordination, risk management, and resource allocation.

The traditional method struggles with managing complex projects due to its separation of design and construction phases. Integrated methods streamline these phases but place more risk on the contractor. The design team method fosters early contractor involvement, improving project feasibility. The two-phase method enhances risk management by separating design and construction phases, and co-contracting offers direct control over segments but demands robust coordination.

Understanding these methods provides the necessary context for exploring how segmentation and segmented contracting can address the inherent complexities in complex infrastructure projects. It sets the stage for the subsequent chapters, which delved deeper into the implementation and impact of segmentation strategies, offering insights into their benefits, challenges, and best practices for successful project delivery.

4. Case study

This chapter presents the empirical findings from the case study on segmentation and segmented contracting in complex infrastructure projects, addressing the second set of sub-questions (2A, 2B, and 2C) "How is segmentation approached, considered, and implemented within project delivery methods by clients and contractors within current and recent complex infrastructure projects?", "What are the key characteristics, legal implications, benefits and challenges of segmentation according to clients and contractors within current and recent complex infrastructure projects?", and "What is the impact of segmentation on project complexity elements according to clients and contractors within current and recent complex infrastructure projects?". The methodology outlined in chapter "2.4 Case studies" employed a comprehensive approach, combining desk research and interviews, to dissect and comprehend the nuances of segmentation strategies in the Dutch civil infrastructure sector. This approach thoroughly explored, identified, and defined the various types of segmentation. The case study examined current and recent projects to identify instances where segmented contracting strategies or similar approaches were used, possibly without a complete understanding of segmenting and segmented contracting as formal strategies. Furthermore, the case study investigated various aspects of segmented contracting from the perspectives of clients and contractors, such as key characteristics of segmentation strategies, the legal implications of segmentation, the challenges and benefits of segmentation, and the impact of segmentation on project complexity elements.

Based on the open dialogue with Dura Vermeer and the predefined selection criteria (2.4.3 Selection criteria), the following five complex infrastructure projects were selected for inclusion in the case study, as illustrated in Figure 19. It should be noted that the case study on the Noord/Zuidlijn project was based solely on desk research, whereas the other cases were based on interviews with the client and contractor(s), as well as desk research.

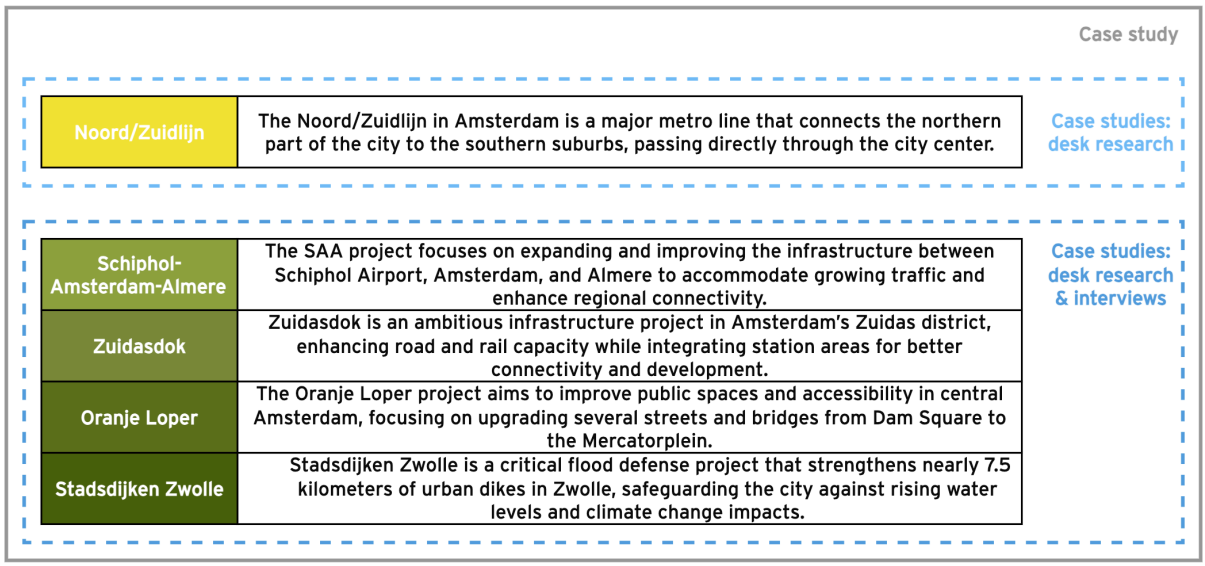


Figure 19. The selected cases for the case study

4.1 Noord/Zuidlijn

The Noord/Zuidlijn, also known as the North/South metro line in Amsterdam, stands as a testament to the complexities inherent in dense urban infrastructure projects. Conceived as a high-profile project, the line connects the northern part of Amsterdam with the vibrant heart of the city and onwards to the southern suburbs (Gemeente Amsterdam, 2009). The Noord/Zuidlijn was strategically segmented into multiple contracts, several posed significant complexities: the three 'Diepe stations', the 'Passage Centraal Station', the 'Boortunnels', the 'Zinktunnel IJ', and the 'Caissons Damrak' (Gemeente Amsterdam, 2009). Across three rounds of tendering, these complex contracts, accounting for 54% of the overall budget, were introduced to the market. The culmination of the tendering process was the successful awarding of these seven complex contracts (Gemeente Amsterdam, 2009). The focus in this case study on the Noord/Zuidlijn project is on the complex contracts. This clearly demonstrates that the client employed segmentation to divide the project scope into numerous segments. Initially, the municipality received counsel to concurrently offer the three deep stations and the bore tunnels as a combined Design & Build contract, leading to four complex contracts in the first tender phase (Gemeente Amsterdam, 2009). Subsequently, an even more segmented approach was adopted, which refined the project scope into the current seven distinct complex agreements (Gemeente Amsterdam, 2009).

The Noord/Zuidlijn project is frequently cited as a prime example of cost overruns (costs nearly quadrupled) in large-scale, complex infrastructure projects, particularly in sensitive urban areas. This metro line's journey through modern urban development highlights the intricate relationship between advanced engineering, historic urban landscape preservation, and the dynamics of social expectations (Gemeente Amsterdam, 2009). The project's extensive media coverage, scholarly analysis, and public debate highlight its status as a key case study in urban infrastructure development.

This subchapter investigates the Noord/Zuidlijn project to understand its approach to segmentation and to identify the type of segmentation and the project delivery method employed. Through a detailed examination of this project, the research seeks to understand the intricate processes of segmenting, unravel the key characteristics and legal considerations involved, and navigate the multifaceted challenges and benefits it presents. This investigation provides insights into the strategic decisions that shaped the Noord/Zuidlijn and evaluates the outcomes that segmentation had on its overall success and delivery. This desk research on the Noord/Zuidlijn utilises the "Rapport van de Enquêtecommissie Noord/Zuidlijn" (Gemeente Amsterdam, 2009) as its primary source, through which insights are gained. Please note that the source, "Rapport van de Enquêtecommissie Noord/Zuidlijn" by Gemeente Amsterdam (2009), is not repeatedly cited in the text of the following subchapters on the Noord/Zuidlijn project.

4.1.1 Complexities of Noord/Zuidlijn

This subchapter delves into the initial complexities of the Noord/Zuidlijn project, highlighting the technical, organisational, and external challenges that shaped the project. The complexities identified are critical to understanding the inherent challenges of carrying out a large and complex infrastructure project in an urban setting. This section serves as a foundational analysis, establishing the context for investigating how subsequent project strategies, particularly segmentation, attempted to address and manage these complexities. Table 2 contains a detailed categorisation and description of these complexities, providing a comprehensive overview of the project's early challenges.

Table 2. TOE Framework analysis of the project complexities in Noord/Zuidlijn

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and complexity elements were sourced from "Rapport van de Enquêtecommissie Noord/Zuidlijn" by Gemeente Amsterdam (2009).

T Technical complexity	O Organisational complexity	E External complexity
High number of project goals The Noord/Zuidlijn project was characterised by many goals, addressing a wide range of development objectives, which contributed very much to the project's complexity.	**High project schedule drive** The urgency to adhere to the project schedule was high, putting pressure on all organisational aspects and often leading to tight deadlines for the project, which contributed very much to the project's complexity.	**Level of competition** The Noord/Zuidlijn project experienced limited competition due to the scarcity of contractors equipped to handle the complexities and scale of such a project, which contributed substantially to the project's complexity.
Uncertainties in scope The scope of the Noord/Zuidlijn project was highly uncertain due to the project's innovative nature and the dense urban environment in which it was situated. This contributed very much to the project's complexity.	**Lack of resource & skills availability** There was a noted deficiency in the availability of required skills and resources, particularly in specialised areas critical to the project's success, which contributed significantly to the project's complexity.	**Political influence** The project was heavily influenced by political decisions and pressures, which impacted the planning, execution, and funding phases, adding very much complexity to the project.
Strict Quality Requirements The project was characterised by extraordinarily high-quality demands that exceeded normal expectations, contributing significantly to the project's complexity and necessitating precise and careful work.	**Lack of experience with parties involved** The project involved many parties who lacked previous experience with similar large-scale projects, which added to the coordination and management challenge, contributing substantially to the project's complexity.	**Dependencies on external stakeholders** The Noord/Zuidlijn project depended on various external stakeholders, including governmental bodies for subsidies and approvals, contractors for construction, and the public for support and feedback, which contributed very much to the project's complexity.
Project duration The Noord/Zuidlijn had a prolonged project timeline, which was significantly longer than standard projects, contributing very much to the project's complexity.	**Interfaces between different disciplines** Managing the interfaces between different technical and organisational disciplines was a crucial and complex aspect, given the multifaceted nature of the project, contributing substantially to the project's complexity.	**Number of external stakeholders** The project interacted with a wide array of external stakeholders, including city residents, businesses, commuters, local government agencies, and environmental groups, contributing very much to the project's complexity.
Size in CAPEX The capital expenditure for the Noord/Zuidlijn was enormous, indicating that the project was a substantial investment with significant financial exposure, contributing very much to the project's complexity.	**Size of project team** The size of the project team was significant, involving a wide range of professionals from various fields, which made management more complex due to the need for extensive coordination and communication, contributing very much to the project's complexity.	**Interference with existing site** The Noord/Zuidlijn project faced significant challenges related to interference with the existing urban environment, especially given its construction in densely populated and historically sensitive areas, contributing very much to the project's complexity.
Number of locations Multiple sites and locations were involved in the project, which added complexity as coordination and integration across these various sites was required, contributing very much to the project's complexity.	**Organisational risks** The client faced significant organisational risks, as it had to manage and coordinate a mega project, contributing very much to the project's complexity.	
Newness of technology Innovative tunnelling techniques were employed, which, while providing advantages such as reduced disruption to the city surface, brought unique challenges and uncertainties due to their limited prior use on similar scales, contributing significantly to the project's complexity.		
Lack of experience with technology There was a noted lack of experience with the specific advanced technologies used for tunnelling and underground construction, increasing the risk and technical demands of the project, thereby contributing significantly to its complexity.		
High number of tasks The project involved a multitude of tasks, each contributing to the overall complexity of the project due to the extensive coordination required, contributing very much to the project's complexity.		

High Variety of Tasks The project involved a wide variety of tasks, from tunnelling to station construction and integration with existing transportation networks, each with its own set of technical requirements and challenges, adding very much complexity to the project. **Dependencies between tasks** The interdependencies between various project tasks, such as sequential construction stages and the integration of technical systems, added to the complexity, as delays or issues in one area could impact others, contributing very much to the project's complexity. **Uncertainty in methods** Significant uncertainties were associated with the technological methods that would be encountered during the project, particularly the involvement of innovative construction techniques, contributing very much complexity to the project. **Involvement of different technical disciplines** The project required the coordination of various technical disciplines, which needed to work together seamlessly to address the multifaceted technical challenges of constructing a major underground metro line, contributing very much to the project's complexity. **Conflicting norms and standards** The project faced challenges in aligning the various applicable norms and standards, which sometimes conflicted, especially given the innovative nature of some of the construction techniques and the stringent safety and quality requirements, contributing significantly to the project's complexity. **Technical risks** The project was fraught with technical risks, including the potential for structural impacts on existing buildings, technical failures, or unforeseen geological conditions, which contributed very much to the project's complexity		

4.1.2 The tender phases of Noord/Zuidlijn

The Noord/Zuidlijn project unfolded through multiple tender phases, each pivotal in refining the project's procurement strategy and addressing emerging challenges. While the initial phase established a foundational segmentation strategy, subsequent phases further nuanced this approach. Specifically, the second tender phase introduced additional segmentation within an existing agreement, playing a critical role in managing the project's complexities. This strategic segmentation significantly enhanced the overall effectiveness and efficiency of the construction process.

In the initial tender phase of the Noord/Zuidlijn, the City of Amsterdam strategically segmented the scope of the project into four segments with four complex contracts: the bore tunnel and the three deep stations. To effectively manage the complexities of the project and ensure a balanced risk allocation, the municipality employed various segmentation strategies. These are identified and classified as horizontal and vertical segmentation. Vertical segmentation was applied to the bore tunnel, which required a contractor with advanced tunneling expertise and specialised equipment. This segment was managed by a contractor specifically selected for their proficiency in advanced tunnelling techniques. Horizontal segmentation was utilised for the three deep stations (Rokin, Vijzelgracht, and Ceintuurbaan). This geographical approach addressed site-specific challenges by considering the

different locations of the stations, aligning each station's needs with the respective contractor's expertise and the geographic complexities involved. This ensured that each station's unique challenges were effectively managed. The segmentation of the project scope resulted in four integrated design and build agreements, each one specifically tailored to a particular segment of the project. The client oversaw the procurement phase, while the contractor or consortium of contractors was responsible for the design and realisation phases of their respective segments. The chosen procurement method was a non-public procedure with a prior selection process. Six major consortiums were invited to submit bids, and five of them registered. Registration could be for the three deep stations individually or together, for the bore tunnel, or for the three deep stations and the bore tunnel as a whole. Table 3 provides an overview of the segmentation within the project scope, detailing the segments, the type of segmentation, and agreements.

Table 3. Overview of segmentation in the scope and agreements for Noord/Zuidlijn (first tender phase)

Note: Information sourced from "Rapport van de Enquêtecommissie Noord/Zuidlijn" by Gemeente Amsterdam (2009).

Scope	Description	Type of segmentation	Segment	Segment intersection(s)	Agreement	Type of agreement	(Consortium of) contractor(s)
A	Bore tunnel	Vertical	A	B, C, & D	A	Design & Build	A
B	Station Rokin	Horizontal	B	A	B	Design & Build	ND
C	Station Vijzelgracht	Horizontal	C	A	C	Design & Build	ND
D	Station Ceintuurbaan	Horizontal	D	A	D	Design & Build	ND

Subsequently, Figure 20 offers a detailed schematic representation of the project delivery model for the Noord/Zuidlijn project, showcasing the four segments, the specific type of segmentation applied to each segment, and the corresponding four agreements.

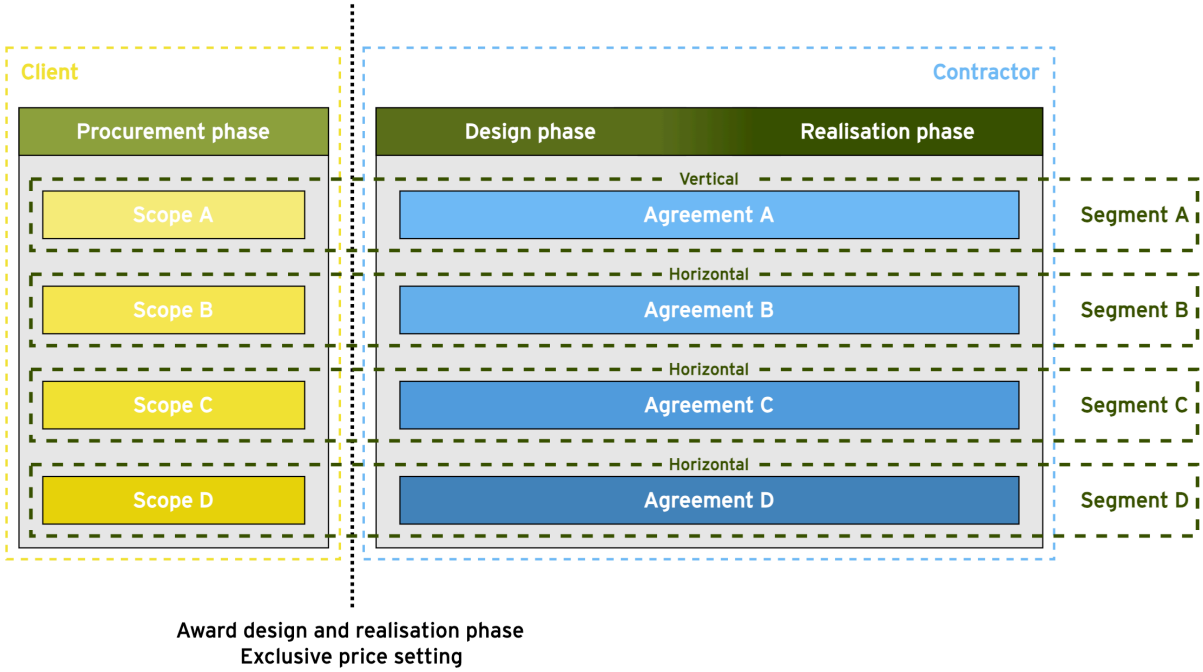


Figure 20. Schematic representation of the segmented PDM for the Noord/Zuidlijn (first tender phase)

This initial tender phase encountered significant challenges leading to its failure, characterised by an overly ambitious scope and an underestimation of risks. Additionally, there was a shortage of sufficiently capable bids from contractors to handle the project's scale and complexity. Attempting to encompass a vast array of work within a single tender proved daunting for potential contractors, who found the risk-to-reward ratio unfavourable. Contractors were hesitant to commit to such a large-scale project under the terms offered, fearing unforeseen complications and cost overruns, especially given the challenging urban environment of Amsterdam. The lack of clear definitions of project scopes and responsibilities further added to the uncertainty and risk perceived by contractors. Notably, only the bore tunnel segment was awarded to a specialised contractor during this phase.

Drawing on the lessons from the initial tender, the City of Amsterdam refined its strategy for the second tender phase of the Noord/Zuidlijn project. Although segmentation was already introduced in the first phase, the agreements were further refined into Design-Bid-Build contracts, each with a clearly predefined risk allocation. This shift resulted in the municipality assuming greater risks compared to the first tender phase. Moreover, the project underwent further segmentation in the second tender phase, resulting in six contracts being simultaneously marketed, with aspects such as technical installations and station completions excluded by vertical segmentation. Originally, the project consisted of seven segments in total. However, the bore tunnel segment had been awarded to a specialised contractor during the previous tender phase, leaving six contracts available for the market. Notably, technical installations and station completions were excluded and would be considered additional to these seven segments. The project scope consists of seven segments, each procured separately by the client, resulting in seven distinct agreements, which make up the full scope and realisation of the project. These agreements were procured to a total of five contractors. The client recognised the need to enhance their segmentation strategy to better mitigate risks and encourage more competitive and realistic bids. This strategic adjustment was crucial for advancing the project and developing a more effective and sustainable procurement strategy. Segmentation allowed for the distribution of contracts among different contractors, each with specific expertise, which proved invaluable in tackling the complex challenges of constructing a metro line through Amsterdam's densely populated and historically rich urban environment. As mentioned earlier, vertical segmentation was implemented for the construction of the bore tunnel, requiring a contractor with advanced specialised expertise and machinery. For the three deep stations, the same segmentation approach from the first tender phase was applied. Additionally, geographical segmentation was employed for segments E, F, and G to address specific project needs and local challenges. The segmentation within the project scope is summarised in Table 4, which details the segments, the type of segmentation, and the agreements.

Table 4. Overview of segmentation in the scope and agreements for Noord/Zuidlijn (second tender phase)

Note: Information sourced from "Rapport van de Enquêtecommissie Noord/Zuidlijn" by Gemeente Amsterdam (2009).

Scope	Description	Type of segmentation	Segment	Segment Intersection(s)	Agreement	Type of Agreement	(Consortium of) contractor(s)
A	Bore tunnel	Vertical	A	B, C, D, E, F, & G	A	Design & Build	A
B	Station Rokin	Horizontal	B	A	B	Design-bid-Build	B
C	Station Vijzelgracht	Horizontal	C	A	C	Design-bid-Build	B
D	Station Ceintuurbaan	Horizontal	D	A	D	Design-bid-Build	B

E	Caissons Damrak	Horizontal	E	A & G	E	Design-bid-Build	C
F	Immersed tube IJ	Horizontal	F	A	F	Design-bid-Build	C & D
G	Passage Central Station	Horizontal	G	E & G	G	Design-bid-Build	D & E

Following the segmentation of the scope and agreements, Figure 21 depicts a schematic representation of the segmented project delivery method for the second tender phase. In this project delivery method, the client is responsible for both procurement and design, while each co-contractor is solely responsible for the realisation of their segment. An exception is the bore tunnel, which was procured in the first phase under a Design & Build agreement.

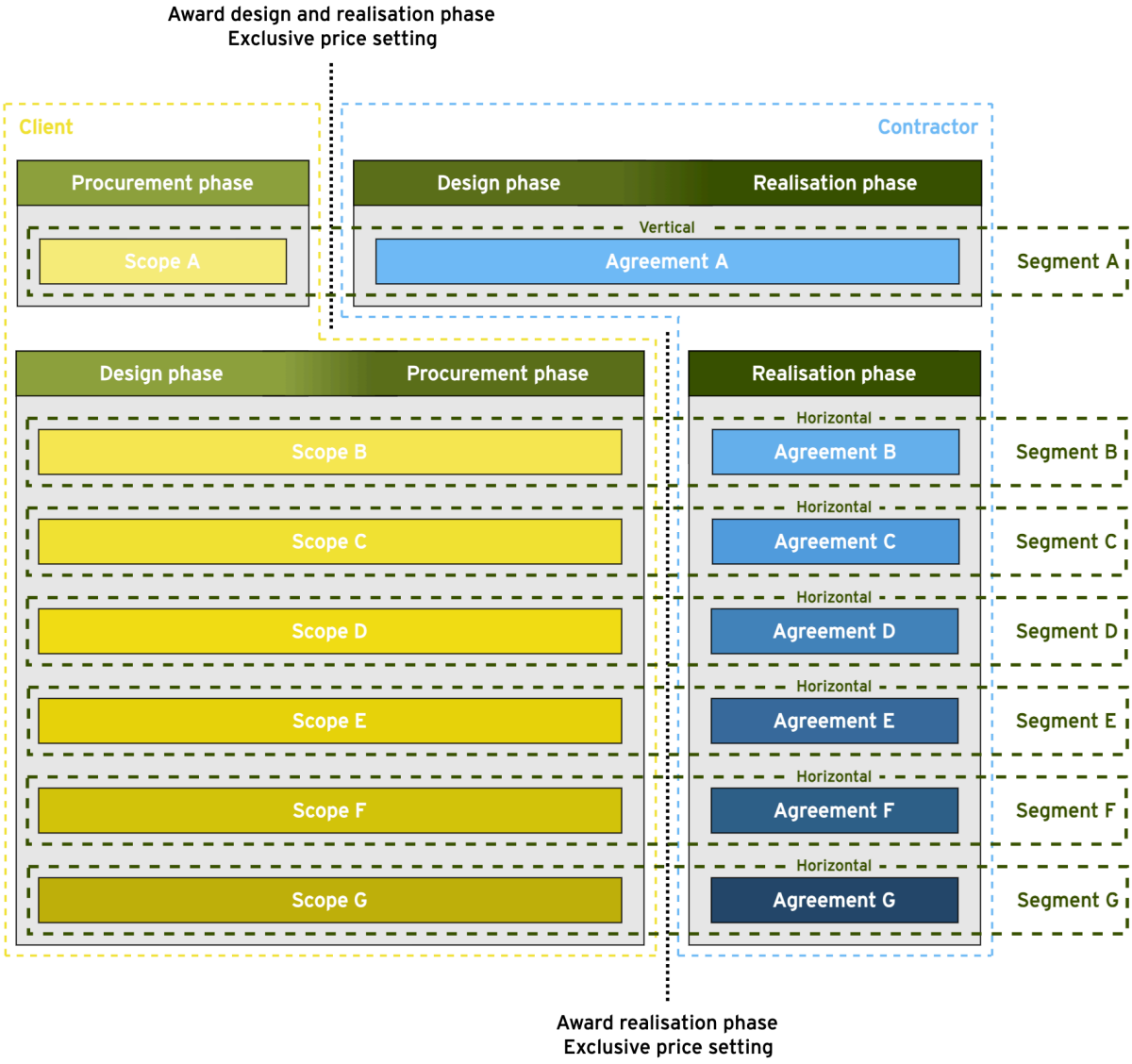


Figure 21. Schematic representation of the segmented PDM for the Noord/Zuidlijn (second tender phase)

The segmented approach also facilitated more targeted and effective risk management strategies, as each segment could be individually assessed and managed according to its specific needs and challenges. The client recognised that contract segmentation increased the number of interfaces for which the municipality was responsible, as well as making the municipality's oversight role more

burdensome. However, no additional measures (financial or project organisation) were implemented to fill this increased oversight role.

The third phase refined the segmentation approach that had been implemented in the first and second tenders. A negotiation-based process was implemented, allowing for direct dealings with bidders while ensuring that contracts stayed within the allocated budget.

Overall, the adoption of horizontal and vertical segmentation, initiated during the first tender phase and continued into the second and third phases, was intended to positively impact each aspect of the project by managing its complexity, enhancing the precision of construction efforts, and maintaining control over the budget and schedule. While this strategy was intended to facilitate the project's structured progression, optimise resource allocation, and improve risk management, it did not fully achieve the desired results for a project as ambitious and complex as the Noord/Zuidlijn.

4.1.3 Understanding segmentation in Noord/Zuidlijn

In the Noord/Zuidlijn project, segmentation emerged as a strategic approach devised to decompose the extensive metro line construction into manageable, functional segments. Each segment was carefully designed to concentrate on specific tasks and objectives, enabling a more specialised and detailed approach to the complex sections of the construction. The decision to employ segmentation was primarily driven by the need to effectively manage the inherent complexities of the project, such as navigating through Amsterdam's dense urban fabric and preserving historical sites. This strategy facilitated the engagement of multiple experts, each specialising in different aspects of construction from tunnelling and station building to systems installation, ensuring that each component was adeptly handled by teams with the most relevant expertise and experience.

The delivery method chosen for the Noord/Zuidlijn was a hybrid of Design-bid-Build and Design-Build contracts, segmented according to specific project components. For example, tunnelling was managed under a design-build contract to allow for faster, integrated delivery of this technically challenging component, while station construction was tackled via design-bid-build contracts to maximise control over architectural quality and costs. This segmentation within the delivery method played a crucial role in addressing the specific risks and requirements of different project parts, providing flexibility and enhanced control over the execution phase.

The project's segmentation brought together a diverse array of actors, including the municipality of Amsterdam as the client, various contracting firms, engineering consultants, and regulatory bodies. The relationships among these actors were defined through contracts that outlined roles, responsibilities, and the nature of interactions for the segmented tasks. These contracts were fundamental in ensuring clear communication channels and defining the expectations and deliverables for each party involved, thereby reducing conflicts and enhancing collaboration across the project.

Segmentation was introduced right from the procurement stage and maintained throughout the design and realisation phases of the project. At each stage, the project management team ensured that the specific requirements and deliverables of the segments were well-aligned with the overall project timeline and objectives. This careful integration helped in maintaining continuity and coherence across the project, despite the division into segments, ensuring that all parts of the project progressed in sync towards the collective goal.

The primary strategic objectives behind segmenting the Noord/Zuidlijn included enhancing the manageability of the project, focusing expertise in critical areas, and isolating risks within manageable confines. By dividing the project into well-defined segments, the management team could apply

targeted resources and attention where needed most, whether in handling technical challenges, meeting safety standards, or preserving historical artefacts during construction. This strategic segmentation effectively reduced the potential for overarching project risks and streamlined management processes.

The criteria for segmenting the project were based on factors like technical complexity, geographic location within the city, and the need for specialised knowledge. Decisions on how to segment were influenced by considerations such as the availability of cutting-edge construction technology, the environmental impact on the urban setting, and regulatory compliance. Each segment was thus tailored to optimise the deployment of technology and expertise in line with the project's extensive demands.

Key decisions regarding the segmentation of the Noord/Zuidlijn were made early in the project lifecycle. These decisions were guided by strategic objectives to enhance control over the project's complex tasks and to streamline management processes across the board. By deciding early on the segmentation approach, the project team could align procurement, design, and construction activities to better manage the interdependencies and logistics required for successful project execution.

This comprehensive approach to segmentation not only facilitated a structured progression of the project but also optimised resource allocation and risk management, essential for the "successful" completion of a project as ambitious and complex as the Noord/Zuidlijn.

4.1.4 Key characteristics of segmentation in Noord/Zuidlijn

Effective coordination was central to navigating the complexities of the segmented Noord/Zuidlijn project. This was achieved through regular strategic meetings, the use of integrated project management tools, and the establishment of clear communication channels. These mechanisms played a crucial role in aligning activities across different segments, ensuring that, despite the division of labour, all teams were synchronised and working towards common deadlines and quality standards. Regular updates and coordination meetings facilitated proactive management of interdependencies and the quick resolution of any issues arising between segments.

Each segment of the Noord/Zuidlijn was managed by dedicated teams, which were overseen by a central project management unit. This structure ensured focused attention on specific tasks while maintaining an overview of the project's progress and alignment with overall objectives. The central project management was instrumental in integrating the segments, making strategic decisions to keep the project on track and ensuring that the execution in one segment did not adversely affect others. This layered management approach was key in maintaining continuity and operational efficiency throughout the project lifecycle.

The economic interests inherent to each segment significantly influenced project dynamics, particularly in terms of decision-making processes, resource allocation, and prioritisation. Economic factors such as cost, potential for financial return, and budget constraints were carefully analysed to make informed decisions that balanced immediate project needs with long-term benefits. Understanding these economic interests helped the project management team prioritise segments that required immediate attention, ensuring optimal use of available resources.

The contractual arrangements for the Noord/Zuidlijn were specifically adapted to accommodate the segmented nature of the project. These contracts included detailed clauses that clearly outlined the responsibilities, expectations, and deliverables for each segment. Such precise contractual definitions ensured that all parties involved were fully aware of their roles and responsibilities, which minimised

conflicts and streamlined the execution process. These adaptations were crucial for maintaining clarity and accountability across the project's diverse teams and contractors.

Segmenting the Noord/Zuidlijn project had significant financial implications, facilitating better budget allocation and more effective cost control. By managing the project in smaller, more manageable parts, financial oversight could be more focused and rigorous, reducing the likelihood of overspending. Segmenting also allowed for isolating financial risks to specific parts of the project, which improved overall financial management and enabled more strategic allocation of financial resources.

In the segmented Noord/Zuidlijn project, risk was strategically allocated based on the specific nature of the work within each segment. This approach involved employing targeted risk management strategies, such as securing appropriate insurance coverages, developing contingency plans, and making necessary contractual adjustments. By localising risk management to specific segments, the project team could tailor their strategies to effectively address the unique challenges and risks of each part of the project.

These key characteristics of segmentation in the Noord/Zuidlijn project illustrate the comprehensive planning and strategic management required to effectively handle a large-scale infrastructure project. Through meticulous coordination, rigorous management, and strategic adaptations, the project could navigate the benefits of segmentation while addressing the associated challenges.

4.1.5 Legal aspects of segmentation in Noord/Zuidlijn

The legal framework surrounding the segmentation practices in the Noord/Zuidlijn project was designed to ensure full compliance with Dutch procurement laws, which emphasise transparency, fairness, and competitive bidding. This adherence was crucial for fostering a fair competitive environment and protecting the municipality from potential legal challenges, thereby maintaining the project's integrity and public trust throughout its duration.

The contract models for the Noord/Zuidlijn were carefully structured to precisely define the scope and responsibilities for each segment, while integrating enough flexibility to accommodate necessary changes. This careful legal structuring was vital for clarifying expectations and roles across different segments, thereby minimising misunderstandings and disputes. Additionally, this flexibility allowed the project management to adapt to unforeseen circumstances or adjustments in project scope without breaching contractual terms.

One of the primary challenges encountered was ensuring that segment-specific contracts aligned with overarching legal frameworks and that conflicts arising from segmented contracting practices were efficiently resolved. These challenges often involved intricate legal negotiations and adaptations to ensure that all contractual arrangements remained coherent with national and European Union procurement standards.

Specific challenges in legal alignment included ensuring that each segmented contract was compliant with procurement regulations and that all contractual obligations were clearly delineated. This required a high level of legal expertise and continuous monitoring to align detailed contractual terms with legal requirements, ensuring that each segment's activities were legally sound and effectively coordinated.

4.1.6 Challenges and benefits of segmentation in Noord/Zuidlijn

Segmentation introduced both challenges and benefits to the Noord/Zuidlijn project. Significant challenges included managing the interfaces between segments, ensuring timely communication among diverse teams, and aligning the segments with the overall project timeline. These challenges necessitated sophisticated coordination strategies and robust project management tools to ensure that information flowed seamlessly and that project milestones were met as planned.

However, the benefits of segmentation were substantial. Segmenting the project allowed for an enhanced focus on specific tasks, where specialised teams could apply their expertise to complex aspects of the project, leading to higher quality outcomes. Improved risk management was another key benefit, as risks could be isolated and managed more effectively within smaller, defined segments. This strategic focus and specialisation ultimately contributed to the project's overall success, showcasing the efficacy of a segmented approach in managing large-scale infrastructure projects. This balance of challenges and strategic advantages underscores the complexities and rewards of implementing segmentation in large infrastructure projects like the Noord/Zuidlijn.

4.1.7 The results of segmentation in Noord/Zuidlijn

The segmentation approach adopted for the Noord/Zuidlijn project provides valuable insights into the efficacy and challenges of managing complex urban infrastructure projects through divided scopes. The segmentation of the Noord/Zuidlijn into multiple contracts proved to be a strategic move to manage its inherent complexities. By dividing the project into manageable segments, each tailored to specific technical and geographic challenges, the project team could allocate resources and expertise more effectively. This strategic division facilitated better control over individual segments, allowing for focused attention on the unique requirements and risks associated with each part of the project.

Segmentation enabled the client to isolate risks within specific parts of the project, facilitating more effective risk management strategies. Detailed risk analyses and tailored mitigation plans were developed for each segment, reducing the likelihood of overarching project risks and enhancing the ability to respond to segment-specific challenges. Segmenting the project also allowed for more precise budgeting and cost control. By managing financial resources at the segment level, the project team could monitor expenditures closely and allocate funds where they were most needed. This focused financial oversight helped maintain the project within budgetary limits, despite the overall complexity and scale.

The commission's report on the Noord/Zuidlijn project stated that, while segmentation provided benefits, such as specialised management and the possibility of more competitive bidding, it also presented significant challenges. Particularly, the municipality faced difficulties in ensuring seamless integration and coordination across the interfaces. These challenges were primarily due to the complexity introduced by having multiple contractors and specialised teams operating without a unified command structure, which often led to inefficiencies, increased risks, and potential delays. The commission concluded that there was a need for stronger central oversight and clearer communication channels to effectively handle the dependencies and interactions between segments. It recommended improving strategic planning and control mechanisms to enhance the municipality's capability to manage these interfaces more effectively. By addressing these issues, the commission suggested that the segmented approach could be optimised to avoid compromising overall project integration and delivery.

Table 5 illustrates the impact of segmentation on the “Noord/Zuidlijn” project complexities, detailing how each complexity was altered as a result of segmentation. It reveals that segmentation decreased

technical complexities such as strict quality requirements, high number of tasks, high variety of tasks, and involvement of different technical disciplines by enabling more focused and specialised management within each segment. However, segmentation also increased organisational complexities, such as managing interfaces between different disciplines, the number of contracts, and organisational risks, due to the need for heightened coordination and the administrative burden of managing multiple contracts. External complexities like the level of competition and dependencies on external stakeholders were influenced as segmentation enabled more contractors to participate and allowed for dealing with stakeholders on a per-segment basis. Additionally, segmentation introduced new external risks associated with managing interfaces and coordination between different segments. This comprehensive evaluation underscores the trade-offs and nuanced effects of segmentation on project complexities, highlighting both the benefits and challenges introduced by this approach.

Table 5. TOE Framework analysis of segmentation impact on the project complexities in Noord/Zuidlijn

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and complexity elements were sourced from "Rapport van de Enquêtecommissie Noord/Zuidlijn" by Gemeente Amsterdam (2009).

T Technical complexity	O Organisational complexity	E External complexity
High number of project goals The Noord/Zuidlijn project was characterised by many goals, addressing a wide range of development objectives, which contributed significantly to the project's complexity. Segmentation allowed for clearer focus on specific goals within each segment and managing numerous goals simultaneously. This led to a decrease in the contribution to the project's complexity.	**High project schedule drive** The urgency to adhere to the project schedule was high, putting pressure on all organisational aspects and often leading to tight deadlines for the project, which contributed very much to the project's complexity. Segmentation made schedule management more feasible, allowing for tighter control and timely adjustments. This led to a decrease in the contribution to the project's complexity.	**Level of competition** The Noord/Zuidlijn project experienced limited competition due to the scarcity of contractors equipped to handle the complexities and scale of such a project, which contributed substantially to the project's complexity. Segmentation allowed for more contractors to enter the bidding process by lowering experience requirements and allowing qualifications to be part of the tender documents, thereby increasing competition and decreasing the contribution to the project's complexity.
Uncertainties in scope The scope of the Noord/Zuidlijn project was highly uncertain due to the project's innovative nature and the dense urban environment in which it was situated. This contributed very much to the project's complexity. Segmentation allowed for more adaptable management of scope uncertainties within each segment, thereby decreasing the contribution to the project's complexity.	**Lack of resource & skills availability** There was a noted deficiency in the availability of required skills and resources, particularly in specialised areas critical to the project's success, which contributed significantly to the project's complexity. By focusing on specific segments, it is easier to allocate the necessary resources and skills more precisely. This led to a decrease in the contribution to the project's complexity.	**Political influence** The project was heavily influenced by political decisions and pressures, which impacted the planning, execution, and funding phases, adding very much complexity to the project. Segmentation did not alter the extent of political influence on the project, which remained heavily affected by political decisions and pressures impacting the planning, execution, and funding phases.
Strict Quality Requirements The project was characterised by extraordinarily high-quality demands that exceeded normal expectations, contributing significantly to the project's complexity and necessitating precise and careful work. Segmentation allowed for a more focused approach to meeting quality requirements within each segment, thus decreasing the contribution to the project's complexity.	**Lack of experience with parties involved** The project involved many parties who lacked previous experience with similar large-scale projects, which added to the coordination and management challenge, contributing substantially to the project's complexity. Segmentation did not alter the lack of experience, but it allowed for more parties to be involved, thereby lowering the load on any single party and decreasing the contribution to the project's complexity.	**Dependencies on external stakeholders** The Noord/Zuidlijn project depended on various external stakeholders, including governmental bodies for subsidies and approvals, contractors for construction, and the public for support and feedback, which contributed very much to the project's complexity. Segmentation did not alter the dependencies on stakeholders, but it allowed for dealing with stakeholders on a per-segment basis, which helped manage these dependencies more effectively, thereby decreasing the contribution to the project's complexity.
Project duration The Noord/Zuidlijn had a prolonged project timeline, which was significantly longer than standard projects, contributing very much to the project's complexity. While segmentation was intended to streamline processes and potentially speed up completion by allowing work on multiple segments simultaneously, managing the interdependencies potentially extended the overall project duration due to coordination complexities. This led to a decrease in the contribution to the project's complexity.	**Interfaces between different disciplines** Managing the interfaces between different technical and organisational disciplines was a crucial and complex aspect, given the multifaceted nature of the project, contributing substantially to the project's complexity. Segmentation significantly increased the complexity of managing these interfaces due to the need for heightened coordination and integration across segments, thereby increasing the contribution to the project's complexity.	**Number of external stakeholders** The project interacted with a wide array of external stakeholders, including city residents, businesses, commuters, local government agencies, and environmental groups, contributing very much to the project's complexity. Segmentation did not alter the number of external stakeholders, but it allowed for more focused attention to stakeholders within each segment, thereby decreasing the contribution to the project's complexity.

Decrease of complexity due to segmentation
Increase of complexity due to segmentation
No impact by segmentation

Size in CAPEX
The capital expenditure for the Noord/Zuidlijn was enormous, indicating that the project was a substantial investment with significant financial exposure, contributing very much to the project's complexity. Segmentation significantly elevated the CAPEX for the Noord/Zuidlijn, reflecting a considerable investment and substantial financial exposure across each project segment, thus increasing the contribution to the project's complexity.

Number of locations
Multiple sites and locations were involved in the project, which added complexity as coordination and integration across these various sites was required, contributing very much to the project's complexity. Segmentation isolated the number of locations, allowing for more focused attention within each segment but increased the need for coordination and integration, thereby increasing the contribution to the project's complexity.

Newness of technology
Innovative tunnelling techniques were employed, which, while providing advantages such as reduced disruption to the city surface, brought unique challenges and uncertainties due to their limited prior use on similar scales, contributing significantly to the project's complexity. Segmentation allowed for the involvement of specialised contractors, which helped manage these new technologies more effectively, thereby decreasing the contribution to the project's complexity.

Lack of experience with technology
There was a noted lack of experience with the specific advanced technologies used for tunnelling and underground construction, increasing the risk and technical demands of the project, thereby contributing significantly to its complexity. Segmentation allowed for the involvement of specialised contractors, which helped mitigate the risks associated with the lack of experience, thereby decreasing the contribution to the project's complexity.

High number of tasks
The project involved a multitude of tasks, each contributing to the overall complexity of the project due to the extensive coordination required, contributing very much to the project's complexity. Segmentation did not directly lower the high number of tasks but allowed for a division of tasks among multiple contractors, which helped manage the workload more effectively, thereby decreasing the contribution to the project's complexity.

High Variety of Tasks
The project involved a wide variety of tasks, from tunnelling to station construction and integration with existing transportation networks, each with its own set of technical requirements and challenges, adding very much complexity to the project. Segmentation did not directly lower the high variety of tasks but allowed for these tasks to be divided among specialised teams, thereby decreasing the contribution to the project's complexity.

Dependencies between tasks
The interdependencies between various project tasks, such as sequential construction stages and the integration of technical systems, added to the complexity, as delays or issues in one area

Number of contracts
Segmentation resulted in an increase in the number of contracts, as the project was divided into smaller, more manageable segments, each requiring its own contractual arrangement. This led to an increase in the contribution to the project's complexity.

Type of contract
Segmentation resulted in a variety of contract types being used in the project. These ranged from traditional contracts to more integrated contracts, each necessitating a distinct management approach. This led to an increase in the contribution to the project's complexity

Size of project team
The size of the project team was significant, involving a wide range of professionals from various fields, which made management more complex due to the need for extensive coordination and communication, contributing very much to the project's complexity. Segmentation did not alter the size of the project team, although it should have been increased to better manage the segments and the segmentation process, thereby increasing the already high contribution to the project's complexity.

Organisational risks
The client faced significant organisational risks in managing and coordinating a mega infrastructure project, contributing very much to the project's complexity. Segmentation complicated the management of the project due to the many segments, interfaces and contractors involved, thereby increasing the contribution to the project's complexity.

Interference with existing site
The Noord/Zuidlijn project faced significant challenges related to interference with the existing urban environment, especially given its construction in densely populated and historically sensitive areas, contributing very much to the project's complexity. Segmentation allowed for better management of these challenges by dividing the project into smaller, more focused sections, thereby isolating disruptions to specific areas and decreasing the contribution to the project's complexity.

could impact others, contributing very much to the project's complexity. Horizontal segmentation decreased the dependencies between tasks within each segment but increased complexity at the interfaces between segments. Additionally, vertical segmentation increased the dependencies at the interfaces with horizontally segmented segments, thereby maintaining the high contribution to the project's complexity. **Uncertainty in methods** Significant uncertainties were associated with the technological methods that would be encountered during the project, particularly the involvement of innovative construction techniques, contributing very much complexity to the project. Segmentation allowed for a specialised focus on these methods within each segment, thereby decreasing the contribution to the project's complexity. **Involvement of different technical disciplines** The project required the coordination of various technical disciplines, which needed to work together seamlessly to address the multifaceted technical challenges of constructing a major underground metro line, contributing very much to the project's complexity. While segmentation did not change the need for multiple technical disciplines, horizontal segmentation enabled the assignment of specialised contractors to specific segments, thereby decreasing the contribution to the project's complexity. **Conflicting norms and standards** The project faced challenges in aligning the various applicable norms and standards, which sometimes conflicted, especially given the innovative nature of some of the construction techniques and the stringent safety and quality requirements, contributing significantly to the project's complexity. Segmentation allowed for addressing conflicting norms and standards within each segment, thereby appropriately tailoring compliance efforts and decreasing the contribution to the project's complexity. **Technical risks** The project was fraught with technical risks, including the potential for structural impacts on existing buildings, technical failures, or unforeseen geological conditions, which contributed very much to the project's complexity. Segmentation allowed for specialised contractors to handle these unique challenges, leveraging their expertise to manage these risks more effectively and thereby decreasing the contribution to the project's complexity. However, segmentation also created interfaces that introduced additional technical complexities, thereby maintaining a high contribution to the project's complexity.		

In conclusion, the Noord/Zuidlijn project's segmentation strategy brought distinct advantages, such as enhanced specialisation and competitive procurement, which were counterbalanced by considerable managerial and coordination challenges. While it enabled precise focus on specific construction aspects, the necessity for intricate interface management and the multiplication of contractual relationships added layers of complexity that demanded an evolved administrative approach. The findings underscore the critical importance of robust project oversight and streamlined communication systems to harness the full potential of segmentation.

4.2 Schiphol-Amsterdam-Almere

In the region between Schiphol, Amsterdam, and Almere, efforts are underway to enhance traffic flow, reduce travel times, and improve liveability. The road expansion programme, known as Schiphol-Amsterdam-Almere (SAA), is crucial for maintaining accessibility as both Amsterdam and Almere experience significant population growth. Recognised as one of the largest road programmes in the Netherlands, SAA encompasses five projects aimed at optimising the transportation network across this vital area (Rijkswaterstaat, 2014). The programme includes the completion of the A10-East to A1 Diemen section in 2014, the A1 Diemen to A6 Almere Havendreef section in 2017 (three years ahead of schedule), the A9 Holendrecht to Diemen (Gaasperdammerweg) due for completion in 2020, the A6 Almere Havendreef to Almere Buiten-Oost finished in 2019 (a year ahead of schedule), and the A9 Badhoevedorp to Holendrecht (Amstelveen) which is expected to be completed by 2026 (Rijkswaterstaat, 2014; see also Appendix G.1 Introduction (perspective client)).

This subchapter delves into the SAA project through desk research and interviews with both the client (Appendix G. Case study: elaboration of the interview with the client of SAA (NL)) and a contractor (Appendix H. Case study: elaboration of the interview with a contractor of SAA (NL)), focusing on the project's strategic approach to segmentation and the project delivery methods employed. This analysis aims to comprehensively understand how segmentation was approached and implemented. Through a qualitative analysis, the research aims to explore the segmentation processes used in managing the multifaceted aspects of the project, uncover the key characteristics and legal considerations of segmentation, and navigate the challenges and benefits presented by such an approach.

4.2.1 Complexities of Schiphol-Amsterdam-Almere

The complexities of the SAA project, as illuminated through the lens of both the client and a contractor, underscore the multifaceted nature of managing large-scale infrastructure projects within defined segments. This subchapter delves into the intricate details of these complexities as experienced and communicated by the client, overseeing the entire project, and a contractor, focused specifically on the A6 segment.

The client outlined the overarching complexities of the SAA project, which were significantly magnified by the political and public scrutiny it attracted. This attention ensured that every operational aspect was carefully examined, thereby placing immense pressure on the project team to adhere to high expectations (Appendix G.1 Introduction (perspective client)). Among the technical challenges, the construction of the Muiderberg railway bridge was highlighted as a critical task requiring precise engineering solutions and attracting global attention due to its complexity. The project also demanded rigorous coordination across various segments, each managed by different teams with unique technical specifications (Appendix G.1 Introduction (perspective client)). Furthermore, managing the expectations and requirements of numerous stakeholders, including local governments and Rijkswaterstaat, introduced additional layers of complexity. Financial pressures exacerbated by external crises like the Icesave debacle necessitated continuous adjustments in financial planning and project design to stay within budget constraints (Appendix G.1 Introduction (perspective client)). These complexities illustrated the intricate dynamics involved in managing a high-profile infrastructure project, demanding a sophisticated and flexible management approach.

The contractor's narrative provided a more localised view of the complexities, specifically within the A6 segment. The challenges highlighted included dealing with difficult soil composition, particularly the need to widen the existing A6 motorway flanked by sea clay, which required specialised construction techniques to ensure the stability of the new road structure (Appendix H.1 Introduction (perspective contractor)). Additionally, the contractor emphasised the importance of coordinating with

the SAAone project and other parties to ensure infrastructural compatibility across project boundaries. This included managing the integration of various infrastructural elements such as water management and underground utilities. The complexities of coordinating the physical and transitional interfaces between old and new road sections were also noted, necessitating meticulous integration of planning, design, and execution phases to maintain functionality and safety in the highway network (Appendix H.1 Introduction (perspective contractor)).

The synthesis of these perspectives offers a comprehensive understanding of the project's complexities at both strategical and operational levels. While the client's overview (Appendix G.1 Introduction (perspective client)) provided a broad perspective on the external pressures and the high-level coordination required across different segments, the contractor's insights (Appendix H.1 Introduction (perspective contractor)) brought forward the on-the-ground challenges faced within a specific segment, highlighting the detailed technical and operational issues that contribute to the overall complexity of the project. Table 6 contains a detailed categorisation and description of these complexities, providing a comprehensive overview of the project's technical, organisational, and external complexities.

Table 6. TOE Framework analysis of the project complexities in SAA

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and complexity elements were sourced from Appendix G.1 Introduction (perspective client) and Appendix H.1 Introduction (perspective contractor).

T Technical complexity	O Organisational complexity	E External complexity
High number of project goals The SAA project was characterised by many goals, addressing a wide range of development objectives, which contributed significantly to the project's complexity.	**High project schedule drive** The urgency to adhere to the project schedule puts significant pressure on all organisational aspects, contributing substantially to the project's complexity.	**Political influence** Political decisions and pressures impact planning, execution, and funding phases, contributing substantially to the project's complexity.
Strict quality requirements The SAA project demands exceptionally high-quality standards, especially critical in infrastructure projects involving bridge construction and highway expansion, contributing very much to the project's complexity.	**Interfaces between different disciplines** Managing interfaces between different technical disciplines across the various project elements, such as road expansion, bridge construction, and integration with existing transportation systems, is crucial and complex, contributing substantially to the project's complexity.	**Dependencies on external stakeholders** The project depends on various external stakeholders, including governmental bodies for subsidies and approvals, contributing very much to the project's complexity.
Project duration The extensive timeline of the SAA project introduces complexities in managing contracts over extended periods, contributing substantially to the project's complexity.	**Size of project team** The significant size of the project team, composed of a diverse range of professionals, adds to the management complexity, contributing substantially to the project's complexity.	**Number of external stakeholders** The project interacts with a wide array of external stakeholders, including various government agencies and contractors, contributing very much to the project's complexity.
Size in CAPEX The SAA project involves substantial capital expenditure, indicating significant financial exposure, contributing very much to the project's complexity.	**Organisational risks** The client faced significant organisational risks, as it had to manage and coordinate a mega infrastructure project, contributing very much to the project's complexity.	**Interference with existing site** The SAA project, which involved extensive highway and infrastructure improvements, encountered substantial interference with existing transportation networks. This contributed very much to the project's complexity.
Number of locations Involving multiple sites, the SAA project requires complex coordination across various geographical areas, contributing very much to the project's complexity.		
High number of tasks & high variety of tasks Reflecting the project's broad scope, encompassing everything from road widening to complex bridge constructions, contributing very much to the project's complexity.		

Dependencies between tasks Sequential construction stages and integration of technical systems across the project add complexity, contributing very much to the project's complexity. **Involvement of different technical disciplines** Coordination of various technical disciplines is critical, given the multifaceted technical challenges of constructing major infrastructural elements, contributing very much to the project's complexity. **Technical risks** Includes risks of structural impacts on existing buildings, technical failures, or unforeseen geological conditions, contributing very much to the project's complexity.		

4.2.2 Segmentation in Schiphol-Amsterdam-Almere

The concept of segmentation within the SAA project was strategically implemented to manage complexity, distribute risks, and enhance overall project efficiency. This subchapter explores the segmentation process as articulated by the client, who has an overarching view of the project, in conjunction with the insights from a contractor responsible for a specific segment, thus providing a comprehensive understanding of how segmentation influences project management at various scales.

From the client's standpoint, segmentation was defined as the division of a large infrastructure project into smaller, independently executable units, each designed to achieve specific objectives that contribute to the overarching goal of the entire project. This approach was adopted to manage the complexity of the project effectively, distribute risks, and enhance overall project efficiency (Appendix G.2 Understanding segmentation (perspective client)). The decision to implement segmentation was primarily inspired by previous experiences with large infrastructure projects where managing project size and complexity presented significant challenges. By making each segment independent in terms of planning and execution, issues within one segment could be isolated, minimising their impact on the entire project. This strategic decision was crucial in maintaining control over the project's progression and ensuring that each component could be managed with a focused approach (Appendix G.2 Understanding segmentation (perspective client)).

Conversely, from the contractor's perspective, segmentation is seen as a fundamental strategy to manage the complexities of the SAA project. This method allows each contractor to focus on distinct segments, optimising resource allocation and responsibilities. It leads to more efficient and effective management of the construction process (Appendix H.2 Understanding segmentation (perspective contractor)). However, segmentation introduces significant challenges, particularly in managing the interfaces between adjacent project segments. These interfaces, where segments meet, require rigorous coordination to ensure seamless integration, necessitating robust collaboration among various contractors and stakeholders (Appendix H.2 Understanding segmentation (perspective contractor)).

This research identifies and classifies the client's segmentation strategy as horizontal segmentation, which involved dividing the project into multiple segments based on geographic location. Each segment, such as segment A (A10-Oost to A1 Diemen) and segment B (A1 Diemen to A6 Almere Havendreef), was defined to manage specific sections of the infrastructure, with clear boundaries. Horizontal segmentation allowed the client to address the unique environmental and regulatory challenges of each area independently (Appendix G.2 Understanding segmentation (perspective client)). This approach facilitated the focused management of each segment, allowing the project teams to concentrate on the distinct requirements and complexities of their respective sections. Furthermore, it enabled the distribution of risks and resources effectively, ensuring that problems in

one segment did not adversely affect the entire project. The client's decision to use horizontal segmentation was driven by the need to enhance project efficiency and maintain better control over the project's overall progression (Appendix G.2 Understanding segmentation (perspective client)). The project scope consists of five segments, each procured separately by the client, resulting in five distinct agreements labelled as Agreement A through Agreement E, which make up the full scope and realisation of the project. These agreements were procured to a total of five contractors. The segmentation within the project scope is summarised in Table 7, which details the segments, the type of segmentation, and the agreements.

Table 7. Overview of segmentation in the scope and agreements for SAA

Note: Overview of segmentation in the scope and agreements for SAA was sourced Appendix G.2 Understanding segmentation (perspective client).

Scope	Description	Type of segmentation	Segment	Segment Intersection(s)	Agreement	Type of Agreement	(Consortium of) contractor(s)
A	A10-Oost - A1 Diemen	Horizontal	A	B	A	D&B	A
B	A1 Diemen - A6 Almere Havendreef	Horizontal	B	A, C, & D	B	DBFM	B
C	A9 Holendrecht - Diemen	Horizontal	C	B & E	C	DBFM	B
D	A6 Almere Havendreef - Almere Buiten - Oost	Horizontal	D	B	D	DBFM	B
E	A9 Badhoevendorp - Holendrecht	Horizontal	E	C	E	DBFM	C

Each segment had its dedicated project team, structured within a matrix organisation that facilitated knowledge sharing and coordination across different segments. This setup was instrumental in ensuring continuous improvement and adaptation of construction organisational forms to meet the dynamic demands of the project, playing a pivotal role in managing the complexity and scale of the extensive infrastructure project (Appendix G.2 Understanding segmentation (perspective client)). Interaction among the various actors was pivotal. These relationships, both functional and contractual, were essential in coordinating efforts and sharing knowledge within the project, facilitating a collaborative environment that enhanced project outcomes (Appendix G.2 Understanding segmentation (perspective client)).

Segmentation was introduced from the tendering phase and played a crucial role throughout all project phases (procurement, design, and realisation). During the tendering phase, segmentation allowed for clear packages to be made available for bidding, enhancing accessibility for potential contractors. In the design phase, it enabled a specialised approach for each segment, optimising technical designs according to specific project requirements (Appendix G.2 Understanding segmentation (perspective client)). Integration involves detailed coordination across different project phases, where managing the interfaces between segments becomes a key focus. The work within the segment is deeply integrated with the broader project objectives, with special attention given to ensuring smooth transitions at the segment interfaces (Appendix G.2 Understanding segmentation (perspective client)). These transitions are crucial for maintaining continuity throughout the project and for achieving the overarching goals.

The strategic goals behind implementing segmentation primarily focused on enhancing project manageability and ensuring predictability in costs and schedules. Segmentation allowed for dividing the project into smaller, manageable units, enabling better control over risks and complexity (Appendix G.2 Understanding segmentation (perspective client)). The specific goals and objectives for the contractor's segment are aimed at timely and within-budget delivery of infrastructure improvements, meeting precise technical specifications and quality standards. These segment-specific goals align with the strategic goals of the entire project, which focus on enhancing traffic flow and safety across the highways surrounding Schiphol, Amsterdam, and Almere (Appendix H.2 Understanding segmentation (perspective contractor)). The contractor underscores the importance of a structured approach to meet these objectives, where effective management of the segment interfaces plays a pivotal role. This includes distributing the workload and optimising the deployment of resources across segments (Appendix H.2 Understanding segmentation (perspective contractor)). Each segment has distinct performance indicators and targets, which are routinely assessed to ensure that the project stays on track and meets the set expectations (Appendix G.2 Understanding segmentation (perspective client)).

In conclusion, the decision to segment the project was based on criteria such as technical specialisations and the physical and operational characteristics of various project parts. This segmentation facilitated effective management of complex project components and ensured that each segment contributed optimally to the overarching project goals.

4.2.3 Segmented project delivery method in Schiphol-Amsterdam-Almere

The project utilised various project delivery methods, which were intricately tailored to accommodate the complex and varied demands of the project. This was influenced significantly by the types of contracts employed across different segments. Notably, Design, Build, Finance, and Maintain (DBFM) contracts were employed for four of the segments, integrating all aspects of project delivery, thereby engaging contractors over the long term. In contrast, the A10-East segment uniquely utilised a Design & Construct (D&C) contract, which focused solely on the design and construction aspects, deliberately excluding financing and maintenance responsibilities (Appendix G.2 Understanding segmentation (perspective client)). This distinct contractual approach in the A10-East segment underscores the project's flexibility in contract strategy to match the specific needs and objectives of each segment.

Subsequently, Figure 22 depicts a schematic representation of the segmented project delivery method (PDM) for SAA (Appendix G.2 Understanding segmentation (perspective client)). Here, the client is solely responsible for the procurement phase, while the contractor is responsible for both the design and the realisation of the project. It is important to note that the finance and maintenance phases are not depicted in this figure, as they fall outside the scope of this research. This study primarily focuses on the procurement, design, and realisation responsibilities. In addition to horizontal segmentation, the client also phased the segments over time to ensure a more manageable project progression, allowing for focused attention on each phase and facilitating better resource allocation and risk management (Appendix G.2 Understanding segmentation (perspective client)). This approach is visually depicted in Figure 22 by the segments shifting progressively to the right, illustrating the gradual phasing method, which indicates that the segments are distributed over time.

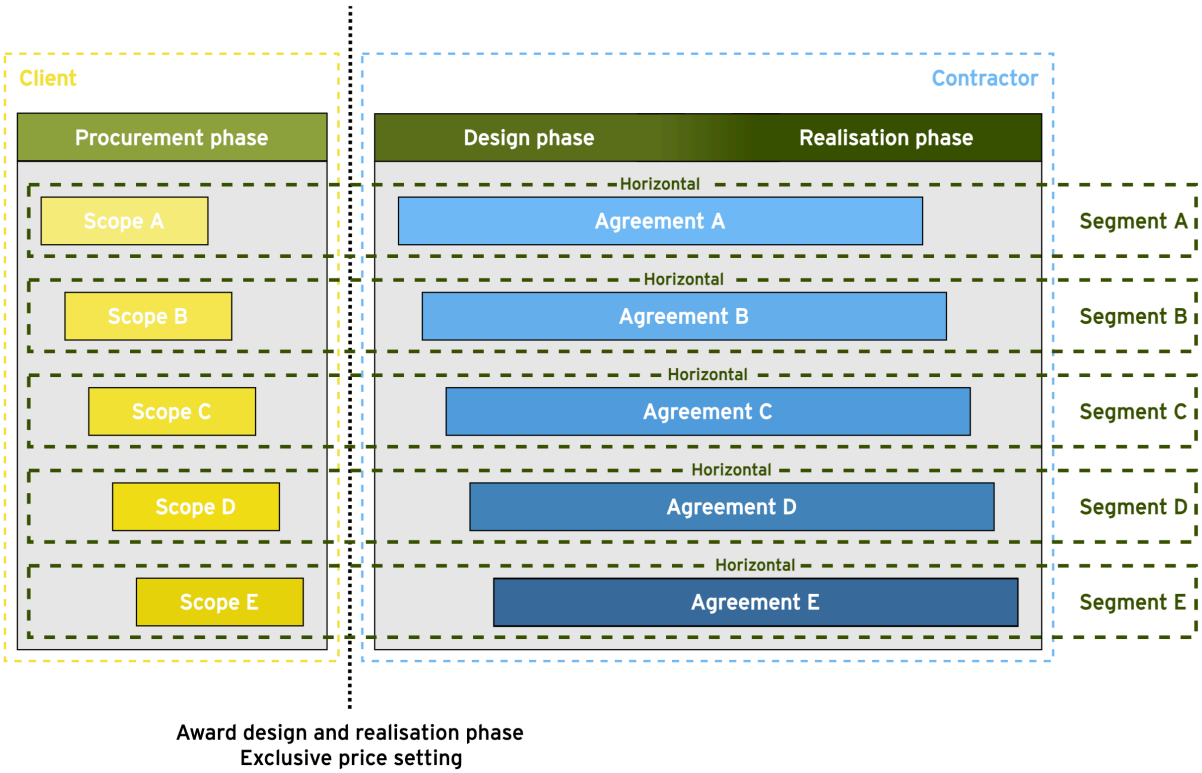


Figure 22. Schematic representation of the segmented PDM for Schiphol-Amsterdam-Almere

Note: Overview of segmentation in the scope and agreements for SAA was sourced Appendix G.2 Understanding segmentation (perspective client).

4.2.3 Key characteristics of segmentation in Schiphol-Amsterdam-Almere

The segmentation of the SAA project introduced several key characteristics that defined its realisation and management. This subchapter explores the strategic coordination techniques, management and integration of segments, economic implications, contractual adjustments, and the risk distribution strategies that shaped the project dynamics, incorporating insights from both the client and a contractor.

The client explained that the coordination strategies for segmenting the project primarily involved defining clear interfaces between the different project segments. A coordination mechanism was established through a 'phasing plane', allowing contractors from different projects to align their phasing steps. This ensured that the deliveries of the final infrastructure remained coherent, regardless of the specific project phase (Appendix G.3 Key characteristics of segmentation (perspective client)). The coordination arrangement in the contract was structured such that the initial contractor laid down the phasing plane and made it available to the subsequent contractor. This critical strategy guaranteed continuity and coherence between the segments, facilitating smooth transitions and consistent progress across the project (Appendix G.3 Key characteristics of segmentation (perspective client)).

From the contractor's perspective (Appendix G.3 Key characteristics of segmentation (perspective client)), various strategies and tools were employed to manage coordination within their segment and with adjacent segments. Specific coordination meetings, including sticker sessions, were held to bring all involved parties together for effective project phase alignment. These sessions were crucial for synchronising activities, especially at transitions between different segments where timing and interfacing are critical (Appendix G.3 Key characteristics of segmentation (perspective client)). The importance of a joint set of drawings that transcends segment boundaries was emphasised to clarify

each phase's details and ensure all parties had a uniform understanding of the project status and expectations (Appendix G.3 Key characteristics of segmentation (perspective client)).

The management and integration of the segments were executed through strict adherence to the established coordination schemes and contractual agreements. Each contractor was required to operate within the phasing plane as per a coordination agreement stipulated in the contract (Appendix G.3 Key characteristics of segmentation (perspective client)). This approach ensured that all segments progressed coherently and remained aligned with the overall project objectives. Regular meetings and updates ensured that all parties involved were kept informed of the progress and could intervene where necessary to uphold the project objectives (Appendix G.3 Key characteristics of segmentation (perspective client)).

Economic interests significantly influenced the project dynamics and decision-making processes. Each segment had its own economic interests and budget, leading to challenges in resource allocation and prioritisation (Appendix G.3 Key characteristics of segmentation (perspective client)). The contractor noted that every decision was carefully considered concerning cost and financial impact, often involving the client in budgeting and financial justification discussions (Appendix H.3 Key characteristics of segmentation (perspective contractor)). This highlighted the need for precise financial planning and the pressure to stay within budget, directly affecting execution strategies and prioritisation within the project. Segmentation had considerable financial implications. By dividing the project into manageable units, specific budgets could be allocated to each segment, leading to better control over costs and efficient use of resources (Appendix G.3 Key characteristics of segmentation (perspective client)). This also helped in monitoring and managing the overall budget of the mega-project by providing detailed insights into expenditures and cost efficiency per segment. The segmentation helped spread financial risks and prevent budget overruns (Appendix G.3 Key characteristics of segmentation (perspective client)).

Risk distribution within the project was strategically organised. Each segment had its own risk profile, and risks were allocated to parties best equipped to manage them. Contractual agreements clearly specified risk responsibilities, essential for effective risk management. Both the client and the contractor described how this risk allocation took place, with some risks lying with specific contractors and others shared between contractors and clients, depending on the nature of the risk and the project phase (Appendix H.3 Key characteristics of segmentation (perspective contractor); Appendix G.3 Key characteristics of segmentation (perspective client)).

This comprehensive analysis underscores the multifaceted approach required to manage a large infrastructure project like the SAA effectively. It highlights the complexities of handling segment interfaces, the necessity of stakeholder collaboration, and the importance of integration across the project lifecycle to achieve both segment-specific and overall project goals.

4.2.4 Legal aspects of segmentation in Schiphol-Amsterdam-Almere

Segmentation within the SAA project brought about significant juridical implications, especially concerning compliance with Dutch procurement law. This subchapter explores the legal consequences, the structure of contractual frameworks, legal challenges encountered, and the alignment of segmentation practices with legal requirements, as detailed by both the client and a contractor.

The client highlighted that segmenting the SAA project into various parts required diligent attention to procurement procedures to ensure compliance with the law. Each segment had to be tendered separately, increasing the complexity of the legal documentation and the tendering process. There was an emphasised necessity for clear contractual arrangements and thorough preparation to meet the

requirements of procurement legislation, critical for ensuring legality and transparency (Appendix G.4 Legal aspects of segmentation (perspective client)). The contractor echoed these sentiments, discussing the necessity of detailed documentation and transparent communication to manage the interfaces and coordination points between segments effectively, ensuring each complied with the legal standards (Appendix H.4 Legal aspects of segmentation (perspective contractor)).

The contractual models for the SAA project were legally structured to facilitate segmentation. According to the client, the contracts included detailed provisions tailored to meet the unique requirements of each segment. These provisions covered risk distribution, responsibilities, and specific delivery terms for each segment. This approach ensured clear legal frameworks that supported the operational and financial separation between the segments while enabling a coherent execution of the project (Appendix G.4 Legal aspects of segmentation (perspective client)). The contractor provided additional insights into the contractual framework, noting the inclusion of an 'interface area' or 'phasing plane' in the contracts, which facilitated collaboration and clear transitions between segments (Appendix H.4 Legal aspects of segmentation (perspective contractor)). Both the client and the contractor emphasised the importance of specific adjustments in contractual agreements to support the segmented structure of the project. These adjustments included detailed descriptions of the responsibilities for each contracting party and coordination mechanisms that were incorporated into the contracts. These changes were designed to minimise ambiguities and facilitate collaboration between different contractors, which was crucial for the successful execution of the project (Appendix G.4 Legal aspects of segmentation (perspective client); Appendix H.4 Legal aspects of segmentation (perspective contractor)).

The client described various legal challenges encountered during the project's segmentation, such as drafting contracts that solidified the coordination between different segments and contractors. Overcoming these challenges involved close collaboration with legal advisors to ensure all contracts and coordination mechanisms complied with legal standards and were practically executable (Appendix G.4 Legal aspects of segmentation (perspective client)). The contractor detailed specific challenges related to managing the phasing planes and coordinating between different contractors, requiring detailed contractual provisions to address these issues effectively (Appendix H.4 Legal aspects of segmentation (perspective contractor)). One notable legal challenge involved the role of the state attorney (landsadvocaat) in approving the project segmentation, particularly the technical and legal feasibility of coordination and warranties between the segments. The state attorney indicated that responsibilities associated with a particular ground plane established by one contractor could not be transferred to another due to warranties and uniform settlement issues, leading to necessary adjustments in the contractual agreements (Appendix G.4 Legal aspects of segmentation (perspective client)).

Specific legal challenges emerged concerning the procurement legislation and the segmentation of the project. Adjustments in the contractual agreements were made to ensure a sound legal and operational basis for the segmentation, emphasising the critical role of clear legal frameworks and detailed coordination provisions in successfully managing the complexities introduced by segmentation. This comprehensive examination of the juridical aspects of the SAA project underscores the complexities of aligning large-scale infrastructure project practices with stringent legal requirements. Both the client and the contractor have highlighted the proactive management of legal challenges and the strategic adjustments made to the contractual frameworks as pivotal in maintaining the project's compliance with Dutch law while facilitating effective project segmentation.

4.2.5 Challenges and benefits of segmentation in Schiphol-Amsterdam-Almere

Segmentation within the SAA project, as detailed by both the client and a contractor, has introduced significant operational dynamics. This subchapter discusses the notable challenges and benefits arising from project segmentation, providing insights from the perspectives of overarching project management and specific segment-focused operations.

From the client's perspective (Appendix G.5 Challenges and benefits of segmentation (perspective client)), one of the most significant challenges arising from segmentation was the coordination between different segments, especially when they were in various development phases. Managing multiple contract forms and aligning work across project boundaries required rigid management and coordination. Additionally, the need to continuously adapt to changing legal and environmental conditions added complexity to the management. Coordination requirements were further complicated by the demands of various stakeholders, including local governments and other public entities (Appendix G.5 Challenges and benefits of segmentation (perspective client)).

The contractor resonated similar concerns, noting that the primary challenges within their project segment were related to coordination and communication between segments. Ensuring consistent and timely information exchange, crucial for maintaining project timelines and work quality, proved difficult (Appendix H.5 Challenges and benefits of segmentation (perspective contractor)). Moreover, physical integration of infrastructure between segments, particularly in connecting technical systems like drainage and lighting, posed significant challenges. These issues necessitated intense collaboration and flexibility among all parties involved to ensure the project functioned as a cohesive whole (Appendix H.5 Challenges and benefits of segmentation (perspective contractor)).

4.2.6 The results of segmentation in Schiphol-Amsterdam-Almere

Despite the challenges, the client noted several important benefits of segmentation. It allowed for a specialised approach to each project part, enhancing efficiency and focusing on specific technical and operational challenges. Segmentation also facilitated risk distribution across different project parts and provided clearer financial and operational oversight for each segment. Moreover, it made the tendering processes for the various segments more accessible and manageable, resulting in better overall project control.

Similarly, the contractor recognised several advantages of segmentation within their project segment. Improved risk management was a significant benefit, as segmentation allowed for risks to be contained and managed within defined project parts, leading to better control over budgets and schedules. Segmentation also fostered specialisation within project teams, allowing each team to focus on specific aspects of their segment, which enhanced the quality of work and efficiency in the construction process.

The results of segmentation in the SAA project highlight a complex interplay between challenges and benefits. While segmentation introduced certain difficulties, particularly in terms of coordination and communication, it also brought significant advantages in terms of risk management, project control, and operational efficiency. These benefits were crucial in managing one of the Netherlands' largest road programs, helping to ensure that project segments like the A10-East to A1 Diemen and the A6 Almere Havendreef to Almere Buiten-Oost were completed ahead of schedule. The strategic use of segmentation facilitated not only the effective management of specific project components but also contributed to the project's overall success by enhancing the capacity to address and adapt to evolving project demands and stakeholder needs.

To further illustrate the impact of segmentation, Table 8 details how each project complexity was altered as a result of segmentation. This table is based on interviews with both the client and the contractor and provides a comprehensive overview of the transformations induced by segmentation strategies within the SAA project. It illustrates how segmentation decreases several technical complexities, including strict quality requirements, project duration, size in CAPEX, number of locations, high number of tasks, high variety of tasks, and technical risks by allowing for more focused management and controlled oversight within each segment. Conversely, segmentation increases organisational complexities, such as high project schedule drive, interfaces between different disciplines, and dependencies between tasks due to the need for careful coordination and integration across multiple segments. However, segmentation also simplifies the management of external complexities, such as political influence and dependencies on external stakeholders, by isolating these interactions within specific segments and aligning stakeholder management with relevant project components. This detailed evaluation highlights the nuanced effects of segmentation, enhancing certain aspects of project management while introducing new challenges in others.

Table 8. TOE Framework analysis of segmentation impact on the project complexities in SAA

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and impact of segmentation on complexity elements were sourced from Appendix G. Case study: elaboration of the interview with the client of SAA (NL) and Appendix H. Case study: elaboration of the interview with a contractor of SAA (NL).

T Technical complexity	O Organisational complexity	E External complexity
High number of project goals The SAA project was characterised by many goals, addressing a wide range of development objectives, which contributed significantly to the project's complexity. Segmentation did not alter the number of project goals but allowed for more focused management of each segment's specific objectives, thereby decreasing the contribution to the project's complexity.	**High project schedule drive** The urgency to adhere to the project schedule puts significant pressure on all organisational aspects, contributing substantially to the project's complexity. Coordinating schedules across multiple segments can complicate the overall project timeline management. However, it also allows segments to progress independently to some extent, mitigating delays in one segment affecting others, thereby maintaining the contribution to the project's complexity.	**Political influence** Political decisions and pressures impact planning, execution, and funding phases, contributing substantially to the project's complexity. By breaking the project into segments, the impact of political decisions and pressures can be isolated to specific aspects of the project rather than influencing the entire project. This simplifies negotiations and adjustments in individual segments, thereby decreasing the contribution to the project's complexity.
Strict quality requirements The SAA project demands exceptionally high-quality standards, especially critical in infrastructure projects involving bridge construction and highway expansion, contributing very much to the project's complexity. Segmentation allows for more focused and specialised attention to each segment's specific quality requirements, thereby decreasing the contribution to the project's complexity.	**Interfaces between different disciplines** Managing interfaces between different technical disciplines across the various project elements, such as road expansion, bridge construction, and integration with existing transportation systems, is crucial and complex, contributing substantially to the project's complexity. Segmentation intensifies the need for careful coordination between different technical and organisational disciplines. Ensuring cohesive integration across segments, especially where different construction activities meet, adds a layer of complexity, thereby increasing the contribution to the project's complexity.	**Dependencies on external stakeholders** The project depends on various external stakeholders, including governmental bodies for subsidies and approvals, contributing very much to the project's complexity. Each segment may deal with a different set of stakeholders, potentially simplifying interactions by reducing the range of concerns and negotiations needed at any one time, thereby decreasing the contribution to the project's complexity.
Project duration The extensive timeline of the SAA project introduces complexities in managing contracts over extended periods, contributing substantially to the project's complexity. Segmentation positively influenced the project duration by facilitating parallel progress in multiple segments, thereby reducing the overall timeline and decreasing the contribution to the project's complexity.	**Size of project team** The significant size of the project team, composed of a diverse range of professionals, adds to the management complexity, contributing substantially to the project's complexity. While the overall project team size is large, segmentation allows for smaller, more focused teams working on each segment, potentially improving management and operational efficiency, thereby decreasing the contribution to the project's complexity.	**Number of external stakeholders** The project interacts with a wide array of external stakeholders, including various government agencies and contractors, contributing very much to the project's complexity. In the SAA project, segmentation has effectively simplified the management of external stakeholders by aligning specific groups of stakeholders with relevant project segments, thereby decreasing the contribution to the project's complexity.
Size in CAPEX The SAA project involves substantial capital expenditure, indicating significant financial	**Organisational risks** The client faced significant organisational risks in managing and coordinating a mega	**Interference with existing site** The SAA project, which involved extensive highway and infrastructure improvements,

Decrease of complexity due to segmentation
Increase of complexity due to segmentation
No impact by segmentation

exposure, contributing very much to the project's complexity. Segmentation of the project's capital expenditure inherently increases transaction costs due to managing multiple budgets and contracts, but it also enhances financial manageability and reduces risk exposure, as dealing with a smaller budget per segment allows for more controlled and precise financial oversight, thereby decreasing the contribution to the project's complexity **Number of locations** Involving multiple sites, the SAA project requires complex coordination across various geographical areas, contributing very much to the project's complexity. Segmentation enabled specialised focus on each segment of the project, streamlining coordination across its multiple sites and geographical areas, thereby decreasing the contribution to the project's complexity **High number of tasks & high variety of tasks** Reflecting the project's broad scope, encompassing everything from road widening to complex bridge constructions, contributing very much to the project's complexity. Segmentation allows for dividing tasks into more manageable portions, where teams can specialise and focus on specific types of tasks within their segment, potentially improving task management and execution quality, thereby decreasing the contribution to the project's complexity. **Dependencies between tasks** Sequential construction stages and integration of technical systems across the project add complexity, contributing very much to the project's complexity. The dependencies between tasks became more complex to manage as the integration of work between segments requires careful synchronisation, especially in sequential construction stages, thereby increasing the contribution to the project's complexity. **Dependencies between tasks** Sequential construction stages and integration of technical systems across the project add complexity, contributing very much to the project's complexity. The dependencies between tasks became more complex to manage as the integration of work between segments requires careful synchronisation, especially in sequential construction stages, thereby increasing the contribution to the project's complexity. **Involvement of different technical disciplines** Coordination of various technical disciplines is critical, given the multifaceted technical challenges of constructing major infrastructural elements, contributing very much to the project's complexity. Segmentation enables specialised teams to focus on the unique technical challenges within their scope of work, promoting deeper expertise and better handling of technical complexities, thereby decreasing the contribution to the project's complexity. **Technical risks** Includes risks of structural impacts on existing buildings, technical failures, or unforeseen geological conditions, contributing very much to the project's complexity. Segmentation allowed for specialised contractors to deal with these unique challenges, leveraging their expertise to manage these risks more effectively. However, segmentation also created interfaces that introduced additional technical complexities,	infrastructure project, contributing very much to the project's complexity. Segmentation complicated the management of the project due to the many segments, interfaces and contractors involved, thereby increasing the contribution to the project's complexity.	encountered substantial interference with existing transportation networks. This contributed very much to the project's complexity. Segmentation enabled targeted management strategies for each segment, thereby decreasing the contribution to the project's complexity.

thereby maintaining a high contribution to the project's complexity.		

In conclusion, the strategic approach to segmentation in the SAA project underscores the importance of accurate planning and coordination in a large-scale and complex infrastructure project. While presenting certain challenges, segmentation has proven to be a valuable strategy for managing complex projects by improving focus, enabling specialisation, and enhancing the overall manageability of large and multifaceted initiatives. depicts the impact of segmentation on complexities of the SAA project, outlining how each complexity changed as a result of segmentation.

4.3 Zuidasdok

The Zuidasdok project stands as a transformative urban development initiative aimed at significantly enhancing the infrastructure and accessibility of Amsterdam and the northern Randstad, an area of great economic importance. This project is integral to the development of the Zuidas into an international top location, fully integrated with the region and city of Amsterdam, according to the objectives outlined in the 'Bestuursovereenkomst Zuidasdok' and the 'Structuurvisie Zuidasdok' (Programmaorganisatie Zuidasdok, 2022, 2023a, 2023b). Central to Zuidasdok's mission is the expansion and untangling of the A10 South, from the 'De Nieuwe Meer' junction to the 'Amstel' junction, including its subterranean positioning at the Zuidas. This arrangement aims to separate through traffic from local traffic into a main and a parallel roadway, improving traffic flow and safety. Additionally, the project involves the sustainable integration of road infrastructure by situating the A10 underground near the central area of Zuidas, creating space for a public transport terminal and enhancing the central environment of Zuidas (Programmaorganisatie Zuidasdok, 2023a; see also Appendix I.1 Introduction (perspective client)). Furthermore, Zuidasdok focuses on the development of a high-quality public transport terminal for trains and metros. This terminal will accommodate the anticipated growth in train traffic and includes space reservation for a potential expansion with a fifth and sixth rail. The regional and urban public transport systems, including the metro, tram, and bus, are also set to be optimally integrated into the public transport terminal, which includes a double-track landing of the North/South line (Programmaorganisatie Zuidasdok, 2023a; see also Appendix I.1 Introduction (perspective client)). The project also emphasises the design of the public space with urban streets and squares, including the construction of a bicycle underpass near the RAI, and ensuring the integration of the A10 to enhance spatial quality and the living environment. Throughout each phase of construction, the project maintains a focus on the accessibility and liveability of the area, underlining Zuidasdok's commitment to creating a complete city and infrastructure (Programmaorganisatie Zuidasdok, 2023a; see also Appendix I.1 Introduction (perspective client)). It is important to note that while the 'De Nieuwe Meer' junction segment is already under contract and in the realisation phase, the other segments are still in the procurement phase.

This subchapter investigates the Zuidasdok project using desk research and interviews with both the client (Appendix I. Case study: elaboration of the interview with the client of Zuidasdok (NL)) and a contractor (Appendix J. Case study: elaboration of the interview with a contractor of Zuidasdok (NL)), focusing on the project's strategic approach to segmentation and the innovative delivery methods employed. This analysis aims to gain a thorough understanding of how segmentation was approached and implemented within this complex urban development initiative. Through qualitative analysis, the research seeks to explore the segmentation processes used to manage the multifaceted aspects of the project, uncover the key characteristics and legal considerations of segmentation, and navigate the challenges and benefits presented by such an approach.

4.3.1 Complexities of Zuidasdok

The complexities of the Zuidasdok project, as explored through the perspectives of both the client and a contractor, highlight the intricate challenges involved in managing large-scale urban development projects within a vibrant metropolitan setting. This subchapter delves into the detailed complexities as experienced and communicated by the client, responsible for the overall coordination of the project, and a contractor, who is specifically focused on the integration and realisation of the traffic junction 'De Nieuwe Meer'.

From the client's perspective (Appendix I.1 Introduction (perspective client)), Zuidasdok represents a substantial overhaul of the Zuidas area, focusing on enhancing the transport hub which involves widening and tunnelling roads, expanding the station, accommodating international trains, and adding new passages. This upgrade aims to facilitate better connectivity and support the growth of Zuidas into a global business hub, which also includes the integration of a bus station and tram connection, and improvements to the North-South connection. The complexities, as identified by the client, arise from the project's ambitious scope and the critical need to integrate various transport modalities while maintaining the area's accessibility and economic viability (Appendix I.1 Introduction (perspective client)).

The contractor highlights (Appendix J.1 Introduction (perspective contractor)) physical constraints as a primary complexity, particularly the limited construction space which necessitates thorough planning and logistical considerations to minimise environmental impact and manage construction activities effectively. The challenges of building within the Amsterdam region, known for its soft soil, require specialised construction techniques and vertical barriers, adding layers of technical difficulty to the project execution (Appendix J.1 Introduction (perspective contractor)).

The Zuidasdok's half-yearly reports (Programmaorganisatie Zuidasdok, 2022, 2023a, 2023b) go into greater detail about the project's complexities, such as geopolitical and market developments that lead to price increases and pressure on delivery times. The procurement of contracts, lack of physical space for the program's execution, and labour market shortages pose significant challenges. Additional complexities include the potential resistance from the local community concerning disturbances, unforeseen significant technical setbacks, and the potential impacts of safety measures on road, rail, and metro traffic, as well as the built environment. The reports also note the prolonged decision-making processes which may delay permit issuance, complicating project timelines.

These complexities reflect the dynamic nature of the Zuidasdok project, and the multifaceted approach required to address these challenges effectively. Managing these complexities involves a delicate balance of strategic planning, stakeholder management, and adaptive measures to ensure the project's objectives are met while minimising the impact on the local community and the environment. Table 9 provides a categorisation and description of the complexities, according to the interviews with both the client and the contractor, as well as desk research, providing an overview of the project's technical, organisational, and external complexities.

Table 9. TOE Framework analysis of the project complexities in Zuidasdok

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and complexity elements were sourced from Appendix I.1 Introduction (perspective client), Appendix J.1 Introduction (perspective contractor), and Programmaorganisatie Zuidasdok (2022, 2023a, 2023b).

T Technical complexity	O Organisational complexity	E External complexity
High number of project goals Zuidasdok is characterised by many goals, addressing a wide range of development objectives, which contributed significantly to the project's complexity.	**High project schedule drive** The urgency to adhere to the project schedule puts significant pressure on all organisational aspects, contributing substantially to the project's complexity.	**Political influence** The restructuring and public visibility of the project indicate significant political implications, affecting decisions and project progress, contributing very much to the project's complexity.
Uncertainties in scope The Zuidasdok project, situated in a rapidly developing business district, faces considerable uncertainty in scope due to evolving urban development plans and stakeholder requirements. This contributes very much to the project's complexity.	**Interfaces between different disciplines** Managing interfaces between different technical disciplines across various project elements, such as road expansion, junctions, tunnels, and the integration with existing transportation systems, is crucial and complex, contributing substantially to the project's complexity.	**Dependencies on external stakeholders** The involvement of various governmental bodies underscores the project's reliance on multiple external stakeholders for approvals and coordination, contributing very much to the project's complexity.
Strict quality requirements Given the project's scale and its impact on a prime business location, high-quality standards are mandatory, contributing very much to the project's complexity.	**Size of project team** Managing the project requires a large team due to the diverse and extensive range of tasks involved, contributing very much to the project's complexity.	**Number of external stakeholders** The project interacts with a wide array of external stakeholders, including city residents, businesses, commuters, local government agencies, and environmental groups, contributing very much to the project's complexity.
Project duration Extended timelines due to the comprehensive nature of the works and the intricate integration required with existing infrastructure, contributing very much to the project's complexity.	**Organisational risks** The client faces significant organisational risks, as it must manage and coordinate a mega infrastructure project, contributing very much to the project's complexity.	**Interference with existing site** The Zuidasdok project, situated in a prime business district, had to manage interference with a highly active urban environment, which contributed very much to the project's complexity
Number of locations The project spans multiple critical points within the Zuidas area, each with unique environmental and logistical challenges, contributing very much to the project's complexity.		
High number of tasks The extensive range of tasks involved includes constructing roads, tunnels, and public transportation facilities, contributing very much to the project's complexity.		
High variety of tasks Each task involves distinct technical requirements, from underground construction to the integration of transportation systems, contributing very much to the project's complexity.		
Dependencies between tasks The coordination between various construction phases and elements is crucial due to dependencies where decisions or delays in one area affect others, contributing very much to the project's complexity.		
Involvement of different technical disciplines The project requires coordination across various engineering and architectural fields, contributing very much to the project's complexity.		
Technical risks Challenges such as constructing in densely populated areas and handling complex underground conditions are significant, contributing very much to the project's complexity.		

4.3.2 Segmentation in Zuidasdok

Segmentation plays a pivotal role in the management and realisation of the Zuidasdok project. This subchapter explores how segmentation has been strategically implemented to enhance project

manageability, facilitate specialised expertise, and mitigate risks associated with the extensive scope of the project. It delves into the rationale behind dividing the project into distinct, manageable parts, each tailored to specific components of the infrastructure development. By examining how these segments are defined, managed, and integrated within the overall project framework, this section aims to provide a comprehensive understanding of the segmentation approach and its impact on the ongoing development of the project.

Segmentation emerged as a critical strategy in the Zuidasdok project due to initial challenges with the project's scope and complexity. Initially, the entire project was awarded to a single consortium of contractors, based on market confidence that no project was too large to handle ((Appendix I.2 Understanding segmentation (perspective client)). However, it soon became evident that the complexity and extended duration of the project (15 years) made it impossible for a contractor to fully understand all risks during the tender phase and to set a fixed price accordingly. This led to significant problems, culminating in the termination of the partnership with the original contractor ((Appendix I.2 Understanding segmentation (perspective client)). To make the project more manageable, it was decided to segment the project into various parts and tender them separately. Some segments remained significantly large, influencing the market's interest in bidding for parts of the project ((Appendix I.2 Understanding segmentation (perspective client)).

The project scope of Zuidasdok consists of seven segments, each procured separately by the client, resulting in seven distinct agreements labelled as Agreement A through Agreement G, which make up the full scope and realisation of the project ((Appendix I.2 Understanding segmentation (perspective client)). This research identifies and classifies the client's segmentation strategy for the Zuidasdok project as incorporating both horizontal and vertical segmentation. Horizontal segmentation involves dividing the project into multiple segments based on geographic location, while vertical segmentation is based on functional requirements. For example, Segment A (Openbaar Vervoer Terminal 1), Segment B (Openbaar Vervoer Terminal 2), Segment C (Openbaar Vervoer Terminal 3), and Segment D (S&C/ICT Metro) were managed using vertical segmentation to focus on the specific technical requirements and specialised expertise needed for each public transportation terminal and metro system. In contrast, horizontal segmentation was used for Segment E (Knooppunt de Nieuwe Meer), Segment F (Knooppunt Amstel), and Segment G (Tunnel A10 Noord & Zuid) to manage the unique environmental and regulatory challenges associated with their distinct geographic locations (Programmaorganisatie Zuidasdok, 2023b). By applying these segmentation strategies, the client was able to address site-specific issues effectively, distribute risks, and allocate resources efficiently. Each segment was/is procured separately, resulting in distinct agreements (Agreements A through G) that collectively encompass the full scope and realisation of the Zuidasdok project ((Appendix I.2 Understanding segmentation (perspective client)). This approach facilitated focused management and has been essential in advancing the project efficiently and effectively. The segmentation within the project scope is summarised in Table 10, which details the segments, the type of segmentation, and the agreements.

Table 10. Overview of segmentation in the scope and agreements for Zuidasdok

Note: Overview of segmentation in the scope and agreements for Zuidasdok was sourced from Appendix I.2 Understanding segmentation (perspective client) and Programmaorganisatie Zuidasdok (2023b).

Scope	Description	Type of segmentation	Segment	Segment Intersection(s)	Agreement	Type of Agreement	(Consortium of) contractor(s)
A	Openbaar Vervoer Terminal - 1	Vertical	A	B, C, & D	A	D&B	A
B	Openbaar Vervoer Terminal - 2	Vertical	B	A, C, & D	B	D&B	A
C	Openbaar Vervoer Terminal - 3	Vertical	C	A, B, & D	C	TBD	TBD
D	S&C/ICT Metro	Vertical	D	A, B, & C	D	Framework agreement	B
E	Knooppunt de Nieuwe Meer	Horizontal	E	G	E	D&B	C
F	Knooppunt Amster	Horizontal	F	G	F	D&B	TBD
G	Tunnel A10 (Noord & Zuid)	Horizontal	G	E & F	G	Two-phase	TBD

Segmentation was introduced following the initial failed tender and a strategic reconsideration. This segmentation occurred during the tendering phase of the new segments, dividing the project into manageable parts that could be independently tendered and executed. The primary strategic goals behind implementing segmentation were to enhance the project's manageability, make the tenders more attractive to a broader range of contractors, and reduce risks by isolating them within specific project segments ((Appendix I.2 Understanding segmentation (perspective client)). The decision to segment the project was partly based on the need to isolate complex parts of the project, such as tunnel construction and station renovations, allowing each to be tendered to contractors with specific expertise. This decision-making process was influenced by clarity about the work and the nature of tasks that could vary from one segment to another ((Appendix I.2 Understanding segmentation (perspective client)).

The contractor did not participate in the project before it was segmented and observes the complexity of his segment, stating it would be unmanageable as a whole. Segmentation has, in his view, helped reduce complexity by assigning specific tasks to segments that align with their expertise. However, there are still challenges with meeting contractual requirements that do not always seem directly applicable to their specific segment, suggesting that segmentation was not entirely thought through, particularly in defining requirements and allocating responsibilities (Appendix J.2 Understanding segmentation (perspective contractor)). The interaction with other stakeholders has been somewhat limited due to the physical separation of project segments in different phases, like tendering or design. Coordination for common resources and planning of infrastructure closures is managed by Zuidasdok, the organising body responsible for synchronising these elements across different project segments (Appendix J.2 Understanding segmentation (perspective contractor)).

The contractor's segment was integrated into the project's lifecycle as a Design & Construct contract, which is part of a larger cycle that started with an extensive design phase by a previous contractor. This

setup leads to segments operating somewhat independently with a pre-established design, complicating coherence and integration with other segments (Appendix J.2 Understanding segmentation (perspective contractor)). The specific goals for the contractor's segment, such as improving traffic flow on the A10 and preparing infrastructure for future expansions like the tunnel, align with the broader strategic goals of improving mobility and accessibility in the Amsterdam region. The contractor notes the importance of meeting timely milestones to avoid impacting the progress of other segments, influencing the overall project's planning and predictability (Appendix J.2 Understanding segmentation (perspective contractor)).

4.3.2 Segmented project delivery method in Zuidasdok

Figure 23 depicts a schematic representation of the segmented project delivery method (PDM) for Zuidasdok ((Appendix I.2 Understanding segmentation (perspective client)). In this PDM, the client manages the procurement phase exclusively, whereas each contractor handles both the design and realisation phases of the project for each segment. Notably, the model includes a segment where a two-phase approach necessitates a decisive 'go' or 'no-go' decision following the design phase and before proceeding to the realisation phase (segment G). It is important to note that the framework agreement, utilised for the fourth segment, is not depicted in this figure, as it falls outside the scope of this research. In addition to horizontal and vertical segmentation, the client also phased the segments over time to ensure a more manageable project progression, allowing for focused attention on each segment and facilitating better resource allocation and risk management. This approach is visually depicted in Figure 23 by the segments shifting progressively to the right, illustrating the gradual phasing method, which indicates that the segments are distributed over time.

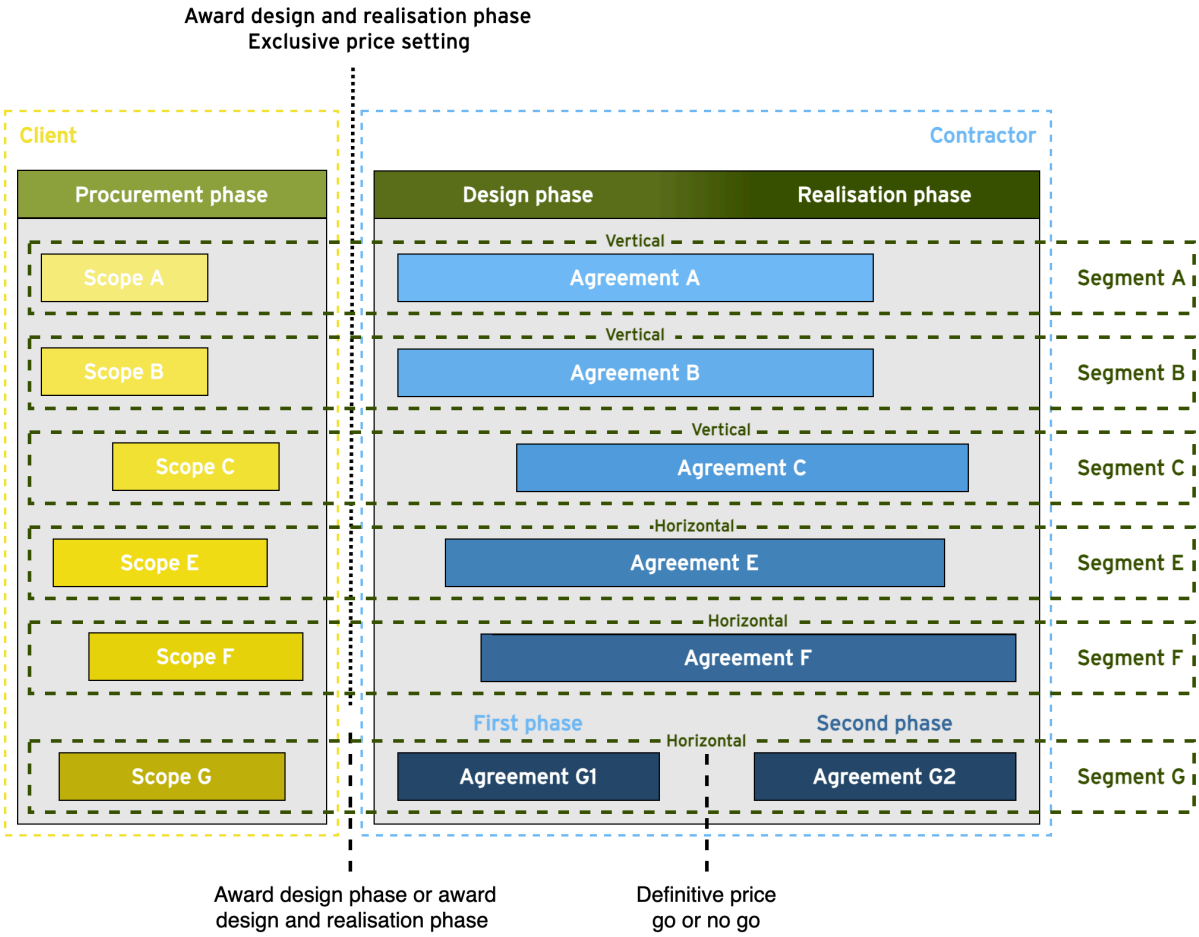


Figure 23. Schematic representation of the segmented PDM for Zuidasdok

Note: Schematic representation of the segmented PDM for Zuidasdok was sourced from Appendix I.2 Understanding segmentation (perspective client) and Programmaorganisatie Zuidasdok (2023b).

4.3.3 Key characteristics of segmentation in Zuidasdok

The implementation of segmentation in Zuidasdok has been pivotal in managing the complexities of a complex infrastructure project. From the client's and contractor's perspective, several key characteristics highlight how segmentation has been effectively utilised to streamline project execution, manage risks, and coordinate across multiple stakeholders.

The client explains that the project's various segments are overseen by a common program direction, ensuring that interfaces between segments are well managed and nothing is overlooked. Regular meetings with project managers across different segments ensure that all parts of the project progress coherently and remain aligned. These meetings are crucial in determining who is responsible for which interfaces, with an emphasis on maintaining an integrated project whole. This level of coordination is instrumental in presenting the project uniformly to all stakeholders, thereby simplifying complex management tasks (Appendix I.3 Key characteristics of segmentation (perspective client)). The contractor highlights that coordination within the segment primarily revolves around the detailed alignment of interfaces and the integration of construction activities with adjacent projects (Appendix J.3 Key characteristics of segmentation (perspective contractor)). This is achieved through regular updates and alignments concerning construction logistics and resource deployment. Special attention is paid to synchronising activities that impact each other, such as the transport and delivery of construction materials and the scheduling of construction work that affects operations in adjoining segments (Appendix J.3 Key characteristics of segmentation (perspective contractor)).

Post-establishment, the segments are managed and integrated through a centralised approach under the oversight of the program directorate. This centralised management is strategic in planning and monitoring segments to ensure that all components of the project stay coherent and aligned with the overall project objectives (Appendix J.3 Key characteristics of segmentation (perspective contractor)). Strict coordination is maintained through regular gatherings of various project managers, which fosters alignment and integration across the project. The management and integration of the segment are handled through strategic planning and alignment with the overall project objectives. This planning requirement enforces tight coordination and synchronisation of work between segments, ensuring cohesive progress and preventing overlaps or conflicts in project activities (Appendix J.3 Key characteristics of segmentation (perspective contractor)).

Economic factors linked to individual segments have significantly influenced project dynamics and decision-making processes. Inflation and other financial changes during the project's duration have necessitated reconsiderations in the project approach. Financial feasibility studies and necessity assessments conducted by external consultants have prompted revisions in the project segments to accommodate budget adjustments and project scope (Appendix I.3 Key characteristics of segmentation (perspective client)). The contractor notes that budget pressures and the allocation of financial resources across different project segments have a considerable impact. Budget transfers and the need for cost savings lead to strategic choices, including the potential simplification of certain project components (Appendix J.3 Key characteristics of segmentation (perspective contractor)).

Segmentation has facilitated more detailed budget allocation and enhanced cost control by breaking down the project into smaller, manageable parts for both the client and the contractor. This division has allowed for better management of financial overruns within individual segments (Appendix I.3 Key characteristics of segmentation (perspective client); Appendix J.3 Key characteristics of segmentation (perspective contractor)). However, it has also increased transaction costs due to multiple tenders and may have reduced potential synergistic benefits that could have been achieved if the project had been tendered as a whole (Appendix I.3 Key characteristics of segmentation (perspective client)).

Risks are distributed among the different segments and contracting parties by setting aside a contingency budget for each project segment. The project directorate manages non-specific unforeseen risks at the program level, allowing for flexibility and adaptability to changing circumstances throughout the project duration. This approach ensures that issues, when they arise, are contained within specific segments, thereby preventing the entire program from being compromised (Appendix I.3 Key characteristics of segmentation (perspective client)). The project has established penalties for delays at interim milestones, which are significantly higher than those for the final milestone. Penalties for not meeting interim milestones are higher because the segments are highly dependent on each other, delays in one segment directly impact the progress of adjacent segments. By implementing higher penalties, an additional incentive is provided to ensure each segment meets its deadlines, thereby minimising the chances of delays affecting the entire project (Appendix I.3 Key characteristics of segmentation (perspective client)).

4.3.4 Legal aspects of segmentation in Zuidasdok

From the client's viewpoint, the segmentation of the Zuidasdok project within the framework of Dutch procurement law did not lead to any direct legal implications that challenged the existing legal boundaries (Appendix I.4 Legal aspects of segmentation (perspective client)). The decision to segment the project followed the termination of the initial contractor consortium, necessitating a shift in the project's structure and approach. This change required a different contractual model, dividing the project into smaller segments, which remained well within legal limits (Appendix I.4 Legal aspects of

segmentation (perspective client)). The segmentation was thus seamlessly integrated into the legal framework, ensuring compliance with Dutch procurement laws.

The contractor discussed the legal implications of segmentation primarily in terms of the structure of penalties related to project milestones. It was noted that penalties for interim milestones are significantly higher than those for the final milestones, a direct consequence of the segmentation (Appendix J.4 Legal aspects of segmentation (perspective contractor)). This reflects a strategic decision to emphasise the importance of timely achievement of these interim milestones to ensure the progress and integration between segments.

The contractual models were specifically designed to facilitate segmentation by employing various contract types suited to the diverse needs of the project. For example, Design & Construct contracts were used for the specific junctions, and a two-phase approach was applied to the other segments such as the public transport terminal and tunnels. This allowed for a separation of design and construction phases, maintaining flexibility in project execution and adapting to the segmented structure without breaching legal requirements (Appendix I.4 Legal aspects of segmentation (perspective client)). The contractor expressed concerns that the contractual framework for the segments often seemed like a straightforward copy and paste from one segment to another, without sufficient adjustments to reflect the unique needs of each segment (Appendix J.4 Legal aspects of segmentation (perspective contractor)). This lack of specificity in the contracts could potentially lead to ambiguities and insufficient clarity on the roles and responsibilities tailored to the particular challenges of each segment. The contractor indicates that while the overall contractual approach was adequate in meeting the legal requirements for segmentation, there was room for improvement to better tailor the contracts to the segmented structure of the project (Appendix J.4 Legal aspects of segmentation (perspective contractor)).

The client reports that no specific legal challenges directly related to the segmentation were encountered. This smooth transition can be attributed to careful planning and the alignment of contractual practices with legal standards, ensuring that all adjustments were legally sound. The adjustments necessary for the project, both in terms of contracts and the overall approach, were carefully crafted to comply with legal standards. This involved thoughtful termination of existing contracts and the precise formulation of new tenders to meet legal obligations. The emphasis was on ensuring that all legal procedures were followed to avoid any legal repercussions, thereby facilitating a legally compliant restructuring of the project (Appendix I.4 Legal aspects of segmentation (perspective client)). The contractor reported minimal segment-specific legal challenges, suggesting that major legal issues directly resulting from segmentation were effectively managed. However, the concern about the generic nature of contracts indicates a potential area for legal complications if not addressed appropriately. Strategies to overcome these challenges involved pushing for more detailed and segment-specific contractual amendments to better align with the operational realities and requirements of each segment (Appendix J.4 Legal aspects of segmentation (perspective contractor)).

4.3.5 Challenges and benefits of segmentation in Zuidasdok

The client highlights that segmentation introduced specific challenges, particularly in maintaining close connections between different segments. A significant challenge was ensuring that teams within each segment did not solely focus on their individual success but also recognised the importance of their contributions to the success of other segments and the overall project cohesion. This required a high level of awareness and coordination to ensure effective collaboration across segments and that critical project elements were not overlooked (Appendix I.5 Challenges and benefits of segmentation (perspective client)). Additionally, segmentation led to increased transaction costs, including multiple tenders and associated costs, which significantly impacted the budget. Despite these challenges,

segmentation also brought substantial benefits to the project. It made project tasks more manageable and predictable, and increased the adaptability of the project management approach (Appendix I.5 Challenges and benefits of segmentation (perspective client)). By dividing the project into smaller, more manageable parts, the tenders became more attractive to a broader range of contractors, making it easier to isolate and manage risks. This also minimised the potential impact of issues occurring in one segment from threatening the progress of the entire project (Appendix I.5 Challenges and benefits of segmentation (perspective client)). This segmented approach facilitated better risk management and enhanced the project's ability to adapt to changes and unforeseen challenges, ultimately contributing to a more controlled and effective project execution.

The contractor underscores that one of the primary challenges stemming from segmentation is the coordination and management of interfaces between different segments. Due to the complexity of the segment involved, optimising the utilisation of resources such as sand and construction space becomes challenging. This is further complicated by the location of the segments (Appendix J.5 Challenges and benefits of segmentation (perspective contractor)). Additional challenges include the alignment of temporary infrastructure and the risk that decisions made in one segment could negatively impact other segments. Managing these interdependencies requires careful planning and coordination to ensure that the actions in one segment do not adversely affect the broader project outcomes (Appendix J.5 Challenges and benefits of segmentation (perspective contractor)). Despite these challenges, the contractor points out significant benefits associated with segmentation. One of the key advantages is the improved manageability of complex parts of the project. By segmenting the project, specific expertise and attention can be focused on individual components, leading to higher quality and efficiency in the realisation phase. Segmentation has allowed for a more targeted approach in managing and executing tasks, enhancing the overall effectiveness and impact of the project activities within his segment (Appendix J.5 Challenges and benefits of segmentation (perspective contractor)).

4.3.6 The results of segmentation in Zuidasdok

The segmentation approach in the Zuidasdok project has been pivotal in managing and overcoming the challenges posed by such a large-scale and complex urban development. From the client's standpoint, segmentation has been instrumental in enhancing project manageability and adaptability. By dividing the project into manageable parts, the client has been able to address specific complexities with more focus and precision. This has facilitated a more structured approach to project management, where each segment can be closely monitored and directed towards the overarching project goals. The regular strategic meetings among different segment managers have ensured that the project progresses cohesively and remains aligned with its initial objectives, despite the underlying complexities. The benefits of segmentation, as identified by the client, include increased manageability of the project tasks and enhanced risk management. Each segment has been tailored to meet specific challenges, enabling a more focused allocation of resources and expertise. This has not only improved the quality of outcomes but also minimised the ripple effects of potential setbacks within individual project segments. However, the client also acknowledges that segmentation has led to increased transaction costs due to multiple tenders and the need for extensive coordination, which has placed additional financial burdens on the project.

From the contractor's view, while segmentation has posed challenges, particularly in terms of coordinating with other segments and managing resource allocation, it has also brought about significant benefits. The contractor highlights that segmentation has allowed for better control over his segment of the project, making it possible to apply specific expertise effectively and achieve high-quality results. This focused approach has facilitated improvements in traffic flow and infrastructure development, which are crucial for the success of the Zuidasdok project. Moreover, the contractor notes that the structured penalties for delays in achieving milestones within segments have been a

critical factor in maintaining discipline and ensuring timely progress. These penalties have underscored the importance of each segment's role in the broader project context, promoting accountability and urgency in meeting project timelines.

Overall, the results of segmentation in the Zuidasdok project highlight a complex balance between the benefits of enhanced manageability, specialised focus, and improved risk control against the challenges of increased costs and the need for intensive coordination. Both the client and the contractor recognise that while segmentation has introduced certain difficulties, the strategic decision to segment the project has fundamentally supported the project's success by enabling a more adaptable and responsive management structure.

Table 11 depicts the impact of segmentation on Zuidasdok's complexities, based on interviews with both the client and the contractor, and shows how each complexity was altered as a result of segmentation. It reveals that segmentation reduces several technical complexities, such as strict quality requirements, project duration, number of locations, high number of tasks, high variety of tasks, and technical risks by allowing for more focused management and better control over specific project segments. On the organisational side, segmentation increases complexities like the number of contracts, size of the project team, and organisational risks due to the need for additional resources and more intricate coordination. However, segmentation also offers benefits by potentially decreasing political influence and dependencies on external stakeholders, as these can be managed more effectively within isolated segments, simplifying negotiations and stakeholder management. This comprehensive evaluation highlights the dual nature of segmentation's impact on project complexities.

Table 11. TOE Framework analysis of segmentation impact on the project complexities in Zuidasdok

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and impact of segmentation on complexity elements were sourced from Appendix I. Case study: elaboration of the interview with the client of Zuidasdok (NL) and Appendix J. Case study: elaboration of the interview with a contractor of Zuidasdok (NL).

T Technical complexity	O Organisational complexity	E External complexity
High number of project goals Zuidasdok is characterised by many goals, addressing a wide range of development objectives, which contributed significantly to the project's complexity. Segmentation allows for more focused management of each segment's specific goals, thereby decreasing the contribution to the project's complexity.	**High project schedule drive** The urgency to adhere to the project schedule puts significant pressure on all organisational aspects, contributing substantially to the project's complexity. Segmentation enables segments to progress independently, mitigating the risk of delays in one segment from affecting others, thereby decreasing the contribution to the project's complexity.	**Political influence** The restructuring and high public visibility of the project have significant political implications, affecting decisions and project progress, contributing very much to the project's complexity. By breaking the project into segments, the impact of political decisions and pressures can be isolated to specific aspects of the project, simplifying negotiations and adjustments, thereby decreasing the contribution to the project's complexity.
Uncertainties in scope The Zuidasdok project, situated in a rapidly developing business district, faces considerable uncertainty in scope due to evolving urban development plans and stakeholder requirements. This contributes very much to the project's complexity. Segmentation enables more adaptable and focused management of scope uncertainties, thereby decreasing the contribution to the project's complexity.	**Interfaces between different disciplines** Managing interfaces between different technical disciplines across various project elements, such as road expansion, junctions, tunnels, and the integration with existing transportation systems, is crucial and complex, contributing substantially to the project's complexity. Segmentation intensifies the need for careful coordination between different disciplines across segments, thereby increasing the contribution to the project's complexity.	**Dependencies on external stakeholders** The involvement of various governmental bodies underscores the project's reliance on multiple external stakeholders for approvals and coordination, contributing very much to the project's complexity. Segmentation allows each segment to handle a different set of stakeholders, simplifying interactions by reducing the range of concerns and negotiations needed at any one time, thereby decreasing the contribution to the project's complexity.
Strict quality requirements Given the project's scale and its impact on a prime business location, maintaining high-quality standards is mandatory, contributing very much to the project's complexity. Segmentation allows for more focused management of quality standards within each segment, ensuring specialised attention to detail that might be harder to maintain across a larger,	**Number of contracts** Segmentation resulted in an increase in the number of contracts, as the project was divided into smaller, more manageable segments, each requiring its own contractual arrangement. This led to an increase in the contribution to the project's complexity.	**Number of external stakeholders** The project interacts with a wide array of external stakeholders, including city residents, businesses, commuters, local government agencies, and environmental groups, contributing very much to the project's complexity. Segmentation simplifies the management of external stakeholders by aligning specific groups of stakeholders with

Decrease of complexity due to segmentation
Increase of complexity due to segmentation
No impact by segmentation

unified project, thereby decreasing the contribution to the project's complexity.

Project duration
The extended timelines due to the comprehensive nature of the works and the intricate integration required with existing infrastructure contribute very much to the project's complexity. Although segmentation initially complicates scheduling, it ultimately streamlines processes by allowing different segments to progress simultaneously, potentially reducing the overall project duration and decreasing the contribution to the project's complexity.

Number of locations
The project spans multiple critical points within the Zuidas area, each presenting unique environmental and logistical challenges, contributing very much to the project's complexity. Segmentation increases the complexity associated with managing multiple locations simultaneously, thereby increasing the contribution to the project's complexity.

High number of tasks
The extensive range of tasks involved, including constructing roads, tunnels, and public transportation facilities, contributes very much to the project's complexity. Segmenting the project allows for a more organised approach to managing the vast array of tasks, enabling teams to focus on specific sets of tasks within their expertise, thereby decreasing the contribution to the project's complexity.

High variety of tasks
Each task involves distinct technical requirements, from underground construction to the integration of transportation systems, contributing very much to the project's complexity. Segmentation helps in managing the variety of tasks more effectively by assigning specialised teams to handle specific types of tasks, thereby decreasing the contribution to the project's complexity.

Dependencies between tasks
The coordination between various construction phases and elements is crucial due to dependencies where decisions or delays in one area affect others, contributing very much to the project's complexity. Segmentation helps in isolating interdependencies within manageable portions, allowing for more controlled and predictable management, thereby decreasing the contribution to the project's complexity.

Involvement of different technical disciplines
The project requires coordination across various engineering and architectural fields, contributing very much to the project's complexity. Segmentation allows for clearer delineation and coordination of different technical disciplines within discrete portions of the project, facilitating better communication and collaboration, thereby decreasing the contribution to the project's complexity.

Technical risks
Challenges such as constructing in densely populated areas and handling complex underground conditions are significant, contributing very much to the project's complexity. Segmentation allows for specialised contractors to manage these unique challenges, leveraging their expertise to handle risks more effectively. However, segmentation also creates

Size of project team
Managing the project requires a large team due to the diverse and extensive range of tasks involved, contributing very much to the project's complexity. While the overall project team size is large, segmentation allows for smaller, more focused teams working on each segment, potentially improving management and operational efficiency, thereby decreasing the contribution to the project's complexity.

Organisational risks
The client faces significant organisational risks in managing and coordinating a mega infrastructure project, contributing very much to the project's complexity. Segmentation complicates the management of the project due to the many segments, interfaces and contractors involved, thereby increasing the contribution to the project's complexity.

relevant project segments, thereby decreasing the contribution to the project's complexity.

Interference with existing site
The Zuidasdok project, situated in a prime business district, had to manage interference with a highly active urban environment, which contributed very much to the project's complexity. Segmentation typically decreased the contribution to complexity by enabling focused and specialised management of interference, thereby decreasing the contribution to the project's complexity.

interfaces that introduce additional technical complexities, thereby maintaining a high contribution to the project's complexity.		

As the Zuidasdok project continues to evolve, the lessons learned from employing segmentation will undoubtedly contribute to refining future infrastructure projects. The insights gained from both the planning and realisation phases will inform better project segmentation strategies, ensuring that large-scale infrastructure projects can be managed more effectively, with risks minimised and resources optimised to meet the dynamic needs of such significant undertakings.

4.4 Oranje Loper

The Oranje Loper project, spanning from Dam Square to Mercatorplein, encompassing seven streets and nine bridges, represents a unique and extensive project within the urban context of Amsterdam. Typically, infrastructure projects in Amsterdam are tackled per individual bridge, street, or intersection. However, Oranje Loper follows an integrated approach, developing an entire corridor collectively ((Appendix K.1 Introduction (perspective client)).

Initiated in 2020, the project is carried out by two design teams (bouwteams): the 'Bouwteam Bruggen en Straten' comprising Mobilis and Dura Vermeer, and the 'Bouwteam Kabels en Leidingen' involving Heijmans and Van Gelder, in collaboration with the municipality of Amsterdam ((Appendix K.1 Introduction (perspective client)). This partnership aims not only to renew the physical infrastructure but also to ensure a cohesive urban design that accommodates the high usage density of this area (Appendix K.1 Introduction (perspective client); Appendix L.1 Introduction (perspective contractor)).

Despite external disruptions such as the COVID-19 pandemic and economic impacts from the war in Ukraine, which led to necessary adjustments in project scope, the project has been continually adapted to remain within budgetary constraints. Initially aimed at the complete replacement of nine bridges and comprehensive street redesign, the focus has now shifted towards the renovation of existing bridges and a more targeted approach to surface-level redesign (Appendix K.1 Introduction (perspective client); Appendix L.1 Introduction (perspective contractor)).

This chapter explores the Oranje Loper project through desk research and interviews with both the client (Appendix K. Case study: elaboration of the interview with the client of Oranje Loper (NL)) and contractors (Appendix L. Case study: elaboration of the interview with a contractor of Oranje Loper (NL); Appendix M. Case study: elaboration of the interview with a contractor of Oranje Loper (NL)), particularly focusing on the project's strategic approach to segmentation and the collaborative project delivery methods employed by the design teams. This analysis aims to thoroughly understand how segmentation was approached and implemented within this extensive urban redevelopment initiative. Through qualitative analysis, the research seeks to explore the segmentation processes used to manage the multifaceted aspects of the project, uncover the key characteristics and legal considerations of segmentation, and navigate the challenges and benefits presented by such an approach.

4.4.1 Complexities of Oranje Loper

The complexities of the Oranje Loper project, as explored through the perspectives of both the client and contractors, underscore the multifaceted challenges involved in managing large-scale urban infrastructure projects within a bustling city centre. This subchapter delves into the detailed complexities as experienced and communicated by the client, responsible for the overall coordination of the project, and two contractors, who are specifically focused on the segmented tasks of bridges,

streets, and utilities within the dense urban fabric of Amsterdam. The interplay between these different perspectives provides a comprehensive understanding of the project's unique complexity elements.

The complexities of the Oranje Loper project, as described by the client (City of Amsterdam), stem not so much from its technical demands but from the intricate interplay of stakeholders, the project's scale, and its contractual arrangements (Appendix K.1 Introduction (perspective client)). A notable complexity arises from the programmatic approach to simultaneously tackling multiple infrastructure components, a methodology that is relatively new for the client (Appendix K.1 Introduction (perspective client)). Additionally, there was limited experience with the use of design teams, presenting a further challenge. These design teams were established to collaboratively refine the project scope with contractors early in the process and to integrate execution expertise to mitigate surprises during the realisation phase. This approach aimed to streamline the management of the project's complex elements by fostering closer cooperation and proactive problem-solving among all parties involved (Appendix K.1 Introduction (perspective client)).

From the perspective of a contractor, the Oranje Loper project is distinguished by its complexities, mainly due to its location in the urban core of Amsterdam at a logistically critical intersection used by many modes of transportation (Appendix L.1 Introduction (perspective contractor)). The project's commencement coincided with the start of the COVID-19 pandemic, making the first two years particularly challenging, followed by the crisis in Ukraine. These external circumstances led to changes in the project scope during the construction team phase. Additionally, the political context surrounding the project played an unexpected role in its execution, which was unusual for contractors who typically become involved at a later stage. These factors significantly altered the initial definition, scope, and conditions of the project, introducing realisation challenges (Appendix L.1 Introduction (perspective contractor)). As contractors accustomed to linearly progressing projects from A to B, dealing with political shifts such as new elections and council members was a novel experience. This required adaptability to a dynamic context that is unique to projects carried out in collaboration with the City of Amsterdam within a construction team setting (Appendix L.1 Introduction (perspective contractor)).

Meanwhile, another contractor emphasised that the complexity of the segment was primarily determined by its location in the centre of Amsterdam, which brought about a busy and constrained construction space. This required meticulous planning to minimise the impact on the immediate environment and maintain accessibility throughout the project (Appendix M.1 Introduction (perspective contractor)). The existing infrastructure had to be renovated, which posed specific challenges as existing structures were not always clear until they were exposed during the construction process. This complexity was heightened by the need to coordinate with multiple stakeholders and adhere to strict regulations, further complicating the execution of tasks (Appendix M.1 Introduction (perspective contractor)). Additionally, the limited space necessitated innovative solutions to manage logistics and materials movement efficiently within the restricted urban setting (Appendix M.1 Introduction (perspective contractor)). Table 12 presents a detailed overview of the complexities of the Oranje Loper project as captured within the TOE Framework.

Table 12. TOE Framework analysis of the project complexities in Oranje Loper

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and complexity elements were sourced from Appendix K.1 Introduction (perspective client), Appendix L.1 Introduction (perspective contractor), and Appendix M.1 Introduction (perspective contractor).

T Technical complexity	O Organisational complexity	E External complexity
Strict quality requirements High-quality standards are essential due to the project's prime business location and its significant impact on the urban environment, contributing very much to the project's complexity.	**Organisational risks** Limited experience with design teams and collaborative project delivery methods introduces additional complexity, contributing very much to the project's complexity.	**Political influence** The political context and changes, such as elections and council members, significantly influence project execution and scope adjustments, contributing very much to the project's complexity.
Uncertainties in scope The Oranje Loper project, which involves substantial urban renovations, encountered significant scope uncertainties as the scope continually adapted to remain within budgetary constraints. This contributes very much to the project's complexity.		**Dependencies on external stakeholders** The project relies on coordination with various governmental bodies, which underscores the importance of external approvals and stakeholder management, contributing very much to the project's complexity.
Project duration The extended project timeline is influenced by the comprehensive nature of the work and the intricate integration required with existing infrastructure, contributing substantially to the project's complexity.		**Interference with existing site** The Oranje Loper project, involving significant urban renovations, faced challenges in managing interference with existing streets and infrastructure, contributes very much to the project's complexity.
Number of locations Multiple critical points within Amsterdam are involved, each presenting unique environmental and logistical challenges, contributing very much to the project's complexity.		
High number of tasks A wide range of tasks, including the construction of bridges and streets, adds to the project's complexity, contributing substantially to the project's complexity.		
High variety of tasks Tasks involve diverse technical requirements, from renovating existing infrastructure to integrating various urban systems, contributing substantially to the project's complexity.		
Technical risks Significant challenges arise from constructing in densely populated areas and dealing with limited space, contributing very much to the project's complexity.		

4.4.2 Segmentation in Oranje Loper

The Oranje Loper project initially began without significant segmentation, treating all bridges and streets as one comprehensive entity. External factors such as budget constraints and changing project insights necessitated adjustments to the initial goals. These were shifted from complete replacements to more targeted and partial renovations of certain bridges and streets. This change prompted the introduction of segmentation, which was affirmed by a city council decision that significantly redirected the project's approach (Appendix K.2 Understanding segmentation (perspective client)).

The client utilised vertical segmentation to divide the work on cables and pipes, as well as streets and bridges, resulting in two co-contractors working in the same geographic location. Additionally, horizontal segmentation was employed for both cables and pipes, and streets and bridges (Appendix

K.2 Understanding segmentation (perspective client)). This research focused primarily on the segmentation within streets and bridges. Consequently, the full scope of the Oranje Loper project, as defined in this research, includes the six segments related to streets and bridges, along with the segment for cables and pipes. The exact number of horizontal segments within the cables and pipes segment is unclear (Appendix K.2 Understanding segmentation (perspective client)). The segmentation within the project scope is summarised in Table 13, which details the segments, the type of segmentation, and the agreements.

Table 13. Overview of segmentation in the scope and agreements for Oranje Loper

Note: Overview of segmentation in the scope and agreements for Oranje Loper was sourced from Appendix K.2 Understanding segmentation (perspective client), Appendix L.2 Understanding segmentation (perspective contractor), and Appendix M.2 Understanding segmentation (perspective contractor).

Scope	Description	Type of segmentation	Segment	Segment Intersection(s)	Agreement	Type of Agreement	(Consortium of) contractor(s)
A	Renovation bridge 135	Horizontal	A	E & G	A	Design & Build	A
B	Renovation bridge 108	Horizontal	B	E & G	B	Design & Build	A
C	Auxiliary bridges	Horizontal	C	E & G	C	Design & Build	A
D	Renovation bridge 117 & streets	Horizontal	D	E & G	D	Design & Build	A
E	Renovation subarea west	Horizontal	E	A, B, C, D, F, & G	E	Design-bid-Build	A
F	Renovation subarea centre	Horizontal	F	E & G	F	Design-bid-Build	A
G	Relocation cables and pipelines	Vertical	G	A, B, C, D, E, & F	G	Design-bid-Build	B

Vertical segmentation was strategically implemented among bridges, streets, and the relocation of cables and utilities, facilitated by different contractors. Mobilis TBI and Dura Vermeer handled bridges and streets, while Van Gelder and Heijmans were responsible for cables and utilities (Appendix K.2 Understanding segmentation (perspective client)). These teams collaborated with the City of Amsterdam on both design and realisation phases, aiming to enhance the municipality's influence within the project (Appendix K.2 Understanding segmentation (perspective client)). This segmentation enabled better management and faster execution, particularly advantageous as relocating cables and utilities in advance could smooth the progress of subsequent project phases. Additionally, segmentation allowed for quicker access to critical infrastructure components and provided phased technical benefits (Appendix K.2 Understanding segmentation (perspective client)).

The primary strategic objectives behind implementing segmentation were to accelerate the project's realisation and to efficiently manage the transition from planning to realisation. By segmenting the project, tenders could be issued more swiftly, allowing earlier commencement of certain segments while others were still in the preparatory phases. This was crucial for segments with longer lead times, enabling their initiation while other parts were still being planned (Appendix K.2 Understanding segmentation (perspective client); Appendix L.2 Understanding segmentation (perspective contractor); Appendix M.2 Understanding segmentation (perspective contractor)).

The decision to segment was based not only on the different readiness states of project components but also on the specific expertise required for each task. Emphasising expertise ensured that each part of the project was managed by teams best suited for those particular challenges, thereby enhancing overall project efficiency and effectiveness (Appendix K.2 Understanding segmentation (perspective client)). Moreover, the City of Amsterdam decided to further split the contracts geographically (horizontal segmentation) (Appendix L.2 Understanding segmentation (perspective contractor)). This geographical segmentation allowed for more localised focus, improving the management and coordination of specific project areas. This approach was also influenced by the task nature and the choice between different types of contracts (UAV or UAV-GC), where a preference for a more detached and evaluative approach by the client was deemed suitable for more complex tasks (Appendix L.2 Understanding segmentation (perspective contractor)).

Segmentation was introduced relatively late in the process, specifically recommended by the City of Amsterdam at the end of the design team phase (Appendix L.2 Understanding segmentation (perspective contractor)). After this phase, the project was divided into various realisation agreements, which commenced at different times depending on the specific requirements and the readiness of their definitive designs. This facilitated a more flexible and potentially faster project execution, allowing different segments to commence independently. Each segment follows its own trajectory within the project lifecycle yet remains integrally linked to the overarching goals and timelines of the entire project (Appendix K.2 Understanding segmentation (perspective client); Appendix L.2 Understanding segmentation (perspective contractor); Appendix M.2 Understanding segmentation (perspective contractor)).

4.4.2 Segmented project delivery method in Oranje Loper

The project delivery method for the Oranje Loper project is structured into seven distinct segments, adopting two different contractual frameworks to enhance flexibility and effectiveness in realisation phase (Appendix K.2 Understanding segmentation (perspective client)). Three of these segments are governed by traditional Design-bid-Build agreements, which align with a conventional design team structure. In this setup, the contractor functions primarily as a consultant during the initial phase, providing expertise and advice on the client's design choices, but not making design decisions (Appendix K.2 Understanding segmentation (perspective client); Appendix L.2 Understanding segmentation (perspective contractor)). Conversely, the remaining three segments operate(d) under integrated Design & Build agreements (Appendix L.2 Understanding segmentation (perspective contractor)), which foster a more collaborative environment known as Bouwteam 2.0 (Bruggeman & Jansen, n.d.). This arrangement resembles the traditional Bouwteam approach but with notable distinctions in the contractor's role and responsibilities during the design phase (Jansen, 2021; Bruggeman & Jansen, n.d.). The Oranje Loper project is divided into six segments. The complete scope of 'Bruggen & Straten' was awarded to a single contractor. This arrangement led to four separate agreements following the design team phase. The client managed the design for segments E and F, while contractor A was responsible for both the design and realisation of segments A to D, and oversaw the realisation of segments E and F. Contractor B was responsible for the realisation of segment G. (Appendix L.2 Understanding segmentation (perspective contractor)). Figure 24 provides an overview of the project delivery method of deployed for the Oranje Loper project (Appendix L.2 Understanding segmentation (perspective contractor)). In addition to horizontal and vertical segmentation, the client also phased the segments over time to ensure a more manageable project progression. This allowed for focused attention on each segment and facilitated better resource allocation. Specifically, completing auxiliary bridges and relocating cables and utilities in advance smoothed the progress of the subsequent phased segments. This approach is visually depicted in Figure 24, where the segments shift progressively to the right, illustrating the gradual phasing method and indicating that the segments are distributed over time.

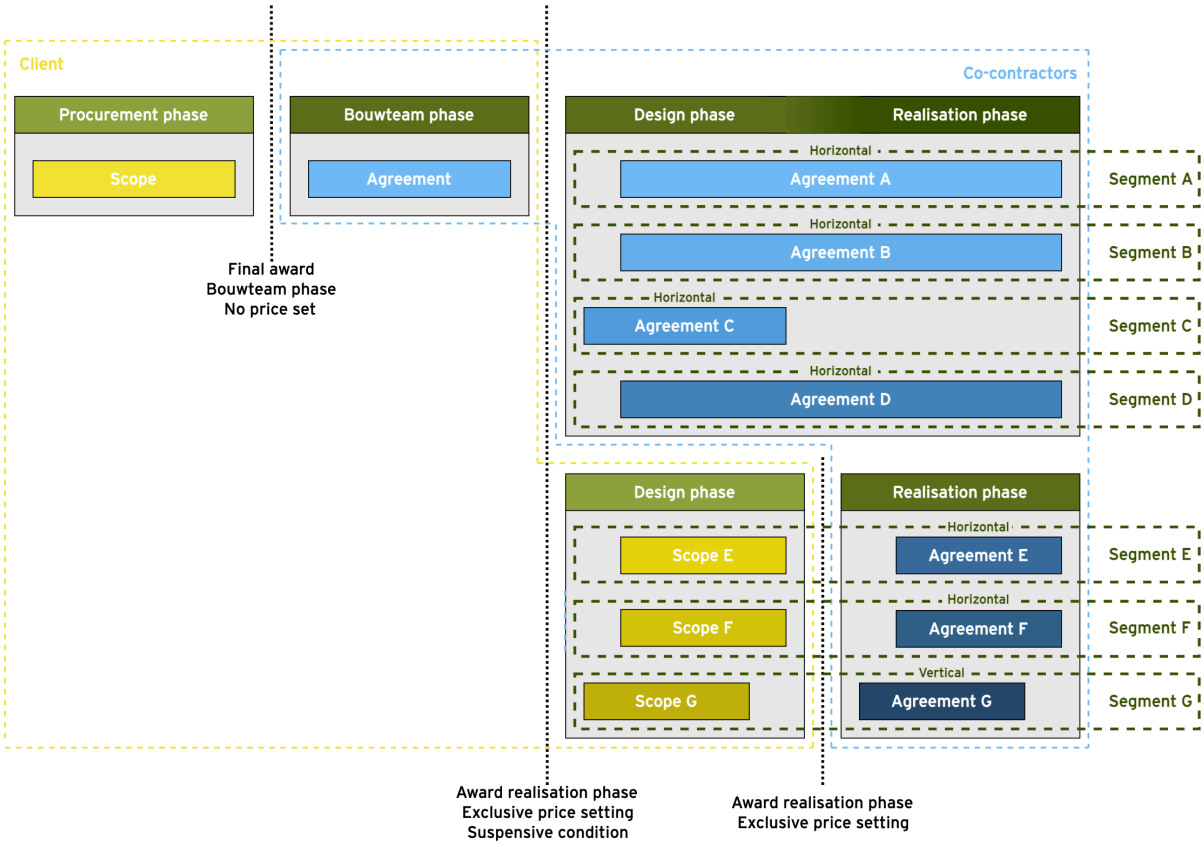


Figure 24. Schematic representation of the segmented PDM for Oranje Loper

Note: Schematic representation of the segmented PDM for Oranje Loper was sourced from Appendix K.2 Understanding segmentation (perspective client), Appendix L.2 Understanding segmentation (perspective contractor), and Appendix M.2 Understanding segmentation (perspective contractor).

Under the Design & Build framework, contractors are empowered to make independent design decisions, either autonomously or in collaboration with the client, depending on the project's specific requirements. This proactive involvement in the design process allows for more tailored and potentially innovative solutions to emerge early in the project lifecycle (Jansen, 2021). After completing the first phase, which may result in either a fully developed final design or a preliminary version, the contractor is granted the exclusive right to set a price for the second phase. This subsequent phase encompasses the completion of the design process and the actual construction work. This model aims to streamline project timelines and reduce inefficiencies by closely integrating design and execution stages, thereby providing a seamless transition from conception to completion (Jansen, 2021).

4.4.3 Key characteristics of segmentation in Oranje Loper

The implementation of segmentation in Oranje Loper has been crucial in managing the complexities of this extensive urban infrastructure project. Several key characteristics, according to the client and contractors, demonstrate how segmentation has been effectively used to streamline project execution, manage risks, and coordinate across multiple stakeholders. This approach has facilitated a more efficient organisation and execution of work within the densely populated city centre of Amsterdam.

The client and contractors' perspectives on the Oranje Loper project both highlight the critical importance of coordination within and between segments. The client emphasises that maintaining rigorous coordination is essential and is managed through regular meetings and strategic communications (Appendix K.3 Key characteristics of segmentation (perspective client)). Design team agreements facilitate collaboration and phasing between different segments, ensuring that each

segment integrates smoothly into the next with oversight from a central project office. This centralised approach guarantees that transitions between segments remain seamless to the public, focusing on consistent execution quality and minimising the visibility of segment boundaries (Appendix K.3 Key characteristics of segmentation (perspective client)).

From the contractor's perspective, segmenting the project into smaller, manageable parts simplifies decision-making and action-taking for discrete project elements, such as individual bridges, rather than addressing the entire project simultaneously. This division brings psychological benefits by making the project more approachable, although it introduces additional complexities due to new interfaces between different contract types and geographical locations within the project (Appendix L.3 Key characteristics of segmentation (perspective contractor)). Responsibility for managing these interfaces, including interactions with subcontractors and other contractors, necessitates clear coordination obligations assigned to a third party. While contractors engage deeply in this coordination process and strive to ensure robust connections between segments, the ultimate responsibility for managing these interfaces effectively resides with the client. The client prefers that coordination and efforts be centralised through one specific contract, overseeing all others. While this arrangement simplifies internal management within the client's own contracts, it presents challenges in effectively extending this coordination to third parties, particularly when they operate outside the same geographical areas (Appendix L.3 Key characteristics of segmentation (perspective contractor)). This situation underscores the complexity of managing multiple contracts and underscores the necessity of robust coordination mechanisms. Ultimately, assigning a coordination obligation to a third party does not inherently resolve the inherent challenges of segmentation. The ultimate responsibility, direction, and consequences of project coordination and segmentation lie with the client. This setup highlights that, despite the contractor's commitment to seamless integration and coordination across segments, the client holds fundamental responsibility for the success of bridging the segmented approach in the Oranje Loper project (Appendix L.3 Key characteristics of segmentation (perspective contractor)).

The client describes a centralised approach in managing and integrating the segments (Appendix K.3 Key characteristics of segmentation (perspective client)). The project uses a unified design team responsible for all bridges and streets, ensuring cohesion and consistency across the board. This central team ensures that all segments are executed to the same high standards and that segmentation does not lead to variability in quality or execution (Appendix L.3 Key characteristics of segmentation (perspective contractor)). The contractor emphasises that to maintain coherent progress, it is essential to effectively manage transitions between segments. This involves meticulous oversight of both physical and temporal interfaces, ensuring that all segments are precisely aligned in terms of their scheduling and physical implementation (Appendix M.3 Key characteristics of segmentation (perspective contractor)).

Economic interests, such as cost control and budget constraints, significantly influence the project's dynamics. The need to stay within budget and the financial viability of the project necessitates continual reconsiderations and adjustments in the project approach. This has led to decisions to change the project scope and modify segmentation to manage resources and better handle financial risks more efficiently (Appendix K.3 Key characteristics of segmentation (perspective client)). Both the client and the contractor highlight that segmentation introduces significant administrative challenges and necessitates distinct management teams for each contract. This structure impacts overall efficiency and cost control, as each contract requires its own project management team, progress reports, and financial oversight. This arrangement results in elevated overhead expenses (Appendix K.3 Key characteristics of segmentation (perspective client); Appendix M.3 Key characteristics of segmentation (perspective contractor)). Additionally, segmentation incurs higher transaction costs due to the necessity of conducting multiple tenders, which substantially affects budget management (Appendix M.3 Key characteristics of segmentation (perspective contractor)).

Both the client and the contractors' note that well-defined agreements and contractual provisions strategically allocate risks to the parties best equipped to manage them, typically determined by their specific expertise or the phase of the project they are involved in. This strategic risk management helps to minimise potential issues and optimise overall project execution (Appendix K.3 Key characteristics of segmentation (perspective client); Appendix L.3 Key characteristics of segmentation (perspective contractor); M.3 Key characteristics of segmentation (perspective contractor)). Risks that cannot be directly influenced are not accepted by the contractor. This is based on the consideration that it would be irresponsible and cost-increasing to ask parties to speculate on risks over which they have no control (Appendix L.3 Key characteristics of segmentation (perspective contractor)). The contractor emphasises that the ultimate question for the client to consider is whether the segmentation of the project offers more benefits than disadvantages. Contractors often follow this assessment closely (Appendix L.3 Key characteristics of segmentation (perspective contractor)). The contractor also notes that managing risks becomes more complex with a diversity of contract forms, such as UAV and UAV-GC, especially when multiple parties are involved with different agreements (Appendix L.3 Key characteristics of segmentation (perspective contractor)).

4.4.4 Legal aspects of segmentation in Oranje Loper

This subchapter explores the legal consequences, the structure of contractual frameworks, legal challenges encountered, and the alignment of segmentation practices with legal requirements in the Oranje Loper project, as detailed by both the client and contractors.

The client emphasises that segmentation within the framework of Dutch procurement legislation did not result in any direct legal issues. However, each segmentation and restructuring of contracts required meticulous adherence to procurement regulations to ensure transparency and fairness. There was a clear necessity to carefully review and adjust procurement procedures to fit the new project structure without violating the legislation (Appendix K.4 Legal aspects of segmentation (perspective client)). Various contract forms, such as Design & Construct (D&C) and more traditional UAV contracts, were used to facilitate segmentation. The choice of these contracts was linked to the specific requirements and complexity of each segment. For the most complex parts, such as new bridges, UAV-GC contracts were used, offering more flexibility in the design and construction process, while UAV contracts were employed for more standard parts (Appendix K.4 Legal aspects of segmentation (perspective client)). The main challenges were related to managing contractual obligations and ensuring consistency in contractual agreements across different segments. To overcome these, clear guidelines and uniform contract conditions were established to ensure all contracts remained within legal norms. There were no specific challenges encountered when aligning segmentation practices with legal requirements. All adjustments to contracts and the project approach were in line with procurement legislation, with extra attention paid to carefully terminating existing contracts and formulating new tenders to meet statutory requirements (Appendix K.4 Legal aspects of segmentation (perspective client)). The legal aspects of segmentation in the Oranje Loper project were managed by ensuring strict compliance with Dutch procurement laws, selecting appropriate contract models for different segments, and establishing clear guidelines to maintain consistency across all contracts. This approach facilitated the effective segmentation of the project while adhering to legal standards and ensuring transparent and fair procurement practices (Appendix K.4 Legal aspects of segmentation (perspective client)).

The contractor explains that legal discussions were more focused on the overall scope changes rather than segmentation itself. This indicates a prior legal approval and preparation that took segmentation into account, ensuring compliance with Dutch procurement laws (Appendix M.4 Legal aspects of segmentation (perspective contractor)). Regarding the contractual framework, the contractor noted that the contracts were designed to accommodate the realisation of the project in multiple segments.

The segmented contracts were set up to allow for phased execution, aligning with the project's needs and ensuring all legal requirements were met Appendix M.4 Legal aspects of segmentation (perspective contractor)). No direct segment-specific legal challenges were reported by the contractor Appendix M.4 Legal aspects of segmentation (perspective contractor)).

4.4.5 Challenges and benefits of segmentation in Oranje Loper

The client emphasises that one of the most significant challenges arising from segmentation is the coordination and management of interfaces between different segments. This includes the complexity of the segment and the challenges in optimising the use of resources such as sand and construction space, complicated by the physical separation of segments (Appendix K.5 Challenges and benefits of segmentation (perspective client)). Other challenges include the need for alignment of temporary infrastructure and the risk that decisions made in one segment could unintentionally have negative impacts on other segments (Appendix K.5 Challenges and benefits of segmentation (perspective client)). The physical and logistical separation of project parts necessitates meticulous planning and coordination to ensure smooth progress and harmonious operation across all segments (Appendix K.5 Challenges and benefits of segmentation (perspective client)). Despite these challenges, the client identifies several key benefits of segmentation. Improved manageability of complex project parts allows for specific expertise and attention to be focused on individual segments, leading to higher quality and efficiency in execution. This focused approach has contributed to better traffic flow and the creation of spaces for public transport, which are essential for the project’s overall objectives (Appendix K.5 Challenges and benefits of segmentation (perspective client)). Segmentation has also helped to reduce complexity by assigning specific tasks to each segment according to their expertise, facilitating more effective project management. By breaking the project into smaller, more manageable parts, it becomes easier to allocate resources, monitor progress, and address issues as they arise, thus enhancing the ability to meet contractual obligations and maintain high standards across the entire project (Appendix K.5 Challenges and benefits of segmentation (perspective client)).

The contractor highlights that the most significant challenge arising from segmentation is the increase in the number of contracts, which requires substantial effort to keep everything coordinated. This aspect cannot be easily delegated to a single party (Appendix L.5 Challenges and benefits of segmentation (perspective contractor)). In an urban environment like Amsterdam, changes to the original plan necessitate continuous coordination among multiple parties, interests, and administrative conditions. This makes the process complex, as agreements with one party can have implications for other stakeholders. Practically, organising this coordination proves to be a major challenge (Appendix L.5 Challenges and benefits of segmentation (perspective contractor)). Despite these challenges, segmentation offers significant benefits, notably the ability to prioritise work, making projects more manageable and comprehensible. By dividing the project into clear packages, it is possible to contract and begin execution on completed parts. This means that not all information and details need to be fully developed to start work on segments of the project, enhancing the process's flexibility and efficiency. Segmenting the project thus allows for a more agile approach to execution, enabling faster commencement of work and better resource allocation (Appendix L.5 Challenges and benefits of segmentation (perspective contractor)).

Another contractor emphasises that the most significant challenges of segmentation were related to the coordination and communication between the different segments, especially when different teams were working on various parts of the project simultaneously. This required an exceptional level of project management skills to ensure that all segments were synchronised and that there were no discrepancies in project execution (Appendix M.5 Challenges and benefits of segmentation (perspective contractor)). Another challenge was managing contracts that were issued early and later had to be adjusted due to changes in the project scope, which caused not only logistical but also

financial complications (Appendix M.5 Challenges and benefits of segmentation (perspective contractor)). Despite these challenges, the contractor highlights that segmentation provided the opportunity to work on different parts of the project in parallel, reducing the overall project duration. This improved efficiency and allowed the project team to be more flexible and responsive in managing the various phases of the project (Appendix M.5 Challenges and benefits of segmentation (perspective contractor)). Segmenting the project enabled better handling of complex urban infrastructure tasks and facilitated more efficient use of resources, ultimately contributing to the successful execution of the Oranje Loper (Appendix M.5 Challenges and benefits of segmentation (perspective contractor)).

4.4.6 The results of segmentation in Oranje Loper

The horizontal and vertical segmentation strategy employed in the Oranje Loper project yielded several notable results, contributing significantly to the project's overall progress and efficiency. Segmentation facilitated a more structured and manageable approach to the extensive Oranje Loper project. By dividing the project into distinct segments, each handled by specialised teams, the complexity of overseeing the entire project as a single entity was significantly reduced. This segmentation allowed for more focused management of individual components such as bridges, streets, and utilities, enabling the project team to address specific challenges more effectively. Regular coordination meetings and strategic communications were integral to maintaining coherence across the segments, ensuring that all parts of the project progressed in harmony and met the project's overarching goals.

The segmentation approach introduced greater flexibility and efficiency in project execution. By allowing certain segments to commence while others were still in the planning or preliminary stages, the project avoided delays that might have occurred if waiting for complete designs of all components. This phased initiation was particularly beneficial for segments with longer lead times, enabling earlier commencement of critical infrastructure works such as utility relocations. Additionally, the segmented approach facilitated quicker tendering processes and faster mobilisation of resources, contributing to an overall acceleration of the project timeline.

A significant advantage of segmentation was the strategic allocation of risks and expertise. By assigning specific segments to teams best equipped to handle their unique challenges, the project minimised potential issues and leveraged specialised knowledge to enhance execution quality. This approach also enabled better risk management, with clear delineation of responsibilities and more effective mitigation strategies tailored to each segment's specific requirements. The segmentation allowed the project to remain adaptable to changes and unforeseen circumstances, such as those introduced by the COVID-19 pandemic and geopolitical events.

Despite the benefits, segmentation introduced challenges related to the coordination and integration of different segments. Ensuring seamless transitions between segments required meticulous planning and robust project management skills. The physical and logistical separation of segments sometimes complicated the alignment of temporary infrastructure and resource utilisation. Additionally, the necessity for multiple contracts and management teams increased administrative overheads and required diligent oversight to maintain consistency and quality across the project. These challenges underscored the importance of having a centralised coordination mechanism to oversee the integration of segmented tasks and manage interfaces between different contracts and teams effectively.

Economically, segmentation influenced the project's financial dynamics, particularly in terms of cost control and budget management. While the approach allowed for better allocation of resources and more efficient use of expertise, it also introduced higher transaction costs associated with multiple tenders and contracts. The need for distinct management teams and progress reports for each segment

led to increased overheads. However, the strategic segmentation decisions helped to keep the project within budgetary constraints, despite external economic pressures. Adjustments in the project scope, driven by segmentation, ensured financial viability and minimised cost overruns.

Ultimately, the horizontal and vertical segmentation strategy contributed positively to the successful execution of the Oranje Loper project. By enabling a more organised and phased approach, the project team managed to overcome numerous challenges associated with large-scale urban redevelopment. The ability to work on different parts of the project in parallel not only reduced the overall project duration but also improved the project's adaptability and responsiveness. This segmented approach proved essential in navigating the complexities of the urban infrastructure landscape, leading to the effective realisation of the project's objectives and the renewal of a significant urban corridor in Amsterdam. Table 14 provides a comprehensive analysis of the impact of segmentation on the complexity elements within the TOE Framework for the Oranje Loper project. This table is based on interviews with both the client and the contractors. It highlights how segmentation decreased technical complexities such as strict quality requirements, project duration, number of locations, high number of tasks, high variety of tasks, and technical risks. In contrast, segmentation introduced and increased organisational complexities, such as the number of contracts, interfaces between different disciplines, and organisational risks. The table also notes that certain elements, such as political influence and dependencies on external stakeholders, were not impacted by segmentation, remaining constant throughout the project's execution. This detailed evaluation underscores the multifaceted effects of segmentation on project complexity management.

Table 14. TOE Framework analysis of segmentation impact on the project complexities in Oranje Loper

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and impact of segmentation on complexity elements were sourced from Appendix K.4 Legal aspects of segmentation (perspective client), Appendix L. Case study: elaboration of the interview with a contractor of Oranje Loper (NL), and Appendix M. Case study: elaboration of the interview with a contractor of Oranje Loper (NL).

T Technical complexity	O Organisational complexity	E External complexity
Uncertainties in scope The Oranje Loper project, which involves substantial urban renovations, encountered significant scope uncertainties as the scope continually adapted to remain within budgetary constraints. This contributes very much to the project's complexity. Segmentation allows for more focused and flexible management of scope uncertainties, thereby decreasing the contribution to the project's complexity.	**Number of contracts** Segmentation resulted in an increase in the number of contracts, as the project was divided into smaller, more manageable segments, each requiring its own contractual arrangement. This leads to an increase in the contribution to the project's complexity.	**Political influence** The political context and changes, such as elections and council members, significantly influenced project execution and scope adjustments. These influences remained external and were not directly affected by segmentation.
Strict quality requirements High-quality standards are essential due to the project's prime business location and its significant impact on the urban environment, contributing very much to the project's complexity. Segmentation allows for more focused attention on quality for each segment, thereby decreasing the contribution to the project's complexity.	**Type of contract** Segmentation resulted in a variety of contract types being used in the project. These ranged from traditional contracts to more integrated contracts, each necessitating a distinct management approach. This led to an increase in the contribution to the project's complexity	**Dependencies on external stakeholders** The project relies on coordination with various governmental bodies, which underscores the importance of external approvals and stakeholder management, contributing very much to the project's complexity. These dependencies were inherent to the project and not influenced by segmentation.
Project duration The extended project timeline is influenced by the comprehensive nature of the work and the intricate integration required with existing infrastructure, contributing substantially to the project's complexity. Segmentation allows for phased initiation, which helps avoid delays by starting work on some segments while others are still being planned, thereby decreasing the contribution to the project's complexity.	**Interfaces between different disciplines** Effective coordination between different design teams and multiple stakeholders is essential to ensure seamless integration across segments. Segmentation introduces new interfaces that require management, thereby increasing the contribution to the project's complexity.	**Interference with existing site** The Oranje Loper project, involving significant urban renovations, faced challenges in managing interference with existing streets and infrastructure, contributes very much to the project's complexity. Segmentation contributes to complexity by allowing for targeted and phased management of interference, thereby decreasing the contribution to the project's complexity.

Decrease of complexity due to segmentation
Increase of complexity due to segmentation
No impact by segmentation

Number of locations Multiple critical points within Amsterdam are involved, each presenting unique environmental and logistical challenges, contributing very much to the project's complexity. By dividing the project into multiple segments, each with its own environmental and logistical challenges, segmentation allows for more manageable and focused execution, thereby decreasing the contribution to the project's complexity. **High number of tasks** A wide range of tasks, including the construction of bridges and streets, adds to the project's complexity, contributing substantially to the project's complexity. Segmentation makes these tasks more manageable by allowing focused management of each component, thereby decreasing the contribution to the project's complexity. **High variety of tasks** Tasks involve diverse technical requirements, from renovating existing infrastructure to integrating various urban systems, contributing substantially to the project's complexity. Segmentation allows specialised teams to handle specific tasks, reducing the complexity and thereby decreasing the contribution to the project's complexity. **Technical risks** Significant challenges arise from constructing in densely populated areas and dealing with limited space, contributing very much to the project's complexity. Segmentation allows for the containment of risks within segments, enabling targeted risk management strategies and quicker responses to technical issues, thereby decreasing the contribution to the project's complexity.	**Organisational risks** Limited experience with design teams and collaborative project delivery methods introduces additional complexity, contributing very much to the project's complexity. Segmentation did not alter this complexity, however, it increased the need for collaboration across segments, making coordination even more crucial, thereby increasing the contribution to the project's complexity.	

In conclusion, the results of segmentation in the Oranje Loper project highlight the critical role of strategic division in managing complex urban infrastructure projects. The approach facilitated enhanced project management, improved efficiency, effective risk management, and ultimately contributed to the successful and timely completion of the project. While challenges in coordination and cost management were evident, the benefits of segmentation in achieving the project's goals and maintaining high execution standards were substantial.

4.5 Stadsdijken Zwolle

The Stadsdijken Zwolle project is a large part of the Flood Protection Programme (Hoogwaterbeschermingsprogramma, HBP) and represents the largest dike reinforcement since the Delta Works. Under the name Dijkteam Zwolle, the Waterschap Drents Overijsselse Delta collaborates with the Dijkzone Alliantie Zwolle (DAZ) (Appendix N.1 Introduction (perspective client)). This consortium consists of Dura Vermeer and Ploegam, supported by partners Tauw, Fugro, and H+N+S Landscape Architects. The project employs a two-phase contract model. The primary objective of this extensive project is to ensure the safety of residents and prevent future flooding disasters. This is achieved by reinforcing the dikes based on modern climate scenarios and new safety standards, which stipulate that everyone has the right to face a maximum of one flood per hundred thousand years. The project involves the reinforcement of dikes along a 7.5-kilometre stretch, which presents unique technical and environmental challenges (Appendix N.1 Introduction (perspective client)). These city dikes run along the Zwolle-IJssel Canal and the southern bank of the Zwarte Water to the Zwolle floodgate. From the floodgate, they continue along the northern and eastern banks of the Zwarte

Water to the mouth of the Vecht. In total, nearly nine kilometres of dikes are involved (Waterschap Drents Overijsselse Delta, n.d.).

One of the core tasks of the water authority is to ensure dry feet during high water. This means strengthening the dikes when necessary to protect Zwolle from high water from the IJssel and the Zwarte Water. Currently, 7.5 kilometres of the (sometimes) invisible city dikes in Zwolle are insufficiently strong and no longer meet the new water safety standards (Appendix N.1 Introduction (perspective client)). Therefore, a dike reinforcement is needed. This is a challenging puzzle as each section of the dike requires customised solutions to address the water safety issues. Over the past few years, the client has been working with the community and other companies to solve this puzzle. The client now has a final design, and the dike reinforcement work has commenced. The first few hundred metres of the total 7.5 km of dike are already high-water safe (Appendix N.1 Introduction (perspective client)).

Within this project, the interviewed contractor, part of the consortium, is responsible for the full coordination and execution of both the preparatory works and the final full realisation agreement. These preliminary agreements, which function as distinct segments, include critical preparatory activities such as ordering sheet piles, setting up construction sites, conducting archaeological and ecological surveys, and relocating cables and pipelines (Appendix O.1 Introduction (perspective contractor)). Moreover, in chapter
4.5.2 Segmentation in Stadsdijken Zwolle. These activities are carefully planned and realised to ensure that, once all necessary permits and subsidies are obtained, the project can proceed without delays.

This subchapter delves into the Stadsdijken Zwolle project, employing desk research and interviews with both the client (Appendix N. Case study: elaboration of the interview with the client of Stadsdijken Zwolle (NL)) and a contractor (Appendix O. Case study: elaboration of the interview with a contractor of Stadsdijken Zwolle (NL)) to focus specifically on the project's strategic segmentation and the collaborative delivery methods utilised. The goal of this analysis is to gain a comprehensive understanding of how segmentation was strategically approached and implemented within this significant dike reinforcement project. Through qualitative analysis, the research explores the processes of segmentation used to manage the complex aspects of the project, identifies key characteristics and legal considerations of segmentation, and examines the challenges and benefits of this approach.

4.5.1 Complexities of Stadsdijken Zwolle

The complexities of the Stadsdijken Zwolle project, as explored through the perspectives of both the client (Appendix N.1 Introduction (perspective client)) and a contractor (Appendix O.1 Introduction (perspective contractor)), highlight the multifaceted challenges involved in managing a large-scale dike reinforcement project within an urban setting. This section delves into the detailed complexities as experienced and communicated by the client and the contractor. The interplay between these different perspectives provides a comprehensive understanding of the project’s unique complexity elements.

From the client's perspective, the complexity of the Stadsdijken Zwolle project is multifaceted. The project entails reinforcing 7.5 kilometres of dikes, presenting unique challenges. These challenges include handling contaminated soil, relocating utilities, and installing new structures such as floodgates and pumping stations (Appendix N.1 Introduction (perspective client)). The project is also bound by stringent environmental regulations, including adherence to new nitrogen models and modifications in construction exemptions, prompting frequent revisions to plans and permits. Intensive coordination is required among diverse stakeholders, including market parties, utility companies, and government agencies, to ensure minimal disruption to crucial infrastructure like the Scania factory (Appendix N.1

Introduction (perspective client)). The project employs a two-phase contract model and incorporates preliminary agreements, which function as distinct segments, within the main contract. This structure demands a high degree of transparency and trust among all parties involved. Risk management and financial predictability are key focuses, aiming to keep cost overruns under 2% (Appendix N.1 Introduction (perspective client)). All these factors underscore the project's complexity and highlight the necessity for careful planning, innovative solutions, and robust communication between all stakeholders.

The complexity within the segment overseen by the interviewed contractor stems from several factors. Obtaining the necessary permits and complying with regulations, such as nitrogen guidelines, presents a major challenge and requires meticulous planning and coordination with various government agencies (Appendix O.1 Introduction (perspective contractor)). The contractor must perform tasks before the full realisation agreement is signed, necessitating the drafting of preliminary assignments and the arrangement of responsibilities and budgets for these tasks. Moreover, the contractor is responsible for the entire realisation agreement, which requires significant risk management and coordination to ensure that all segments align seamlessly and that the project is completed within the set time and budget constraints (Appendix O.1 Introduction (perspective contractor)). The project requires close collaboration among various parties, including the water authority, contractors, and utility companies. Coordinating this collaboration and ensuring a unified approach is crucial. Advance planning for activities such as ordering sheet piles and implementing ecological measures necessitates good risk management. This planning must account for the possibility that the full realisation agreement might not proceed, and arrangements must be made for handling materials and costs in such an event (Appendix O.1 Introduction (perspective contractor)). Additionally, the project involves conducting ecological and archaeological surveys, which must be performed within certain seasonal time limits, adding further pressure to the schedule. The contractor is responsible for the integration and coordination of all these segments, necessitating a high degree of care and precision to ensure that all project components align seamlessly and that any risks are effectively managed (Appendix O.1 Introduction (perspective contractor)).

Table 15 provides a comprehensive overview of the complexities of Stadsdijken Zwolle as represented by the TOE framework, as detailed in the interviews with the client (Appendix N.1 Introduction (perspective client)) and the contractor (Appendix O.1 Introduction (perspective contractor)).

Table 15. TOE Framework analysis of the project complexities in Stadsdijken Zwolle

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and complexity elements were sourced from Appendix N.1 Introduction (perspective client) and Appendix O.1 Introduction (perspective contractor).

T Technical complexity	O Organisational complexity	E External complexity
Strict quality requirements The project must comply with stringent environmental regulations, introducing complex quality control processes, contributing very much to the project's complexity.	**Interfaces between different disciplines** Coordination among various stakeholders, including market parties, utility companies, government agencies, and local residents, contributing very much to the project's complexity.	**Dependencies on external stakeholders** There is high dependency on government agencies for permits and regulations, utility companies for infrastructure modifications, and coordination with the Scania factory to minimise disruptions, contributing very much to the project's complexity.
Project duration The extended duration is due to the complexity and size of the project, contributing very much to the project's complexity.	**Type of contract** The type of contract employed in the Stadsdijken Zwolle project is a two-phase contract, which depends on transparent collaboration, contributing substantially to the project's complexity.	**Interference with existing site** Minimising disruptions to essential infrastructure, such as the Scania factory, and local residents, contributing substantially to the project's complexity.
Number of locations The project covers 7.5 kilometres of dikes, involving multiple locations along the Zwolle-	**Organisational risks** There are risks related to coordination, timely completion, and financial planning and control to	**External risks** Risks are associated with regulatory changes, public opposition, or delays in obtaining

IJssel Canal and Zwarte Water, contributing very much to the project's complexity. **High number of tasks** Tasks include dealing with contaminated soil, relocating utilities, and integrating new infrastructure, contributing very much to the project's complexity. **High variety of tasks** The project involves contaminated soil handling, utilities relocation, installation of floodgates and pumping stations, and conducting ecological and archaeological surveys, contributing very much to the project's complexity. **Technical risks** A high degree of technical risk management is needed due to the complexity of tasks and strict environmental regulations, contributing very much to the project's complexity.	manage budget allocation, cost control, and ensure financial predictability, contributing substantially to the project's complexity.	necessary approvals, contributing substantially to the project's complexity.

4.5.2 Segmentation in Stadsdijken Zwolle

Segmentation within the Stadsdijken Zwolle project is strategically structured to optimise the project's realisation phase.

The project scope of Stadsdijken Zwolle consists of seven segments, each procured separately by the client, resulting in seven distinct agreements labelled as Agreement A through Agreement G, which make up the full scope and realisation of the project. This research identifies and classifies the client's segmentation strategy for the Stadsdijken Zwolle project as vertical segmentation based on functionality, as each segment is realised in the same geographic location.

The scope of the project is segmented into six distinct preliminary agreements, labelled as Agreements A through E and G, with the final full realisation of the project defined as Agreement F (Appendix N.2 Understanding segmentation (perspective client); Appendix O.2 Understanding segmentation (perspective contractor)). Each of these agreements represents a crucial segment of the overall project, addressing specific early-stage tasks such as relocating cables and pipelines, conducting soil remediation, and other preparatory activities. The integration of these preliminary agreements into Agreement F, which incorporates the full realisation of the Stadsdijken Zwolle as defined by the client, is carefully planned to ensure that they integrate seamlessly. This segmentation ensures a controlled and systematic approach to the project, facilitating a smooth and effective transition to the final realisation phase (Appendix N.2 Understanding segmentation (perspective client); Appendix O.2 Understanding segmentation (perspective contractor)). These agreements will be procured to one consortium of contractors (Appendix N.2 Understanding segmentation (perspective client)). The segmentation within the project scope is summarised in Table 13, which details the segments, the type of segmentation, and the agreements. Lastly, Segment G, the relocation of cables and pipelines was procured under an agreement with a co-contractor, the details of this agreement are not determined in the research.

Table 16. Overview of segmentation in the scope and agreements for Stadsdijken Zwolle

Note: Overview of segmentation in the scope and agreements for Stadsdijken Zwolle was sourced from Appendix N.2 Understanding segmentation (perspective client) and Appendix O.2 Understanding segmentation (perspective contractor).

Scope	Description	Type of segmentation	Segment	Segment Intersection(s)	Agreement	Type of Agreement	(Consortium of) contractor(s)
A	Preliminary conditioning	Vertical	A	F	A	Preliminary agreement	A
B	Preliminary sheet piling	Vertical	B	F	B	Preliminary agreement	A
C	Preliminary site layout	Vertical	C	F	C	Preliminary agreement	A
D	Preliminary site office	Vertical	D	C & F	D	Preliminary agreement	A
E	Preliminary additional activities	Vertical	E	F	E	Preliminary agreement	A
F	Realisation	Vertical	F	A, B, C, D, & E	F	Two-phase	A
G	Relocation cables and pipelines	Vertical	G	A & F	G	ND	B

The project involves close collaboration among various actors with specific functional and contractual relationships. The Water Authority, as the client, is responsible for overall leadership and project approval. The Dijkzone Alliantie Zwolle, consisting of Dura Vermeer and Ploegam, serves as the main contractor, coordinating the realisation of the work. Partners like Tauw, Fugro, and H+N+S Landscape Architects provide specialist knowledge in design, environmental issues, and risk management (Appendix N.2 Understanding segmentation (perspective client)). Additionally, utility companies collaborate in a utility alliance with the Water Authority and the DAZ for tasks such as the relocation of cables and pipelines. Contractually, there is a primary agreement between the Water Authority and the DAZ, with subcontracts for specific tasks such as remediation and relocations (Appendix N.2 Understanding segmentation (perspective client)).

The strategic goals and criteria for implementing segmentation were focused on risk management, financial predictability, and streamlined execution. By dividing the project into manageable parts, specific challenges, such as utility relocations, soil remediation, and ecological conditioning, could be addressed in advance (Appendix N.2 Understanding segmentation (perspective client)). This ensured controlled and disruption-free realisation of the project. Additionally, the aim was to limit cost overruns to a maximum of 2%, requiring a high degree of financial predictability. The ultimate goal was to realise the project as efficiently and effectively as possible, with minimal risks and maximum control over execution (Appendix N.2 Understanding segmentation (perspective client)).

The contractor views segmentation as an effective method for managing the complexity of large projects. By splitting the project into different segments, specific tasks and activities can be carried out in advance, helping to minimise potential risks and delays in later stages (Appendix O.2 Understanding segmentation (perspective contractor)). Segmentation significantly impacts the contractor's work, requiring detailed planning and coordination to ensure each segment is completed on time and efficiently. This also necessitates close collaboration with various parties to ensure all project components align seamlessly. By focusing on specific tasks and completing them before the full

execution begins, the contractor contributes to a streamlined and effective project implementation (Appendix O.2 Understanding segmentation (perspective contractor)).

The contractor's segment is integrated into all phases of the project lifecycle, from tendering to design and realisation. During the tendering phase, the segment is defined, and specifications and expectations are established. This includes identifying the preliminary assignments needed for smooth project realisation. In the design phase, the contractor works with the client and other stakeholders to develop detailed plans and specifications. This involves refining the design to the level of execution designs (UO) and ensuring all technical details and requirements are documented. Examples include mapping out sheet pile locations and conducting conditioning tasks like utility relocations and ecological measures (Appendix N.2 Understanding segmentation (perspective client); Appendix O.2 Understanding segmentation (perspective contractor)). During the realisation phase, the preparatory tasks outlined in the preliminary assignments, carried out in the first phase of the two-phase approach, are seamlessly integrated into the overall project execution. These tasks include purchasing materials, setting up construction sites, and performing preliminary construction activities. Once the full execution agreement is signed, the contractor ensures that all segments and preparatory tasks are completed correctly and on time, allowing the overall project to proceed without delays (Appendix N.2 Understanding segmentation (perspective client); Appendix O.2 Understanding segmentation (perspective contractor)).

The specific goals and objectives for the contractor's segment include timely and efficient execution of all preparatory tasks and minimising risks and delays during the realisation phase. This involves successfully completing preliminary assignments like conditioning, ordering sheet piles, and setting up construction sites. By completing these tasks before the full realisation agreement, the contractor ensures that the project's realisation proceeds smoothly and without unforeseen obstacles (Appendix O.2 Understanding segmentation (perspective contractor)). These objectives align closely with the strategic goals of the overall project, namely the timely and budget-compliant completion of the dike reinforcement at Stadsdijken Zwolle. The project aims to achieve a safe and sustainable flood defence that meets the latest safety standards. By planning and executing the segments effectively, the contractor contributes to achieving these strategic goals and ensures the project's success (Appendix O.2 Understanding segmentation (perspective contractor)).

4.5.3 Segmented project delivery method in Stadsdijken Zwolle

In the Stadsdijken Zwolle project, the client engaged co-contractors to procure the project scope. Together with the client, these co-contractors detailed the entire scope during the first phase. The consortium crafted multiple preliminary agreements (Agreements A to E, and G) that were strategically realised before progressing to the full realisation of Agreement F (Appendix N.2 Understanding segmentation (perspective client); Appendix O.2 Understanding segmentation (perspective contractor)). This approach exemplifies a two-phase project delivery method, where the design and planning in the first phase are critical for setting the foundation for the subsequent realisation phase (Appendix N.2 Understanding segmentation (perspective client)). Each preliminary agreement tackled essential early-stage tasks, ensuring they were adequately addressed, which allowed for a seamless transition and integration into the definitive Agreement F. This method ensures continuity and alignment across the project's lifecycle, reinforcing the integrity of the overall project delivery. Figure 25 provides an overview of the project delivery method deployed for Stadsdijken Zwolle.
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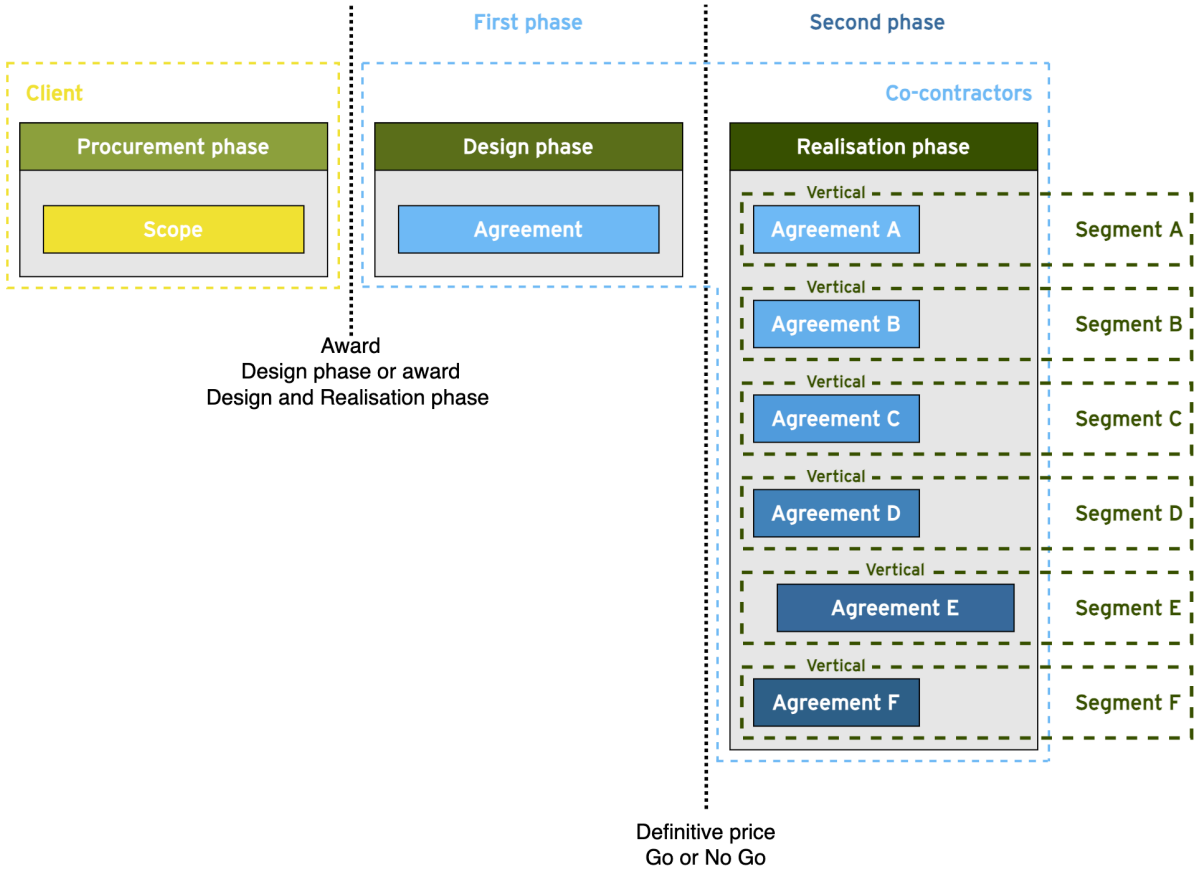

Figure 25. Schematic representation of the segmented PDM for Stadsdijken Zwolle

Note: Schematic representation of the segmented PDM for Stadsdijken Zwolle was sourced from Appendix N.2 Understanding segmentation (perspective client) and Appendix O.2 Understanding segmentation (perspective contractor).

4.5.3 Key characteristics of segmentation in Stadsdijken Zwolle

From the client's perspective, the coordination of efforts between various segments of the Stadsdijken Zwolle project relied heavily on an integrated area information model, which served as the 'single source of truth' for storing and sharing project information. This approach ensured that all parties worked with consistent, up-to-date information, thereby minimising misunderstandings and errors (Appendix N.3 Key characteristics of segmentation (perspective client)). Regular meetings with involved parties, such as utility companies and the consortium, were essential for discussing progress and addressing issues early on, particularly for critical tasks like relocating cables and remediating contaminated soil (Appendix N.3 Key characteristics of segmentation (perspective client)). After establishing the segments, they were managed using strict project management methods and continuous monitoring. The integrated area information model enabled close tracking of each segment's progress, while preliminary assignments like utility relocations and remediation were seamlessly integrated into the main contract, thus preventing delays and avoiding the need for re-coordination (Appendix N.3 Key characteristics of segmentation (perspective client)). Regular audits and assessments helped monitor the project's maturity and adherence to schedules and budgets, ensuring that all segments progressed coherently and remained aligned with the overall project objectives, such as limiting cost overruns to a maximum of 2% (Appendix N.3 Key characteristics of segmentation (perspective client)).

The client emphasised that the economic interests significantly influenced the dynamics and decision-making processes within the project. For instance, ensuring uninterrupted production at the Scania

factory required scheduling work on their site during their summer vacation to avoid production loss, leading the client to adjust the schedule accordingly (Appendix N.3 Key characteristics of segmentation (perspective client)). Strategic financial decisions, such as purchasing steel and relocating pipelines, were made to mitigate future costs and risks, impacting the overall project strategy. The segmentation of the project had substantial financial implications. By advancing specific tasks like the relocation of cables and pipelines and remediation, the client could avoid potential cost overruns and delays later on, resulting in better cost control and more predictable financial management. The governing body granted credit to execute these preliminary assignments, increasing financial flexibility and enabling strategic investments, which made budget allocation more efficient and reduced the risk of unexpected costs (Appendix N.3 Key characteristics of segmentation (perspective client)). In managing risks, the project utilised clear contractual agreements and defined responsibilities. The consortium of Dura Vermeer and advisory firms was fully responsible for design and realisation, including associated risks. For specific segments, like the pipeline relocation at the VARO tank storage, separate agreements held VARO accountable for execution with their own contractors. Risk management strategies included using a detailed area information model, regular risk assessments, and an advisory board to provide significant guidance in case of disputes, ensuring that risks were identified and managed early on, with a clear division of responsibilities among the various parties (Appendix N.3 Key characteristics of segmentation (perspective client)).

The contractor expresses that coordination within the segment and with adjacent segments was primarily achieved through detailed planning and the integrated area information model, which served as a 'single source of truth' containing all necessary information in one place. This ensured consistent and up-to-date data for all involved parties. Regular meetings and updates were organised to discuss progress and address issues early (Appendix O.3 Key characteristics of segmentation (perspective contractor)). Additionally, a phased approach in planning ensured that preparatory work, such as cable and pipeline relocations, conditioning, and site setups, was carried out on time without disrupting the rest of the project, allowing various segments to transition smoothly into each other and be effectively integrated into the overall project execution (Appendix O.3 Key characteristics of segmentation (perspective contractor)). The contractor’s segment was managed and integrated into the overall project through clear phasing and close collaboration with the client. In the first phase, a planning agreement (PU) was made that included all preparatory tasks like conditioning, purchasing sheet piles, and setting up construction sites. These preliminary assignments were defined and executed, then incorporated into the full execution agreement (UO), ensuring a seamless transition from the preparatory phase to the execution phase, with all segments and preparatory tasks completed correctly and on time. Establishing an exit clause defined handling if the full execution agreement was not concluded, ensuring flexibility and risk management (Appendix O.3 Key characteristics of segmentation (perspective contractor)).

The contractor notes that economic interests influenced project decision-making and dynamics. Financial security was essential to avoid unexpected costs and budget overruns, particularly when executing high-risk or critical preliminary assignments like ordering sheet piles or carrying out conditioning tasks. By performing these tasks early, economic risks were reduced, and the realisation phase could start without delays. Regular consultations with the governing body helped justify the necessity and benefits of certain investments and expenditures before full project execution (Appendix O.3 Key characteristics of segmentation (perspective contractor)). Segmentation significantly impacted budget allocation and cost control by allowing specific budgets for each task, ensuring they were carried out within set financial frameworks. This prevented cost overruns and provided better control over expenditures. Agreements on payment methods for preliminary tasks, whether on a cost-plus basis or predetermined costs, facilitated detailed financial planning and control, keeping the entire project within budget and minimising unexpected costs (Appendix O.3 Key characteristics of segmentation (perspective contractor)). Risk management within the segment was achieved through detailed planning, early identification of high-risk tasks, and executing preliminary assignments to

minimise these risks. Conditioning tasks, such as relocating cables and pipelines and conducting archaeological and ecological surveys, were carried out in advance to prevent delays later. Detailed agreements on responsibilities and budgets for these preliminary tasks, including exit clauses, ensured risks were well managed, providing flexibility to address unforeseen problems without jeopardising the project's progress (Appendix O.3 Key characteristics of segmentation (perspective contractor)).

4.5.4 Legal aspects of segmentation in Stadsdijken Zwolle

The contract models within the Stadsdijken Zwolle project were legally structured to facilitate segmentation in the form of subcontracts. This was achieved through a modular contract model where preliminary assignments, such as cable and pipeline relocations and remediation, received separate contracts that were later integrated into the main contract (Appendix N.4 Legal aspects of segmentation (perspective client)). The contractual framework for segments is legally structured through a two-phase approach. The contractor describes a planning agreement (PU) for the first phase, which outlines preparatory tasks and design responsibilities. Then, specific preliminary assignments are defined for tasks that need to be completed before the full execution agreement (UO) is signed. Each preliminary assignment is separately contracted with a basic agreement and a specific task specification (Appendix O.4 Legal aspects of segmentation (perspective contractor)). This structure ensures that each segment has clear responsibilities and budgets and that all preparatory tasks are ultimately integrated into the full execution agreement. This approach helps manage legal risks and protects all parties through clear and detailed contracts.

One major legal challenge of segmenting into subcontracts was maintaining the consistency and coherence of the project while complying with all legal requirements. When segmenting the Stadsdijken Zwolle project into various subcontracts, the client had to ensure that each segment was legally independent yet an integral part of the main project. This was addressed by drafting legal contracts so that preliminary assignments like remediation and cable and pipeline relocations were automatically absorbed into the main contract upon realisation (Appendix N.4 Legal aspects of segmentation (perspective client)). Furthermore, clear agreements were needed regarding the responsibilities and liabilities of each party to prevent disputes. This was achieved by working closely with legal advisors and regularly reviewing and adjusting contractual clauses to align with the project's progress and requirements (Appendix N.4 Legal aspects of segmentation (perspective client)).

The contractor discusses several legal challenges that arose due to segmentation. One significant challenge was ensuring a seamless transition between different segments and preventing conflicts of responsibility. Some segments had to be executed early, such as ordering sheet piles or carrying out conditioning tasks, which posed legal risks as there was no full execution agreement yet. To address these challenges, detailed contracts and task specifications were drafted for each preliminary assignment (Appendix O.4 Legal aspects of segmentation (perspective contractor)). Additionally, exit clauses were included to specify what would happen if the full execution agreement did not materialise. These strategies ensured that legal responsibilities were clear and that all parties were protected against unforeseen issues (Appendix O.4 Legal aspects of segmentation (perspective contractor)).

4.5.5 Challenges and benefits of segmentation in Stadsdijken Zwolle

The segmentation of the Stadsdijken Zwolle project brought significant challenges, primarily related to ensuring the integration and coordination of various subcontracts. As these subcontracts were executed independently, the client had to ensure that the results of each segment seamlessly connected with others (Appendix N.5 Challenges and benefits of segmentation (perspective client); Appendix O.5 Challenges and benefits of segmentation (perspective contractor)). Another challenge

was the legal and contractual documentation of these subcontracts. Since the project was divided into smaller contracts, a clear legal framework had to be created for each segment to ensure they could eventually be incorporated into the main contract. This necessitated precise legal clauses and detailed agreements to safeguard liability and responsibilities (Appendix N.5 Challenges and benefits of segmentation (perspective client); Appendix O.5 Challenges and benefits of segmentation (perspective contractor)).

Despite these challenges, segmentation also yielded several benefits for the Stadsdijken Zwolle project. One major advantage was the increased flexibility and manageability it provided. By dividing the project into smaller, more manageable subcontracts, the client could better respond to unforeseen events and risks, resulting in greater control over project progress and the ability to make quick adjustments as needed (Appendix N.5 Challenges and benefits of segmentation (perspective client)). Additionally, segmentation led to improved focus and specialisation. Each segment could be assigned to specialised contractors and teams with specific expertise in that area of work, enhancing the quality and efficiency of the tasks (Appendix N.5 Challenges and benefits of segmentation (perspective client)). Another benefit was financial security. By carefully planning and managing the costs and risks of different segments, the client could minimise budget overruns and ensure financial stability, aiming to limit cost overruns to a maximum of 2% of the average expected value (Appendix N.5 Challenges and benefits of segmentation (perspective client)).

The contractor faced several challenges due to the segmentation of the project. A significant challenge was ensuring a seamless transition between different segments and preventing conflicts of responsibility. Clear agreements had to be made regarding responsibilities and coordination between the segments to avoid redundant work or omissions (Appendix O.5 Challenges and benefits of segmentation (perspective contractor)). Additionally, there was the risk of starting certain tasks earlier than planned due to pending permits and subsidies. This required careful planning and flexibility to ensure the project remained on schedule (Appendix O.5 Challenges and benefits of segmentation (perspective contractor)).

Despite these challenges, segmentation provided various benefits to the project. One of the main advantages was the ability to advance certain tasks, thereby shortening the overall project duration. For example, by ordering sheet piles and other materials early in the project, delivery and production times could be shortened, leading to a quicker project realisation (Appendix O.5 Challenges and benefits of segmentation (perspective contractor)). Another benefit was the increased stability and predictability of the project. By conducting extensive preliminary conditioning tasks, such as investigating cables and pipelines, remediation, and archaeology, the project team could identify and address potential risks and obstacles early on (Appendix O.5 Challenges and benefits of segmentation (perspective contractor)). This resulted in a more stable schedule and reduced the likelihood of unexpected delays during the realisation phase. Segmentation also allowed for greater flexibility in adapting to changes and unforeseen circumstances. By dividing the project into smaller, manageable segments, the team could quickly respond to new developments, such as the Ukraine crisis that disrupted global supply chains. Early ordering of materials helped the project team minimise the impact of these disruptions and keep the schedule on track (Appendix O.5 Challenges and benefits of segmentation (perspective contractor)).

4.5.6 The results of segmentation in Stadsdijken Zwolle

The segmentation within the Stadsdijken Zwolle project was precisely structured to optimise the realisation phase. By dividing the project into five distinct preliminary agreements, each addressing specific early-stage tasks, the project could advance critical preparatory activities such as relocating cables and pipelines, conducting soil remediation, and setting up construction sites. These preliminary

agreements were essential for laying a solid foundation for the final full realisation agreement, ensuring that all preparatory tasks were thoroughly planned and executed in advance. This approach facilitated a smooth and effective transition to the comprehensive completion of the project.

From the client's perspective, the segmentation strategy significantly contributed to managing the project's multifaceted challenges. The integrated area information model served as a 'single source of truth,' ensuring that all parties had access to consistent, up-to-date information. This minimised misunderstandings and errors, enabling efficient coordination among various stakeholders, including utility companies, market parties, and government agencies. Regular meetings and continuous monitoring ensured that critical tasks such as utility relocations and soil remediation were seamlessly integrated into the main contract, preventing delays and re-coordination efforts. Regular audits and assessments helped monitor the project's maturity, adherence to schedules, and budgets, ensuring that all segments progressed coherently and remained aligned with the overall project objectives, such as limiting cost overruns to a maximum of 2%. The client's emphasis on economic interests also shaped the project dynamics and decision-making processes. Strategic financial decisions, such as purchasing steel and relocating pipelines, were made to mitigate future costs and risks, impacting the overall project strategy. The segmentation approach had substantial financial implications. By advancing specific tasks, the client could avoid potential cost overruns and delays later on, resulting in better cost control and more predictable financial management. This strategic financial planning, facilitated by the segmentation, ensured financial flexibility and enabled efficient budget allocation, reducing the risk of unexpected costs.

From the contractor's perspective, the segmentation approach also presented several challenges and benefits. Ensuring a seamless transition between different segments and preventing conflicts of responsibility required meticulous planning and continuous communication. Clear agreements on responsibilities and coordination were essential to avoid redundant work or omissions. Additionally, starting certain tasks earlier than planned due to pending permits and subsidies required careful planning and flexibility to keep the project on schedule. Despite these challenges, segmentation provided various benefits. It allowed the contractor to advance certain tasks, thereby shortening the overall project duration. For example, early ordering of sheet piles and other materials reduced delivery and production times, leading to a quicker project realisation. Extensive preliminary conditioning tasks, such as investigating cables and pipelines, remediation, and archaeological surveys, helped identify and address potential risks and obstacles early on. This proactive approach resulted in a more stable schedule and reduced the likelihood of unexpected delays during the realisation phase. Segmentation also enabled greater flexibility in adapting to changes and unforeseen circumstances, such as the Ukraine crisis that disrupted global supply chains. Early ordering of materials helped minimise the impact of these disruptions and keep the project on track.

Table 17 provides a structured analysis of the impact of segmentation on the complexities of the Stadsdijken Zwolle project across the three dimensions of the TOE Framework. The table illustrates how segmentation has shaped the project by introducing more manageable components, leading to enhanced control and predictability. Specifically, segmentation has reduced technical and organisational risks by enabling specialised focus and improving coordination, respectively. It also facilitated earlier engagement with external stakeholders, reducing dependency and aiding in smoother project realisation. This detailed breakdown highlights the dynamic interplay of segmentation effects, ensuring that project complexities are not only addressed but also strategically managed for optimal project delivery.

Table 17. TOE Framework analysis of segmentation impact on the project complexities in Stadsdijken Zwolle

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and impact of segmentation on complexity elements were sourced from Appendix N. Case study: elaboration of the interview with the client of Stadsdijken Zwolle (NL) and Appendix O. Case study: elaboration of the interview with a contractor of Stadsdijken Zwolle (NL).

T Technical complexity	O Organisational complexity	E External complexity
Strict quality requirements The project must comply with stringent environmental regulations, introducing complex quality control processes, contributing very much to the project's complexity. Segmentation maintained strict quality requirements consistently across segments, as it did not impact the quality standards upheld throughout the project.	**Interfaces between different disciplines** Coordination among various stakeholders, including market parties, utility companies, government agencies, and local residents, contributes very much to the project's complexity. Segmentation decreased the interfaces between different disciplines due to preliminary agreements, streamlining coordination among various stakeholders.	**Interference with existing site** Minimising disruptions to essential infrastructure, such as the Scania factory, and local residents, contributes substantially to the project's complexity. Segmentation allowed for specialised focus, which helped minimise disruptions by effectively managing interference with existing sites, thereby decreasing the contribution to the project's complexity.
Project duration The extended duration is due to the complexity and size of the project, contributing very much to the project's complexity. Segmentation enabled phased initiation of preliminary tasks, allowing some segments to begin while others were still in planning, effectively minimising delays.	**Number of contracts** The project is divided into multiple segments, each managed through separate contracts, contributing substantially to the project's complexity. Segmentation introduced complexity in contract management due to multiple contracts, with five preliminary agreements and one final agreement, each having different scopes, terms, and conditions, thereby increasing the contribution to the project's complexity.	**Dependencies on external stakeholders** There is high dependency on government agencies for permits and regulations, utility companies for infrastructure modifications, and coordination with the Scania factory to minimise disruptions, contributing very much to the project's complexity. Segmentation reduced dependencies on external stakeholders, as preliminary agreements allowed for earlier coordination with government agencies, utility companies, and efforts to minimise disruptions at the Scania factory.
Number of locations The project covers 7.5 kilometres of dikes, involving multiple locations along the Zwolle-IJssel Canal and Zwarte Water, contributing very much to the project's complexity. Segmentation had no impact on the number of these locations.	**Type of contract** The type of contract employed in the Stadsdijken Zwolle project is a two-phase contract, which depends on transparent collaboration, contributing substantially to the project's complexity. Segmentation slightly increased the complexity by introducing a two-phase structure that integrates preliminary contracts into the main contract, requiring detailed coordination and transparency, thereby increasing the contribution to the project's complexity.	**External risks** Risks are associated with regulatory changes, public opposition, or delays in obtaining necessary approvals, contributing substantially to the project's complexity. Segmentation did not necessarily change the management of external risks but allowed for some permits to be gathered earlier in the process, thereby slightly decreasing the contribution to the project's complexity.
High number of tasks Tasks include dealing with contaminated soil, relocating utilities, and integrating new infrastructure, contributing very much to the project's complexity. Segmentation allowed for preliminary tasks to be managed effectively, which helped decrease the overall perception of a high number of tasks by segmenting them into more manageable components.	**Organisational risks** There are risks related to coordination, timely completion, and financial planning and control to manage budget allocation, cost control, and ensure financial predictability, contributing substantially to the project's complexity. Segmentation decreased organisational risks as the preliminary agreements helped streamline coordination, improve the timeliness of completion, and enhance financial planning and control, thereby aiding in more effective management of budget allocation and cost control.	
High variety of tasks The project involves contaminated soil handling, utilities relocation, installation of floodgates and pumping stations, and conducting ecological and archaeological surveys, contributing very much to the project's complexity. Segmentation decreased the variety of tasks handled simultaneously by realising some parts as preliminary tasks.		
Dependencies between tasks The coordination between various construction phases and elements is crucial due to dependencies where decisions or delays in one area affect others, contributing very much to the project's complexity. Segmentation introduced the ability to isolate and manage dependencies between tasks within manageable portions,		

Decrease of complexity due to segmentation
Increase of complexity due to segmentation
No Impact by segmentation

enhancing control and predictability, thereby decreasing the contribution to the project's complexity. **Technical risks** A high degree of technical risk management is needed due to the complexity of tasks and strict environmental regulations, contributing very much to the project's complexity. Segmentation allows for specialised focus, enabling targeted technical risk management tailored to the complexity of tasks and strict environmental regulations, thereby decreasing the contribution to the project's complexity.		

In conclusion, the segmentation strategy in the Stadsdijken Zwolle project has proven to be a crucial element in managing its complexity and ensuring its success. By dividing the project into manageable segments, both the client and the contractor could address specific challenges in advance, ensuring a streamlined and controlled realisation phase. This approach has facilitated efficient project execution, improved financial predictability, and enhanced the overall stability and flexibility of the project. The successful integration and coordination of the preliminary agreements into the final realisation agreement underscore the effectiveness of the segmentation strategy in large-scale infrastructure projects.

4.6 Conclusion of the case study

This chapter has thoroughly explored the application and outcomes of segmentation in complex infrastructure projects through a detailed case study approach, as outlined in Chapter 2.4. The case studies of the Noord/Zuidlijn, Schiphol-Amsterdam-Almere (SAA), Zuidasdok, Oranje Loper, and Stadsdijken Zwolle projects provide comprehensive insights into the implementation and impact of segmentation strategies in managing large-scale, complex infrastructure projects. Each case illustrates the nuanced effects of segmentation on project complexities, highlighting both the benefits and challenges associated with this approach.

In the Noord/Zuidlijn project, segmentation was employed as a strategic move to manage its inherent complexities. By dividing the project into multiple contracts tailored to specific technical and geographic challenges, the project team could allocate resources and expertise more effectively. This approach facilitated better control over individual segments, enhanced risk management, and allowed for more precise budgeting and cost control. However, the segmentation also presented significant challenges, such as ensuring seamless integration and coordination across interfaces, managing multiple contractors, and addressing increased organisational complexities. The commission's report highlighted the need for stronger central oversight and clearer communication channels to handle the dependencies and interactions between segments effectively.

The SAA project demonstrated how segmentation could enhance efficiency and focus on specific technical and operational challenges. By distributing risks across different project segments and providing clearer financial and operational oversight for each segment, segmentation facilitated better overall project control. The contractor's perspective highlighted the benefits of improved risk management and specialisation within project teams. However, the project also faced challenges related to coordination and communication across segments. Despite these difficulties, segmentation contributed to the project's success by enabling the effective management of specific project components and ensuring timely completion.

In the Zuidasdok project, segmentation was pivotal in managing and overcoming the challenges posed by a large-scale urban development. The client benefited from increased manageability and

adaptability, while the contractor achieved better control over project segments. Segmentation facilitated specialised focus, improved risk management, and maintained high-quality outcomes. However, it also introduced increased transaction costs, the need for extensive coordination, and administrative burdens. The project's progress underscores the importance of strategic planning, robust project management tools, and regular coordination meetings to maintain coherence across segments.

The Oranje Loper project highlighted the structured and manageable approach facilitated by segmentation. By dividing the project into distinct segments handled by specialised teams, the complexity of overseeing the entire project was significantly reduced. This approach allowed for more focused management of individual components, enabling the project team to address specific challenges effectively. Segmentation also introduced greater flexibility and efficiency in project execution, improved risk management, and better control over project costs. However, challenges related to coordination, integration of segments, and increased administrative overheads were evident.

The Stadsdijken Zwolle project demonstrated the benefits of segmentation in optimising the realisation phase. By dividing the project into distinct preliminary agreements, critical preparatory activities were advanced, ensuring a smooth transition to the final full realisation agreement. From the client's perspective, segmentation facilitated efficient coordination among stakeholders, improved financial predictability, and enhanced project stability and flexibility. From the contractor's perspective, segmentation allowed for early task advancement, reduced project duration, and minimised the impact of disruptions. However, strict planning and continuous communication were essential to ensure seamless transitions and prevent conflicts of responsibility.

In conclusion, the strategic use of segmentation in these case studies highlights its critical role in managing complex infrastructure projects. Segmentation enables specialised focus, improved risk management, precise budgeting, and better control over project components. However, it also introduces challenges related to coordination, integration, increased administrative burdens, and the need for robust project management. The lessons learned from these projects underscore the importance of early and thorough planning, clear communication protocols, strong central oversight, and flexible legal frameworks to navigate the complexities of segmented project delivery methods. By adopting these strategies, future projects can leverage the benefits of segmentation while addressing its inherent challenges, ultimately contributing to the successful execution of complex infrastructure projects.

5. Framework and typology

This chapter presents the findings from a detailed analysis of the impact of horizontal and vertical segmentation on various complexity elements. It leverages insights from the case study to illustrate the practical effects of segmentation on these elements within a structured framework, thereby addressing the third set of sub-questions (3A and 3B), "What is the impact of segmentation on various complexity elements in complex infrastructure projects?" and "What are the different segmented project delivery methods, and what are their benefits and drawbacks?". It also introduces the different segmented project delivery methods gathered throughout the case study, showcasing the benefits and drawbacks of each model, and organises them into a typology. This chapter aims to provide a thorough understanding of segmented contracting, detailing the aspects of segmentation and segmented project delivery methods that constitute this strategic approach.

5.1 Segmentation framework

Segmentation is a strategic approach in the management of complex infrastructure projects, aimed at enabling project teams to handle the intricacies of complex projects more effectively. By breaking down projects into smaller, more manageable parts, segmentation helps address specific complexity elements. The case study highlighted various ways segmentation can be deployed and demonstrated its impact on complexity elements. The research distinguishes between two ways to segment a project: horizontal segmentation and vertical segmentation. Horizontal segmentation involves dividing the project into geographic segments. Vertical segmentation, on the other hand, divides the project based on functional requirements. The following framework (Table 18) outlines the impact of both horizontal and vertical segmentation on various complexity elements within complex infrastructure projects.

Table 18. The impact of horizontal and vertical segmentation on complexity elements

Note: TOE Framework by Bosch-Rekveldt et al. (2018) and impact of segmentation on complexity elements were sourced from chapter 4. Case study, Appendix G. Case study: elaboration of the interview with the client of SAA (NL), Appendix H. Case study: elaboration of the interview with a contractor of SAA (NL), Appendix I. Case study: elaboration of the interview with the client of Zuidasdok (NL), Appendix J. Case study: elaboration of the interview with a contractor of Zuidasdok (NL), Appendix K. Case study: elaboration of the interview with the client of Oranje Loper (NL), Appendix L. Case study: elaboration of the interview with a contractor of Oranje Loper (NL), Appendix M. Case study: elaboration of the interview with a contractor of Oranje Loper (NL), Appendix N. Case study: elaboration of the interview with the client of Stadsdijken Zwolle (NL), Appendix O. Case study: elaboration of the interview with a contractor of Stadsdijken Zwolle (NL).

	Complexity element	Type of segmentation	Impact of segmentation on complexity element	Remarks
T Technical complexity	High number of project goals	Horizontal segmentation	Generally reduces complexity by allowing the client and contractors to focus more specifically on the goals within each geographic segment. This focused management approach typically leads to clearer strategies and execution plans, thereby reducing the overall project complexity.	The Noord/Zuidlijn, SAA, and Zuidasdok projects were characterised by many goals addressing a wide range of development objectives, significantly contributing to their complexities. Segmentation allowed for clearer focus on specific goals within each segment and facilitated more focused management of each segment's objectives, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly, vertical segmentation often reduces complexity by allowing each co-contractor to concentrate on achieving specific functional goals. This separation enables each segment to work towards its objectives more effectively, decreasing the project's overall complexity.	
	Uncertainties in scope	Horizontal segmentation	Typically decreases complexity by enabling the client and contractors to manage uncertainties within each geographic segment. This approach allows for adjustments and changes to be confined to specific segments, improving overall project adaptability.	Projects like Noord/Zuidlijn, SAA, Zuidasdok, and Oranje Loper often encountered significant scope uncertainties, contributing to their compelxities. Segmentation helped manage these uncertainties by confining changes to specific segments, thereby decreasing the contribution to the project's complexity.

Decrease of complexity due to segmentation
Increase of complexity due to segmentation
No impact by segmentation

T Technical complexity	Strict quality requirements	Vertical segmentation	Similarly reduces complexity by allowing co-contractors to manage uncertainties within their specific functional areas. This targeted approach ensures that scope changes are handled within each segment, reducing the project's overall complexity.	All the projects, including Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle, demanded high-quality standards, contributing significantly to their complexities. Segmentation allowed for more focused and specialised attention to quality requirements within each segment, ensuring that stringent standards were consistently upheld. This approach decreased the contribution to the project's complexity.
		Horizontal segmentation	Typically decreases complexity by enabling the client and contractors to focus on maintaining high-quality standards within each geographic segment. This allows for detailed and specialised quality control processes, ensuring consistency and reducing the project's overall complexity.	
		Vertical segmentation	Similarly decreases complexity by allowing co-contractors to manage quality within their specific functional areas. This targeted approach ensures high standards are upheld within each segment, reducing the project's complexity.	
	Project duration	Horizontal segmentation	Can often reduce the overall project duration by enabling multiple segments to progress concurrently. The client and contractors benefit from parallel advancements, although this requires effective coordination to ensure alignment across segments. The net effect is typically a decrease in project complexity.	The extended timelines of the Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle projects introduced significant complexities. Segmentation enabled phased initiation and parallel progress in multiple segments, which helped reduce the overall project duration by allowing some segments to begin while others were still being planned or executed. This effectively decreased the contribution to the project's complexity.
		Vertical segmentation	Frequently streamlines timelines within functional segments by allowing co-contractors to advance independently. This approach mitigates delays caused by interdependencies, although it demands careful coordination, potentially adding some complexity.	
	Size in CAPEX	Horizontal segmentation	Often increases complexity due to the need to manage multiple budgets and contracts, leading to higher transaction costs. However, it also enhances financial control by breaking down large investments into smaller, more manageable segments. This allows the client to track expenses more accurately and allocate resources efficiently, reducing risk exposure.	Projects like Noord/Zuidlijn, SAA, and Zuidasdok involved substantial capital expenditures, contributing significantly to their complexities. While segmentation increased transaction costs due to managing multiple budgets and contracts, it also enhanced financial manageability by dealing with smaller budgets per segment, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly increases complexity by necessitating multiple budget allocations and contract management, also resulting in higher transaction costs. However, it improves financial oversight within each functional segment, making it easier for the client and co-contractors to control costs and manage financial risks.	
	Number of locations	Horizontal segmentation	Typically reduces complexity by isolating management within specific geographic areas. Each contractor can focus on the unique challenges of their segment, reducing the need for extensive coordination across multiple sites. However, it increases the need for strong coordination between segments to ensure overall project coherence, adding complexity.	Managing multiple sites, as seen in Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle, added considerable complexity. Segmentation allowed for more focused attention within each segment, streamlining coordination across multiple locations. This approach often decreased the contribution to the project's complexity, although it sometimes increased the need for coordination.
		Vertical segmentation	Not applicable as it does not affect the geographic distribution of locations but focuses on functional distinctions within the same geographic areas.	
	Newness of technology	Horizontal segmentation	Often reduces complexity by allowing specialised contractors to manage new technologies within specific geographic segments. This approach enables better handling of innovative techniques and reduces the risks associated with their implementation.	In projects like Noord/Zuidlijn, the introduction of innovative technologies brought unique challenges and uncertainties. Segmentation allowed for the involvement of specialised contractors who could manage these new technologies more effectively, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly reduces complexity by leveraging specialised expertise within each technical discipline. Each co-contractor can focus on	

T Technical complexity			mastering and applying new technologies specific to their functional requirements, reducing the project's overall complexity.	
	Lack of experience with technology	Horizontal segmentation	Typically reduces complexity by involving specialised contractors familiar with new technologies in each geographic segment. This helps mitigate the risks associated with the lack of experience, ensuring each segment benefits from expert knowledge and skills.	The lack of experience with advanced technologies, as noted in Noord/Zuidlijn, increased project complexity. Segmentation facilitated the involvement of specialised contractors, mitigating risks associated with the lack of experience and thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly decreases complexity by concentrating specialised expertise within each functional segment. This allows co-contractors to focus on developing and applying their knowledge of new technologies, reducing the project's overall technical risks.	
	High number of tasks	Horizontal segmentation	Often reduces complexity by distributing tasks across multiple geographic segments, improving manageability. Each contractor can handle a specific set of tasks, which reduces the overall workload on any single team and allows for more effective task management.	A multitude of tasks, as seen in Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle, contributed significantly to project complexity. Segmentation did not directly reduce the number of tasks but allowed for their division among multiple contractors, making management more effective and decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly reduces complexity by dividing tasks among specialised technical teams. Each co-contractor can focus on tasks related to their functional area, enhancing efficiency and reducing the potential for task overload.	
	High variety of tasks	Horizontal segmentation	Typically reduces complexity by assigning specific task types to different geographic segments. This allows contractors to specialise in particular areas, improving task execution and reducing the overall variety of tasks managed by any single team.	A multitude of tasks, as seen in Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle, contributed significantly to project complexity. Segmentation did not directly reduce the number of tasks but allowed for their division among multiple contractors, making management more effective and decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly decreases complexity by allowing specialised teams to handle distinct technical tasks within functional segments. Each team can focus on tasks related to their area of expertise, reducing the overall project's complexity.	
	Dependencies between tasks	Horizontal segmentation	Generally results in fewer dependencies within each geographic segment, allowing for more straightforward management of tasks by the client and contractors. However, it increases the complexity at the interfaces between segments, as coordination is required to ensure seamless integration between geographic areas. This means while tasks within a segment are less dependent on each other, the dependency shifts to managing the boundaries between segments, often complicating the overall project.	Managing interdependencies between tasks added significant complexity to projects like Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle. Horizontal segmentation reduced dependencies within segments but increased complexity at interfaces. Vertical segmentation increased dependencies at interfaces with horizontally segmented segments, maintaining a high contribution to the project's complexity.
		Vertical segmentation	Often increases complexity by requiring alignment of functions managed by different co-contractors. Each functional segment depends on the others to progress effectively, meaning careful coordination is necessary to align their work. This frequently results in increased interdependencies and potential for misalignment, thereby increasing the project's overall complexity.	
	Uncertainty in methods	Horizontal segmentation	Often reduces complexity by focusing on specific methods within geographic segments. This allows contractors to develop detailed plans and execution strategies for innovative construction techniques, reducing uncertainties.	Projects like Noord/Zuidlijn faced significant uncertainties due to innovative methods, adding complexity. Segmentation allowed for a specialised focus on these methods within each segment, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Typically decreases complexity by allowing detailed planning and specialised expertise within each functional segment. This helps co-	

T Technical complexity			contractors manage the uncertainties associated with new methods more effectively, reducing the project's overall complexity.	
	Involvement of different technical disciplines	Horizontal segmentation	Generally reduces complexity by clarifying responsibilities within geographic segments. Each contractor can focus on specific technical disciplines, improving coordination and reducing the potential for conflicts.	Coordination across various technical disciplines was crucial in projects like Noord/Zuidlijn, SAA, Zuidasdok, and Oranje Loper, contributing significantly to complexity. Horizontal segmentation enabled the assignment of specialised contractors to specific segments, facilitating better coordination and decreasing the contribution to the project's complexity.
		Vertical segmentation	Often decreases complexity by delineating tasks within functional segments. This facilitates better communication and collaboration among co-contractors, reducing the project's overall complexity.	
	Conflicting norms and standards	Horizontal segmentation	Typically decreases complexity by tailoring compliance efforts within geographic segments. Each contractor can focus on meeting specific norms and standards relevant to their location, reducing conflicts.	Aligning various norms and standards sometimes conflicted, especially in Noord/Zuidlijn, contributing significantly to the project's complexity. Segmentation allowed for addressing these conflicts within each segment, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Generally reduces complexity by addressing norms and standards within functional segments. This allows for more targeted compliance efforts, ensuring each segment meets the necessary requirements without conflicting with other segments.	
	Technical risks	Horizontal segmentation	Typically decreases complexity by containing risks within geographic segments, allowing for targeted risk management strategies. However, it introduces interface complexities that need careful management to ensure overall project safety.	Technical risks, such as structural impacts and unforeseen conditions, were significant in projects like Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle. Segmentation allowed for specialised contractors to manage these risks more effectively. However, it also introduced additional complexities at interfaces, maintaining a high contribution to the project's complexity.
		Vertical segmentation	Often reduces complexity within functional segments by leveraging specialised expertise to manage technical risks. However, it increases interface risks between horizontally segmented areas, requiring careful coordination to mitigate these risks.	
O Organisational complexity				
	High project schedule drive	Horizontal segmentation	Often reduces complexity by allowing segments to progress independently, mitigating the risk of delays in one segment affecting others. This enables more flexible scheduling and reduces overall project timeline pressure.	The urgency to adhere to the project schedule put significant pressure on all organisational aspects, often leading to tight deadlines, contributing very much to the project's complexity. Segmentation generally made schedule management more feasible by allowing for tighter control and timely adjustments within each segment. This helped mitigate the risk of delays in one segment affecting others, thereby decreasing the contribution to the project's complexity. However, coordinating schedules across multiple segments can sometimes complicate the overall timeline management, particularly in projects like SAA and Zuidasdok, where careful synchronisation is required.
		Vertical segmentation	Similarly reduces complexity by allowing segments to progress independently based on their functional requirements, thus reducing schedule-driven complexities.	
	Interfaces between different disciplines	Horizontal segmentation	Generally increases complexity due to enhanced coordination and integration needs across geographic segments. Ensuring seamless integration across segments requires meticulous planning and management by the client and contractors, increasing the project's organisational complexity.	Managing interfaces between different technical and organisational disciplines was crucial and complex, contributing substantially to the project's complexity. Segmentation significantly increased the complexity of managing these interfaces due to the need for heightened coordination and integration across segments. This was particularly evident in projects like SAA and Zuidasdok, where ensuring cohesive integration across different construction activities added a layer of complexity, thereby increasing the contribution to the project's complexity.
		Vertical segmentation	Also increases complexity by requiring careful management of interfaces between technical disciplines. Coordination and integration across functional segments is crucial to ensure that all components integrate smoothly, adding to the project's complexity.	
	Number of contracts	Horizontal segmentation	Typically increases complexity by necessitating multiple contracts for each geographic segment. This adds administrative overhead and requires careful management to ensure all	Segmentation invariably resulted in an increase in the number of contracts, as the project was divided into smaller, more manageable segments, each requiring its own contractual arrangement.

O Organisational complexity			contracts align with the overall project objectives.	This led to an increase in the contribution to the project's complexity across all cases, such as Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle, due to the higher transaction costs and administrative burdens associated with managing multiple contracts.
		Vertical segmentation	Often has a similar impact, increasing the number of contracts for each functional segment. This requires detailed contract management to ensure that all segments meet their specific requirements while aligning with the broader project goals.	
		Horizontal segmentation	Horizontal segmentation often results in a variety of contract types, as different geographic locations require distinct contractual approaches. This variety increases the contribution to the project's complexity due to the need for coordinating different contractual terms and ensuring compliance across all segments	Segmentation resulted in a variety of contract types being used in projects, ranging from traditional contracts to more integrated Design and Construct contracts. This variety necessitated distinct management approaches for each contract type, increasing the contribution to the project's complexity.
	Type of contract	Vertical segmentation	Vertical segmentation often results in a variety of contract types, as different functions require distinct contractual approaches. This variety increases the contribution to the project's complexity due to the need for coordinating different contractual terms and ensuring compliance across all segments	
		Horizontal segmentation	Often decreases complexity by enabling smaller, focused teams within geographic segments. Each team can concentrate on their specific segment, improving management and operational efficiency.	Managing large project teams, composed of diverse professionals, added to the management complexity and significantly contributed to the project's complexity. While segmentation did not alter the overall size of the project team, it allowed for smaller, more focused teams working on each segment, potentially improving management and operational efficiency. This approach often decreased the contribution to the project's complexity, as seen in projects like Zuidasdok and Oranje Loper, although it should have been increased to better manage the segments and the segmentation process.
	Size of project team	Vertical segmentation	Typically decreases complexity similarly by allowing specialised teams within functional segments. This allows for more efficient management of team resources and reduces the overall project's complexity.	
		Horizontal segmentation	Often increases complexity due to the need for alignment across multiple geographic segments. Ensuring all segments work towards the overall project goals requires careful coordination, integration, and management by the client and contractors, adding to the project's organisational risks	The client faced significant organisational risks in managing and coordinating mega infrastructure projects, contributing very much to the project's complexity. Segmentation often complicated the management of these projects due to the increased number of segments, interfaces, and contractors involved. This was particularly challenging in projects like Noord/Zuidlijn, SAA, Zuidasdok, and Oranje Loper, where the added complexity of managing multiple segments and their interdependencies increased the contribution to the project's complexity. However, in some cases like Stadsdijken Zwolle, segmentation helped streamline coordination and improve financial planning and control, thereby aiding in more effective management of budget allocation and cost control, thus slightly decreasing organisational risks.
	Organisational risks	Vertical segmentation	Generally increases complexity similarly by requiring coordination and integration across functional segments. Managing the interdependencies between segments is crucial to maintaining project cohesion and success, increasing the project's organisational risks.	
E External complexity		Horizontal segmentation	Generally decreases complexity by allowing for the specialised allocation of resources and skills within each geographic segment. This enables more effective utilisation of available resources and reduces the project's overall complexity.	There was often a deficiency in the availability of required skills and resources, particularly in specialised areas critical to the project's success, significantly contributing to the project's complexity. Segmentation allowed for more precise allocation of necessary resources and skills within specific segments, thus decreasing the contribution to the project's complexity. This was notably beneficial in projects like Noord/Zuidlijn and Oranje Loper, where specialised contractors could focus on their areas of expertise.
	Lack of resource & skills availability	Vertical segmentation	Often decreases complexity similarly by concentrating specialised resources and skills within functional segments. This allows for more efficient resource management and reduces the project's overall complexity.	
	Lack of experience with parties involved	Horizontal segmentation	Often decreases complexity similarly by concentrating specialised resources and skills within functional segments. This allows for more efficient resource management and reduces the project's overall complexity.	Many projects, including Noord/Zuidlijn, involved parties lacking previous experience with similar large-scale projects, which added to the coordination and management challenges, substantially contributing to the project's

E External complexity		Vertical segmentation	Often decreases complexity similarly by involving co-contractors with specialised expertise within functional segments. This ensures that each segment benefits from experienced parties, reducing the project's overall complexity.	complexity. While segmentation did not alter the overall lack of experience, it allowed for more parties to be involved, thereby distributing the workload more evenly and reducing the burden on any single party. This approach decreased the contribution to the project's complexity by lowering the load on each party.
	Political influence	Horizontal segmentation	Generally decreases complexity by isolating political impacts within specific geographic segments. This allows for more focused negotiations and adjustments, reducing the overall project's political complexity.	Political decisions and pressures often significantly impacted planning, execution, and funding phases across projects like Noord/Zuidlijn, SAA, and Zuidasdok, contributing very much to their complexity. By breaking these projects into segments, the influence of political decisions could be isolated to specific aspects rather than affecting the entire project. This isolation simplified negotiations and adjustments within individual segments, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Typically reduces complexity by managing political influences within functional segments. This enables more targeted interactions with political stakeholders, reducing the project's political complexity.	
	Dependencies on external stakeholders	Horizontal segmentation	Often decreases complexity by allowing specific stakeholder interactions within geographic segments. This simplifies stakeholder management for the client and contractors and reduces the range of concerns and negotiations needed at any one time.	Dependencies on various external stakeholders, including governmental bodies for subsidies and approvals, contractors for construction, and the public for support and feedback, contributed very much to the project's complexity in projects like Noord/Zuidlijn, SAA, and Zuidasdok. Segmentation did not change the dependencies on stakeholders but allowed for more effective management by dealing with stakeholders on a per-segment basis. This approach helped in managing these dependencies more effectively, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Typically decreases complexity similarly by aligning stakeholder management with functional segments. This allows for more focused and effective interactions with external stakeholders, reducing the project's overall complexity.	
	Number of external stakeholders	Horizontal segmentation	Often decreases complexity by aligning specific stakeholder groups with relevant geographic segments. This simplifies the management of external stakeholders by reducing the number of interactions required for each segment.	Interacting with a wide array of external stakeholders, such as city residents, businesses, commuters, local government agencies, and environmental groups, added significant complexity to projects like Noord/Zuidlijn, SAA, and Zuidasdok. Segmentation did not reduce the number of external stakeholders but allowed for more focused attention within each segment. This approach simplified stakeholder management, thereby decreasing the contribution to the project's complexity.
		Vertical segmentation	Similarly reduces complexity by aligning stakeholder groups with functional segments. This targeted approach to stakeholder management simplifies interactions and reduces the project's overall complexity.	
	Interference with existing site	Horizontal segmentation	Generally decreases complexity by isolating site interferences within specific geographic segments. This allows for more focused management of disruptions and reduces the project's overall complexity.	In projects like Noord/Zuidlijn, SAA, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle, minimising disruptions to essential infrastructure and local residents contributed very much to the project's complexity. Segmentation allowed for specialised focus on managing interference with existing sites, helping to minimise disruptions. This specialised focus decreased the contribution to the project's complexity by ensuring that essential infrastructure and local residents were less affected by the construction activities.
		Vertical segmentation	Typically decreases complexity by managing site interferences within functional segments. This specialised focus helps minimise disruptions and reduces the project's overall complexity	

The framework analysis of horizontal and vertical segmentation reveals a nuanced impact on the complexity elements within large infrastructure projects. Each segmentation type offers distinct advantages and challenges, which vary according to the specific complexity elements involved.

Horizontal segmentation generally reduces complexity by allowing the client and contractors to focus more specifically on the goals within each geographic segment. This approach leads to clearer strategies and execution plans, thereby reducing the overall project complexity. For instance, strict quality requirements can be more easily managed through detailed and specialised quality control processes, ensuring consistency and reducing the project's overall complexity. Furthermore, horizontal segmentation reduces the complexity associated with managing new technologies and a lack of experience by involving specialised contractors who can better handle the unique challenges within

each segment. This segmentation also simplifies the management of multiple locations by isolating responsibilities within specific geographic areas.

However, horizontal segmentation also presents challenges. Dependencies between tasks often increase at the interfaces between segments, necessitating enhanced coordination and potentially complicating the overall project. Additionally, managing multiple budgets and contracts can increase transaction costs, though it also enhances financial control by breaking down large investments into smaller segments. The need for meticulous planning and management increases due to the enhanced coordination and integration needs across geographic segments. Horizontal segmentation typically necessitates multiple contracts for each geographic segment, adding administrative overhead and requiring careful management to ensure alignment with overall project objectives.

Vertical segmentation, on the other hand, decreases complexity by allowing co-contractors to manage quality within their specific functional areas, ensuring high standards are consistently upheld. It also reduces the risks associated with new technologies by leveraging specialised expertise within each technical discipline. By dividing tasks among specialised teams within functional segments, vertical segmentation allows for focused expertise, thereby reducing the overall project complexity.

Nonetheless, vertical segmentation increases complexity as different functions need to be aligned by various co-contractors, requiring careful coordination and integration. This segmentation type often involves a variety of contract types within functional segments, increasing complexity due to the need for coordinating different contractual terms and ensuring compliance across all segments. Vertical segmentation also requires enhanced coordination across functional segments, adding to the project's organisational risks due to the need for managing interdependencies and ensuring alignment with project goals.

In general, both segmentation types can streamline processes by enabling parallel advancements, although they also introduce complexities in managing interdependencies and ensuring alignment across segments. Both types can reduce complexity by isolating political impacts and stakeholder interactions within specific segments, simplifying negotiations and stakeholder management. Additionally, segmentation allows for more focused management of disruptions, thereby reducing the project's overall complexity.

Overall, the framework highlights that while segmentation, whether horizontal or vertical, introduces certain complexities, it also offers significant benefits by enabling more focused management and specialised approaches. The choice of segmentation type should be tailored to the specific needs and challenges of each project, leveraging the strengths of each approach to mitigate complexities effectively.

5.2 Segmented project delivery methods typology

This section explores the segmented project delivery methods gathered throughout the case study, providing insights into the benefits and drawbacks of each model. It creates a typology of segmented project delivery methods to systematically classify and understand the various models.

5.2.1 Segmented traditional project delivery method

The segmented traditional project delivery method applies segmentation principles to the traditional project delivery method, evolving it into what is known as the co-contracting project delivery method, also referred to as the segmented traditional project delivery method in this thesis. In this approach, the client divides the construction project into multiple segments and establishes separate contracts

with different contractors for each segment. Each contractor is responsible for a distinct part of the project, and these contractors, operating concurrently on various facets of the same project, are termed co-contractors.

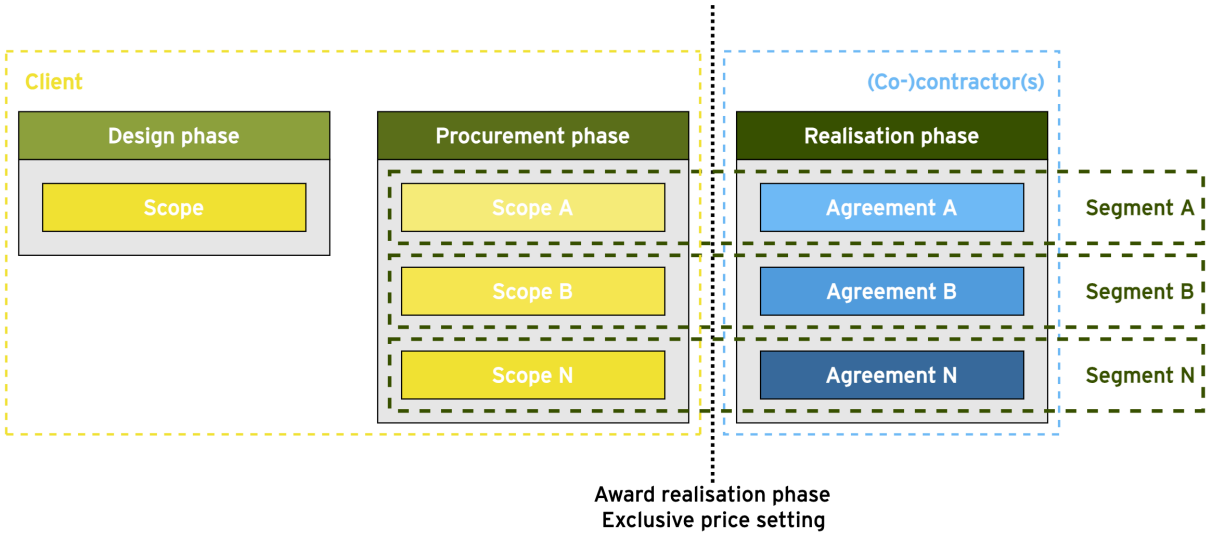

Figure 26. Schematic representation of the segmented traditional project delivery method

Note: This figure depicts segmentation during the procurement phase and realisation phase, but it is also possible to segment the scope during the design phase depending on project needs.

In the co-contracting framework, the client enters into separate agreements with each co-contractor for the realisation of the project. While these contractors usually do not share a contractual relationship among themselves, their work is intricately connected, with the output of one contractor often serving as a foundation for another's work. A co-contractor may also outsource aspects of their job to subcontractors, becoming a client to these subcontractors.

A distinguishing aspect of co-contracting is the assignment of specific segments to different co-contractors, who have no control over how the other co-contractors carry out their tasks. Coordination of activities among co-contractors is essential to ensure that each contractor can effectively accomplish their duties. This necessitates a detailed schedule outlining when each co-contractor should start, execute, and complete their segments, as well as the order and manner of their tasks. It is critical that all co-contractors adhere to this schedule. Given the client's contractual relationships with each co-contractor, the client is best positioned to set and oversee this schedule authoritatively, ensuring that work progresses smoothly.

However, the client may choose to delegate coordination duties to an assistant or one of the co-contractors. When coordination responsibility is assigned to a co-contractor, the agreement with that co-contractor includes a service obligation to not only perform their tasks but also coordinate the activities of the other co-contractors. The coordinating co-contractor must prepare an acceptable work plan in collaboration with the others and ensure its adherence. Any delays must be promptly addressed to minimise disruption to the overall timeline. Despite this, the coordinating contractor's role is one of care, not an absolute guarantee of outcome.

Dividing a project among co-contractors can lead to cost savings for the client by avoiding the markups associated with subcontracting through a primary contractor. Direct contracting with co-contractors provides more control over the progress of work. However, this approach places significant responsibility on the client for coordinating the activities of multiple co-contractors. The client may be held accountable for any deficiencies in coordination, leading to potential delays and quality issues. To mitigate these challenges, a coordination agreement involving all co-contractors is often necessary.

In conclusion, the segmented traditional project delivery method, or co-contracting, offers both benefits and challenges. It allows for specialised focus on distinct project segments, potentially enhancing project management efficiency and integrating innovative construction techniques. However, it also increases coordination responsibilities and complexities, requiring meticulous planning and oversight to ensure cohesive project progress.

5.2.2 Segmented integrated project delivery method

In the segmented integrated project delivery method, or segmented contracting, principles of segmentation are applied to the integrated project delivery method, creating a co-contracting variant. This approach divides the project into multiple segments, each handled by different co-contractors who are responsible for both design and construction within their assigned segments. This method combines the benefits of integrated project delivery and co-contracting, aiming to enhance project management efficiency and improve coordination.

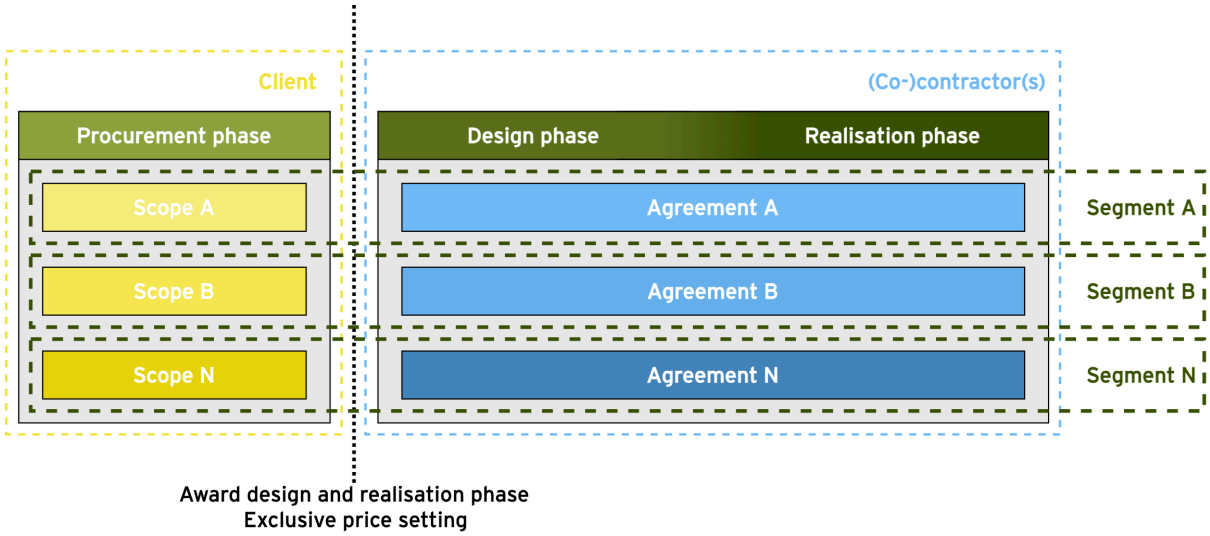

Figure 27. Schematic representation of the segmented integrated project delivery method

Coordination is a crucial element in the segmented integrated project delivery method. Each contractor, overseeing both design and construction, is responsible for ensuring seamless integration across all segments. This includes creating a comprehensive schedule, outlining when each co-contractor should start, execute, and complete their segments, and ensuring adherence to this timeline. Effective coordination mitigates interface risks and ensures that design and construction activities are aligned across segments.

However, each contractor may choose to delegate some coordination duties to co-contractors or hire a coordination assistant. When coordination responsibility is assigned to a co-contractor, the agreement includes a service obligation for coordinating the activities of other co-contractors. This necessitates a detailed work plan and proactive management to address any delays or issues promptly.

The segmented integrated project delivery method offers several advantages. It allows for specialised focus on distinct project segments, leveraging the expertise of co-contractors to manage design and construction within their areas effectively. This approach can lead to cost savings for the client by avoiding the markups associated with subcontracting through a primary contractor. Direct contracting with co-contractors provides more control over the progress of work and ensures that specialised skills are applied effectively.

However, this method also introduces challenges. The client is responsible for coordinating the activities of multiple co-contractors, which can lead to potential delays and quality issues if not managed effectively. Coordination agreements involving all co-contractors are often necessary to mitigate these risks. Additionally, while each contractor assumes significant responsibility for design risks, the segmented nature of the project requires careful management to ensure cohesive progress and alignment of project goals across all segments.

Overall, the segmented integrated project delivery method combines the benefits of integrated project delivery and co-contracting, offering a nuanced approach to managing complex infrastructure projects. It demands meticulous planning, robust coordination mechanisms, and effective management of contractual relationships to ensure successful project delivery.

5.2.3 Segmented design team project delivery method

In the segmented design team project delivery method, the principles of segmentation are applied to the collaborative design team approach, creating a co-contracting variant. This method divides the project into multiple segments, each managed by different co-contractors who participate in both the design and construction phases within their assigned segments. This approach combines the benefits of early contractor involvement and segmentation, aiming to enhance project management efficiency and coordination.

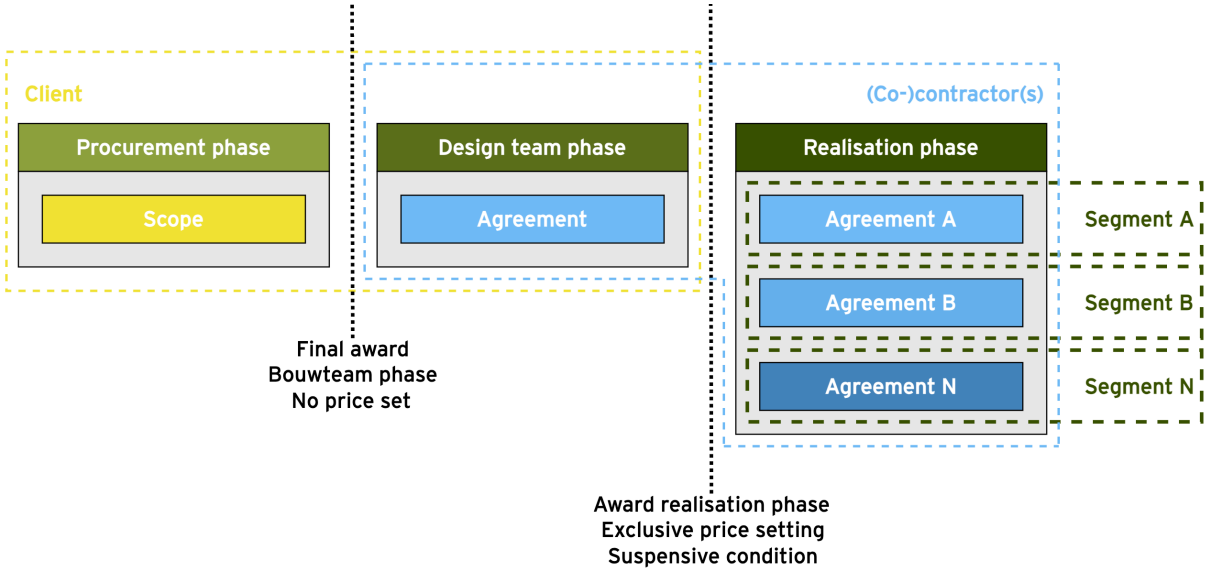

Figure 28. Schematic representation of the segmented design team (traditional) project delivery method

Note: This figure depicts segmentation during the realisation phase, but it is also possible to segment the scope during the procurement and design team phase depending on project needs.

The segmented design team project delivery method 2.0 builds upon the traditional segmented design team approach by incorporating more integrated and collaborative elements. This advanced model uses Design & Build conditions to foster deeper collaboration and integration between the client, contractors, and consultants. By leveraging the principles of the integrated project delivery method within the segmented design team framework, this approach aims to further streamline processes, improve risk management, and enhance overall project outcomes.

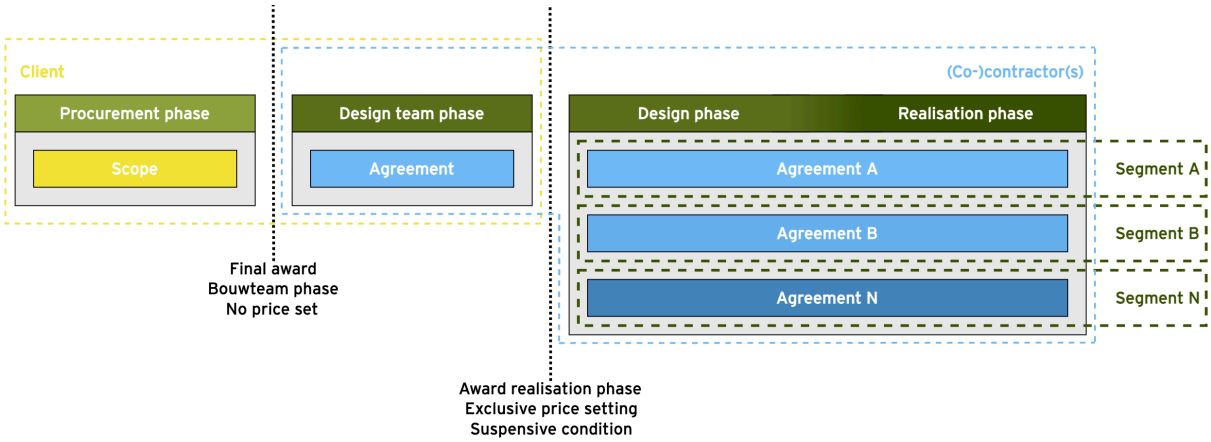

Figure 29. Schematic representation of the segmented design team (2.0) project delivery method

Note: This figure depicts segmentation during the realisation phase, but it is also possible to segment the scope during the procurement and design team phase depending on project needs.

Coordination is a critical aspect of the segmented design team project delivery method. The design team, comprising architects, consulting engineers, and contractors, collaborates closely to ensure seamless integration across all segments. This collaboration includes developing a comprehensive schedule that outlines when each co-contractor should start, execute, and complete their segments, and ensuring adherence to this timeline. Effective coordination helps mitigate interface risks and ensures that design and construction activities are aligned across segments.

However, the primary contractor or the client may choose to delegate some coordination duties to specific co-contractors or hire a coordination assistant. When coordination responsibility is assigned to a co-contractor, the agreement includes a service obligation for coordinating the activities of other co-contractors. This necessitates a detailed work plan and proactive management to address any delays or issues promptly.

The segmented design team project delivery method offers numerous benefits. This approach leverages the specialised expertise of co-contractors, allowing for a more tailored and effective management of design and construction within distinct project segments. By involving contractors early in the design phase, the segmented design team method ensures that practical insights and cost-effective strategies are integrated into the project from the outset. This early involvement can lead to significant cost savings for the client, as it avoids the markups typically associated with subcontracting through a primary contractor. Direct contracting with co-contractors also provides the client with greater control over the progress of work and the application of specialised skills, enhancing overall project quality and efficiency.

Moreover, the segmented design team method fosters a collaborative environment where designers and contractors work closely together to align their efforts with the project goals. This collaboration helps to optimise design solutions, improve constructability, and ensure that project risks are managed more effectively. The segmented approach allows for concurrent progress in different segments, potentially accelerating the overall project timeline and improving resource utilisation.

However, this method also presents several challenges. One of the primary disadvantages is the complexity of coordinating the activities of multiple co-contractors. Effective coordination mechanisms and robust communication strategies are essential to ensure that all segments align with the overall project objectives. The client or a designated coordination contractor must manage these interactions carefully to prevent delays, conflicts, and quality issues. The segmented nature of the project requires meticulous planning and coordination to ensure cohesive progress and alignment of project goals across all segments.

Additionally, the need for multiple contracts can increase administrative overheads and transaction costs. Managing these contracts requires detailed oversight to maintain clarity and accountability among all parties involved. The client is responsible for overseeing the coordination and integration of various project segments, which can be particularly challenging in complex infrastructure projects with diverse scopes of work. Ensuring that all co-contractors adhere to the agreed schedule and quality standards demands vigilant oversight and proactive problem-solving.

Overall, the segmented design team project delivery method, including its 2.0 variant, offers a sophisticated approach to managing complex infrastructure projects. It combines the benefits of early contractor involvement with the focused expertise and efficiency of segmented contracting. While it requires careful planning and robust coordination, the potential benefits in terms of cost savings, improved quality, and enhanced risk management make it a valuable approach for complex projects.

5.2.5 Segmented two-phase project delivery method

The segmented two-phase project delivery method combines the principles of the two-phase method with the segmentation approach, creating a co-contracting variant. In this method, the project is divided into multiple segments, each managed by different co-contractors who participate in both the design and construction phases within their assigned segments. This approach leverages the benefits of both early contractor involvement and segmentation, aiming to enhance project management efficiency and coordination.

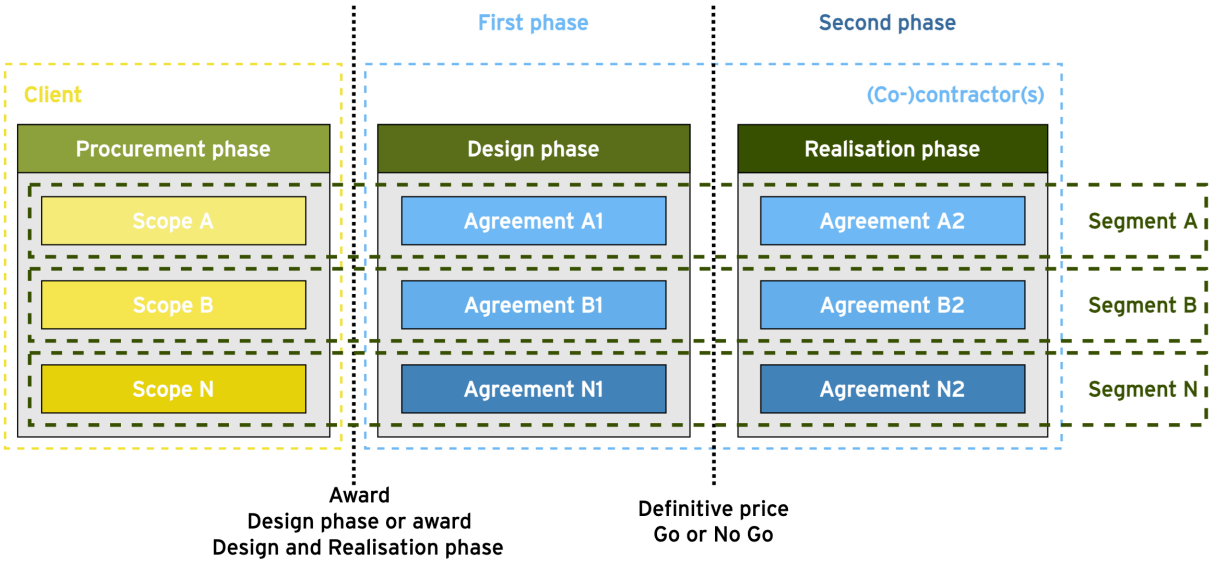

Figure 30. Schematic representation of the segmented two-phase project delivery method

Coordination is crucial in the segmented two-phase project delivery method. During the design phase, the client and co-contractors collaborate to develop detailed plans for each segment. Effective coordination ensures that the transition from the design phase to the construction phase is seamless, minimising disruptions and ensuring that all segments align with the overall project goals.

The two-phase approach necessitates a detailed work plan, outlining when each co-contractor should commence their segment, the sequence and order of their tasks, and the completion timelines. This plan must be adhered to meticulously to ensure that all segments are progressing according to the overall project schedule. The client plays a pivotal role in managing and overseeing this coordination effort, ensuring that the design details from the first phase translate effectively into the construction phase of each segment.

When coordination responsibility is assigned to a co-contractor, the agreement includes a service obligation for coordinating the activities of other co-contractors. This necessitates a detailed work plan and proactive management to address any delays or issues promptly. The coordinating co-contractor must work closely with others to ensure that their tasks are aligned and that any problems are swiftly resolved to maintain the project schedule.

The segmented two-phase project delivery method provides several distinct advantages. By separating the project into phases and segments, it allows for a thorough and detailed design phase, reducing uncertainties and financial risks before entering the construction phase. This segmentation enables a more tailored approach, where each segment can be managed with specific expertise and focus, resulting in higher quality and efficiency. The segmented approach also facilitates better risk management, as detailed planning in the design phase allows for more accurate cost estimation and risk allocation, thus improving the financial predictability of the project.

Another significant advantage is the enhanced collaboration between the client and multiple co-contractors during the design phase. This early involvement of co-contractors ensures that practical insights and innovations can be integrated into the design, potentially leading to cost savings and improved constructability. The segmented nature of the project allows for parallel progress in different segments, which can accelerate the overall timeline and improve resource allocation.

However, the segmented two-phase method also presents challenges. One of the main disadvantages is the complexity of coordinating multiple segments and co-contractors. This requires robust coordination mechanisms and effective communication strategies to ensure all segments align with the overall project objectives. The client or a designated coordination contractor must carefully manage these interactions to prevent delays, conflicts, and quality issues. Additionally, the need for multiple contracts can increase administrative overheads and transaction costs, requiring meticulous contract management to maintain clarity and accountability.

The method also places significant responsibility on the client to oversee the coordination and integration of various project segments. This can be particularly challenging in large-scale projects where the scope and scale of work can vary greatly between segments. Ensuring that all co-contractors adhere to the agreed schedule and quality standards demands vigilant oversight and proactive problem-solving.

Overall, the segmented two-phase project delivery method offers a strategic approach to managing complex infrastructure projects. It combines the detailed planning and risk management benefits of the two-phase method with the focused expertise and efficiency of segmented contracting. While it demands careful planning and coordination, the potential benefits in terms of cost savings, improved quality, and better risk management make it a valuable approach for complex projects.

5.4 Conclusion on framework and typology

This chapter has presented a comprehensive analysis of the impact of horizontal and vertical segmentation on various complexity elements, using insights from case studies to demonstrate the practical effects of segmentation within a structured framework. Additionally, it has introduced different segmented project delivery methods gathered throughout the case study, organising them into a typology to systematically classify and understand each model.

The framework analysis has revealed that both horizontal and vertical segmentation offer unique advantages and challenges in managing complex infrastructure projects. Horizontal segmentation generally reduces complexity by allowing the client and contractors to focus more specifically on the goals within each geographic segment, leading to clearer strategies and execution plans. However, it also introduces challenges such as increased dependencies at segment interfaces and the need for meticulous coordination. Vertical segmentation reduces complexity by leveraging specialised expertise within functional areas, ensuring high standards are upheld and innovative technologies are managed effectively. Nonetheless, it requires careful alignment of functions managed by different co-contractors, necessitating robust coordination mechanisms.

The typology of segmented project delivery methods provides a detailed classification of various models, showcasing their benefits and drawbacks. This includes segmented traditional, integrated, design team, and two-phase project delivery methods. Each model offers distinct approaches to managing complexities, emphasising the importance of early contractor involvement, specialised focus, and efficient resource management. However, they also present challenges such as increased administrative overhead, transaction costs, and the need for effective coordination and communication.

In this research, the findings on the conceptual definition of segmented contracting are formulated by combining the segmentation framework with the typology of segmented project delivery methods, as segmented contracting is defined in this thesis as the comprehensive approach that implements segmentation and segmented project delivery methods within a project, where each segment is individually legally contracted by the client to a contractor. Figure 31 shows a schematic representation of this interpretation.

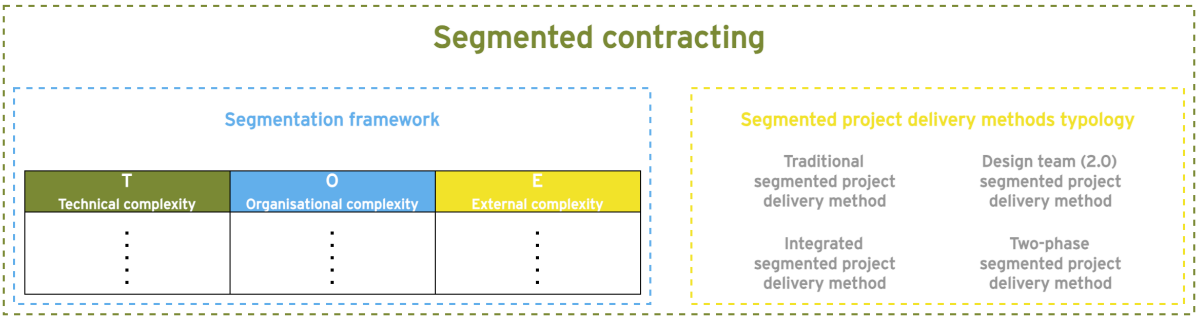

Figure 31. Segmented contracting

Overall, this chapter aims to provide a thorough understanding of segmented contracting, detailing the aspects of segmentation and segmented project delivery methods that constitute this strategic approach. By leveraging the insights from the case studies and organising them into a coherent framework and typology, this research offers valuable guidance for managing the complexities inherent in complex infrastructure projects. This comprehensive analysis highlights the potential of segmented contracting to enhance project management efficiency, improve quality, and reduce risks, while also addressing the challenges that need to be carefully managed to ensure successful project outcomes.

6. (Legal) Expert interviews

This chapter presents valuable insights from experts and legal authorities in the field of complex infrastructure projects, addressing the final sub-question (4): “What are the perspectives of experts and legal experts on key aspects of segmentation and segmented contracting, including coordination, integration, communication, procurement, benefits, and challenges?”. It investigates their perspectives on key aspects of segmented contracting, segmentation, and segmented project delivery methods. These insights provide a comprehensive understanding of the strategic approaches required for successfully managing and realising segmented complex infrastructure projects, emphasising the critical factors and best practices that drive project success.

6.1 Insights of experts

This section delves into the valuable insights provided by experts in the field of complex infrastructure projects. By examining their perspectives on various aspects such as segmentation, co-contracting, market consultation, coordination and integration, risk management, project delivery methods, and finance and budget, a comprehensive understanding of the strategic approaches necessary for managing and executing successful segmented complex infrastructure projects is gained. These expert opinions highlight the critical factors and best practices that drive successful project outcomes.

6.1.1 Segmentation

Segmentation of complex infrastructure projects could be a strategic approach to managing complexity and optimising project outcomes. Various experts have provided insights into how segmentation should be approached, emphasising the importance of carefully planning and defining segments to ensure efficiency, reduce risks, and enhance overall management of the project. These experts highlight different criteria and methods for segmenting projects, considering factors such as functionality, geographical location, project phasing over time, and external and internal project drivers.

An expert views the client’s choice to segment projects as a strategic method to manage complexity and optimise the risk-reward ratio. The expert sees segmentation as an effective approach to address specific project goals, with each segment tailored to its unique requirements and challenges (Appendix AA.1 Segmentation). This method, as the expert advised, also stimulates market competition by providing more opportunities to different contractors who may be specialised in certain aspects of the work (Appendix AA.1 Segmentation). For large and complex infrastructure projects, the expert views segmentation as an essential tool for efficient management. According to the expert, segmentation should be carefully planned and implemented in the early stages of the project cycle, such as the procurement and design phases, to ensure clear scope definition and responsibility allocation from the start, which is critical for successful project execution (Appendix AA.1 Segmentation). This expert highlighted that the most strategic goals for segmentation should focus on maximising project efficiency, controlling costs, and reducing risks. The expert recommends that decisions to implement segmentation should be influenced by a thorough analysis of project requirements to ensure each segmentation and segment is feasible and optimal (Appendix AA.1 Segmentation).

The expert indicated that the decision to segment a project is based on various factors. Firstly, the scope and size of the project are considered. For very large projects, such as infrastructure projects costing millions or even billions of euros, it is often impractical to tender them as a single unit. The scale and complexity of such projects necessitate dividing them into smaller, manageable segments (Appendix AA.2 Criteria). Another important factor, according to the expert, is the technical and functional complexity of the project. Segmentation can be applied to better manage specific technical

challenges and to utilise specialised expertise where needed. For example, in a project involving various types of infrastructure (such as roads, tunnels, and bridges), it can be beneficial to treat each type as a separate segment. This allows for the engagement of specialised contractors with experience in the specific requirements of each segment (Appendix AA.2 Criteria). The expert also mentioned that the geographical location of different parts of the project plays a role. For projects spread over a large area, it can be logical to divide the work into geographical segments. This facilitates logistics and management of construction activities and can help minimise disruptions to the surrounding area. By segmenting geographically, different parts of the project can be carried out simultaneously without interfering with each other (Appendix AA.2 Criteria). Timing and phasing of the project are also crucial considerations. The expert emphasised the importance of phasing to minimise disruptions and ensure continuous project progress. By dividing the project into phases, certain parts of the work can be completed and utilised while others are still under construction. This leads to more efficient execution and better resource utilisation (Appendix AA.2 Criteria). Lastly, the expert noted that market consultation is an important part of the decision-making process. By consulting with potential contractors and other stakeholders, the client can better assess how the project can best be segmented. These consultations help gain insights into the capabilities and preferences of the market, contributing to a more realistic and effective segmentation of the project (Appendix AA.2 Criteria).

The expert also acknowledged that segmentation within complex construction projects presents significant challenges, but the expert is also convinced of the substantial benefits this approach can offer. One of the primary challenges of implementing segmentation, as the expert noted, is the increased complexity of coordination (Appendix AA.6 Considerations). When a project is divided into multiple segments, precise collaboration between different teams and contractors is required, necessitating an advanced and meticulous coordination strategy. This, the expert explained, can lead to increased management costs and a greater need for detailed planning and communication. The need for constant alignment between the different project segments can be time-consuming and demands extra effort from the project management team (Appendix AA.6 Considerations). Additionally, the expert advised that segmentation brings a heightened risk of misunderstandings and miscommunication, especially if coordination mechanisms are not well-established. Each segment, according to the expert, can have its own dynamics and unique challenges, leading to inconsistent performance and potential delays if the segments are not well-aligned. The absence of a central coordinating entity, the expert suggested, can make it difficult to ensure streamlined and integrated project execution. Despite these challenges, the expert sees significant advantages in segmenting projects (Appendix AA.6 Considerations). One of the most prominent benefits, as highlighted by the expert, is the improved focus that segmentation allows. By dividing the project into specific segments, teams can concentrate on their own areas of expertise, leading to higher quality work and more efficient use of resources. Specialisation, the expert advised, enables each segment to make optimal use of available technologies and skills, contributing to the overall effectiveness of the project (Appendix AA.6 Considerations).

Furthermore, the expert noted that segmentation promotes the participation of various market players, including smaller specialised companies that might not have the resources or capacity to participate in a large project otherwise. This, according to the expert, can increase competition and lead to innovations and improvements in project execution. By giving more parties the opportunity to participate, segmentation can also help integrate a broader range of ideas and approaches, ultimately benefiting the quality and efficiency of the project (Appendix AA.6 Considerations). One of the key insights, as the expert shared, is the importance of early planning and clear communication. It is essential, the expert advised, to establish clear guidelines and coordination mechanisms in the early stages of the project to ensure that all segments are well-aligned and contribute to the overall project objectives (Appendix AA.6 Considerations). Lessons from previous projects, according to the expert, highlight the need for a robust project structure and effective communication channels to address and overcome the challenges of segmentation. Segmentation, the expert concluded, offers a way to reduce

the complexity of these projects by breaking them down into more manageable parts. By leveraging the benefits of specialised resource allocation and increased market participation, segmentation can be a powerful tool for improving project execution (Appendix AA.6 Considerations).

According to another expert, a logical segmentation is characterised by minimising the interfaces between different project segments. The expert advised that segmentation is considered logical when it reduces dependencies between the segmented parts of the project to a minimum. This, as the expert explained, is essential to ensure that disruptions or delays in one segment do not cause chain reactions that affect other parts of the project (Appendix X.1 Segmentation). By minimising the number of interfaces, the expert suggested, potential conflicts and coordination issues between different teams and project phases are limited. The expert emphasised that a logically segmented project not only promotes more efficient project management but also increases the overall feasibility of the project by reducing the risk of delays and cost accumulation. The expert pointed out that this allows contractors to allocate resources more effectively and manage the project in a more controlled and predictable manner. Additionally, the expert noted, it helps create clear areas of responsibility, which is crucial for maintaining order and accountability within large construction projects (Appendix X.1 Segmentation).

Another expert highlighted the complexity of segmenting construction projects and discussed the criteria used to decide how projects are divided into segments. The expert described the importance of approaching projects from both outside-in and inside-out, which is a strategic method for determining the project approach to segmentation (Appendix Y.3 Segmentation). According to the expert, a key aspect of this decision-making is segmentation along disciplines, where projects are divided based on the various technical specialisations required for their realisation. This inside-out approach ensures a clear delineation of responsibilities and areas of expertise, which is essential for the quality and efficiency of the work. This method is particularly useful for technically complex projects, where the internal requirements and functionalities of the project guide the final execution (Appendix Y.3 Segmentation). In contrast, the outside-in approach, as the expert suggested, focuses on external factors such as the impact on the environment, interaction with the public, and other stakeholders. This ensures that the project aligns well with external requirements and expectations, which can be crucial for public acceptance and the project's success (Appendix Y.3 Segmentation). The expert emphasised that choosing the right segmentation method depends on various factors, including the nature of the project, stakeholder expectations, and the specific challenges each project presents. By carefully planning the segmentation and applying the correct criteria, clients and contractors can ensure more efficient execution and better management of risks and costs, ultimately leading to more successful project outcomes.

An additional expert discussed in detail the approaches for effective segmentation in complex infrastructure projects and explored how and where logical divisions can be made within the projects. The expert emphasised the importance of a systematic approach for successfully and efficiently implementing project segmentation, advising that the client should focus on creating clearly defined segments that simplify and optimise project execution (Appendix Z.4 Segmentation). The expert explained that successful project segmentation begins with a thorough analysis of the entire project, where project goals, key milestones, and technical requirements are assessed. Based on this evaluation, segments are formed, each comprising a specific set of tasks and responsibilities. These segments, as the expert advised, are designed to have internal cohesion and minimal dependency on each other, reducing interaction between different teams and making the project's complexity more manageable (Appendix Z.4 Segmentation).

The expert highlighted that determining where logical separations can be made involves considering various aspects of the project. For instance, technical complexity is a crucial criterion, and segments should be designed so that technically complex tasks are grouped together. This allows specialist teams to focus on specific challenges without affecting the progress of other parts of the project (Appendix

Z.4 Segmentation). Additionally, efficient resource management is important, according to the expert, and by designing segments with minimal overlap in resource usage, resources are utilised optimally. Another key aspect, as the expert advised, is risk management, where risks are identified and assigned to the segments where they can be managed most effectively (Appendix Z.4 Segmentation). Furthermore, significant deadlines and milestones serve as anchor points for forming segments, each with clear start and end points. Once the segments are defined, the expert noted that their implementation requires that each team is given clear guidelines about their specific goals and their contribution to the overall project objective. This process demands continuous communication and coordination to ensure all teams are aligned and any discrepancies between the segments are promptly addressed (Appendix Z.4 Segmentation). The expert emphasised that well-executed segmentation leads to improved focus, allowing teams to concentrate on specific tasks without being distracted by the overall project's complexity. It also results in increased operational efficiency through clear responsibilities and fewer overlapping tasks. Moreover, the expert noted that more effective risk management within controlled environments makes it easier to monitor and maintain quality (Appendix Z.4 Segmentation).

In conclusion, experts agree that segmentation is a vital strategy for managing large and complex construction projects, but they highlight different aspects of its implementation. One expert advises that the client's choice to segment projects based on time, geography, or functionality is essential for managing complexity and optimising the risk-reward ratio. This approach, according to the expert, should be introduced early in the project cycle to ensure clear scope definition and responsibility allocation, ultimately focusing on maximising efficiency, controlling costs, and reducing risks. Another expert emphasises that the decision to segment a project should consider the project's scope, size, technical and functional complexity, geographical location, and timing. This expert advises that segmenting projects into smaller, manageable units can better handle specific technical challenges and attract specialised contractors, facilitating logistics and improving resource utilisation. Furthermore, a third expert advises that logical segmentation minimises dependencies between segments, reducing potential conflicts and coordination issues. This expert highlight that effective segmentation promotes more efficient project management and resource allocation, creating clear areas of responsibility. Another expert highlights the importance of adopting a strategic approach to segmentation, using an inside-out method to focus on core technical aspects and an outside-in method to address environmental impacts and stakeholder interactions. This dual approach enhances public acceptance and overall project success. Finally, an expert underscores the importance of a systematic approach to segmentation, advising that project goals, key milestones, and technical requirements should guide the formation of segments. These expert stresses that well-defined segments with minimal dependency on each other facilitate improved focus, operational efficiency, and effective risk management.

Overall, while there is consensus on the importance of segmentation, the experts provide diverse perspectives on the criteria and methods for effective segmentation. They agree that segmentation should be carefully planned and tailored to the unique requirements of each project, with a focus on clear communication, continuous coordination, and strategic alignment. The subsequent chapters will dive deeper into these aspects and explore how experts advise implementing them effectively.

6.1.2 Co-contracting

The choice between employing co-contractors or a main contractor with subcontractors in segmented infrastructure projects is a crucial decision that could significantly impacts project efficiency and success. Experts provide detailed insights into the advantages and challenges associated with each approach, offering guidance on how to navigate these choices based on project requirements, scale, and the need for specialised expertise.

An expert highlights several crucial considerations in the context of choosing between main contractors and co-contractors. This expert explains that when segmentation is directed by the client, co-contractors are often employed to manage distinct project segments. Conversely, when segmentation is managed internally by the contractor, a main contractor is typically responsible for coordinating various subcontractors. This distinction ensures that the segmentation strategy aligns with the specific project requirements and optimises both coordination and project outcomes (Appendix Y.2 Co-contractors or main contractors). The expert points out that certain tasks can be so specialised that only a limited number of suppliers qualify. In such cases, appointing a specialised co-contractor ensures adequate competence and expertise within the project. For instance, a supplier may be specifically prescribed due to their unique experience or capabilities in a particular region or specialised work (Appendix Y.2 Co-contractors or main contractors). The expert also discusses how, in some projects, the main contractor might take on different segments themselves, engaging subcontractors in the process. According to the expert, this can become complex, especially in large-scale projects requiring specialised skills. Challenges increase when the main contractor prefers certain subcontractors, while the client sometimes favours directly appointing specialised contractors or local SMEs (Small and Medium-sized Enterprises) or as co-contractors due to their specific knowledge and skills, which contribute to the project's success (Appendix Y.2 Co-contractors or main contractors). The expert advises that the decision to appoint a co-contractor instead of having the main contractor coordinate all tasks is often driven by the need to deploy specialised competencies that the main contractor might not possess (Appendix Y.2 Co-contractors or main contractors). The expert notes that the project's scale also plays a role. In extensive projects, placing all responsibilities on one party can be risky. This not only increases the risk for the main contractor but can also affect the overall manageability of the project. By dividing segments and assigning specific tasks to qualified co-contractors, risks are spread, and the project can be managed more efficiently. The expert acknowledges that making these choices can be complex, particularly because it may appear that the client is exerting too much influence over the selection of subcontractors. This requires careful consideration and strong coordination skills to ensure smooth project execution and satisfaction of all parties involved (Appendix Y.2 Co-contractors or main contractors). The expert emphasises that this necessitates open communication and collaboration between the contractors and the client, with both parties keeping the common goal in mind: successfully completing the project with the best possible expertise (Appendix Y.2 Co-contractors or main contractors).

Another expert had a nuanced view on co-contracting, acknowledging that using co-contractors offers certain advantages such as flexibility and the ability to deploy specialised expertise for different segments of a project. Each co-contractor has a direct contractual relationship with the client, meaning they can work independently and report directly to the client. One of the main benefits of co-contracting, as highlighted by the expert, is the promotion of competition. By engaging multiple co-contractors, market competition is stimulated as more companies have the opportunity to participate in the project. This can lead to innovative use of specialised techniques and a better price-quality ratio (Appendix AA.3 Co-contractors or main contractor). Additionally, co-contractors can fully concentrate on their specific segment, increasing the likelihood of higher quality work. However, the expert also pointed out the challenges of co-contracting. One of the biggest issues is the coordination between different co-contractors. Without a central contractor bearing overall responsibility, the alignment between various segments can be complex and time-consuming. This requires strong coordination from the client and clear communication channels to ensure all co-contractors are aligned and working towards common project goals (Appendix AA.3 Co-contractors or main contractor). Furthermore, the absence of a central coordinating entity can lead to difficulties in resolving conflicts and managing interfaces between different project parts. This can result in delays and budget overruns if effective conflict resolution and coordination mechanisms are not implemented. In comparison to the main contractor with subcontractors' model, where the main contractor has central responsibility for the coordination and integration of all project segments, co-contracting offers less structure for central control. According to the expert, this makes it more challenging to ensure streamlined and integrated

project execution (Appendix AA.3 Co-contractors or main contractor). The expert emphasised that the choice between these two models heavily depends on the specific needs and complexity of the project. The expert concluded that while co-contracting can offer significant benefits in terms of flexibility and competition, it is essential for the client to ensure robust coordination mechanisms and clear communication channels. This is necessary to overcome the challenges inherent in this approach and to ensure that the project is successfully executed within the set time and budget limits (Appendix AA.3 Co-contractors or main contractor).

The insights from the experts on co-contracting provides a comprehensive understanding of the strategic considerations involved in segmented project delivery methods. Experts agree that co-contracting offers flexibility and the ability to leverage specialised expertise, enhancing competition and potentially leading to innovative solutions and better price-quality ratios. However, they also caution about the coordination challenges and the need for strong client involvement to ensure alignment and communication across all segments. The experts advise that careful planning, robust coordination mechanisms, and clear communication channels are essential to mitigate the risks associated with co-contracting. Ultimately, the choice between co-contracting and using a main contractor should be guided by the project's specific needs, complexity, and the available specialised expertise. By implementing these expert recommendations, clients can better manage their projects, ensuring successful outcomes within the set time and budget constraints.

6.1.3 Market consultation

Market consultation is a critical component for segmented project delivery methods, as highlighted by various experts. These consultations enable clients to obtain valuable insights from a range of stakeholders, including contractors and industry experts. By integrating these insights, clients can make more informed decisions, ensuring that segmentation strategies are aligned with market realities and are both practical and feasible.

An expert emphasised the importance of market consultations in developing segmentation strategies. According to the expert, market consultations allow clients to gain valuable insights from contractors, experts, and sometimes competitors, all of whom can contribute to more informed decision-making. The expert advised that these consultations are essential for adjusting segmentation plans to market realities, identifying potential challenges and opportunities, and ensuring that the chosen segmentation strategies are both practical and feasible (Appendix X.4 Market consultation). The expert described how these consultations help refine project approaches, for example, by highlighting which technological or methodological innovations can be integrated to improve project execution. The expert stressed that without this crucial market input, projects may suffer from inefficiencies or missed opportunities that could otherwise be minimised through external expertise (Appendix X.4 Market consultation). Additionally, the expert explained that market consultations not only serve to optimise project approaches but also act as a powerful tool for risk management. By understanding which segmentation practices work best under specific market conditions, project leaders can better allocate and manage risks. This approach, as the expert noted, reduces the likelihood of project delays and budget overruns and ensures a more robust project management framework (Appendix X.4 Market consultation).

Another expert also emphasised the importance of market consultation. It is crucial to consult contractors about the segmentation of the infrastructure project and the manageability of risks. According to the expert, this was previously insufficiently done, but there is now increasing focus on it (Appendix Y.7 Procurement and market consultation). The expert explained that involving the market in the decision-making process is important to improve risk management. This involvement, the expert

advised, helps gain a better understanding of the practical feasibility and potential challenges of the proposed segmentation (Appendix Y.7 Procurement and market consultation).

An additional expert emphasised the crucial importance of market consultations for segmentation. The expert clarified that a deep understanding of market dynamics is essential to determine how and where logical segmentations within a project can be made (Appendix Z.5 Market consultation). These consultations, according to the expert, play a key role in identifying the best practices, technologies, and methodologies that can be applied to optimise project segmentation and realisation. The expert explained that market consultations help gather essential insights from the market. These insights are invaluable for shaping a project's segmentation strategy. By consulting the market, project managers and planners can better understand which segmentation approaches are feasible and what specific challenges and opportunities each segment might present. This process, as the expert noted, helps not only in identifying the most efficient ways to allocate resources but also provides a platform for anticipating potential risks and adjusting the project strategy accordingly. (Appendix Z.5 Market consultation). The expert highlighted how integrating feedback from market consultations directly influences decision-making regarding the placement of logical cuts within the project. This feedback, according to the expert, can include specific recommendations about technical complexity, risk management, and overall project planning. For instance, if market consultations reveal that certain technologies or processes can make specific segments more efficient, these segments can be isolated to ensure specialised attention and resources (Appendix Z.5 Market consultation). The expert pointed out that improving risk assessment through insights from external parties allows clients to better estimate the risks associated with each segment and how best to manage them (Appendix Z.5 Market consultation). Additionally, market consultations, as the expert advised, can provide guidance on how resources can be more effectively utilised within the various segments of the project. They also stimulate innovation by learning about new techniques, materials, and methods from the market, which can enhance project efficiency and effectiveness (Appendix Z.5 Market consultation).

The insights from experts on the role of market consultations in project segmentation reveal several key takeaways. The three experts unanimously agree that market consultations are essential for refining segmentation strategies and ensuring that they are practical and feasible. By involving the market, clients can gain critical insights that help align segmentation plans with market realities. This process not only aids in identifying the most efficient ways to allocate resources but also provides a robust platform for risk management. Experts highlight that without market input, projects risk suffering from inefficiencies and missed opportunities. They also emphasise that market consultations help in better understanding the practical feasibility and potential challenges of proposed segmentations, thus allowing for more informed decision-making. Furthermore, experts advise that integrating feedback from these consultations directly influences project planning, technical complexity, and risk management. This ensures that segmentation approaches are optimised for efficiency and effectiveness, ultimately leading to more successful project outcomes.

6.1.4 Coordination and integration

Coordination and integration are crucial components for infrastructure projects, particularly in large complex, and segmented projects. Experts agree that the degree of interdependence between project segments determines the complexity of coordination responsibilities and the necessary management approaches. Effective coordination involves detailed planning, clear communication, and the use of advanced project management tools to ensure that all segments work seamlessly together. This section explores the insights and recommendations of various experts on managing coordination and integration in segmented construction projects.

An expert begins by explaining the complexity of coordination responsibility, which depends on the degree of interdependence between segments (Appendix Y.1 Coordination). According to the expert, in less dependent segments, effort-based obligations can be used, focusing on the contractor's effort without guaranteeing a specific end result. This means that the contractor must strive to perform the work properly, but no specific outcome is assured (Appendix Y.1 Coordination). For more integrated segments, the expert advises that clear agreements and result-based obligations must be made. This involves timely and clear communication of changes in one segment that affect other segments. The expert explains that the client plays a facilitating role by organising the consultation structure, while the involved contractors are responsible for tracking progress and reporting deviations. The expert emphasises that this is a continuum, where the interdependence of the segments determines how coordination responsibility is distributed (Appendix Y.1 Coordination). The expert illustrates this with an example where a contractor, not being the main contractor, is given a result-based obligation. This is complex because the contractor cannot be held fully responsible for the end result if co-contractors also play a significant role. Therefore, there must be a system where the client is responsible for the medium and the consultation structure. The expert notes that the involved contractors must continuously communicate their progress and deviations, especially when changes in their work impact other segments (Appendix Y.1 Coordination).

In discussing the integration of different segments, the expert highlights the essential importance of accurately specifying the interfaces between the segments. The expert points out that the practical challenge is to fully realise these specifications, given the complexity often involved in large projects (Appendix Y.4 Integration). According to the expert, it is critical that the output of one segment seamlessly serves as the input for the next segment, requiring a meticulously planned and flawlessly executed handover. The expert advises that while theoretical planning is often detailed and well-structured, actual implementation can be more complex than initially anticipated. This is because, in practice, not all interfaces can be fully specified in advance (Appendix Y.4 Integration). The expert underscores the importance of flexibility and adaptability in project execution and the necessity of continuous communication and collaboration between the involved parties. To effectively manage integration, the expert recommends paying special attention to coordinating the handover between segments. This includes regularly updating all parties on progress and any changes in project scope or specifications. Facilitating clear and regular communication channels is essential to ensure that all stakeholders are aligned and that any discrepancies between segments are promptly addressed (Appendix Y.4 Integration). The expert emphasises that effective integration management relies not only on technical execution but also on the project leadership's ability to cultivate a collaborative environment where openness and teamwork are encouraged. This is crucial for navigating the complexity associated with large construction projects and ensuring that the final product meets quality standards, timelines, and budgets (Appendix Y.4 Integration).

Another expert begins by emphasising the crucial importance of coordination between different segments of a construction project. The expert describes effective coordination as the backbone of successful project management, especially in complex projects involving multiple teams and technical disciplines (Appendix Z.1 Coordination and integration). According to the expert, effective coordination requires that each segment be carefully planned with well-defined interfaces and handover points, ensuring the seamless flow of work and information between segments (Appendix Z.1 Coordination and integration). The expert explains that this thorough approach to project coordination minimises the chances of errors and delays, thereby improving the overall efficiency of the project. The expert asserts that seamless integration of segments is essential for achieving project objectives and optimising resources. This process helps in delivering projects on time and within budget while ensuring the quality of the work (Appendix Z.1 Coordination and integration). Additionally, the expert emphasises the importance of advanced project management tools and techniques, which are crucial for accurate planning and execution of projects. The expert suggests that the use of these tools should be widely accepted and applied across the industry, not just within their own firm. These technologies

facilitate the complex task of project coordination, enabling project managers to proactively respond to changes and efficiently handle challenges that arise during project execution. This focus on precise coordination and integration of project segments using advanced technologies and methodologies underscores the importance of a structured approach in project management (Appendix Z.1 Coordination and integration). According to the expert, this approach allows project leaders to manage the complexity of large construction projects, improve collaboration between different teams, and ultimately contribute to the successful and efficient completion of projects (Appendix Z.1 Coordination and integration).

An additional expert explains that effective coordination between different project segments is essential for successful execution (Appendix AA.4 Coordination). The expert advises the use of advanced project management tools and regular coordination meetings. Project management tools play a crucial role in planning, monitoring, and coordinating various segments of a project. These tools help visualise project timelines, track the progress of each segment, and identify potential bottlenecks before they cause problems. By maintaining a shared project database, all involved parties can receive updates on the status of different segments, enabling better synchronisation. Additionally, regular coordination meetings are essential to ensure that all parties are aligned and have an open communication channel for discussing issues and finding solutions (Appendix AA.4 Coordination). The expert recommends that these meetings should take place at both strategic and operational levels. Strategic meetings, held by the client and key stakeholders, focus on the overall project progress, major milestones, and strategic decisions. Operational meetings, conducted by key stakeholders and the contractors, concentrate on daily progress and resolving operational issues, focusing on daily tasks, bottlenecks, and immediate coordination needs (Appendix AA.4 Coordination). The expert emphasises that coordination must balance flexibility and structure. Flexibility is necessary to quickly respond to unexpected events and changes in project conditions. Simultaneously, a robust structure is essential to ensure that all segments progress according to plan, avoiding misunderstandings or overlaps. This can be achieved by defining clear roles and responsibilities, as well as establishing protocols and procedures that are consistently followed. Each segment must have clear communication lines with the central project management team. This includes having designated contact persons for each segment responsible for communication and coordination with other segments and the central management. Regular reporting and updates on progress and any issues should be mandatory, ensuring that the central management always has a complete overview of the project's status (Appendix AA.4 Coordination).

After the establishment of the segments, they must be managed and integrated through a standardised yet adaptable management process. The expert advises that this process should be flexible enough to adjust to the specific requirements and circumstances of each segment, but also standardised to ensure consistency and coherence in project management (Appendix AA.4 Coordination). The expert suggests assigning integration (or interface) managers responsible for overseeing the interfaces between segments. Integration managers play a crucial role in ensuring cohesion between the different segments of the project. Their tasks include overseeing interfaces, identifying and resolving issues between segments, acting as a communication link between the various segments and the central project management team, and fostering a culture of collaboration and joint problem-solving. These integration managers must ensure that the interfaces between segments run smoothly and that no issues hinder the project's progress. They should identify and resolve problems between segments, ensuring a coordinated approach that supports the overall project objectives (Appendix AA.4 Coordination). By implementing a standardised yet adaptable management process and appointing integration managers, it can be ensured that all segments progress coherently and remain aligned with the overall project goals. This requires regular evaluations to assess the progress of each segment and ensure they contribute to the broader project objectives. Any deviations should be promptly addressed and corrected to keep the project on track (Appendix AA.4 Coordination).

The experts collectively highlight the paramount importance of effective coordination and integration in segmented infrastructure projects. They emphasise that the degree of interdependence between segments dictates the complexity of coordination responsibilities. In projects with less interdependence, effort-based obligations are recommended, focusing on the contractor's effort rather than a guaranteed outcome. Conversely, for highly integrated segments, clear result-based obligations are necessary, along with timely and clear communication of changes impacting other segments. The client plays a crucial role in facilitating the consultation structure, while contractors must track progress and report deviations. Furthermore, the experts stress the necessity of meticulously planning interfaces and handover points to ensure seamless integration. They underscore the significance of advanced project management tools for planning, monitoring, and coordinating project segments. Regular strategic and operational coordination meetings are advised to maintain alignment and open communication among all parties. Balancing flexibility and structure are crucial. The experts also recommend the appointment of integration (or interface) managers to oversee segment interfaces, resolve issues, and foster collaboration. Effective integration management hinges not only on technical execution but also on cultivating a collaborative environment where openness and teamwork are encouraged. This approach ensures that large construction projects meet quality standards, timelines, and budgets, ultimately leading to successful project outcomes.

6.1.5 Risk management

Effective risk management is a critical component for the successful realisation of a segmented infrastructure project. The complexity of these projects necessitates careful consideration of how risks are allocated, managed, and communicated among various stakeholders. Insights from experts highlight the importance of clear agreements on responsibilities and liabilities, strategic risk allocation, and fostering a culture of transparency and accountability within project teams. These elements are vital for minimising potential problems and ensuring the seamless execution of large-scale infrastructure projects.

An expert advised that when allocating risks across interfaces or connection points, it is essential to make clear agreements about responsibilities and liabilities to avoid problems (Appendix Y.6 Risk allocation). The expert discussed the differences between large contractors and (smaller) SME contractors. According to the expert, large builders can better handle complex coordination and large projects due to their capacity and systems, while SME contractors benefit more from manageable segmentations and compartmentalisations. The expert explained that large builders have the resources and systems to manage large, complex projects and maintain coordination, whereas SME contractors find better-managed segmentations and compartmentalisations more advantageous. This difference, the expert noted, must be considered when segmenting projects (Appendix Y.6 Risk allocation).

Another expert placed considerable emphasis on the importance of effective risk management within the context of segmented construction projects (Appendix Z.3 Risk management). The expert clarified that effective risk allocation is essential for the success of projects, especially when they are divided into multiple, often complex segments. The expert’s approach includes a series of strategic steps designed to manage and minimise risks throughout the project (Appendix Z.3 Risk management). According to the expert, effective risk management begins with a detailed risk analysis conducted before the project starts. This initial analysis aims to identify and quantify all possible risks that might affect each segment of the project (Appendix Z.3 Risk management). The expert stressed the importance of this step as it provides a thorough understanding of potential obstacles and challenges each segment may encounter. This enables proactive measures to be planned and implemented before the project begins, significantly reducing the likelihood of unforeseen problems. Following the risk analysis is the strategic allocation of risks to the parties best equipped to manage them (Appendix Z.3 Risk management). The expert explained that this allocation is carefully considered based on the

expertise and capabilities of each party. By assigning risks to the most suitable parties, the chances of successful mitigation are maximised. This approach ensures not only more efficient risk management but also contributes to the overall stability and predictability of the project (Appendix Z.3 Risk management).

Another crucial aspect the expert highlighted is promoting a culture of transparency and accountability within the entire project team. The expert noted that in a segmented project, where different teams may work on various components, it is essential that all stakeholders are fully aware of the risks and their potential impact (Appendix Z.3 Risk management). This openness ensures that all teams are not only aware of the risks they manage but also understand how their actions might affect other segments of the project. This informed approach, according to the expert, helps build a stronger, more cohesive working relationship between all segments and enhances overall project efficiency (Appendix Z.3 Risk management).

In conclusion, the insights from experts underline the paramount importance of effective risk management in segmented construction projects. The experts agree that clear risk allocation, tailored to the capacities of both large contractors and smaller (SME) contractors, is essential for managing complex projects. Detailed risk analysis before the commencement of the project is critical for identifying and quantifying potential risks, allowing for proactive mitigation strategies. Moreover, the strategic allocation of risks to the most capable parties ensures better management and enhances the project's stability and predictability. The experts also highlight the necessity of fostering a culture of transparency and accountability among all stakeholders. This culture ensures that each team is fully aware of the risks and their potential impacts, promoting a cohesive and collaborative working environment. By implementing these expert recommendations, clients and contractors can significantly reduce the likelihood of delays and budget overruns, ensuring successful outcomes.

6.1.6 Project delivery methods and contract forms

The choice of a project delivery method is a critical aspect that significantly influences the efficiency and success of construction projects. Various experts provide insights into the complexities and considerations involved in selecting the most suitable approach, particularly for segmented projects.

An expert discussed the critical aspect of the procurement procedure. The expert advises the client to start thinking about segmentation from the very beginning of project initiation. (Appendix Y.9 Procedure). When a project is proposed, the client should consult with the involved parties to determine whether the project should be executed as a single unit or in multiple segments. This conversation, the expert noted, should occur even before the procurement strategy is defined (Appendix Y.9 Procedure). Throughout the process, the expert explained, there is contemplation on whether the project should be tendered as one or multiple procurements. The expert noted that the concept of segmented contracting should be considered early on (Appendix Y.9 Procedure). The expert emphasised the importance of a holistic approach, clear communication, and close collaboration between all involved parties. These insights, the expert highlighted, underscore the complexity and the necessity of careful planning and coordination in the segmentation of construction projects to effectively address both technical and organisational challenges (Appendix Y.9 Procedure).

The expert advised that the choice of a project delivery method depends on the specifics of the project. The expert highlighted that an integral approach can be complex, while a segmented approach requires clear coordination responsibilities and close collaboration between various parties (Appendix Y.8 Project delivery method). The expert discussed how segmentation contributes to the functionality and management of the environment. According to the expert, it is important to minimise dependencies between segments and to adopt an outside-in or inside-out perspective when making decisions about

segmentation. The expert emphasised that the choice of the construction delivery method should be tailored to the specifics of the task and the coherence between the segments (Appendix Y.8 Project delivery method). The expert advised that it is crucial to thoroughly consider how the coherence between segments can be managed in advance, including sequencing, overruns, planning, phasing, and optimisation within and between work packages (Appendix Y.8 Project delivery method).

Another expert highlighted that employing uniform contract forms across a segmented project offers significant benefits in terms of contract manageability and procurement speed. However, in practice, a combination of different contract forms is often used, depending on the technical and operational requirements of each project segment (Appendix AA.7 Project delivery method). The expert stressed that market consultation plays a significant role in determining the most suitable contract forms by gaining insights into the capabilities and preferences of potential contractors. In conclusion, the expert emphasised that the choice of a project delivery method depends heavily on the context and requirements of the project (Appendix AA.7 Project delivery method). Finding a balance between flexibility and manageability is essential, as is using market consultation to determine the best-suited contract forms. By employing a combination of contract forms and effective coordination and communication channels, segmented construction projects can be successfully managed and executed (Appendix AA.7 Project delivery method).

In conclusion, the insights provided by both experts underscore the complexity and importance of choosing the appropriate project delivery method and contract forms for segmented construction projects. Key considerations include early and strategic planning, clear coordination responsibilities, and the careful management of dependencies between segments. Experts advocate for a holistic approach, combining different contract forms tailored to the specific requirements of each project segment. The importance of market consultation to understand the capabilities and preferences of contractors is also highlighted. By balancing flexibility with manageability and ensuring robust communication and coordination, segmented construction projects can achieve greater efficiency, reduced risks, and successful outcomes.

6.1.7 Finance and budget

Effective financial management is critical for the successful realisation of segmented complex infrastructure projects. This section explores expert insights on budgeting challenges and strategies to ensure financial health and project efficiency.

An expert advised that in the context of budgeting and cost control, challenges arise when projects are divided into separate segments (Appendix Y.5 Finance). According to the expert, this segmentation can make budgeting significantly more rigid, reducing operational flexibility and potentially leading to inefficiencies. The expert noted that this rigidity in budgeting can be problematic, especially when unforeseen adjustments become necessary. Additionally, the expert explained that the rigid budgeting practices inherent in segmented projects complicate dynamic financial management (Appendix Y.5 Finance). The expert cited situations where a specific segment might require more financial resources to function efficiently or to support another segment. The strict financial boundaries between segments make shifting budgets difficult, which can lead to suboptimal outcomes, higher total costs, and extended project durations (Appendix Y.5 Finance). The expert emphasised the importance of flexibility within the financial planning and management of construction projects. The expert advocated for a more fluid approach to budgeting where adjustments can be made as project conditions change. This requires a proactive stance from all involved parties, anticipating potential financial hurdles and planning ahead rather than merely reacting to problems as they arise. The expert stated that such an approach is crucial to ensure the financial health and success of large-scale

construction projects and to ensure projects are completed within budget and on schedule (Appendix Y.5 Finance).

An additional expert provided a detailed analysis of the budgeting challenges specifically related to the segmentation of construction projects (Appendix Z.2 Finance). The expert explained how traditional budgeting methods often fall short in addressing the dynamic and often unpredictable nature of complex infrastructure projects. According to the expert, these traditional methods are usually rigid and offer little room for adjustments once the project is underway, which is inefficient given the reality of construction where changes and unforeseen events are more common than not. The expert advised that effective project segmentation requires a much more flexible approach to financial management (Appendix Z.2 Finance). The expert suggested that in an ideal financial management system, clients should have the autonomy and resources to quickly respond to changing circumstances. This means that within the project's segmentation, each segment should have a certain degree of financial flexibility to reallocate funds in response to immediate needs or unforeseen challenges (Appendix Z.2 Finance). The expert emphasised that a more flexible budgeting system not only enhances the financial resilience of a project but also significantly contributes to minimising risks associated with budget overruns and unexpected costs. By giving integration managers, the ability to manage funds within their assigned segments, a more responsive and adaptive financial flow is created, better equipped to handle the complexity and volatility of modern construction projects (Appendix Z.2 Finance).

A crucial aspect highlighted by the expert is the necessity for transparent collaboration between all segments and involved parties. The expert noted that transparency in financial matters and project progress is essential to build mutual trust and to keep all stakeholders informed about the project's status and needs (Appendix Z.2 Finance). Transparency, according to the expert, not only facilitates communication and collaboration between different teams but also enables them to act proactively and respond collectively to the dynamic project environment (Appendix Z.2 Finance). Furthermore, the expert illustrated how this flexible budget management is an integral part of a broader strategy for cost control and efficiency improvement. By giving each segment control over part of the budget, integration manager become more engaged and responsible for the financial outcomes of their specific part of the project. This, as the expert advised, promotes a deeper understanding of the cost structure within each segment and fosters a more cost-conscious culture throughout the entire project team (Appendix Z.2 Finance).

In conclusion, the experts collectively emphasised the need for flexible and dynamic financial management in segmented infrastructure projects. They advised that a rigid budgeting approach can lead to inefficiencies and higher costs, whereas a flexible system allows for better risk management and financial control. Transparent collaboration and proactive planning were highlighted as essential elements to ensure financial health and project success. By empowering integration managers with budgetary control and fostering a transparent and collaborative environment, complex infrastructure projects can be more effectively managed and executed within budget.

6.1.8 Partnerships

Effective partnerships are crucial for achieving successful outcomes. However, the approach to segmentation can significantly impact these partnerships. As contractors in a consortium could become co-contractors, the nature of their collaboration might change, necessitating different coordination and integration efforts to maintain effective teamwork. An expert expressed concern about how segmentation might undermine the integrity of collaborative partnerships (Appendix X.3 Partnerships). The expert highlighted that in an industry where chain collaboration and integrated contracts are becoming increasingly important, dividing projects into separate segments can disrupt the natural synergies that arise from teamwork and shared responsibilities. These synergies are often vital, as they

enable contractors within a consortium to effectively collaborate and manage the complexities of complex projects. When projects are segmented, this collaborative dynamic can be compromised, potentially hindering the ability to tackle complex tasks efficiently. (Appendix X.3 Partnerships). The expert emphasised that a fragmented approach could lead to an "every man for himself" mentality, which is counterproductive for projects that rely on the seamless integration of diverse expertise and services. The expert concluded that segmentation brings both benefits and significant risks. While segmentation can help make complex projects more manageable by breaking them into smaller, more controllable parts, the expert warned that it can also lead to issues with collaboration and coordination between different contractors and clients. This is particularly problematic in an industry that increasingly values chain collaboration and integrated contract forms (Appendix X.3 Partnerships). The expert stressed that logical segmentation, which creates minimal interfaces and dependencies between segments, is essential to mitigate the negative effects of segmentation. However, the expert noted that even with careful planning, segmenting projects can disrupt the natural synergies that come from teamwork and negatively impact project efficiency (Appendix X.3 Partnerships). The expert suggested that segmentation might be useful primarily in situations where budget constraints are significant or where specific technical or geographical challenges justify it. However, the expert advised against segmentation as a standard approach, especially when it can undermine the integrity of collaborative partnerships and hinder the larger project goals (Appendix X.3 Partnerships).

6.1.9 Conclusion expert interviews

The insights from experts on segmentation in complex infrastructure projects reveal a nuanced understanding of the benefits and challenges associated with this approach. The segmentation strategy, while essential for managing large and complex projects, requires strict planning and robust coordination mechanisms to be effective. Experts universally agree on the importance of segmentation in enhancing project manageability and efficiency. By dividing projects into smaller, more manageable segments, clients can allocate resources and expertise more effectively, tailor risk management strategies, and maintain better control over budgets and schedules. This strategic division facilitates focused attention on specific tasks and challenges, leading to higher quality outcomes and more predictable project trajectories. However, experts also highlight significant challenges associated with segmentation. The need for seamless integration and coordination across multiple segments is paramount. Without a unified command structure, projects can face inefficiencies, increased risks, and potential delays. Ensuring effective communication and coordination among various contractors is crucial to address these challenges. Experts emphasise the necessity of well-defined coordination agreements that outline roles, responsibilities, and procedures for managing interfaces and resolving conflicts. These agreements should also incorporate clear communication protocols and regular updates to maintain alignment and project progress. Furthermore, the integration of segmented project components demands detailed contractual provisions. Adjustments to standard contracts, such as UAC 2012 or UAC-IC 2005, are necessary to fit the specific demands of segmented projects. Experts recommend incorporating flexible terms for managing changes, robust risk allocation strategies, and clear protocols for issue resolution. They also underscore the importance of supplementary agreements outside the primary contract to support the project's dynamic needs. Procurement processes in segmented projects require a nuanced approach. Selecting contractors based on technical competence, experience, and financial stability is critical, particularly for large and complex projects. Detailed technical specifications and clear project requirements in tender documents are essential to avoid misunderstandings. Transparent and open tendering processes, including pre-bid meetings, help foster competitive bidding and ensure that all contractors fully grasp their responsibilities. Despite the benefits of segmentation, experts caution about the risks to collaborative partnerships. Segmentation could lead to different types of collaboration between contractors, which could be worrisome for those whose business models rely on working in consortiums. As contractors in a consortium become co-contractors, the nature of their collaboration might change, requiring different coordination and

integration efforts. Effective partnerships are crucial for successful outcomes, and the approach to segmentation can significantly impact these partnerships, potentially requiring a different mentality from contractors as they could become co-contractors in a segmented project.

In conclusion, the experts' insights provide a comprehensive understanding of the critical factors and best practices for managing segmented infrastructure projects. Effective segmentation hinges on early and strategic planning, robust coordination mechanisms, transparent communication, and flexible legal frameworks. By addressing the challenges associated with segmentation and implementing these expert recommendations, clients and contractors can enhance project integration, mitigate risks, and achieve successful outcomes in large-scale infrastructure projects.

6.2 Insights of legal experts

This chapter showcases the perspectives of various legal experts on how segmentation impacts the coordination, communication, integration, and procurement processes within complex infrastructure projects. These experts explore the inherent complexities and benefits of segmenting projects, highlighting the critical factors that influence the effectiveness of segmented project delivery methods.

6.2.1 Segmentation

This chapter delves into general insights from various legal experts on how segmentation impacts the coordination, communication, integration, and procurement processes within complex infrastructure projects. These experts explore the inherent complexities and benefits of segmenting projects, highlighting the critical factors that influence the effectiveness of segmented project delivery methods.

One legal expert noted that coordination, communication, integration, and procurement are largely consistent across different segmented project delivery methods (Appendix T.1 Segmentation). The expert highlighted the critical need for precise coordination among various contractors, each with specific obligations to the client. This need remains unchanged despite the diversity in relationships brought about by segmentation. Effective segmentation requires meticulous planning and a deep understanding of the interfaces between project segments (Appendix T.1 Segmentation). The complexity of segmentation increases with the project's size and demands thorough coordination to ensure smooth cooperation among all segments. Flexibility in segmentation is influenced by the type of project delivery method, and segmentation can complicate procurement processes if not managed carefully. Each segment requires its own procedure, potentially complicating coordination if segment definitions and transitions are not managed effectively (Appendix T.1 Segmentation).

Another legal expert emphasised that segmentation, while making projects more manageable by breaking them into smaller parts, significantly increases the need for precise coordination and communication (Appendix U.1 Segmentation). The complexity of segmentation arises from the necessity to integrate various segments, demanding thorough coordination and meticulous alignment between different co-contractors (Appendix U.1 Segmentation). The chosen project delivery method significantly impacts how segmentation is approached. In an integrated project delivery method, where a main contractor assumes full responsibility for design and realisation, segmentation can be managed internally, leading to tighter control and less fragmentation. However, in a segmented project delivery method involving multiple co-contractors, segmentation leads to more complex interactions and extensive coordination needs (Appendix U.1 Segmentation). The choice of project delivery method greatly determines the approach to segmentation and how coordination, communication, and integration are handled. Each method offers different advantages and challenges, and selecting a specific approach must be carefully tailored to the project requirements, available resources, and ultimate project goals (Appendix U.1 Segmentation). The expert also discussed the dynamics between

co-contracting and main contracting with subcontractors in segmented project delivery models. The expert noted that co-contractors are often used for specialised work outside the main contractor's core competencies, promoting direct client-specialist relationships for better control over project parts. Conversely, main contractors managing subcontractors streamline communication and simplify contractual relationships by acting as the sole client contact. The choice between these approaches depends on project-specific factors, complexity, and the need for specialised knowledge. Both methods aim for efficiency, effective project management, and risk management. Regardless of the structure, transparency in responsibilities, clear communication, and a solid contractual foundation are essential to prevent conflicts and ensure project success within time and budget.

A third legal expert acknowledged that segmenting can be an essential strategy within complex infrastructure projects, especially to increase efficiency by dividing large projects into manageable parts. However, the expert also emphasised the challenges associated with this approach, such as the need for rigorous coordination and effective communication among various involved parties (Appendix W.1 Segmentation). The expert indicated that segmenting often leads to the engagement of co-contractors, which can introduce complexities in project management. Each of these co-contractors has a direct contractual relationship with the client, which can sometimes lead to coordination and communication issues due to the absence of a central authority managing the integration of all segments. This can cause inefficiencies and misunderstandings unless very clear guidelines and contractual provisions are established (Appendix W.1 Segmentation). The expert believed that although segmenting offers certain benefits, such as flexibility and the efficient use of specialised expertise, it is essential to establish a solid framework of coordination and communication. This helps to ensure the overall project goals are met and that all segments work seamlessly together to achieve the project's end objective (Appendix W.1 Segmentation).

In sum, while segmentation can improve the manageability and efficiency of complex infrastructure projects, it also introduces significant challenges, particularly in coordination, communication, and integration. The effectiveness of segmented project delivery methods largely depends on how well these aspects are managed. The subsequent chapters will provide a comprehensive analysis of each element, offering deeper insights by the legal experts into coordination, communication, integration, and procurement within segmented project delivery methods.

6.2.2 Coordination in segmented project delivery methods

Effective coordination is a critical factor in the success of segmented infrastructure projects, which involve multiple segments and various stakeholders. This section draws on insights from several legal experts who discuss the complexities and essential strategies for achieving efficient coordination. Each expert offers unique perspectives on the roles, responsibilities, and mechanisms necessary to ensure seamless integration and communication across all project segments.

According to one legal expert, effective coordination in segmented project delivery methods is complex due to potential misalignment of segments, and thorough early-stage design and planning are necessary to ensure seamless integration (Appendix T.2 Coordination in segmented project delivery methods). Building Information Modelling (BIM) is highlighted as an effective tool, and all these aspects should preferably be like this. The legal expert advises that while clients can appoint a co-contractor for coordination, preference often lies with the contractor handling the main bulk of the project, as they are more involved in daily execution and have a better overview of interactions between segments and participants, including co-contractors and subcontractors, and this should preferably be the approach (Appendix T.2 Coordination in segmented project delivery methods). The legal expert recommends that an effective coordination agreement should outline roles and responsibilities, procedures for coordination failure, and conflict resolution mechanisms, and all these aspects should

preferably be included. The agreement, according to the legal expert, must ensure a fair distribution of tasks, considering varying contractor capacities, and anticipate issues like delays, budget overruns, and quality problems, with steps for resolution, and this should preferably be the standard (Appendix T.2 Coordination in segmented project delivery methods). The legal expert suggests that coordination obligations are usually documented separately, allowing both parties to define specific duties and responsibilities, independent of the main agreements, and this should preferably be the practice. Conflict resolution, as advised by the legal expert, is often included, outlining dispute management procedures, including possible arbitration, and all these aspects should preferably be adopted (Appendix T.2 Coordination in segmented project delivery methods).

According to another legal expert, effective coordination is essential for the success of segmented construction projects (Appendix U.2 Coordination in segmented project delivery methods). The expert highlighted the need for strategic design in coordination, focusing on clear communication, defined roles, and regular updates. The legal expert advised that coordination responsibilities can vary, sometimes the client is best suited, especially for projects needing high integration, while other times a main contractor or independent coordinator is more appropriate (Appendix U.2 Coordination in segmented project delivery methods). A thorough coordination agreement, as recommended by the expert, should include clear communication procedures, project milestones, and roles, along with risk management and conflict resolution protocols. The coordinator's responsibilities include monitoring progress, facilitating team interactions, and resolving conflicts (Appendix U.2 Coordination in segmented project delivery methods). The expert noted that coordination obligations can be part of the standard contract or a separate agreement, with predefined mechanisms for resolving disputes (Appendix U.2 Coordination in segmented project delivery methods). The legal expert also stressed the importance of early and continuous involvement of key project figures to ensure shared understanding and cooperation, which is vital for the success of a segmented approach (Appendix U.2 Coordination in segmented project delivery methods).

Two legal experts emphasised that coordination in segmented construction projects requires careful planning, with a clear structure and communication paths essential to managing project complexity (Appendix V.2 Coordination in segmented project delivery methods). The responsibility for coordination can vary depending on project size and complexity, it may be best handled by the client, especially when high integration is needed. The appointed coordinator should oversees project progress, ensuring adherence to timelines and budgets, and acts as the central contact for all project-related issues, including authorising changes and managing conflicts (Appendix V.2 Coordination in segmented project delivery methods). The legal experts highlighted that a well-crafted coordination agreement is crucial for project success, clearly defining the roles, responsibilities, and expectations of all parties involved, thus reducing ambiguity and minimising conflicts. This agreement should include clear communication protocols, detailed responsibilities, and procedures for issue escalation to maintain efficiency and project progress. Regular coordination meetings are essential for structured updates and addressing potential problems promptly. The agreement should also contain sanctions and incentives to ensure compliance and reward performance, fostering a motivated environment. Legal clarity is vital, making the agreement binding and enforceable, often requiring review by legal experts (Appendix V.2 Coordination in segmented project delivery methods). According to the legal experts, while coordination obligations are often part of the standard contract, a separate agreement is preferable for particularly complex coordination needs, providing a clearer legal basis and formal structure for large or technically complicated projects. This approach addresses specific coordination details and nuances, formalising expectations and responsibilities that standard contracts might not cover. Finally, successful coordination relies on transparency, mutual respect, and regular communication between clients and contractors, essential to avoiding significant delays and cost overruns (Appendix V.2 Coordination in segmented project delivery methods).

The fifth legal expert emphasised that coordination can often lead to misunderstandings if not clearly defined, making it crucial for all parties to precisely understand what is meant by coordination (Appendix W.2 Coordination in segmented project delivery methods). The legal expert advised that clear agreements must be made on how coordination will be structured. According to this expert, the responsibility for coordination can vary based on the specific requirements and structure of the project. The legal expert noted that it can be assigned to one of the contractors or an external coordinator, but it often starts with the client making strategic decisions about the procurement and organisation of the project (Appendix W.2 Coordination in segmented project delivery methods). An effective coordination agreement, as recommended by the expert, should include a clear plan that all relevant parties understand and endorse. This plan must clearly outline responsibilities, timelines, and methods of information provision to prevent misunderstandings and conflicts (Appendix W.2 Coordination in segmented project delivery methods). According to the expert, the coordinator's tasks and powers include collecting and distributing information from all involved parties to ensure a successful realisation of the infrastructure project. Although the coordinator's focus may vary, the legal expert advised that it usually involves managing the schedule and overseeing interactions between different parties to ensure the project is completed efficiently and within the set time limits (Appendix W.2 Coordination in segmented project delivery methods). The expert noted that coordination obligations are sometimes included in a standard contract but can also be addressed through a separate agreement, depending on the project's complexity and specific requirements. According to the legal expert, conflicts over coordination are often resolved through mediation or arbitration, especially when they arise between different contractors and the client (Appendix W.2 Coordination in segmented project delivery methods). The expert stressed the importance of having clear conflict resolution mechanisms in place to avoid hindering project progress. Additionally, the legal expert highlighted the importance of good communication and information sharing among all involved parties as essential aspects of coordination, with timely and relevant information sharing being crucial to keeping everyone informed of the project's requirements and changes (Appendix W.2 Coordination in segmented project delivery methods).

The legal expert interviews have provided valuable insights into the coordination of segmented project delivery methods, highlighting the complexities and essential strategies for ensuring successful project outcomes. Legal experts agree that effective coordination in segmented construction projects is complex due to potential misalignment of segments and necessitates thorough early-stage design and planning, with BIM recommended as an effective tool. While the responsibility for coordination can vary, the preference often lies with the contractor handling the main bulk of the project, as they are more involved in daily execution and have a better overview of interactions between segments and participants, while the client is advised to oversee the broad outlines and interfaces between segments. Experts emphasised the importance of a comprehensive coordination agreement that clearly outlines roles, responsibilities, procedures for coordination failure, and conflict resolution mechanisms. These agreements should ensure a fair distribution of tasks, considering the varying capacities of contractors and subcontractors, and anticipate potential issues such as delays, budget overruns, and quality problems. Additionally, the legal experts stressed the necessity of clear communication protocols and regular updates to maintain efficiency and project progress. Coordination obligations should be documented, often in separate agreements, to provide a clearer legal basis and formal structure, especially for large or technically complex projects. In conclusion, the experts unanimously agree that successful coordination in segmented complex infrastructure projects hinges on meticulous planning, clear communication, and well-defined roles and responsibilities. By implementing these strategies, clients can enhance project integration, mitigate risks, and achieve project objectives efficiently. Effective coordination not only promotes smoother realisation of the project but also fosters a collaborative culture among stakeholders, ultimately contributing to the overall success of segmented construction projects.

6.2.3 Communication and information provision in segmented project delivery methods

Effective communication and information provision are fundamental to the success of segmented project delivery methods in construction. These projects involve multiple segments and stakeholders, necessitating clear communication protocols and structured information sharing to ensure all parties are aligned and the project progresses smoothly. Insights from various legal experts highlight the critical elements and strategies required to establish strong communication frameworks within segmented projects.

The first legal expert highlighted that clear communication agreements are essential for optimising collaboration among all involved parties, including contractors and the client (Appendix T.3 Communication and information provision in segmented project delivery methods). The legal expert advised that these agreements should cover update frequency, communication channels, division of responsibilities, and escalation procedures. Establishing these parameters, according to the first legal expert, helps manage expectations and ensures streamlined information transfer. The expert stressed the importance of sharing crucial information such as technical drawings, schedule updates, and design changes consistently and promptly to keep all project segments aligned and allow for quick adjustments, thus reducing delays and enhancing overall project efficiency (Appendix T.3 Communication and information provision in segmented project delivery methods). The legal expert noted that communication and information obligations are typically documented in contracts, project management plans, and communication protocols. These documents, as advised by the first legal expert, define the legal and operational frameworks for project communication, ensuring all parties adhere to these guidelines. Specific obligations for contractors, according to the first legal expert, include regularly and promptly reporting relevant project information, maintaining high transparency, and immediately reporting potential or actual conflicts. These obligations, as the first legal expert recommended, promote openness and proactive problem-solving within the project (Appendix T.3 Communication and information provision in segmented project delivery methods). Protecting confidential information is another critical component. The legal expert recommended using non-disclosure agreements, secure communication systems, and restricting access to sensitive information to ensure privacy and data security (Appendix T.3 Communication and information provision in segmented project delivery methods). Finally, the expert discussed resolving conflicts over information exchange and communication. This approach, as advised by the first legal expert, includes predefined conflict resolution procedures, employing impartial mediators, and, if necessary, taking legal action. These mechanisms, according to the first legal expert, ensure disputes are handled effectively and efficiently, minimising their impact on the project. (Appendix T.3 Communication and information provision in segmented project delivery methods)

The second legal expert emphasised the importance of having clear and functional communication protocols (Appendix U.3 Communication and information provision in segmented project delivery methods). The legal expert advised that essential communication agreements between (co-)contractors and the client must specify who is responsible for sharing which information and within what timeframe. According to the legal expert, a system of regular updates is necessary (Appendix U.3 Communication and information provision in segmented project delivery methods). The legal expert advised that crucial information for seamless project operations, such as technical drawings, work schedules, safety protocols, and project changes, must be shared and accessible to all relevant parties. This ensures everyone is aware of the most current project data and plans. These communication and information obligations are typically documented in project contracts or other legal documents prepared before the work begins, legally binding all parties to adhere to the agreed communication protocols, as advised by the legal expert. Such documentation also specifies procedures for updating information and mechanisms for data sharing, according to the expert. Specific communication obligations include the need for subcontractors to regularly inform each other and the client about progress and any issues that may impact other project segments. This includes reporting delays,

technical problems, or changes in the work scope (Appendix U.3 Communication and information provision in segmented project delivery methods). To safeguard the confidentiality of sensitive project information, the legal expert recommended using non-disclosure agreements and protecting data through secure communication channels and platforms, ensuring only authorised parties have access (Appendix U.3 Communication and information provision in segmented project delivery methods). The legal expert noted that conflict resolution over communication is usually managed through predetermined procedures included in the agreements. This might involve a neutral third party, such as an arbitrator, to help resolve disputes over information exchange or communication, according to the expert (Appendix U.3 Communication and information provision in segmented project delivery methods). The effectiveness of communication and information provision within a segmented construction project strongly depends on the initial design of the communication structure, the accuracy of its implementation, and its consistent application throughout the project's lifespan. This fosters a collaborative culture and ensures the smooth execution of complex projects (Appendix U.3 Communication and information provision in segmented project delivery methods).

In segmented complex infrastructure projects, implementing a robust communication and information system that spans all project aspects is essential, as advised by two legal experts (Appendix V.3 Communication and information provision in segmented project delivery methods). These experts highlighted that establishing effective communication channels and clear information exchange protocols is crucial for the success of these complex projects. According to the legal experts, the successful realisation of segmented projects requires carefully planned communication agreements. These agreements should specify the frequency and methods of communication, as well as detailed responsibilities for all parties involved. This communication structure ensures continuity and consistency in information transfer, which is vital for synchronising activities across different project segments (Appendix V.3 Communication and information provision in segmented project delivery methods). The experts advised that sharing crucial information, such as technical drawings, detailed project timelines, and regular progress updates, is fundamental. This information must be accessible to all parties to ensure everyone is aligned and the project proceeds according to plan. Such transparency helps identify and address potential problems before they significantly impact the project (Appendix V.3 Communication and information provision in segmented project delivery methods)t. Legal experts emphasised that these communication and information obligations are typically formalised through contractual agreements. These documents are essential as they not only specify communication expectations but also provide the legal certainty necessary to maintain order within the project. These contracts detail protocols for meeting frequency, communication technologies, and procedures for updating project information (Appendix V.3 Communication and information provision in segmented project delivery methods). The use of non-disclosure agreements, secure communication platforms, and strict access controls is crucial for protecting confidential information, according to the experts. These measures ensure sensitive data is protected from external threats and internal leaks, safeguarding the project's integrity (Appendix V.3 Communication and information provision in segmented project delivery methods). The legal experts also highlighted the need for clearly defined conflict resolution mechanisms, which should be included in the project documentation. These mechanisms are essential for quickly and effectively addressing the inevitable disagreements and misunderstandings that arise in complex, segmented projects (Appendix V.3 Communication and information provision in segmented project delivery methods). Finally, the experts stressed that a thorough and detailed communication strategy is not only an operational necessity but also a strategic one. By creating an open and transparent communication environment, risks are managed, and a culture of trust and collaboration is fostered. This is critical in segmented projects, where the effectiveness of coordination directly impacts the project's success (Appendix V.3 Communication and information provision in segmented project delivery methods).

The fifth legal expert emphasised that effective communication and information provision are crucial in segmented project delivery methods (Appendix W.3 Communication and information provision in

segmented project delivery methods). This expert advised that essential communication agreements between subcontractors and clients should include the continuous sharing of all necessary information, such as schedules, technical drawings, and permits. Such information sharing ensures smooth progress and aids the master planner in maintaining the overall project schedule, which is vital for both the planning and coordination of the project (Appendix W.3 Communication and information provision in segmented project delivery methods). Furthermore, the expert mentioned that communication and information obligations are typically documented contractually in project agreements or annexes. This documentation must be clear and detailed, so all parties know exactly what information needs to be shared and when (Appendix W.3 Communication and information provision in segmented project delivery methods). The expert noted that specific obligations for contractors should include regular updates on work progress and any issues that might impact the schedule or quality (Appendix W.3 Communication and information provision in segmented project delivery methods). Finally, the legal expert explained that conflicts over information exchange and communication are usually resolved through mediation. The expert stressed the importance of having clear conflict resolution procedures to minimise project disruptions and ensure all parties can continue constructively (Appendix W.3 Communication and information provision in segmented project delivery methods).

In conclusion, legal experts consistently emphasise the crucial role of robust communication and information systems in segmented complex infrastructure projects. They agree that clear communication agreements, including update frequency, communication channels, and defined responsibilities, are essential for optimising collaboration among all parties. Legal experts highlight the importance of promptly sharing critical information, such as technical drawings and schedule updates, to maintain alignment and reduce delays. Contractually documenting communication and information obligations ensures adherence to agreed protocols, promoting transparency and proactive problem-solving. Protecting confidential information through non-disclosure agreements and secure systems is vital for maintaining project integrity. The experts also stress the importance of having predefined conflict resolution procedures to handle disputes efficiently and minimise project disruptions. By implementing these strategies, segmented complex infrastructure projects can achieve integration, improve overall project efficiency, and foster a collaborative culture essential for successful project delivery.

6.2.4 Integration in segmented project delivery methods

Effective integration is crucial for the success of segmented projects. Legal experts provide various insights into how contractual provisions can ensure this integration, emphasising the importance of clear agreements, flexible terms, and robust risk management strategies. This chapter synthesises the legal experts' advice on the necessary adjustments to standard contracts to facilitate seamless integration across project segments.

For segmented infrastructure projects to succeed, the first legal expert emphasised the importance of integration (Appendix T.4 Integration in segmented project delivery methods). The expert advised that this integration is ensured contractually by including clear agreements and clauses that specifically address collaboration and communication between different segments (Appendix T.4 Integration in segmented project delivery methods). According to the legal expert, a key aspect of this is the role of the client, who is often contractually responsible for overseeing integration and serving as the central communication point between segments. The first legal expert explained that this approach helps maintain cohesion and ensures that project objectives are met within the set timelines and budgets (Appendix T.4 Integration in segmented project delivery methods). Regarding adjustments to standard UAC 2012 or UAC-IC 2005 contracts to ensure effective integration of project segments, the legal expert pointed out several specific changes. Firstly, the expert advised that it is essential to clearly define the roles and responsibilities of all parties concerning their contribution to the integration of work. This

may involve including more detailed obligations on information exchange methods, required coordination mechanisms, and conflict escalation procedures. Additionally, the expert noted that contracts must offer flexibility for adjustments in work without leading to extensive contract modifications, which often requires revising standard terms related to change management and compensation (Appendix T.4 Integration in segmented project delivery methods). Furthermore, the legal expert advised including incentives for achieving integration objectives and penalties for failing to meet integration commitments. Another important adjustment, as recommended by the legal expert, concerns risk allocation, where the contract should specify how risks arising from the integration of different segments are managed and distributed among the involved parties. This, according to the legal expert, provides clarity and prevents disputes over who is responsible for specific problems that may arise due to integration issues (Appendix T.4 Integration in segmented project delivery methods).

Another legal expert highlighted how contractual provisions are used to ensure this integration and the necessary adjustments to standard contracts to guarantee effective integration (Appendix U.4 Integration in segmented project delivery methods). According to this legal expert, integration of project segments is contractually ensured through specifically designed clauses that govern the interaction and collaboration between different segments. The expert advised that these clauses typically include requirements for regular coordination meetings, the use of shared project management software, and detailed reporting procedures. These measures, according to the legal expert, encourage and obligate all parties to work closely together, facilitating integration across various project segments (Appendix U.4 Integration in segmented project delivery methods). Regarding necessary contractual adjustments to standard agreements, the expert emphasised that modifications are often required to meet the unique needs of segmented infrastructure projects. These adjustments can include incorporating specific provisions related to the performance of integration-specific tasks such as sharing essential information and resources between segments, establishing joint responsibilities for risk management, and setting up an overarching project management team responsible for segment integration (Appendix U.4 Integration in segmented project delivery methods). The expert noted that these adjustments should also provide a clear definition of the boundaries between segments and how interfaces will be managed. It is essential, according to the legal expert, to have clear protocols for resolving issues between segments and mechanisms for conflict resolution specifically aimed at issues that could affect project integration (Appendix U.4 Integration in segmented project delivery methods).

Two other experts indicated that the integration of project segments is contractually ensured by including specific clauses that regulate the interaction and coordination between the various contractors (Appendix V.4 Integration in segmented project delivery methods). These clauses, as advised by the experts, are essential because they ensure a consistent level of communication and that all activities are carried out in line with an integrated project plan. According to the experts, this often involves setting up a central management team responsible for overseeing the integration of the project segments. This team, as the experts noted, plays a crucial role in monitoring progress and facilitating coordination between the segments to ensure the project proceeds according to plan (Appendix V.4 Integration in segmented project delivery methods). The experts highlighted that standard building agreements usually need to be adjusted to accommodate the specifics of segmented projects. These adjustments, the experts suggested, include strengthening the integration clauses that detail how the various segments should collaborate. This involves establishing clear responsibilities for each contractor involved in the project, ensuring adequate information exchange, and jointly managing risks. These adjustments, as noted by the experts, ensure that every party knows exactly what is expected of them and how they should contribute to the project's overall objectives (Appendix V.4 Integration in segmented project delivery methods). The experts further stated that it is often necessary to introduce flexibility clauses that allow for contract adjustments in response to changing circumstances within the project. This aspect of contractual flexibility, according to the experts, is of great importance in segmented projects, as it enables project managers to proactively respond to

challenges and opportunities that arise throughout the project's lifespan (Appendix V.4 Integration in segmented project delivery methods).

The fifth legal expert indicated that the integration of project segments is often considered an illusion of certainty within contracts, with genuine assurance relying on making very detailed and robust agreements within the contractual framework (Appendix W.4 Integration in segmented project delivery methods). According to this legal expert, although the contract provides a framework, actual integration depends on the agreements made, which often go beyond the written contract. The legal expert advised that contracts frequently refer to yet-to-be-made agreements that are crucial for the integration of project segments (Appendix W.4 Integration in segmented project delivery methods). Regarding specific adjustments to contracts to ensure effective integration, the expert noted that these standard contracts are not always sufficient to cover complex integrations. This is because they often do not provide for the dynamic and detailed coordination required in segmented projects. The expert stressed the need for flexibility and the ability to add project-specific provisions and annexes that support integration, emphasising the importance of thinking beyond standard contractual frameworks to ensure effective integration (Appendix W.4 Integration in segmented project delivery methods).

In summary, the legal experts emphasise the critical role of integration in the success of segmented infrastructure projects. Their collective insights underscore that effective integration requires detailed contractual provisions, including clauses that specify the roles and responsibilities of all parties, as well as mechanisms for collaboration and communication. They highlight the necessity of adjusting standard contracts like UAC 2012 or UAC-IC 2005 to fit the specific demands of segmented projects, incorporating flexible terms for managing changes and robust risk allocation strategies. Furthermore, the experts stress the importance of creating clear protocols for issue resolution and maintaining a central management team to ensure cohesive project execution. They also point out that actual integration often depends on supplementary agreements outside the primary contract, which must be thorough and robust to support the project's dynamic needs. By implementing these legal expert recommendations, clients and contractors participating in segmented complex infrastructure projects can achieve seamless integration, thereby enhancing project efficiency, and adherence to timelines and goals.

6.2.5 Procurement of segmented project delivery methods

The procurement of segmented complex infrastructure projects requires a nuanced approach to contractor selection, technical specifications, and tendering processes. Legal experts emphasise the importance of particular criteria that go beyond common selection criteria in order to ensure favourable results for a project. This chapter synthesises the legal experts' insights into the essential factors for selecting contractors and the necessary adjustments to procurement processes to address the complexities of segmented projects.

The first expert emphasised that selecting contractors for segmented infrastructure projects demands criteria beyond standard selection methods (Appendix T.5 Procurement of segmented project delivery methods). The technical competencies of contractors, particularly their experience and proficiency in the specific project segments, are crucial. Efficient communication and collaboration skills are also essential, given the need for integration between segments. Financial stability could also be a critical factor for very large and complex segmented infrastructure projects. These criteria help ensure that only the most qualified and reliable contractors are selected, increasing the likelihood of project success (Appendix T.5 Procurement of segmented project delivery methods). Moreover, technical specifications and project requirements must be precisely defined in tender documents for segmented projects. Clear explanations help contractors fully understand expectations, reducing misunderstandings or conflicts during the realisation phase. Drafting these specifications requires

thorough preparation and input from technical experts to ensure all technical and operational aspects are adequately covered, particularly at the interfaces of the segments (Appendix T.5 Procurement of segmented project delivery methods). To ensure a level playing field, the expert suggested using clear, transparent, and uniform tendering processes accessible to all qualified contractors. This includes clear communication of tender requirements, realistic deadlines, and sufficient time for bid preparation. Organising pre-bid meetings where potential bidders can ask questions is also crucial for an open and fair tendering procedure (Appendix T.5 Procurement of segmented project delivery methods). Furthermore, segmented contracting can increase market competition by dividing projects into smaller, manageable units that both large and smaller companies can bid on. This approach increases opportunities for smaller contractors and can lead to more innovative solutions and competitive prices (Appendix T.5 Procurement of segmented project delivery methods). By segmenting the project, a broader range of contractors can participate, improving overall quality and cost efficiency. Additionally, segmented contracts should be designed to attract both large and smaller contractors. Adjusting the project size within segments to be feasible for smaller contractors but also challenging for larger ones is essential. Conditions to maintain the interest of large contractors include ensuring sufficiently large and technically challenging segments, fair risk distribution, and clear contractual agreements on expectations and responsibilities (Appendix T.5 Procurement of segmented project delivery methods).

The second expert highlighted that the procurement process for segmented infrastructure projects must be fair, competitive, and inclusive (Appendix U.5 Procurement of segmented project delivery methods). Specific criteria for selecting contractors should go beyond the usual requirements such as experience and financial stability. Contractors must possess technical competence and proven experience in segmented projects. Effective communication and collaboration with stakeholders and other contractors are crucial. Additionally, their capacity to complete projects on time and within budget, with a strong track record in risk management and problem-solving, should be considered (Appendix U.5 Procurement of segmented project delivery methods). Building on this, technical specifications and project requirements in tender documents must be defined with utmost clarity. Detailed descriptions of each project segment, including specific requirements and expectations, are essential. This level of detail provides potential contractors with a clear understanding of the project, enabling realistic and accurate bids. To ensure competition, the tendering process must be open and transparent. All potential contractors should have equal access to tender documents and sufficient time to prepare bids. Pre-bid meetings where contractors can interact with the client are important (Appendix U.5 Procurement of segmented project delivery methods). According to the expert, segmented contracting could enhance competition by breaking projects into smaller segments accessible to a broader range of contractors, leading to more competitive bidding and innovative solutions (Appendix U.5 Procurement of segmented project delivery methods).

Further experts agreed on the need for a fair and competitive tendering process for segmented projects (Appendix V.5 Procurement of segmented project delivery methods). The selection criteria must encompass effective communication and collaboration skills, experience with segmentation in segmented projects, and technical competence. It is also essential to possess the capacity to manage projects within the constraints of time and budget, as well as a track record of effective problem-solving and risk management. The technical specifications and project requirements must be precise and unambiguous, providing a detailed account of each segment and its unique requirements. This guarantees that prospective contractors comprehend the project and can submit reasonable bids (Appendix V.5 Procurement of segmented project delivery methods). The tendering process should be transparent and open to all potential contractors, with equal access to tender documents and sufficient preparation time, according to the experts. It is important that the client conduct pre-bid meetings with contractors to ensure that the contractors obtain clarification on segmentation. The experts acknowledge that segmented contracting has the potential to promote competition by dividing projects into smaller segments, allowing both large and small contractors to participate (Appendix V.5 Procurement of segmented project delivery methods).

A different expert noted that the criteria for selecting contractors for segmented infrastructure projects should be directly linked to the specific tasks, necessary expertise, and proportionality, with a special focus on the interfaces of segments (Appendix W.5 Procurement of segmented project delivery methods). According to the expert, if the contractors have personal experience with similar segmented projects, it may be beneficial for the project. Technical specifications and project requirements in tender documents must be clear and specific so that all parties understand them. Detailed descriptions of tasks and expectations help to avoid misinterpretations and facilitate segment integration (Appendix W.5 Procurement of segmented project delivery methods). In terms of competition conditions, the expert stated that equal opportunities must be provided to both large and small contractors. This enables specialised subcontractors to act as co-contractors, increasing competition and facilitating participation by smaller parties (Appendix W.5 Procurement of segmented project delivery methods).

In conclusion, the procurement of segmented complex infrastructure projects requires a multifaceted approach to ensure effective integration and successful project delivery. Experts agree that selecting contractors based on technical competence, experience, and financial stability is critical, especially for large and complex projects. Precise technical specifications and clear project requirements in tender documents are essential to avoid misunderstandings and ensure all contractors fully grasp their responsibilities. Transparent and open tendering processes, including pre-bid meetings, level the playing field and foster competitive bidding. Segmented contracting can increase competition, encourage innovative solutions, and involve a broader range of contractors. To maintain the interest of both large and smaller contractors, agreements must balance feasibility and challenge, distribute risks fairly, and clearly define expectations and responsibilities. By implementing these strategies, clients can enhance project integration, mitigate risks, and achieve project objectives efficiently, ultimately contributing to the overall success of segmented construction projects.

6.2.5 Conclusion legal expert interviews

The insights from legal experts on segmentation, segmented project delivery methods, and segmented contracting underscore the multifaceted nature of managing complex infrastructure projects. Legal experts collectively highlight both the benefits and the significant challenges of segmentation, emphasising the importance of planning, coordination, communication, and integration to achieve successful project outcomes.

Legal experts agree that segmentation can significantly enhance the manageability and efficiency of complex infrastructure projects. By breaking down the project into smaller, more manageable segments, clients can focus resources and expertise where they are most needed, facilitating better control over individual segments. However, segmentation also introduces complexities, particularly in coordination, communication, and integration. The effectiveness of segmented project delivery methods depends largely on how well these aspects are managed. Legal experts emphasise the necessity of early and thorough planning to define clear segments based on functionality or geography, which helps in optimising efficiency, controlling costs, and reducing risks.

Coordination in segmented projects is complex due to potential misalignments between segments. Legal experts highlight the critical need for comprehensive coordination agreements that outline roles, responsibilities, procedures for coordination failure, and conflict resolution mechanisms. They stress that effective coordination relies on early-stage design and planning, with tools like BIM recommended to ensure seamless integration. Legal experts suggest that while the responsibility for coordination can vary, the contractor handling the main bulk of the project is often preferred for daily execution, with the client overseeing broad outlines and interfaces. Clear communication protocols and regular updates are essential to maintain efficiency and project progress.

Robust communication and information systems are vital in segmented projects. Legal experts agree that clear communication agreements, detailing update frequency, communication channels, and responsibilities, are crucial for optimising collaboration among the client and co-contractors. Prompt sharing of critical information, such as technical drawings and schedule updates, is necessary to maintain alignment and reduce delays. Contractually documenting communication obligations promotes transparency and proactive problem-solving. Protecting confidential information through non-disclosure agreements is essential for maintaining project integrity. Predefined conflict resolution procedures are also critical to handle disputes efficiently and minimise project disruptions.

Effective integration requires detailed contractual provisions that specify roles, responsibilities, and mechanisms for collaboration and communication. Adjustments to standard contracts like UAC 2012 or UAC-IC 2005 are necessary to accommodate the specific demands of segmented projects. Legal experts recommend incorporating flexible terms for managing changes and robust risk allocation strategies. Clear protocols for issue resolution and maintaining a central management team are essential to ensure cohesive project execution. Supplementary agreements outside the primary contract are often necessary to support the project's dynamic needs, ensuring thorough and robust integration.

A multifaceted approach is required for the procurement of segmented projects to ensure effective integration and successful project delivery. Experts emphasise that selecting contractors based on technical competence, experience, and financial stability is critical, especially for large and complex projects. Detailed technical specifications and clear project requirements in tender documents are essential to avoid misunderstandings. Transparent and open tendering processes, including pre-bid meetings, level the playing field and foster competitive bidding. Segmented contracting can increase competition, encourage innovative solutions, and involve a broader range of contractors. Balancing feasibility and challenge in agreements, distributing risks fairly, and clearly defining expectations and responsibilities are necessary to maintain the interest of both large and smaller contractors.

In conclusion, the legal experts' insights provide a comprehensive understanding of the critical factors and best practices for managing segmented infrastructure projects. While segmentation offers significant benefits in terms of manageability and efficiency, it also poses challenges that require careful planning and strategic management. By addressing these challenges and implementing the expert recommendations, clients and contractors can better navigate the complexities of large-scale infrastructure projects, ensuring successful outcomes.

7. Discussion

This chapter delves into the critical analysis of the findings from the research, providing an in-depth examination of the implications and interpretations of the data collected. It reflects on the research process, acknowledges its limitations, and explores the broader impacts of the study's outcomes. The discussion aims to bridge the gap between theory and practice, offering valuable insights for both academic and professional audiences. By synthesising the conclusions drawn from the literature review, case studies, framework analysis, and expert interviews, this chapter highlights the practical and theoretical contributions of the research to the field of infrastructure project management.

7.1 Interpretation

The findings of this research indicate that segmentation, segmented project delivery methods, and segmented contracting could play a vital role in managing complex infrastructure projects within the Dutch civil infrastructure sector. The literature review established the context of segmentation within various project delivery methods, revealing that traditional methods often struggle with complexity due to the separation of design and construction phases, whereas integrated methods offer streamlined processes but impose greater risks on contractors. Case studies such as the Noord/Zuidlijn, Schiphol-Amsterdam-Almere, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle provided practical insights into the implementation and impacts of segmentation strategies. These case studies highlighted that segmentation facilitates better control, specialised focus, precise budgeting, and enhanced risk management. However, they also underscored the challenges associated with coordination, integration, and increased administrative burdens. The expert interviews further reinforced these findings, stressing the importance of strategic planning, robust coordination and integration mechanisms, and flexible legal frameworks. The framework and typology developed in this research provided a structured analysis of the impacts of horizontal and vertical segmentation. Horizontal segmentation generally reduces complexity by allowing focused management within geographic segments, while vertical segmentation leverages specialised expertise within functional areas. Both approaches offer distinct advantages and challenges, necessitating careful planning and coordination.

7.2 Reflection

Reflecting on the research process, it becomes clear that segmentation is not a one-size-fits-all solution. The success of segmented contracting depends heavily on the specific context and characteristics of each project. Effective segmentation requires thorough early-stage planning, clear definition of segments, and robust coordination mechanisms to manage the interfaces and dependencies between segments. The insights gained from the case studies and expert interviews highlight the importance of a balanced approach to segmentation. While segmentation can significantly enhance manageability and efficiency, it also requires meticulous coordination and communication to avoid potential pitfalls such as misalignment and delays. The role of the client in overseeing and coordinating segmented projects is crucial, as is the need for flexible and adaptive project management strategies. While segmentation positively impacts technical complexities by enabling focused management and specialised expertise, it is crucial to note, with heavy emphasis, that the organisational risks are extremely significant and must be meticulously managed. It is essential for clients and contractors to truly understand that failing to address these risks can easily lead to the failure of complex projects. Almost all interviewees echoed a sentiment that has become almost a famous quote: "wie knipt, moet plakken," which highlights the critical importance of integration in segmented projects. Segments without solid integration could lead to drastic expenses and, again, even failure. Finally, the writer wants to reflect on the enthusiasm, passion, and care that all interviewees

exhibited, whether client or contractor, for building infrastructure to better the Netherlands. Each interviewee expressed a strong desire to construct the best possible infrastructure, working together in collaboration with each other and the people affected by these often complex infrastructure projects. This shared commitment underscores the collaborative spirit essential for the successful delivery of such projects.

7.3 Limitations

This research, while comprehensive, has several notable limitations that should be considered when interpreting the findings. Firstly, the case study was confined to five projects. Although these projects represent some of the largest and most complex infrastructure undertakings in the Netherlands, a broader sample of projects would provide more robust data and allow for stronger generalisations. The inclusion of additional projects could offer a wider variety of perspectives and experiences, further enriching the study. Another significant limitation is the number of interviewees. For most cases, only two individuals were interviewed. This small sample size limits the diversity of insights and experiences regarding segmented contracting. While the interviewees were highly capable and often held senior positions within their respective projects, their limited number constrains the range of perspectives and potentially introduces bias. More interviews would provide a more comprehensive understanding of the challenges and benefits associated with segmented contracting. Furthermore, complexity in infrastructure projects is inherently subjective and challenging to quantify. As expressed throughout the research, complexity is perceived differently by each individual, which limits the applicability of the framework used. Although the interviewees had substantial insights into the complexities of their projects, this variability in perception can affect the consistency and reliability of the findings. The subjective nature of qualitative data also introduces potential biases. The personal experiences and perspectives of the interviewees could influence their responses, which may not fully capture the objective realities of the projects. This subjectivity must be acknowledged, and findings should be interpreted with an understanding of these potential biases. Additionally, the research focuses primarily on the Dutch context, which may limit the generalisability of the findings to other countries with different regulatory environments, cultural attitudes towards construction, and project management practices. The specificities of the Dutch civil infrastructure sector could mean that some of the conclusions drawn may not be directly applicable elsewhere. The dynamic nature of infrastructure projects also means that the scope of these projects often changes. Consequently, some of the provided information, tables, and figures may be outdated. However, the writer believes that the core message this research provides is not easily outdated, as it offers fundamental insights into the benefits and challenges of segmentation in project management. In conclusion, while the research provides valuable insights into segmented contracting in complex infrastructure projects, these limitations highlight the need for cautious interpretation of the findings.

7.4 Implications

The implications of this research are significant for both practitioners and policymakers in the field of infrastructure project management. For practitioners, the findings highlight the need for strategic and well-planned segmentation to manage complex projects effectively. This involves not only dividing projects into manageable segments but also ensuring robust coordination and communication mechanisms are in place. The research underscores the importance of early and thorough planning, the establishment of clear communication protocols, and the necessity for strong central oversight. These elements are crucial for clients to mitigate risks and avoid the common pitfalls associated with segmented projects, such as misalignment and inefficiencies.

Contractors can benefit from understanding the nuanced challenges and benefits of segmentation as outlined in this research. The study emphasises the importance of specialised expertise and effective

collaboration among contractors working on different segments. By leveraging the findings, contractors can improve their project management strategies, enhance coordination efforts, and ensure that their work aligns seamlessly with other segments. The insights into procurement processes, risk management, and integration can help contractors navigate the complexities of segmented projects more effectively, leading to improved project outcomes.

For policymakers, the research underscores the importance of developing and promoting flexible legal frameworks that support segmented contracting. This includes providing guidelines and standards for segmentation practices, as well as fostering a collaborative environment among all stakeholders involved in infrastructure projects. By creating policies that encourage strategic segmentation and robust coordination, policymakers can help facilitate more efficient and effective infrastructure project management. These frameworks should be designed to accommodate the dynamic nature of infrastructure projects, ensuring that new methods and technologies can be integrated as they emerge.

The dynamic nature of infrastructure projects means that new developments and changes in practices may have occurred since the data was collected. This temporal limitation means that some findings may become outdated as new methods and technologies are adopted in the field of project management and segmented contracting. Nevertheless, the core message of this research remains relevant: strategic segmentation and effective coordination are critical for managing complex infrastructure projects.

The enthusiasm, passion, and care that all interviewees, whether clients or contractors, expressed for building infrastructure to better the Netherlands is a testament to the importance of collaboration. Each interviewee emphasised their commitment to constructing the best possible infrastructure, working together in harmony and considering the people affected by these complex projects. This spirit of collaboration is essential for the successful implementation of segmentation strategies.

Overall, this research provides a well-informed basis for discussions between clients and contractors, helping them to align their expectations, responsibilities, and goals. By incorporating the findings and recommendations from this study, both clients and contractors can enhance their practices, leading to more efficient, effective, and successful infrastructure projects. The principles and best practices identified in this research, while focused on the Dutch civil infrastructure sector, offer valuable insights that can be adapted and applied to other regions and sectors facing similar complexities in infrastructure project management.

7.5 Contribution to knowledge

This research makes several significant contributions to the field of infrastructure project management, particularly in the context of segmentation and segmented contracting within the Dutch civil infrastructure sector. The study provides a comprehensive understanding of how these strategies can enhance project delivery and manage complexity in infrastructure projects, addressing the main research question: “What solutions can segmentation and segmented contracting offer to address complexity elements inherent in complex infrastructure projects, and what are the benefits, challenges, and considerations for their adoption?”

Firstly, the research contextualises the pressing need for infrastructure replacement and renovation in the Netherlands, highlighting the aging civil infrastructure and the ambitious goals for sustainability and circularity. This backdrop sets the stage for understanding the operational challenges faced by clients and contractors in the sector. By detailing the various project delivery methods, including traditional, integrated, design team, two-phase, and co-contracting models, the study establishes a robust theoretical foundation. This comprehensive overview helps to identify the unique challenges

and benefits associated with each method, providing a necessary context for exploring segmentation. Secondly, the detailed case study analysis of five major Dutch infrastructure projects, Noord/Zuidlijn, Schiphol-Amsterdam-Almere (SAA), Zuidasdok, Oranje Loper, and Stadsdijken Zwolle, offers practical insights into the implementation and impact of segmentation strategies. These case studies demonstrate how segmentation can manage complex project elements, enhance efficiency, and improve risk management. However, they also highlight the significant challenges related to coordination, integration, and administrative burdens. The findings from these case studies underscore the importance of strategic planning, robust project management tools, and effective communication in managing segmented projects. Thirdly, the development of a framework and typology for segmented project delivery methods represents a significant theoretical advancement. The framework analysis reveals how horizontal and vertical segmentation can address different complexity elements, offering a structured approach to managing large-scale projects. The typology classifies various segmented delivery methods, showcasing their benefits and drawbacks. This theoretical contribution provides a systematic understanding that helps both researchers and practitioners evaluate and implement segmentation strategies effectively. Finally, insights from expert interviews enrich the understanding of segmented project management by capturing the perspectives of industry professionals. These insights emphasise best practices, critical factors, and potential pitfalls associated with segmentation. Experts universally agree on the importance of segmentation in enhancing project manageability and efficiency, but they also highlight the need for seamless integration and coordination across multiple segments. This practical perspective is invaluable for both clients and contractors seeking to apply segmentation in real-world projects.

Overall, this research contributes to the field of infrastructure project management by providing a detailed analysis of segmentation, segmented project delivery methods, and segmented contracting, supported by practical case studies, theoretical frameworks, and expert insights. It offers valuable guidance for practitioners and policymakers, promoting a more efficient and effective approach to managing complex infrastructure projects. By advancing the understanding of segmentation strategies, this research helps pave the way for improved project delivery and better infrastructure outcomes, ultimately benefiting the Dutch civil engineering sector and contributing to the broader body of knowledge in project management.

8. Conclusion

This research has thoroughly examined the concept of segmentation, segmented project delivery methods, and segmented contracting within the Dutch civil infrastructure sector. By addressing the main research question “What solutions can segmentation and segmented contracting offer to address complexity elements inherent in complex infrastructure projects, and what are the benefits, challenges, and considerations for their adoption?”, the study provides a comprehensive understanding of how these strategies can enhance project delivery. This final chapter synthesises the findings from the literature study, case studies, framework and typology analysis, and expert interviews to answer the research questions and offer a holistic conclusion.

Reflecting on the context and challenges outlined in chapter “1.1 Context” and chapter “1.2 Problem description”, the aging infrastructure in the Netherlands presents significant hurdles that require innovative solutions. This thesis has explored segmented contracting as a viable strategy to address these challenges. Moreover, as identified in chapter “1.5 Knowledge gap”, the lack of comprehensive understanding and application of segmented contracting highlights a significant knowledge gap. This research contributes to filling this gap by providing detailed insights into the benefits, challenges, and considerations of segmented contracting, thereby paving the way for its broader adoption. Ultimately, embracing segmented contracting can significantly enhance the Dutch civil engineering sector's ability to meet its infrastructure renewal and sustainability goals, fostering a more resilient and adaptive built environment.

Sub-question 1	What is the context of segmentation within established project delivery methods in the Dutch civil infrastructure sector?

The literature study established that segmentation operates within various project delivery methods, including traditional, integrated, design team, two-phase, and co-contracting approaches. Each project delivery method presents unique challenges and benefits concerning coordination, risk management, and resource allocation. The traditional project delivery method struggles with managing complex projects due to its separation of design and construction phases, whereas integrated project delivery methods streamline these phases but place more risk on the contractor. The design team project delivery method fosters early contractor involvement, improving project feasibility. The two-phase project delivery method enhances risk management by separating design and construction phases, and the co-contracting project delivery method offers direct control over segments but demands robust coordination.

Sub-question 2A	How is segmentation approached, considered, and implemented within project delivery methods by clients and contractors within current and recent complex infrastructure projects?

The case studies of the Noord/Zuidlijn, Schiphol-Amsterdam-Almere, Zuidasdok, Oranje Loper, and Stadsdijken Zwolle projects revealed that segmentation is approached strategically to manage project complexities. Clients and contractors divide projects into manageable segments based on specific technical and geographic challenges. This segmentation facilitates better control over individual segments, allows for more precise budgeting, and enhances risk management. However, the implementation also presents challenges, such as ensuring seamless integration across interfaces, managing multiple contractors, and addressing increased organisational complexities.

Sub-question 2B	What are the key characteristics, legal implications, benefits, and challenges of segmentation according to clients and contractors within current and recent complex infrastructure projects?

Segmentation enables specialised focus, improved risk management, and better control over project components. Key characteristics include dividing the project into distinct segments managed by specialised teams, which helps in addressing specific challenges effectively. Legal implications involve the necessity of detailed contractual provisions to manage roles, responsibilities, and integration of segments. Benefits include enhanced efficiency, targeted risk management, and precise budgeting. However, challenges include the need for robust coordination mechanisms, clear communication channels, and effective integration strategies to mitigate the risks of inefficiencies and delays.

Sub-question 2C	What is the impact of segmentation on project complexity elements according to clients and contractors within current and recent complex infrastructure projects?

The impact of segmentation on project complexity elements is nuanced. While it reduces technical complexities by enabling focused management and specialised expertise, it increases organisational complexities due to the need for extensive coordination and integration efforts. For instance, the Noord/Zuidlijn project demonstrated that segmentation could manage inherent complexities effectively but also highlighted the need for stronger central oversight and clearer communication channels. Similarly, the Schiphol-Amsterdam-Almere and Zuidasdok projects showed that segmentation can enhance efficiency and focus but require strict planning and robust project management to address coordination challenges. The Oranje Loper and Stadsdijken Zwolle projects further exemplified how segmentation can improve project manageability and risk management.

Sub-question 3A	What is the impact of segmentation on various complexity elements in complex infrastructure projects?

The framework analysis revealed that both horizontal and vertical segmentation offer unique advantages and challenges. Horizontal segmentation reduces complexity by allowing specific focus on geographic segments, leading to clearer strategies and execution plans. However, it introduces dependencies at segment interfaces requiring meticulous coordination. Vertical segmentation leverages specialised expertise within functional areas, ensuring high standards and effective management of innovative technologies. Nonetheless, it requires careful alignment of functions managed by different co-contractors, necessitating robust coordination mechanisms.

Sub-question 3B	What are the different segmented project delivery methods, and what are their benefits and drawbacks?

As explained in chapter “1.4.2 Segmented contracting”, the concept of segmented contracting serves as an umbrella term for various project delivery methods that incorporate segmentation principles. This broad concept encompasses a typology of segmented project delivery methods includes segmented traditional, segmented integrated, segmented design team (2.0), and segmented two-phase project delivery methods. Each model offers distinct approaches to managing complexities. The segmented traditional project delivery method allows direct control over segments but demands robust coordination. The segmented integrated project delivery method streamlines phases but places more risk on the contractor. The segmented design team project delivery method fosters early contractor involvement, improving feasibility. The segmented two-phase project delivery method separates design and construction phases, enhancing risk management. However, all segmented project delivery method present challenges such the need for effective coordination, communication,

and integration. A comprehensive overview of the segmented project delivery methods is visually presented in Figure 32.

Figure 32. Segmented project delivery methods

Note: Segmented design team 2.0 project delivery method excluded for figure clarity. The segmented project delivery method illustrates segmentation during both the procurement and realisation phases. However, segmentation can also occur during the design phase, depending on project needs. Similarly, the segmented design team project delivery method demonstrates segmentation during the realisation phase but can also be applied during the procurement and design phases based on project requirements.

Sub-question 4	What are the perspectives of experts and legal experts on key aspects of segmentation and segmented contracting, including coordination, integration, communication, procurement, benefits, and challenges?

Expert interviews highlighted the importance of early and strategic planning, robust coordination mechanisms, transparent communication, and flexible legal frameworks for effective segmentation. Experts emphasised the need for seamless integration and coordination across segments to prevent inefficiencies and delays. They also underscored the importance of well-defined coordination agreements and detailed contractual provisions. Legal experts stressed the necessity of comprehensive coordination agreements, clear communication protocols, and robust risk allocation strategies. Both groups recognised the benefits of segmentation in improving manageability and efficiency but cautioned about the risks to collaborative partnerships and the need for meticulous planning and strategic management.

Main question	What solutions can segmentation and segmented contracting offer to address complexity elements inherent in complex infrastructure projects, and what are the benefits, challenges, and considerations for their adoption?

Segmentation, segmented project delivery methods, and segmented contracting offer several solutions to address complexity elements in complex infrastructure projects. By breaking down projects into smaller, manageable segments, clients and contractors can allocate resources and expertise more effectively, tailor risk management strategies, and maintain better control over budgets and schedules. This approach facilitates specialised focus on specific tasks, enhances project manageability, and improves the predictability of project outcomes. Segmentation enables targeted attention on specific project components, allowing teams to apply specialised expertise where it is most needed. By isolating risks within specific segments, clients and contractors can develop tailored mitigation strategies and enhance overall project stability. Additionally, segmentation facilitates better financial oversight and resource allocation, helping to keep projects within budgetary constraints. This method allows for the segmentation of projects to adapt more easily to changes and unforeseen circumstances, ensuring timely completion and high-quality outcomes.

However, segmentation also presents significant challenges. Ensuring seamless integration across segments requires robust coordination mechanisms and clear communication protocols. Without these, projects can face inefficiencies, increased risks, and potential delays. The segmentation introduces additional administrative overhead and transaction costs, necessitating strict planning and strategic management. Moreover, segmentation might disrupt the natural synergies that arise from teamwork and shared responsibilities, potentially leading to an "every man for himself" mentality. This shift may necessitate a different approach from contractors, who could become co-contractors in a segmented project, requiring them to adapt their collaboration strategies to achieve successful outcomes. Detailed contractual provisions are necessary to manage roles, responsibilities, and integration of segments. Adjustments to standard contracts are often required to accommodate the specific demands of segmented projects.

For the adoption of segmentation, early and thorough planning is crucial to define clear segments based on functionality or geography. Comprehensive coordination agreements that outline roles, responsibilities, procedures for coordination failure, and conflict resolution mechanisms are essential. Clear communication agreements detailing update frequency, communication channels, and responsibilities are vital for optimising collaboration. Adjustments to standard contracts and the inclusion of supplementary agreements are necessary to support the dynamic needs of segmented

projects. Strong central oversight and clear communication channels are vital to handle dependencies and interactions between segments effectively.

In conclusion, segmentation, segmented project delivery methods, and segmented contracting provide valuable solutions for managing the complexities inherent in complex infrastructure projects. By adopting these strategies and addressing the associated challenges through strict planning, robust coordination, and flexible legal frameworks, clients and contractors can enhance project manageability, improve efficiency, and achieve successful outcomes in complex infrastructure projects.

9. Recommendations

The findings of this research underline the importance of segmentation, segmented project delivery methods, and segmented contracting as effective strategies for managing the complexities inherent in complex infrastructure projects. The insights gained from literature, case studies, framework and typology development, and expert interviews lead to several practical and theoretical recommendations for clients, contractors, policymakers, and researcher. These recommendations aim to optimise the implementation of segmentation, segmented project delivery methods, and segmented contracting to enhance the outcomes of complex infrastructure projects and encourage further exploration of this topic in future research.

9.1 Recommendations for clients

For clients, early and thorough planning is essential. It is recommended that clients engage in a detailed initial phase to define clear segments based on functionality or geography. This planning phase is critical for identifying the unique needs of each segment and preparing accordingly. By considering segmentation as early as possible in the project lifecycle, clients can define clear segments that align with the project's functionality or geographic considerations. Clients are advised to ensure that segmentation is technically feasible with a proper design of the interfaces. It is recommended that clients assess the possibility of creating interfaces involving as few stakeholders as possible, simplifying the segmentation process and making it more manageable. Clients should use market consultations to leverage the expertise of contractors, who can provide valuable insights into creating feasible “physical cuts” and determining whether horizontal or vertical segmentation is most appropriate.

It is essential to emphasise (again) that the organisational risks are of great significance and must be carefully managed, despite the fact that segmentation has a positive impact on technical complexities by facilitating focused management and specialised expertise. Therefore, it is highly recommended that clients upscale their management capacity (and capability) to coordinate and integrate segments effectively. Robust management by the client is crucial for the success of segmentation. Clients should establish clear roles and responsibilities for all parties involved, supported by contracts that delineate these roles and provide a framework for segmentation. These contracts should focus on risk allocation, coordination, communication, and integration at the interfaces of segments.

To ensure successful project delivery, it is recommended that clients implement robust coordination and integration mechanisms. This includes establishing regular coordination meetings and appointing a central oversight body to maintain alignment and coherence across all segments. Clients should also develop clear communication protocols that detail the frequency, channels, and responsibilities for communication between all stakeholders. This helps maintain alignment and prevents misunderstandings. Flexible legal frameworks are recommended to accommodate the dynamic nature of large projects. Clients should ensure that these frameworks allow for adjustments based on segment-specific needs and challenges, including provisions for change management and issue resolution. Contracts should support segmentation with a focus on risk allocation, coordination, and integration of segment interfaces.

Drawing from the conclusions of the case study, clients are recommended to focus on establishing strong central oversight and clearer communication channels to manage the dependencies and interactions between segments effectively. Lessons from projects like Noord/Zuidlijn, Schiphol-Amsterdam-Almere, and Zuidasdok show that stronger oversight and clear communication protocols are critical for managing project complexities. Clients should ensure that these elements are in place to avoid misalignment and delays. The framework and typology analysis highlights the need for clients to develop strategies that balance the benefits of segmentation with its inherent challenges. It is

recommended that clients adopt horizontal segmentation to reduce complexity by allowing focused management within geographic segments. However, clients should be prepared for the meticulous coordination required at segment interfaces. Similarly, clients should leverage vertical segmentation to harness specialised expertise within functional areas but must ensure robust alignment mechanisms across functions managed by different contractors. From the expert interviews, it is clear that clients should emphasise the importance of seamless integration and coordination across segments. It is recommended that clients adopt comprehensive coordination agreements that outline roles, responsibilities, procedures for managing interfaces, and conflict resolution mechanisms. Clients should also implement clear communication agreements that promote proactive problem-solving and maintain alignment throughout the project lifecycle.

By following these recommendations, clients can effectively manage the increased organisational complexity brought on by segmentation. Regular meetings and established communication channels will help maintain good interfaces, while flexible legal frameworks will allow for the dynamic adjustments necessary in large, complex infrastructure projects. Ultimately, these practices will enable smoother coordination and integration of project segments, leading to better project outcomes.

9.2 Recommendations for contractors

For contractors, leveraging specialised expertise for specific segments and collaborating closely with other contractors is recommended to ensure seamless integration. Specialised expertise ensures high-quality outcomes for each segment, while collaboration prevents gaps and overlaps in project execution.

Proactive risk management strategies tailored to the specific risks of each segment are recommended for contractors. This includes regular risk assessments and mitigation plans. By implementing these proactive strategies, contractors can anticipate and address potential issues, maintaining project stability and reducing the likelihood of delays and cost overruns. This approach was demonstrated in the SAA project, where tailored risk management facilitated better overall project control. It is recommended that contractors invest in enhanced coordination and integration efforts, using digital tools like Building Information Modelling (BIM) for better interface management. Enhanced coordination tools and practices ensure that all segments are integrated smoothly, preventing misalignments and ensuring that the overall project progresses as planned. The use of BIM, as highlighted in expert interviews, is essential for maintaining clear communication and alignment across segments, which is crucial for the success of complex infrastructure projects.

Contractors should focus on developing strong relationships with clients and other contractors. It is recommended that contractors participate in regular coordination meetings and adhere to clear communication protocols. This helps maintain alignment and coherence across all segments, preventing misunderstandings and ensuring that project goals are met. The Zuidasdok project underscored the importance of these practices, where regular coordination and clear communication are key to managing a complex infrastructure project effectively. Additionally, contractors are advised to adopt flexible project management strategies that can adapt to the dynamic nature of segmented projects. This includes being prepared to adjust plans based on segment-specific needs and challenges. Flexible management strategies help accommodate changes and unforeseen circumstances, ensuring timely completion and high-quality outcomes. The case studies demonstrated that adaptability is vital in segmented projects, where each segment may present unique challenges.

It is recommended that contractors engage in market consultations and pre-bid meetings to better understand the project requirements and client expectations. These consultations provide valuable insights into the feasibility of segmentation and help contractors prepare more accurate and

competitive bids. By participating in these early-stage discussions, contractors can align their strategies with client goals and improve their chances of successful project delivery.

From the framework and typology analysis, it is recommended that contractors adopt horizontal segmentation to focus on specific geographic segments or vertical segmentation to leverage specialised expertise. However, contractors must ensure robust coordination and integration mechanisms to manage the dependencies between segments effectively. This balanced approach helps mitigate the risks associated with segmentation while maximising its benefits. Drawing from expert interviews, it is recommended that contractors develop comprehensive coordination agreements with clients and other contractors. These agreements should outline roles, responsibilities, and procedures for managing interfaces and resolving conflicts. Clear communication protocols should also be established to promote proactive problem-solving and maintain alignment throughout the project lifecycle. By implementing these best practices, contractors can enhance their collaboration with clients and other contractors, leading to more efficient and successful project outcomes.

In conclusion, by following these recommendations, contractors can effectively leverage their specialised expertise, manage risks proactively, enhance coordination and integration, and adopt flexible project management strategies. These practices will help ensure the successful delivery of segmented infrastructure projects, ultimately leading to better project outcomes and improved collaboration with clients and other contractors.

9.3 Recommendations for policymakers

For policymakers, developing and promoting standardised guidelines for segmentation practices is essential. It is recommended to establish comprehensive guidelines that encompass best practices for segmentation, coordination, and integration to provide a consistent framework for the industry. These guidelines should be informed by successful case studies, such as those of the Noord/Zuidlijn and Schiphol-Amsterdam-Almere projects, which demonstrated the critical role of clear segmentation and coordination strategies in managing complex infrastructure projects effectively.

It is recommended that policymakers foster a collaborative environment among stakeholders through policies that incentivise teamwork and shared responsibilities in segmented projects. Collaborative environments enhance synergies between different stakeholders, leading to more cohesive and efficient project realisation. Encouraging the adoption of innovative technologies and methodologies, such as BIM and other digital tools, is recommended to facilitate better coordination and management of segmented projects. Technological advancements can significantly improve the efficiency and effectiveness of project management practices, particularly in managing the interfaces and dependencies of segmented projects. The integration of digital tools was a key recommendation from expert interviews, emphasising their role in enhancing project alignment and reducing misalignments.

It is recommended that policymakers develop flexible legal frameworks that accommodate the dynamic nature of complex infrastructure projects. These frameworks should allow for adjustments based on segment-specific needs and challenges, including provisions for change management and issue resolution. Contracts should support segmentation by focusing on risk allocation, coordination, and integration at segment interfaces. Policymakers should also consider revising procurement policies to facilitate segmented contracting. It is recommended to design procurement processes that enable the division of large projects into manageable segments, ensuring that contracts are awarded based on technical competence, experience, and financial stability. Transparent and open tendering processes, including pre-bid meetings, can help foster competitive bidding and ensure all contractors fully understand their responsibilities. These procurement strategies were underscored in the expert interviews as essential for successful segmented contracting.

Furthermore, it is recommended that policymakers promote research and development in the field of segmentation, segmented project delivery methods, and segmented contracting. Supporting academic and industry research can lead to the development of new methodologies and best practices, enhancing the overall body of knowledge. Insights from ongoing research can be used to update guidelines, training programs, and legal frameworks, ensuring they remain relevant and effective.

By implementing these recommendations, policymakers can create a more supportive environment for segmented contracting, leading to improved project outcomes and enhanced collaboration among stakeholders. These practices will help ensure that segmented projects are managed efficiently, ultimately benefiting the civil infrastructure sector and contributing to the successful delivery of complex infrastructure projects.

9.4 Recommendations for researchers

It is recommended that future research expands the scope of case studies to include a wider variety of projects, both in terms of size and geographical location. A broader range of case studies will provide more comprehensive insights and validate the findings across different contexts and project types. This research has set the foundation for segmentation, segmented project delivery methods, and segmented contracting, advising researchers to explore each of these elements in more detail. Conducting longitudinal studies to track the long-term impacts of segmentation and segmented contracting on project outcomes is also recommended. These studies will help understand the sustained benefits and challenges of segmentation, providing deeper insights into its long-term effectiveness.

Researchers are encouraged to delve deeper into what constitutes feasible "physical cuts" with a technical perspective. Examining the technical aspects of creating interfaces that involve as few stakeholders as possible will simplify the segmentation process and make it more manageable. It is recommended that studies focus on identifying best practices for defining and managing these interfaces to enhance project efficiency and integration. Furthermore, understanding the technical feasibility of segmentation can provide practical guidelines for future projects. It is recommended that researchers also focus on segmented project delivery methods, with more legal research concentrating on the legal challenges of segmented project delivery methods and the contracts that could support this approach. Legal frameworks and contractual agreements play a crucial role in the success of segmented projects. Detailed studies on the legal implications and best practices for drafting contracts that accommodate segmentation will provide valuable insights for policymakers and practitioners. Researchers should examine how different legal frameworks can support or hinder the segmentation process and propose improvements. Exploring segmented contracting overall is another crucial area for future research. It is recommended that studies investigate the holistic implementation of segmented contracting, considering both its benefits and challenges. Research should aim to identify strategies to overcome the common pitfalls associated with segmented contracting, such as coordination, communication, and integration issues. By providing a comprehensive analysis, researchers can offer actionable recommendations for improving segmented contracting practices in complex infrastructure projects.

Given that three out of the five cases studied are still ongoing, it is recommended that more research be conducted on the final outcomes of segmentation in these projects. Longitudinal studies that follow these projects to completion will provide valuable data on the long-term impacts of segmentation. This ongoing research will help determine the ultimate success of segmentation strategies and refine best practices for future projects.

Finally, a more quantitative approach to researching segmented contracting is also recommended. Quantitative studies focusing on the numerical aspects of segmentation, such as cost-benefit analyses, risk assessments, and performance metrics, can provide a different perspective on the effectiveness of segmented contracting. By quantifying the impacts, researchers can offer concrete evidence of the benefits and challenges associated with segmentation, further supporting the adoption of this strategy in complex infrastructure projects.

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Appendices

Appendix A. Data management plan

0. Administrative questions

1. Name of data management support staff consulted during the preparation of this plan.

My faculty data steward, Xinyan Fan, has reviewed this DMP on 20-03-2024.

2. Date of consultation with support staff.

2024-03-20

I. Data description and collection or re-use of existing data

3. Provide a general description of the type of data you will be working with, including any re-used data:

Type of data	File format(s)	How will data be collected (for re-used data: source and terms of use)?	Purpose of processing	Storage location	Who will have access to the data
Project documents, such as contracts, performance reports, general project documents	.docx, .xlsx, & .pdf	Re-use of existing confidential company project documents with an NDA in place	Project information	OneDrive - Delft University of Technology	Graduation Committee and myself
Interview recordings	.mp4	Recorder (mobile phone)	Project information and sharing expertise	OneDrive - Delft University of Technology	Myself
Interview transcripts	.docx	Interview recordings	Extract information to support research findings	OneDrive - Delft University of Technology	Myself
De-identified transcripts	.docx	Interview recordings	Extract information to support research findings	OneDrive - Delft University of Technology	Graduation Committee and myself
Informed consent	.docx	Hard paper will be digitalised	HREC requirement	OneDrive - Delft University of Technology	Graduation Committee and myself

4. How much data storage will you require during the project lifetime?

< 250 GB

II. Documentation and data quality

5. What documentation will accompany data?

Methodology of data collection

III. Storage and backup during research process

6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?

OneDrive - Delft University of Technology

IV. Legal and ethical requirements, codes of conduct

7. Does your research involve human subjects or 3rd party datasets collected from human participants?

Yes

8A. Will you work with personal data? (information about an identified or identifiable natural person)

Yes. Personal data such as the interviewee's employment function, interview recordings, and interview transcripts.

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

Yes. Project documents, such as contracts and project information, are subject to an NDA.

9. How will ownership of the data and intellectual property rights to the data be managed?

All parties have signed the graduation agreement between TU Delft and a Company (CME-2 Form). The personal information is only available to me. Non-personal, anonymised data will be shared. If consent is provided, this anonymised data will be included in the thesis as an appendix and uploaded to the educational repository of the TU Delft. I am the principal researcher to oversee the access rights to the data.

10. Which personal data will you process? Tick all that apply

- Photographs, video materials, performance appraisals or student result.
- Email addresses and/or other addresses for digital communication.
- Names and addresses.
- Data collected in Informed Consent form (names and email addresses).
- Signed consent forms.

11. Please list the categories of data subjects

Project, Contract, and Technical Managers from contracting firms and client organisations.

12. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?

No

15. What is the legal ground for personal data processing?

Informed consent

16. Please describe the informed consent procedure you will follow:

Before the interview begins, all study participants will be asked for written consent to participate in the study and have their data processed.

17. Where will you store the signed consent forms?

- Same storage solutions as explained in question 6
- Informed consent in hard copy will be kept in a locked cabinet at my supervisor's office.

18. Does the processing of the personal data result in a high risk to the data subjects?

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply). If two or more of the options listed below apply, you will have to complete the DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to receive support with DPIA. If you have any additional comments, please add them in the box below.

None of the above applies

19. Did the privacy team advise you to perform a DPIA?

No

22. What will happen with personal research data after the end of the research project?

Personal research data will be destroyed after the end of the research project

V. Data sharing and long-term preservation

26. What data will be publicly shared?

No data can be publicly shared - please explain below why data cannot be publicly shared:

The research thesis's appendix will only contain anonymous data.

27. Apart from personal data mentioned in question 22, will any other data be publicly shared?

No other data can be publicly shared - please explain below why data cannot be publicly shared:

My thesis may include data gathered from interviews and project documents. As a result, it is only shared as an appendix to the thesis and will not be made available on its own in a repository.

VI. Data management responsibilities and resources
33. Is TU Delft the lead institution for this project?

Yes, leading the collaboration - please provide details of the type of collaboration and the involved parties below:

The study is being conducted as part of a graduation internship at Dura Vermeer. The graduation agreement between Delft University of Technology and Dura Vermeer has been signed (CME-2).

34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?

Chair of the graduation committee: Ad Straub (A.Straub@tudelft.nl)
First supervisor: Evelien Bruggeman (E.M.Bruggeman@tudelft.nl)

35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

There will be no costs.

Appendix B. Informed consent form (NL)

Studietitel: Gesegmenteerd contracteren
Onderzoek niveau: Masterthesis Construction Management & Engineering
Onderzoeker: Demian Dortmundt
Instelling: Technische Universiteit Delft

Geachte deelnemer,

U bent van harte uitgenodigd om deel te nemen aan een onderzoek voor een masterthesis dat gesegmenteerde contract oplossingen voor complexe infrastructuurprojecten onderzoekt. Dit onderzoek, uitgevoerd als onderdeel van het programma Construction Management & Engineering aan de Technische Universiteit Delft en in samenwerking met Dura Vermeer, beoogt het begrip van segmentatie binnen traditionele contractuele regelingen uit te breiden naar meer geïntegreerde contractmodellen, met een focus op de Nederlandse sector van civiele techniek.

Als Project-, Contract- of Technisch Manager is uw expertise van onschatbare waarde voor de voortgang van dit onderzoek. Uw deelname zal bestaan uit het verstrekken van inzichten door middel van interviews, wat aanzienlijk zal bijdragen aan de bevindingen van de studie. Daarnaast kan het zijn dat u gevraagd wordt om projectdocumenten te delen, zoals contracten, voortgangsrapporten en algemene projectdocumenten, die met de grootste zorgvuldigheid zullen worden behandeld en enkel zullen worden gebruikt binnen de grenzen van dit onderzoek, conform de gestelde voorwaarden in de geheimhoudingsverklaring (NDA). Deze documenten zullen helpen om een vollediger beeld van de onderzoeksonderwerpen te krijgen en zullen op een veilige locatie worden opgeslagen met toegang beperkt tot de Afstudeercommissie en mijzelf.

Alle persoonlijke informatie die uit de interviews en gedeelde documenten voortkomt, zal worden geanonimiseerd om uw privacy en de vertrouwelijkheid van de gegevens te waarborgen. De opgeslagen data, waaronder de interviews en eventuele projectdocumenten, zullen worden gehost op OneDrive van de Technische Universiteit Delft. Deze maatregelen zijn getroffen om te verzekeren dat de integriteit van uw persoonlijke en professionele informatie te allen tijde beschermd blijft.

Er worden geen risico's voor u voorzien in verband met uw deelname, en er zijn uitgebreide beveiligingen ingesteld om uw persoonlijke gegevens te beschermen. U heeft het volledige recht om op elk moment zonder enige consequentie uit het onderzoek terug te treden. Let op dat er geen financiële vergoeding staat tegenover deelname aan deze studie. Als u vragen heeft of de studie verder wilt bespreken, neem dan alstublieft contact met mij op via D.Dortmundt@student.tudelft.nl. Mocht u klachten of zorgen hebben, dan kunt u contact opnemen met mijn eerste begeleider, Evelien Bruggeman, op E.M.Bruggeman@tudelft.nl.

Het invullen van het toestemmingsformulier houdt in dat u met uw handtekening bevestigt dat u de informatie op het formulier heeft gelezen en begrepen. Door te tekenen, stemt u in met uw deelname aan de studie en erkent u dat u het recht heeft om op elk gewenst moment uw deelname te beëindigen, zonder dat dit voor u negatieve gevolgen heeft.

Hartelijk dank voor het overwegen van deze mogelijkheid om bij te dragen aan zinvol onderzoek in het veld van gesegmenteerd contracteren binnen de infrastructuursector.

Met vriendelijke groet,

Demian Dortmundt

Vink alstublieft de toepasselijke vakjes aan.	Ja	Nee
A: ALGEMENE OVEREENKOMST – DOEL VAN HET ONDERZOEK, TAKEN VAN DE DEELNEMER EN VRIJWILLIGE DEELNAME		
1. Ik heb de informatie over het onderzoek gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.	☐	☐
2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.	☐	☐
3. Ik begrijp dat mijn deelname aan het onderzoek inhoudt dat er interviews worden gehouden die audio-opgenomen worden met een mobiele telefoon, welke vervolgens worden getranscribeerd naar tekst. De audio-opnames worden na transcriptie vernietigd.	☐	☐
4. Ik begrijp dat mijn deelname aan het onderzoek niet wordt gecompenseerd	☐	☐
5. Ik begrijp dat de studie eindigt op 01-08-2024.	☐	☐
B: MOGELIJKE RISICO'S VAN DEELNAME (INCLUSIEF GEGEVENSBESCHERMING)		
6. Ik begrijp dat mijn deelname betekent dat er persoonlijke identificeerbare informatie en onderzoek data worden verzameld, met het risico dat ik hieruit geïdentificeerd kan worden.	☐	☐
7. Ik begrijp dat de volgende stappen worden ondernomen om het risico van een databreuk te minimaliseren: de verzamelde data wordt geanonimiseerd, veilig opgeslagen met beperkte toegang, en persoonlijke informatie wordt beschermd door de transcripties te de-identificeren.	☐	☐
8. Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals mijn naam en functie, niet gedeeld worden buiten het studieteam.	☐	☐
9. Ik begrijp dat de persoonlijke data die over mij verzameld wordt, vernietigd wordt na het einde van het onderzoeksproject	☐	☐
C: PUBLICATIE, VERSPREIDING EN TOEPASSING VAN HET ONDERZOEK		
12. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor de masters thesis. Anonieme data kunnen worden opgenomen als bijlage in de thesis en worden geüpload naar de onderwijs repository van de TU Delft.	☐	☐
13. Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages anoniem te quoten in resulterende producten.	☐	☐

Handtekening		
_____	_____	_____
Naam deelnemer	Handtekening	Datum
Ik, **de onderzoeker**, verklaar dat ik de informatie en het instemmingsformulier correct aan de potentiële deelnemer heb voorgelezen en, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.		
_____	_____	_____
Naam onderzoeker	Handtekening	Datum
Contactgegevens van de onderzoeker voor verdere informatie: E-mailadres: d.dortmundt@student.tudelft.nl		

Appendix C. Case study: interview questions for the client (EN)

Prior to the interview, all candidates will be clearly informed that, when referred to as 'you' in the questions, it specifically pertains to their role as either the client or the contractor, depending on the context of the conversation.

Appendix C.1 Introduction (perspective client)

1. Project overview: “Could you provide a brief overview of the project you're involved in?”
2. Project complexity: “What makes this project complex? Could you detail the specific challenges or characteristics that contribute to its complexity?”

Appendix C.2 Understanding segmentation (perspective client)

3. Definition and decision on segmenting: "As the client, could you define the concept of segmenting within the context of this project? What prompted the decision to employ segmentation?"
4. Project delivery method: “Could you provide a schematic overview or representation of the project delivery method applied to the project?”
5. Actors and their relationships: "Could you provide a schematic representation or overview that outlines the various actors involved in this project, such as clients, (co-)contractors, and consultants, and illustrates both their functional and contractual relationships and interactions with one another?"
6. Segmentation integration in the project lifecycle: "During the project lifecycle (procurement, design, and realisation), where was segmentation introduced? Can you discuss how it was integrated at each of these stages?"
7. Strategic goals behind segmenting: "What were the strategic objectives that guided the decision to implement segmentation?
8. Criteria for segmenting: "What specific criteria were employed when deciding to segment the project? Were these decisions influenced by factors such as specialisation, geography, time, or other considerations?"

Appendix C.3 Key characteristics of segmentation (perspective client)

9. Coordination strategies: "Could you detail the strategies or tools that were utilised to coordinate efforts between different project segments? What has been your approach to managing the coordination required by segmenting?"
10. Management and integration of segments: "Once segments were established, how were they managed and integrated? What methods ensured that all segments progressed cohesively and remained aligned with the project's overall objectives?"
11. Economic interests affecting project dynamics: "How have the economic interests tied to individual segments influenced the dynamics and decision-making processes of the project?"
12. Financial implications of segmenting: "Can you describe the financial implications of segmenting the project? Specifically, how did segmenting affect the budget allocation, cost control, and overall financial management?"
13. Risk allocation in segmented projects: "How is risk allocated among the different segments and contracting parties in this project, and what strategies have you employed to manage these risks effectively?"

Appendix C.4 Legal aspects of segmentation (perspective client)

14. Legal implications: "Can you discuss the legal implications of segmentation within the frameworks provided by Dutch procurement laws?"
15. Contractual framework: "How are contract models legally structured to accommodate segmenting within your projects?"
16. Legal obstacles: "Can you discuss any legal challenges you've faced with segmented contracting and the strategies employed to overcome them?"
17. Legal alignment: "Are there specific challenges you have faced in aligning segmenting practices with legal requirements under the Dutch procurement laws?"

Appendix C.5 Challenges and benefits of segmentation (perspective client)

18. Segmenting challenges: "Can you identify and elaborate on the most significant challenges that emerged as a result of segmenting?"
19. Beneficial outcomes of segmenting: "Despite these challenges, what have been some of the beneficial outcomes or advantages that segmenting has provided to the project?"

Appendix C.6 Conclusion (perspective client)

20. Lessons learned: "From your experience, what lessons have been learned through the process of implementing segmenting in this project?"
21. Future of segmenting in infrastructure projects: "How do you see the concept of segmenting evolving in the civil infrastructure sector? Do you anticipate changes in how projects are segmented in the future?"
22. Additional insights and areas for further investigation: "Is there any additional information or experiences related to project segmentation that you think is important to share? What areas related to segmenting complex projects require further investigation or research?"

Appendix D. Case study: interview questions for the client (NL)

Voorafgaand aan het interview worden alle kandidaten duidelijk geïnformeerd dat, wanneer in de vragen naar 'u' wordt verwezen, dit specifiek betrekking heeft op hun rol als opdrachtgever of aannemer, afhankelijk van de context van het gesprek.

Appendix D.1 Introductie (perspectief opdrachtgever)

1. Projectoverzicht: “Kunt u een kort overzicht van het project waar u bij betrokken bent geven?”
2. Complexiteit van het project: “Wat maakt dit project zo complex? Kunt u de specifieke uitdagingen of eigenschappen die tot deze complexiteit bijdragen toelichten?”

Appendix D.2 Begrip van segmentatie (perspectief opdrachtgever)

3. Definitie en besluitvorming over segmentering: "Kunt u als opdrachtgever het concept van segmentering binnen de context van dit project definiëren? Wat was de aanleiding voor de beslissing om segmentering toe te passen?"
4. Bouworganisatievorm: "Kunt u een schematisch weergave of representatie bieden van de toegepaste bouworganisatievorm binnen het project?"
5. Actoren en hun relaties: "Kunt u een schematisch overzicht of representatie bieden die de diverse betrokken partijen bij dit project weergeeft, zoals opdrachtgevers, (neven)aannemers en consultants, en die zowel hun functionele als contractuele relaties en interacties met elkaar illustreert?"
6. Integratie van segmentering in de projectlevenscyclus: "In welke fasen van de projectlevenscyclus (aanbesteding, ontwerp, en realisatie) werd segmentering geïntroduceerd? Kunt u bespreken hoe dit in elk van deze stadia werd geïntegreerd?"
7. Strategische doelen achter segmentering: "Wat waren de strategische doelen die de beslissing om segmentering te implementeren leidden?"
8. Criteria voor segmentering: "Op basis van welke specifieke criteria is besloten om het project te segmenteren? Waren deze besluiten beïnvloed door aspecten zoals specialisatie, geografie, tijd of andere factoren?"

Appendix D.3 Kernkenmerken van segmentatie (perspectief opdrachtgever)

9. Coördinatiestrategieën: "Kunt u de strategieën of hulpmiddelen toelichten die ingezet zijn om de inspanningen tussen de verschillende segmenten van het project te coördineren? Hoe heeft u de benodigde coördinatie voor segmentering aangepakt?"
10. Beheer en integratie van segmenten: "Hoe zijn de segmenten na oprichting beheerd en geïntegreerd? Welke methoden zorgden ervoor dat alle segmenten coherent vorderden en uitgelijnd bleven met de algemene doelstellingen van het project?"
11. Economische belangen die de projectdynamiek beïnvloeden: "Op welke wijze hebben de economische belangen gekoppeld aan individuele segmenten de dynamiek en besluitvormingsprocessen binnen het project beïnvloed?"
12. Financiële gevolgen van segmentering: "Kunt u de financiële gevolgen van de segmentering van het project beschrijven? Hoe heeft de segmentering specifiek de budgettoewijzing, kostenbeheersing en het algemene financiële beheer beïnvloed?"
13. Risicoverdeling in gesegmenteerde projecten: "Hoe wordt het risico verdeeld onder de verschillende segmenten en contractpartijen binnen dit project, en welke strategieën heeft u toegepast om deze risico’s effectief te beheren?"

Appendix D.4 Juridische aspecten van segmentatie (perspectief opdrachtgever)

14. Juridische gevolgen: "Kunt u de juridische gevolgen bespreken van het gebruik van segmenteren binnen de kaders van de Nederlandse aanbestedingswetgeving?"
15. Contractueel kader: "Hoe zijn contractmodellen juridisch opgezet om segmentatie binnen uw projecten mogelijk te maken?"
16. Juridische obstakels: "Kunt u eventuele juridische uitdagingen toelichten die u bent tegengekomen bij segmenteren en de strategieën die u heeft toegepast om deze te overwinnen?"
17. Juridische afstemming: "Bent u specifieke uitdagingen tegengekomen bij het afstemmen van segmenteringspraktijken op de juridische vereisten van de Nederlandse aanbestedingswetgeving?"

Appendix D.5 Uitdagingen en voordelen van segmentatie (perspectief opdrachtgever)

18. Uitdagingen van segmentering: "Kunt u de meest significante uitdagingen noemen en toelichten die voortkwamen uit de segmentering?"
19. Voordelen van segmentering: "Ondanks deze uitdagingen, welke voordelen of positieve resultaten heeft segmentering opgeleverd voor het project?"

Appendix D.6 Conclusie (perspectief opdrachtgever)

20. Lessen geleerd: "Welke lessen heeft u geleerd uit het implementeren van segmentering in dit project?"
21. Toekomst van segmentering in infrastructuurprojecten: "Hoe ziet u de ontwikkeling van segmentering binnen de sector van de civiele infrastructuur? Verwacht u veranderingen in hoe projecten in de toekomst gesegmenteerd zullen worden?"
22. Aanvullende inzichten en gebieden voor verder onderzoek: "Is er nog aanvullende informatie of ervaringen gerelateerd aan projectsegmentering die u belangrijk vindt om te delen? Welke gebieden met betrekking tot het segmenteren van complexe projecten vereisen verder onderzoek of verbetering?"

Appendix E. Case study: interview questions for a contractor (EN)

Prior to the interview, all candidates will be clearly informed that, when referred to as 'you' in the questions, it specifically pertains to their role as either the client or the contractor, depending on the context of the conversation.

Appendix E.1 Introduction (perspective contractor)

1. Segment overview: “Could you provide a brief overview of the segment of the project you're involved in?”
2. Complexity within your segment: “What makes your segment of the project complex? Could you detail the specific challenges or characteristics that contribute to its complexity?”

Appendix E.2 Understanding segmentation (perspective contractor)

3. Perception of segmenting: "From your perspective as a contractor, how do you perceive the concept of segmenting within this project? What impact does segmentation have on your work?"
4. Interaction with other actors: "Could you describe how you interact with other actors involved in the project, such as clients, (co-)contractors, and consultants, within the scope of your segment?"
5. Integration of your segment in the project lifecycle: "How was your segment integrated into the overall project lifecycle (procurement, design, and realisation)?"
6. Goals and objectives for your segment: "What are the specific goals and objectives for your segment of the project? How do these align with the strategic goals of the overall project?"

Appendix E.3 Key characteristics of segmentation (perspective contractor)

7. Coordination within your segment: "What strategies or tools do you use to coordinate efforts within your segment and with adjacent segments?"
8. Management and integration of your segment: "How is your segment managed and integrated with the overall project? What methods ensure cohesive progress?"
9. Economic interests within your segment: "How do the economic interests tied to your segment influence your decision-making processes and project dynamics?"
10. Financial management of your segment: "How does segmenting affect budget allocation, cost control, and financial management within your segment?"
11. Risk management in your segment: "How is risk managed within your segment, and what strategies do you employ to address these risks?"

Appendix E.4 Legal aspects of segmentation (perspective contractor)

12. Legal implications of segmenting: "Considering your involvement in a specific project segment, what are the legal implications of segmenting, especially in terms of compliance with the Dutch procurement laws?
13. Contractual framework for segments: "How is the contractual framework for your segment legally structured to accommodate segmenting?”
14. Segment-specific legal challenges: "Can you discuss any legal challenges specific to your project segment that have arisen from segmenting, and the strategies you've employed to address these?"

Appendix E.5 Challenges and benefits of segmentation (perspective contractor)

15. Segmenting challenges: "Can you identify and elaborate on the most significant challenges that emerged as a result of segmenting within your project segment?"
16. Beneficial outcomes of segmenting: "Despite these challenges, what have been some of the beneficial outcomes or advantages that segmenting has provided to your segment of the project?"

Appendix E.6 Conclusion (perspective contractor)

17. Lessons learned: "From your experience, what lessons have been learned through the process of implementing segmenting within your segment of the project?"
18. Future of segmenting in infrastructure projects: "How do you see the concept of segmenting evolving in the civil infrastructure sector, especially from the perspective of a contractor responsible for a specific segment? Do you anticipate changes in how segments are managed or integrated in the future?"
19. Additional insights and areas for further investigation: "Is there any additional information or experiences related to project segmentation within your segment that you think is important to share? What areas related to segmenting complex projects require further investigation or improvement from a contractor's viewpoint?"

Appendix F. Case study: interview questions for a contractor (NL)

Voorafgaand aan het interview worden alle kandidaten duidelijk geïnformeerd dat, wanneer in de vragen naar 'u' wordt verwezen, dit specifiek betrekking heeft op hun rol als opdrachtgever of aannemer, afhankelijk van de context van het gesprek.

Appendix F.1 Introductie (perspectief aannemer)

1. Overzicht van uw segment: "Kunt u een kort overzicht geven van het segment binnen het project waar u bij betrokken bent?"
2. Complexiteit binnen uw segment: "Wat maakt uw segment van het project complex? Kunt u de specifieke uitdagingen of kenmerken die bijdragen aan deze complexiteit gedetailleerd beschrijven?"

Appendix F.2 Begrip van segmentatie (perspectief aannemer)

3. Perceptie van segmentering: "Hoe ziet u, als aannemer, het concept van segmentatie binnen dit project? Welke invloed heeft de segmentatie op uw werk?"
4. Interactie met andere actoren: "Kunt u beschrijven hoe u samenwerkt met andere betrokkenen bij het project, zoals opdrachtgevers, (neven)aannemers en consultants, binnen de reikwijdte van uw segment?"
5. Integratie van uw segment in de projectlevenscyclus: "Hoe is uw segment geïntegreerd in de algemene projectlevenscyclus (aanbesteding, ontwerp en realisatie)?"
6. Doelen en doelstellingen voor uw segment: "Wat zijn de specifieke doelen en doelstellingen voor uw segment van het project? Hoe sluiten deze aan bij de strategische doelen van het algehele project?"

Appendix F.3 Kernkenmerken van segmentatie (perspectief aannemer)

7. Coördinatie binnen uw segment: "Welke strategieën of hulpmiddelen gebruikt u om inspanningen binnen uw segment en met aangrenzende segmenten te coördineren?"
8. Beheer en integratie van uw segment: "Hoe wordt uw segment beheerd en geïntegreerd met het totale project? Welke methoden zorgen voor een samenhangende voortgang?"
9. Economische belangen binnen uw segment: "Hoe beïnvloeden de economische belangen gekoppeld aan uw segment de besluitvormingsprocessen en dynamiek van het project?"
10. Financieel beheer van uw segment: "Hoe beïnvloedt segmentatie de budgettoewijzing, kostenbeheersing en financieel beheer binnen uw segment?"
11. Risicobeheer in uw segment: "Hoe wordt risico beheerd binnen uw segment en welke strategieën past u toe om deze risico's aan te pakken?"

Appendix F.4 Juridische aspecten van segmentatie (perspectief aannemer)

12. Juridische gevolgen van segmentering: "Gezien uw betrokkenheid bij een specifiek projectsegment, wat zijn de juridische gevolgen van segmentering, met name wat betreft de naleving van de Nederlandse aanbestedingswetten?"
13. Contractueel kader voor segmenten: "Hoe is het contractuele kader van uw segment juridisch gestructureerd om segmentatie te accommoderen?"
14. Segment-specifieke juridische uitdagingen: "Kunt u eventuele juridische uitdagingen bespreken die specifiek voor uw projectsegment zijn ontstaan door segmentering, en de strategieën die u heeft toegepast om deze aan te pakken?"

Appendix F.5 Uitdagingen en voordelen van segmentatie (perspectief aannemer)

15. Uitdagingen van segmentering: "Kunt u de meest significante uitdagingen benoemen en toelichten die zijn ontstaan als gevolg van segmentatie binnen uw projectsegment?"
16. Voordelige uitkomsten van segmentering: "Ondanks deze uitdagingen, welke voordelen of positieve resultaten heeft segmentatie opgeleverd voor uw segment van het project?"

Appendix F.6 Conclusie (perspectief aannemer)

17. Geleerde lessen: "Welke lessen heeft u geleerd uit het implementeren van segmentatie binnen uw segment van het project?"
18. Toekomst van segmentering in infrastructuurprojecten: "Hoe ziet u de ontwikkeling van segmenteren binnen de civiele infrastructuursector, specifiek vanuit het perspectief van een aannemer verantwoordelijk voor een specifiek segment? Verwacht u veranderingen in hoe segmenten worden beheerd of geïntegreerd in de toekomst?"
19. Aanvullende inzichten en gebieden voor verder onderzoek: "Is er aanvullende informatie of ervaringen gerelateerd aan projectsegmentatie binnen uw segment die u belangrijk vindt om te delen? Welke gebieden met betrekking tot het segmenteren van complexe projecten vereisen verder onderzoek of verbetering vanuit het perspectief van een aannemer?"

Appendix P. Expert interview questions (EN)

Before the interview, the candidate is extensively informed about the content of the research, including the conceptual definitions of segmentation and segmented contracting. Additionally, the results of the corresponding case study are explained, providing insight into the benefits and challenges of segmentation. The candidate is also educated on which strategic considerations and criteria can be used for segmentation. Furthermore, the candidate is informed about the advantages and disadvantages of these approaches and the various segmented project delivery methods. All this is aimed at ensuring that the interviewee is well-prepared and informed before participating in the interview.

Appendix P.1 Segmentation

1. Choice evaluation: “How do you assess the client's decision to segment a project based on geography or functionality?”
2. Complexity strategy: “How do you evaluate the client’s choice for project segmentation as a strategy to manage complexity and thereby optimise the risk-reward ratio?”
3. Stimulating competition: “How do you view the use of project segmentation by the client as a means to stimulate competition in the market?”
4. Ideal implementation of segmentation: “In your opinion, how should segmentation ideally be implemented in large complex infrastructure projects?”
5. Strategic goals: “What do you consider to be the most ideal strategic goals that should lead to the decision to undertake project segmentation?”
6. Criteria: “Based on what ideal criteria would you recommend project segmentation? How should these decisions be influenced by factors such as geography or functionality?”
7. Project phases: “In which ideal phases of the project lifecycle, such as procurement, design, and realisation, would you like to see segmentation introduced?”
8. Co-contractors or subcontractors: “How do you evaluate the practice of working with co-contractors in segmented project delivery methods compared to subcontractors in traditional project delivery methods? What are the advantages or challenges of each model?”

Appendix P.2 Key characteristics of segmentation

9. Theoretical coordination strategies for segmentation: "What strategies or tools should ideally be used to ensure coordination between the different project segments? How should the necessary coordination for effective segmentation theoretically be approached?"
10. Management and integration of segments in theory: "How should segments be managed and integrated after establishment according to ideal practice? What methods would ensure that all segments make coherent progress and remain aligned with the overall project objectives?"
11. Economic interests and project dynamics: "In what ways should the economic interests associated with individual segments ideally influence the dynamics and decision-making processes within a project?"
12. Financial implications of segmentation in theory: "Can you describe what financial implications segmentation should ideally have on a project? How should segmentation theoretically influence budget allocation, cost control, and overall financial management?"
13. Risk distribution in segmented projects: "How should risk be theoretically distributed among the different segments and contracting parties within a project, and what strategies should be applied to effectively manage these risks?"

Appendix P.3 Segmented project delivery methods

14. “How do you feel about segmented project delivery methods, and do you have a preference for a specific segmented project delivery methods within complex infrastructure projects?”

Appendix P.4 Challenges and benefits of segmentation

15. Theoretical challenges of segmentation: "What challenges are typically encountered in the implementation of segmentation, and how do you think these can best be addressed?"
16. Theoretical advantages of segmentation: "Despite the challenges, what benefits do you believe segmentation can bring to complex infrastructure projects?"

Appendix P.5 Conclusion

1. Lessons from segmentation: "What lessons do you think can be learned from the implementation of segmentation in complex projects?"
2. Future of segmentation in civil infrastructure: "How do you expect the use of segmentation to develop within the civil infrastructure sector? Do you anticipate significant changes in how projects may be segmented in the future?"
3. Additional insights and areas for further research: "Are there any additional insights or experiences related to project segmentation that you believe are important to share? What areas regarding the segmentation of complex projects do you think deserve further research or improvement?"

Appendix Q. Expert interview questions (NL)

Voorafgaand aan het interview wordt de kandidaat uitgebreid geïnformeerd over de inhoud van het onderzoek, inclusief de conceptuele definities van segmenteren en gesegmenteerd contracteren. Daarbij worden de resultaten van de bijbehorende case study toegelicht, die inzicht bieden in de effectiviteit en uitdagingen van segmenteren. Er wordt uitgelegd welke strategische overwegingen en criteria gebruikt kunnen worden voor het segmenteren van projecten. Daarnaast wordt de kandidaat ingelicht over de voor- en nadelen van deze benaderingen en de diverse gesegmenteerde bouworganisatievormen. Dit is allemaal gericht op het garanderen dat de geïnterviewde goed voorbereid en geïnformeerd aan het interview deelneemt.

Appendix Q.1 Segmenteren

1. Beoordeling keuze: “Hoe beoordeelt u de keuze van de opdrachtgever om een project te segmenteren op basis van geografie of functionaliteit?”
2. Strategie voor complexiteit: “Hoe beoordeelt u de keuze van de opdrachtgever voor projectsegmentatie als strategie om complexiteit te beheersen en daarmee de ratio risico-beloning te optimaliseren?”
3. Competitie stimuleren: “Hoe beoordeelt u de inzet van projectsegmentatie door de opdrachtgever als middel om de competitie op de markt te stimuleren?”
4. Ideale realisatie van segmentatie: “Hoe zou segmentatie, in uw optiek, idealiter moeten worden gerealiseerd in grote complexe infrastructuurprojecten?”
5. Strategische doelen: “Wat zouden volgens u de meest ideale strategische doelen moeten zijn die de beslissing om tot projectsegmentatie over te gaan leiden?”
6. Criteria: “Op basis van welke ideale criteria zou u segmentatie van een project aanbevelen? Hoe zouden deze besluiten beïnvloed moeten worden door factoren zoals geografie of functionaliteit?
7. Project fasen: “In welke ideale fasen van de projectlevenscyclus, aanbesteding, ontwerp, en realisatie, zou u willen zien dat segmentatie wordt geïntroduceerd?”
8. Nevenaannemers of onderaannemers: “Hoe beoordeelt u de praktijk van werken met nevenaannemers in gesegmenteerde bouworganisatievormen vergeleken met onderaannemers in traditionele bouworganisatievormen? Wat zijn de voordelen of uitdagingen van elk model?”

Appendix Q.2 Kernkenmerken van segmenteren

9. Theoretische coördinatiestrategieën voor segmentatie: "Welke strategieën of instrumenten zouden idealiter gebruikt moeten worden om coördinatie tussen de verschillende projectsegmenten te waarborgen? Hoe zou de noodzakelijke coördinatie voor effectieve segmentatie theoretisch moeten worden aangepakt?"
10. Beheer en integratie van segmenten in theorie: "Hoe zouden segmenten na oprichting beheerd en geïntegreerd moeten worden volgens de ideale praktijk? Welke methoden zouden ervoor zorgen dat alle segmenten coherente vooruitgang boeken en in lijn blijven met de algemene projectdoelstellingen?"
11. Economische belangen en projectdynamiek: "Op welke manieren zouden economische belangen, verbonden aan individuele segmenten, idealiter de dynamiek en besluitvormingsprocessen binnen een project moeten beïnvloeden?"
12. Financiële gevolgen van segmentatie in theorie: "Kunt u beschrijven welke financiële gevolgen segmentatie idealiter zou moeten hebben op een project? Hoe zou de segmentering de budgettoewijzing, kostenbeheersing en algemeen financieel beheer theoretisch moeten beïnvloeden?"

13. Risicoverdeling in gesegmenteerde projecten: "Hoe zou het risico theoretisch verdeeld moeten worden onder de verschillende segmenten en contractpartijen binnen een project, en welke strategieën zouden toegepast moeten worden om deze risico's effectief te beheren?"

Appendix Q.3 Gesegmenteerde bouworganisatievorm

14. "Hoe staat u tegenover gesegmenteerde bouworganisatievormen en heeft u wellicht een voorkeur voor een specifieke vorm van gesegmenteerde bouworganisatievormen binnen complexe infrastructuurprojecten?"

Appendix Q.4 Uitdagingen en voordelen van segmentatie

15. Theoretische uitdagingen van segmentatie: "Welke uitdagingen worden typisch ondervonden bij de implementatie van segmentatie en hoe kunnen deze volgens u het best worden aangepakt?"
16. Theoretische voordelen van segmentatie: "Ondanks de uitdagingen, welke voordelen meent u dat segmentatie kan opleveren voor complexe infrastructuurprojecten?"

Appendix Q.5 Conclusie

17. Lessen uit segmentatie: "Welke lessen meent u dat kunnen worden geleerd uit de implementatie van segmentatie in complexe projecten?"
18. Toekomst van segmentatie in de civiele infrastructuur: "Hoe verwacht u dat de inzet van segmentatie zich zal ontwikkelen binnen de civiele infrastructuursector? Anticipeert u belangrijke veranderingen in hoe projecten in de toekomst mogelijk gesegmenteerd zullen worden?"
19. Aanvullende inzichten en gebieden voor verder onderzoek: "Zijn er aanvullende inzichten of ervaringen gerelateerd aan projectsegmentering die volgens u belangrijk zijn om te delen? Welke gebieden betreffende de segmentatie van complexe projecten verdienen naar uw mening verder onderzoek of verbetering?"

Appendix R. Legal expert interview questions (EN)

Before the interview, the candidate is extensively informed about the content of the research, including the conceptual definitions of segmentation and segmented contracting. Additionally, the results of the corresponding case study are explained, providing insight into the benefits and challenges of segmentation. The candidate is also educated on which strategic considerations and criteria can be used for segmentation. Furthermore, the candidate is informed about the advantages and disadvantages of these approaches and the various segmented project delivery methods. All this is aimed at ensuring that the interviewee is well-prepared and informed before participating in the interview.

Appendix R.1 Segmentation

1. Role and impact of segmentation: "To what extent are the aspects of coordination, communication, integration, and procurement within segmented project delivery methods primarily the result of segmentation itself, or are they also influenced by the specific project delivery method?"

Appendix R.2 Coordination in segmented project delivery methods

2. Design of coordination: "How should coordination ideally be structured in construction projects with a segmented project delivery method?"
3. Responsibility for coordination: "Who should primarily be responsible for the coordination within such projects: the client, a (co-)contractor, or an external, independent coordinator?"
4. Contents of coordination agreements: "What should an effective coordination agreement look like? Can you describe the essential components of such an agreement?"
5. Tasks and obligations of the coordinator: "What specific tasks and responsibilities should a coordinator have? Are there any special powers or obligations associated with this role?"
6. Focus of the coordinator: "Does the coordinator focus solely on certain risks or on the coordination of the entire project?"
7. Contractual obligations: "Are coordination obligations typically included in a standard contract or are they arranged through a separate agreement?"
8. Conflict resolution in coordination: "How are conflicts over coordination between (co-)contractors and clients resolved?"
9. Important aspects of coordination: "Are there any other important aspects of coordination that you would like to highlight?"

Appendix R.3 Communication and information provision in segmented project delivery methods

10. Essential communication agreements: "What essential agreements need to be made between (co-)contractors and with the client regarding communication and information provision within segmented project delivery methods?"
11. Mandatory information exchange: "What specific types of information, such as technical drawings, must be mandatorily shared between involved parties?"
12. Documentation of communication obligations: "In what manner and in which documents are these communication and information obligations typically contractually recorded?"
13. Communication obligations: "Are there specific obligations for (co-)contractors regarding communication and informing each other or the client? If so, can you describe these?"
14. Confidential information: "How is confidential information protected in communication between different parties within the project?"

15. Conflict resolution over communication: "How are conflicts over information exchange and communication between (co-)contractors and clients resolved?"

Appendix R.4 Integration in segmented project delivery methods

16. Guaranteeing integration: "How is the integration of project segments contractually guaranteed?"
17. Contractual adjustments: "What specific adjustments are needed in the standard UAC/UAC-IC contracts to ensure effective integration of project segments?"

Appendix R.5 Procurement of segmented project delivery methods

18. Criteria for contractor selection: "What specific criteria should be used in the selection of contractors for segmented project delivery methods?"
19. Definition of specifications: "How should technical specifications and project requirements be clearly defined in procurement documents for segmented project delivery methods?"
20. Equal competition conditions: "What steps can be taken to ensure equal competition conditions in the procurement of segmented project delivery methods?"
21. Promotion of market competition: "How can segmented contracting contribute to increasing competition within large, complex projects?"
22. Promotion of market competition: "In what way can segmented contracts be designed to encourage participation from both large and smaller contractors, thereby promoting market competition?"
23. Conditions: "What specific conditions are necessary to maintain the interest of large contractors in extensive segmented projects?"

Appendix S. Legal expert interview questions (NL)

Voorafgaand aan het interview wordt de kandidaat uitgebreid geïnformeerd over de inhoud van het onderzoek, inclusief de conceptuele definities van segmenteren en gesegmenteerd contracteren. Daarbij worden de resultaten van de bijbehorende case study toegelicht, die inzicht bieden in de effectiviteit en uitdagingen van segmenteren. Er wordt uitgelegd welke strategische overwegingen en criteria gebruikt kunnen worden voor het segmenteren van projecten. Daarnaast wordt de kandidaat ingelicht over de voor- en nadelen van deze benaderingen en de diverse gesegmenteerde bouworganisatievormen. Dit is allemaal gericht op het garanderen dat de geïnterviewde goed voorbereid en geïnformeerd aan het interview deelneemt.

Appendix S.1 Segmentatie

1. Segmentatie en de bouworganisatievorm: “In hoeverre zijn de aspecten van coördinatie, communicatie, integratie en aanbesteding binnen gesegmenteerde bouworganisatievormen primair het gevolg van het segmenteren zelf, of worden deze ook beïnvloed door de gekozen bouworganisatievorm?”

Appendix S.2 Coördinatie in gesegmenteerde bouworganisatievormen

2. Ontwerp van coördinatie: “Op welke wijze dient coördinatie idealiter te worden vormgegeven bij bouwprojecten met gesegmenteerde organisatiestructuren?”
3. Verantwoordelijkheid voor coördinatie: “Wie zou primair verantwoordelijk moeten zijn voor de coördinatie binnen dergelijke projecten: de opdrachtgever, een (neven)aannemer, of een externe, onafhankelijke coördinator?”
4. Inhoud van coördinatieovereenkomsten: “Hoe zou een effectieve coördinatieovereenkomst eruit moeten zien? Kunt u de essentiële componenten van een dergelijke overeenkomst beschrijven?”
5. Taken en bevoegdheden van de coördinator: “Welke specifieke taken en verantwoordelijkheden zou een coördinator moeten hebben? Zijn er bijzondere bevoegdheden of verplichtingen die hieraan verbonden zijn?”
6. Focus van de coördinator: “Richt de coördinator zich uitsluitend op bepaalde risico's of op de coördinatie van het gehele project?”
7. “Contractueel vastlegging: “Worden coördinatieverplichtingen doorgaans opgenomen in een standaardcontract of worden ze geregeld via een aparte overeenkomst?”
8. Conflictresolutie in coördinatie: “Hoe worden conflicten over coördinatie tussen (neven)aannemers en opdrachtgevers opgelost?”
9. Belangrijke coördinatieaspecten: “Zijn er nog andere belangrijke aspecten met betrekking tot coördinatie die u zou willen benadrukken?”

Appendix S.3 Communicatie en informatievoorzieningen in gesegmenteerde bouworganisatievormen

10. Essentiele communicatieafspraken: “Welke essentiële afspraken dienen te worden gemaakt tussen (neven)aannemers onderling en met de opdrachtgever over communicatie en informatievoorziening binnen gesegmenteerde bouwprojecten?”
11. Informatie-uitwisseling: “Welke specifieke soorten informatie, zoals technische tekeningen, moeten verplicht gedeeld worden tussen betrokken partijen?”
12. Documentatie van communicatieverplichting: “Op welke wijze en in welke documenten worden deze communicatie- en informatieverplichtingen typisch contractueel vastgelegd?”

13. Communicatieverplichtingen: “Bestaan er specifieke verplichtingen voor (neven)aannemers met betrekking tot het communiceren en informeren van elkaar of de opdrachtgever? Zo ja, kunt u deze beschrijven?”
14. Vertrouwelijke informatie: “Hoe wordt vertrouwelijke informatie beschermd in de communicatie tussen verschillende partijen binnen het project?”
15. Conflictresolutie over communicatie: “Hoe worden conflicten over informatie-uitwisseling en communicatie tussen nevenaannemers en opdrachtgevers opgelost?”

Appendix S.4 Integratie in gesegmenteerde bouworganisatievormen

16. Waarborgen integratie: “Hoe wordt integratie van projectsegmenten contractueel gewaarborgd?”
17. Contractuele aanpassingen: “Welke specifieke aanpassingen zijn nodig in de standaard UAV/UAV-GC contracten om een effectieve integratie van projectsegmenten te garanderen?”

Appendix S.5 Aanbesteding van gesegmenteerde bouworganisatievormen

18. Criteria voor aannemersselectie: “Welke specifieke criteria zouden gehanteerd moeten worden bij de selectie van aannemers voor gesegmenteerde bouwprojecten?”
19. Definitie van specificaties: “Hoe dienen technische specificaties en projectvereisten duidelijk gedefinieerd te worden in aanbestedingsdocumenten voor gesegmenteerde projecten?”
20. Concurrentievoorwaarden: “Welke stappen kunnen worden ondernomen om gelijke concurrentievoorwaarden te garanderen bij aanbestedingen van gesegmenteerde bouwprojecten?”
21. Bevordering van marktcompetitie: “Hoe kan gesegmenteerd contracteren bijdragen aan het verhogen van de competitie binnen grote, complexe projecten?”
22. Bevordering van marktcompetitie: “Op welke manier kunnen gesegmenteerde contracten worden vormgegeven om deelname van zowel grote als kleinere aannemers te stimuleren, en zo de marktcompetitie te bevorderen?”
23. Voorwaarden: “Welke specifieke voorwaarden zijn noodzakelijk om de interesse van grote aannemers in omvangrijke gesegmenteerde projecten te behouden?”