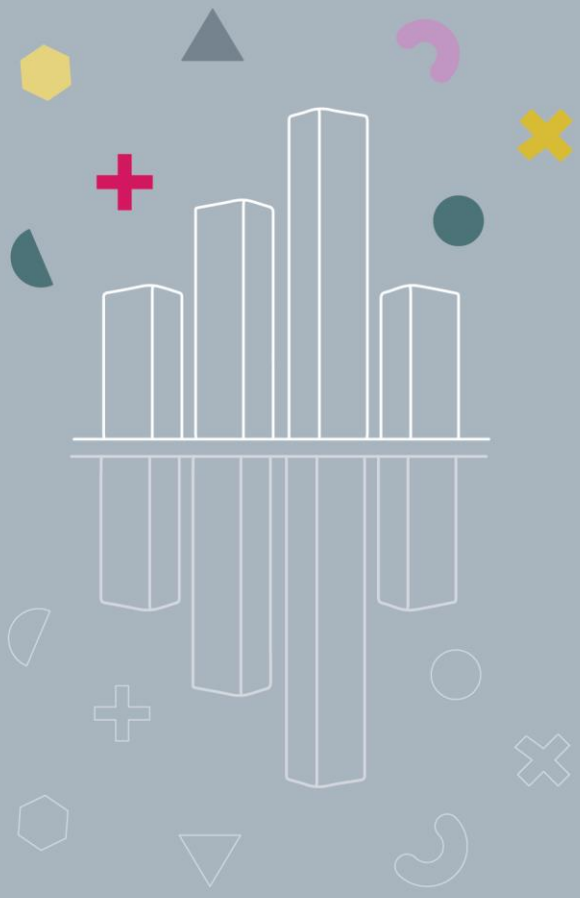
From BIM to Digital Twins: Towards a successful data exchange through public procurement

a case study research within the Dutch building industry



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Preface

The world around us is rapidly changing, and digital information and technology have and will have a major influence on the world. Also in the construction sector, digitization is becoming increasingly crucial. The amount of digital information available is growing exponentially, computer power is expanding rapidly, and digitization technologies are becoming more advanced. This rapid digitalization intrigues me. With this graduation research, I only touch upon a very small part of this change, but I still hope that it can be of impact and that this idea can be an inspiration for other projects.

I'm proud of the final result you are reading right now, as well as the research process that led to it. This graduation research was developed within the track Management in the Built Environment, which is positioned in the MSc program Architecture, Urbanism and Building Sciences at the Delft University of Technology. The research is an effort to contribute to the topic of digitalization within the building industry, particularly from a legal perspective.

The research would not have been possible without the support of a large number of people who were willing to take the time to be part of my graduation and learning process. I appreciated how many people expressed their enthusiasm for their profession and helped me with all sorts of questions and suggestions during meetings. In particular, I would like to thank my committee both from the TU Delft and the Rijksvastgoedbedrijf, for sharing their knowledge with me. First, I would like to sincerely thank my supervisor Mr.dr. E.M. Bruggeman for the guidance, useful feedback, and extensive knowledge on the subject. Furthermore, I would like to thank Dr.Ir. A. Straub for helping me develop the methodological approach with corresponding research questions and feedback. I would also like to thank my supervisors from Rijksvastgoedbedrijf for giving me insight into the organization, connecting me to the right people, and for the weekly coffee breaks. And I would like to extend sincere gratitude to the interviewees for their time and for providing me with valuable information. Finally, I'd want to express my gratitude to my family, boyfriend, housemates, and friends for their support and welcome distraction.

I hope you will enjoy reading this research.

Ilse van Milaan

Delft, June 2022

Abstract

The construction sector is experiencing a fundamental shift towards greater digitization. Building information modeling (BIM), augmented and virtual reality (AR/VR), the internet of things (IoT), Artificial Intelligence (AI), and Digital twins are all becoming more prevalent in the architecture, engineering, and construction (AEC) industry. Greater digitization introduces additional data flows in construction projects that are collected, analyzed, and exchanged. Furthermore, the construction process, procedures, responsibilities, and obligations of the various stakeholders change. Dealing with the large volumes of data and the changing process necessitates a more robust and efficient data strategy than ever before. Tender documents will comprise, in addition to the standard documentation for physical construction work, several new or revised documents or regulations related to digital construction and data exchange. By understanding and controlling data exchange in projects, project advantages and organization-wide success may be realized. Currently, limited research is done in the field of public procurement and data exchange. Comparative case studies, in particular, have received little attention in this area.

Therefore, this thesis addresses the following research question: "*How can contracting authorities (re)design the procurement phases to enhance successful data exchange in construction projects?*" Through a theoretical study, followed by in-depth interviews and case studies, an attempt was made to gain insight into two important aspects of the tender: (I) the requirements of the product and process concerning data in the demand specification, and (II) the use of selection and award phase. Interviews with experts were conducted to provide external validation.

The research demonstrated that more attention should be paid to data exchange within public organizations, with a specific focus on asset management. The great majority of contracting authorities lack the necessary maturity to deal with the growing data in projects. In the procurement process, accurate data exchange is not or hardly prioritized, because public organizations are uncertain and even unaware of what they want and of the possibilities. As a result, a lot of data is lost during the life cycle of a building. For data and information management to become a component of asset management, a contracting authority must first pay attention to the softer, cultural, and organizational factors and define an associated organization-wide vision. By formulating unambiguous process and product requirements following the vision, it will be clear to market parties what the assignment entails and what is expected of them. In doing so, clients need to collaborate more with each other and contractors to achieve a successful data exchange.

Keywords: Digitalization, Data, Procurement, Procurement Law, Contracting authorities, Construction industry

Executive summary

Introduction

The construction industry is undergoing a significant transformation towards greater digitalization. A growing number of construction and installation companies are utilizing data and digital technologies. Hereby, digitalization increases the complexity of the construction projects (Adriaanse, et al., 2020) and related processes by an additional flow of data that will be exchanged, and ultimately managed. Working with data, as a result, causes a greater emphasis on new abilities or a greater emphasis on existing skills, necessitates greater cooperation from all parties, and introduces new roles and responsibilities.

Contracting authorities face significant challenges in exploiting the potential benefits of emerging digitalization. Contracting authorities will have to make explicit requirements concerning the data delivery and the associated process. As a result, in addition to the standard documents regarding physical building work, tender documents will include several new or modified documents and requirements. Thereby, understanding the data management capabilities of a contractor is an essential prerequisite for owners when selecting the most appropriate party to take on a project.

Legal challenges related to BIM and data exchange have been highlighted as demanding attention in research to achieve the potential benefits. Therefore, the thesis addresses the following research question: "*How can contracting authorities (re)design the procurement phases to enhance successful data exchange in construction projects?".* Four sub-questions have been established to offer an answer to the research question:

1. What does digitalization in the construction industry entail?
2. How can a contracting authority enhance data exchange within Dutch public procurement legislation?
3. How do contracting authorities currently enhance data exchange throughout the procurement phase?
4. What organizational and legal conditions should be addressed to improve data exchange and accelerate digitization for the contracting authorities and their construction partners?

Figure: The relationship between the sub-research questions and theory and practice

The purpose of this research is to provide contracting authorities and practitioners advice to develop and enhance their procurement strategy regarding data exchange. Thereby, contributing significant knowledge to the academic literature on procuring data in (public) projects.

Methodology

The research made use of multimethod qualitative research through a combination of empirical and scientific literature research. First, a literature review was conducted to investigate the current state of knowledge in the Dutch building domain regarding digitalization and associated data exchange. The second section of this study included case studies and in-depth interviews with stakeholders from various projects to identify how contracting authorities are currently using the procurement phase to enhance data exchange and related experiences. The case study included 15 semi-structured

interviews with various stakeholders from four reconstruction projects in the B&U and GWW-sector. The resulting findings were validated by external expert interviews.

Results

Research shows that the engineering and construction industry is making a shift towards increasing digitalization (Winfield, 2020). Examples of new technologies include BIM, Virtual and augmented reality (VR/AR) Internet of Things (IoT), wireless sensors, 3D printing, and Digital Twins. Where BIM, in particular, plays a central role in the construction industry's digitalization. Initially, BIM was employed in the design phase of building projects, with architects and engineers being the primary users. Gradually, the application of BIM is extended to the construction phase as well as the operation and maintenance phase of construction objects. The main benefit for contracting authorities applying BIM in the operation and maintenance phase is that it improves current manual information handover methods, therefore enhancing the accuracy of facility management data and increasing the efficiency of work order execution. It may henceforth be utilized for energy and space management, as well as emergency and retrofit planning. In doing so, BIM is making a transition from a 3D digital model comprising only static building data to a digital model that incorporated all types of data collected during the building's life cycle. Previously seen as a by-product of digitization, data is increasingly seen as a valuable asset. The usage of data translated into information and knowledge can significantly improve the efficiency of construction and maintenance processes.

Working with new technology and data necessitates a larger emphasis on either new or current abilities. It necessitates comprehension of data in addition to their usual design and/or development operations. Second, digitalization necessitates more collaboration from all parties involved and places a greater focus on soft skills. To realize the potential for enhanced project information and efficiency, the project team must practice communication, conflict management, negotiation, teamwork, and leadership. Thereby, new roles and responsibilities are introduced.

Various documents can be used by the contracting authorities to define their data needs and related process requirements. The Information Delivery Specification (ILS) eventually supported by an Object Type Library (OTL) specifies what data is required, in what format, how it is structured and when it must be delivered by the contractor. Other, primarily contractual, commitments can be recorded using the BIM protocol. Thereby, several (open) standards have been developed by the industry to facilitate data exchange. The documents will be increasingly standardized under the NEN-ISO-19650. However, a limited number of clients already include an ILS in their contracts. The ILSs that are produced vary greatly and partially comply with the NEN-ISO 19650. The structure and terminology used by the various clients vary, resulting in contractors being frequently presented with varied (contractual) information requirements.

The selection phase includes an assessment of potential suppliers' suitability and capacity to undertake the contract that will be awarded after the procurement process. Among the suitability requirements referred to in Article 2.90 (2)(b) of the Act, the level of technical expertise may be particularly relevant to the tendering of a data-related project. The level of technical competence can be measured or demonstrated utilizing references, certification, or other standards and through performance indicators. For the award phase, the tenderer can demonstrate with the use of the execution plan, the quality it will deliver in the context of BIM in the tender by providing insight into their work process, planning, and expertise. The execution plan might be connected to an evaluation system that adheres to the equity and transparency criteria. Second, the (BIM) model can be utilized to demonstrate that the tenderer can fulfill the BIM-related award criterion. In practice, award and selection

criteria concerning data and information management are rarely used. Only one of the case studies indicated that a BIM selection criterion had been established.

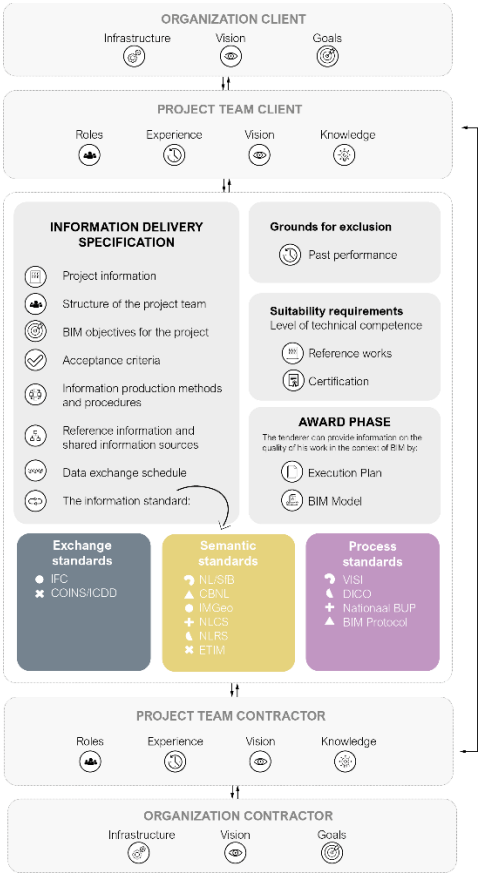


Figure: Theoretical framework

To improve data exchange and accelerate digitization some organizational and legal conditions should be addressed. The research revealed that contracting authorities have a limited understanding of what information is required for effective asset management and therefore do not know what information to request for new projects. According to the findings, developing an organization-wide vision for data and information management is crucial for a contracting authority. Thereby, contracting authorities need to cooperate more with each other and contractors to achieve a uniform information delivery specification so the market is not constantly confronted with new demands and knows what to expect Many contractors can fulfill (higher) data-related product and process requirements, as well as criteria for selection and award, but it must fit their system.

Conclusions

The benefits of successful data exchange for the contracting authorities are mainly in asset management. To make data and information management a part of asset management, a contracting authority should first consider softer, cultural, and organizational elements, as well as develop an organization-wide vision. Digitalization is complex and without the right requirements, accurate data will not be exchanged and the objectives cannot be realized. Therefore, the client must define clear requirements based on the needs of asset management. By formulating unambiguous process and product requirements under NEN-EN-ISO 19650, and in line with the vision, it will be clear to market parties what the assignment entails and what is expected of them.

Thereby, is recommended that an execution plan for data management be requested by the contracting authority. By requesting an execution plan, the candidates are encouraged to think carefully about the process-oriented aspects of BIM and what they can contribute. As a result, improved process agreements may be created at a later stage, resulting in enhanced data deliveries. An execution plan also illustrated the extent to which it is practically feasible and how (labor) intensive the process is to secure the data. Thereby, contractors can help with developing and mapping out client information needs for asset and facilities management.

Recommendations

Based on the research, several recommendations can be made. The following recommendations are made for research:

1. First, further research could broaden the scope, beyond the limitations of this thesis project. For example, the research could be done into contracting authorities outside the Dutch context, subcontractors or suppliers may be included, and emphasis could be placed on groups outside the context of construction projects in other industries and sectors.

2. Further research can be considered at the organizational level of the public commissioner. To gain insight into what the vision and policy are within the organization and how the ambitions with regard to digitization are and can be translated into the various projects and associated tenders.

3. Research could be carried out into the introduction of standards, such as NEN and ISO standards, for information management to make digitization compulsory on the part of the government.

The following recommendations are made for practice:

1. Before the tendering procedure, formulate a widely supported vision, regarding data and information management at the organizational level.

2. Despite the technical nature of data and information management, its effectiveness is mostly driven by softer aspects such as people and organizational structure. This will be the main focus in the future to promote implementation.

3. To facilitate changes, supporting factors relating to the technological and organizational aspects must be in place.

4. As a contracting authority, the vision must be translated into tangible product and process requirements for the contract being tendered.

5. Make sure that as a contracting authority, you consciously select the right people who have an intrinsic and lived motivation and ensure that those with less experience with BIM and data-driven work be included as well.

6. References might be required in the selection phase to ensure that the parties' visions are supported by evidence.

7. Make sure that technical and process-related aspects are included in the award phase.

Eventually, the building sector must move towards a sector-wide ILS under the ISO 19650 standard. If there is one ILS, the market is not continually faced with changing requirements and can prepare. Contracting authorities must therefore work in co-creation with market parties to come up with the best information specifications.

Management samenvatting

Inleiding

De bouwsector ondergaat een belangrijke transformatie in de richting van meer digitalisering. Een groeiend aantal bouw- en installatiebedrijven maakt gebruik van data en digitale technologieën. Daarbij verhoogt de digitalisering de complexiteit van de bouwprojecten (Adriaanse, et al., 2020) en het daarmee samenhangende proces door de toevoeging van een extra data stroom die moet worden uitgewisseld en uiteindelijk beheerd. Het werken met data legt bijgevolg een grotere nadruk op nieuwe vaardigheden of een grotere nadruk op bestaande vaardigheden, vereist een grotere samenwerking van alle partijen, en introduceert nieuwe rollen en verantwoordelijkheden.

Aanbestedende diensten staan voor aanzienlijke uitdagingen bij het benutten van de potentiële voordelen van de opkomende digitalisering. Publieke opdrachtgevers zullen expliciete eisen moeten stellen met betrekking tot de dataverstrekking en het bijbehorende proces. Als gevolg daarvan zullen aanbestedingsdocumenten, naast de standaarddocumenten betreffende fysieke bouwwerkzaamheden, een aantal nieuwe of gewijzigde documenten en eisen bevatten. Inzicht in de datamanagementcapaciteiten van een opdrachtnemer is dan ook een essentiële voorwaarde voor eigenaren bij het selecteren van de meest geschikte partij om een project aan te nemen.

Juridische uitdagingen met betrekking tot BIM en data uitwisseling zijn naar voren gekomen als aandacht vragend in onderzoek om de potentiële voordelen te bereiken. Daarom wordt in dit onderzoek de volgende onderzoeksvraag behandeld: "*Hoe kunnen aanbestedende diensten de aanbesteding fasen (her)inrichten om succesvolle data uitwisseling in bouwprojecten te bevorderen?*" Vier deelvragen zijn opgesteld om een antwoord te bieden op de onderzoeksvraag:

1. Wat houdt digitalisering in de bouw in?
2. Hoe kan een aanbestedende dienst de data uitwisseling binnen de Nederlandse aanbesteding wetgeving bevorderen?
3. Hoe bevorderen aanbestedende diensten op dit moment de data uitwisseling gedurende de aanbestedingsfase?
4. Welke organisatorische en juridische voorwaarden moeten worden aangepakt om de data uitwisseling te bevorderen en de digitalisering te versnellen voor de aanbestedende diensten en hun bouwpartners?

Figuur: De relatie tussen de deelonderzoeksvragen en theorie en praktijk

Het doel van dit onderzoek is om aanbestedende diensten en praktijkmensen advies te geven bij het ontwikkelen en verbeteren van hun aanbestedingsstrategie met betrekking tot data uitwisseling. Daarmee wordt een belangrijke bijdrage geleverd aan de wetenschappelijke literatuur over het aanbesteden van data in (openbare) projecten.

Methodologie

Het onderzoek maakte gebruik van een Multi methodisch kwalitatief onderzoek door een combinatie van empirisch en wetenschappelijk literatuuronderzoek. Allereerst is een literatuuronderzoek uitgevoerd naar de huidige stand van kennis in het Nederlandse bouwdomein met betrekking tot digitalisering en bijbehorende data uitwisseling. Het tweede deel van deze studie omvatte casestudies en diepte-interviews met stakeholders van verschillende projecten om te achterhalen hoe aanbestedende diensten momenteel de

aanbestedingsfase gebruiken om data uitwisseling te verbeteren en welke ervaringen hiermee zijn opgedaan. De casestudy omvatte 15 semigestructureerde interviews met verschillende belanghebbenden van vier renovatieprojecten in de B&U- en GWW-sector. De daaruit voortvloeiende bevindingen zijn gevalideerd door interviews met externe deskundigen.

Resultaten

Uit onderzoek blijkt dat de ingenieurs- en bouwindustrie een verschuiving maakt naar toenemende digitalisering (Winfield, 2020). Voorbeelden van nieuwe technologieën zijn BIM, Virtual en Augmented Reality (VR/AR) Internet of Things (IoT), draadloze sensoren, 3D-printen en Digitale Tweelingen. Waarbij met name BIM een centrale rol speelt in de digitalisering van de bouwsector. Aanvankelijk werd BIM gebruikt in de ontwerpfase van bouwprojecten, waarbij architecten en ingenieurs de primaire gebruikers waren. Geleidelijk aan wordt de toepassing van BIM uitgebreid tot de bouwfase en de beheer- en onderhoudsfase van bouwobjecten. Het belangrijkste voordeel van BIM voor publieke opdrachtgevers in de exploitatie- en onderhoudsfase is dat het de huidige handmatige methoden voor informatieoverdracht verbetert, waardoor de nauwkeurigheid van de facilitaire gegevens toeneemt en de uitvoering van werkopdrachten efficiënter wordt. Het kan daarbij worden gebruikt voor energie- en ruimtebeheer, alsmede voor nood- en retrofitplanning. Daarbij maakt BIM een overgang van een digitaal 3D-model dat alleen statische bouwdata bevat, naar een digitaal model dat alle soorten data bevat die tijdens de levenscyclus van het gebouw worden verzameld.

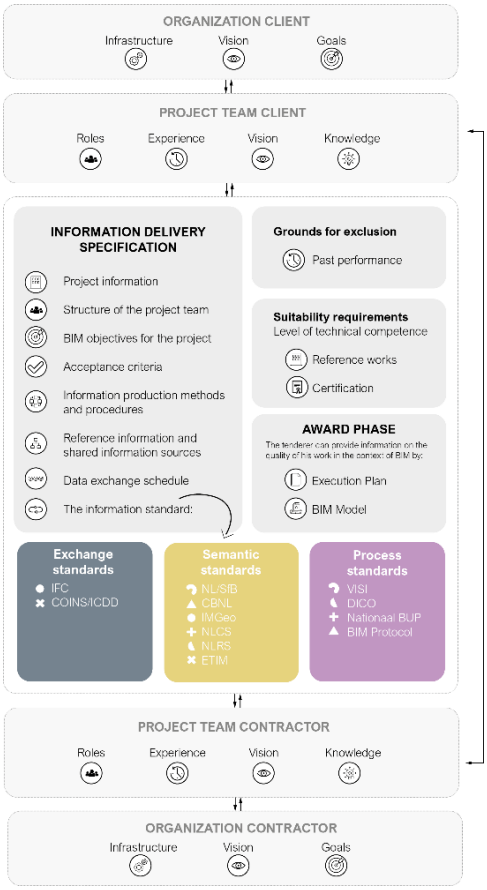
Voorheen werd data gezien als een bijproduct van digitalisering, maar nu wordt het steeds meer gezien als een waardevol bezit. Het gebruik van data vertaald in informatie en kennis kan de efficiëntie van bouw- en onderhoudsprocessen aanzienlijk verbeteren.

Werken met nieuwe technologie en data vereist een grotere nadruk op nieuwe of huidige vaardigheden. Het vereist een begrip van data naast de gebruikelijke ontwerp- en/of ontwikkelingsactiviteiten. Ten tweede vereist digitalisering meer samenwerking van alle betrokken partijen en een grotere nadruk op zachte vaardigheden. Om het potentieel voor verbeterde projectinformatie en efficiëntie te realiseren, moet het projectteam zich oefenen in communicatie, conflictbeheersing, onderhandeling, teamwerk en leiderschap. Daarbij worden nieuwe rollen en verantwoordelijkheden geïntroduceerd.

Diverse documenten kunnen door de aanbestedende diensten worden gebruikt om hun databehoeften en daarbij horende procesvereisten te definiëren. De informatie leveringsspecificatie (ILS), eventueel ondersteund door een Object Type Library (OTL), specificeert welke data vereist zijn, in welk formaat, hoe ze gestructureerd zijn en wanneer ze door de opdrachtnemer moeten worden aangeleverd. Andere, voornamelijk contractuele, verplichtingen kunnen worden vastgelegd met behulp van het BIM-protocol. Daarbij zijn door de industrie verschillende (open) normen ontwikkeld om de uitwisseling van data te vergemakkelijken. De documenten zullen in toenemende mate worden gestandaardiseerd volgens de NEN-ISO-19650. Een beperkt aantal opdrachtgevers neemt momenteel al een ILS op in hun contracten. De ILS'en die worden opgesteld lopen sterk uiteen en voldoen gedeeltelijk aan de NEN ISO 19650. De structuur en terminologie die door de verschillende opdrachtgevers wordt gehanteerd varieert, waardoor opdrachtnemers vaak uiteenlopende (contractuele) informatie-eisen voorgelegd krijgen.

De selectiefase omvat een beoordeling van de geschiktheid en de capaciteit van potentiële opdrachtnemer om de opdracht uit te voeren die aan het eind van de aanbestedingsprocedure zal worden gegund. Van de geschiktheidseisen, bedoeld in artikel 2.90, tweede lid, onder b, van de

wet, kan met name het niveau van technische deskundigheid van belang zijn voor de aanbesteding van een data gerelateerd project. Het niveau van technische deskundigheid kan worden gemeten of aangetoond door middel van referenties, certificering of andere normen en door middel van prestatie-indicatoren. Voor de gunningsfase kan de inschrijver met behulp van het uitvoeringsplan aantonen welke kwaliteit hij in het kader van BIM in zijn inschrijving levert door inzicht te geven in zijn werkproces, planning en deskundigheid. Het uitvoeringsplan kan worden gekoppeld aan een evaluatiesysteem dat voldoet aan de criteria van gelijkheid en transparantie. Ten tweede, kan het (BIM-)model worden gebruikt om aan te tonen dat de inschrijver kan voldoen aan het BIM-gerelateerde gunningscriterium. In de praktijk worden gunnings- en selectiecriteria betreffende data- en informatiebeheer zelden gebruikt. Slechts één van de casestudies gaf aan dat er een BIM-selectiecriterium was vastgesteld.



Figuur: Theoretisch framework

Om de data uitwisseling te verbeteren en de digitalisering te versnellen, moeten sommige organisatorische en juridische voorwaarden worden aangepakt. Uit het onderzoek is gebleken dat opdrachtgevers slechts een beperkt inzicht hebben in welke informatie nodig is voor een doeltreffend vastgoedbeheer en bijgevolg niet weten welke informatie zij voor nieuwe projecten moeten vragen. Volgens de bevindingen is de ontwikkeling van een organisatie brede visie op data- en informatiebeheer van cruciaal belang voor een aanbestedende dienst. Daarbij moeten aanbestedende diensten meer met elkaar en met opdrachtnemers samenwerken om te komen tot een uniforme specificatie voor informatieverstrekking, zodat de markt niet voortdurend wordt geconfronteerd met nieuwe eisen en weet wat hij kan verwachten. Veel opdrachtnemers kunnen voldoen aan (hogere) data gerelateerde product- en proceseisen, alsmede aan criteria voor selectie en gunning, maar het moet wel in hun systeem passen.

Conclusies

De voordelen van succesvolle data uitwisseling voor de publieke opdrachtgever ligt vooral op het gebied van vastgoedbeheer. Om gegevens- en informatiebeheer tot een onderdeel van asset management te maken, moet een aanbestedende dienst eerst zachtere, culturele en organisatorische elementen in overweging nemen en een organisatie brede visie ontwikkelen. Digitalisering is complex en zonder de juiste vereisten zullen nauwkeurige data niet worden uitgewisseld en kunnen de doelstellingen niet worden gerealiseerd. Daarom moet de opdrachtgever duidelijke eisen definiëren op basis van de behoeften van asset management. Door het formuleren van eenduidige proces- en producteisen conform NEN-EN-ISO 19650, en in lijn met de visie, zal het voor marktpartijen duidelijk zijn wat de opdracht inhoudt en wat er van hen verwacht wordt.

Hierbij is het aan te bevelen dat een uitvoeringsplan voor data management

wordt opgevraagd door de aanbestedende dienst. Door het opvragen van een uitvoeringsplan worden de gegadigden gestimuleerd om goed na te denken over de procesmatige aspecten van BIM en wat zij kunnen bijdragen. Als gevolg daarvan kunnen in een later stadium betere procesafspraken worden gemaakt, die resulteren in verbeterde dataleveringen. Een uitvoeringsplan illustreert ook in welke mate het praktisch haalbaar is en hoe (arbeids)intensief het proces is om de data veilig te stellen. opdrachtnemers kunnen zo helpen bij het ontwikkelen en in kaart brengen van de informatiebehoeften van klanten voor asset- en facility management.

Aanbevelingen

Op basis van het onderzoek kunnen een aantal aanbevelingen worden gedaan. Voor verder onderzoek worden de volgende aanbevelingen gedaan:

1. Ten eerste zou verder onderzoek de reikwijdte kunnen verbreden, voorbij de beperkingen van dit thesisproject. Er zou bijvoorbeeld onderzoek gedaan kunnen worden naar aanbestedende diensten buiten de Nederlandse context, onderaannemers of toeleveranciers zouden meegenomen kunnen worden, en de nadruk zou gelegd kunnen worden op groepen buiten de context van bouwprojecten in andere industrieën en sectoren.

2. Verder onderzoek kan overwogen worden op organisatieniveau van de publieke opdrachtgever. Om inzicht te krijgen in wat de visie en het beleid zijn binnen de organisatie en hoe de ambities met betrekking tot digitalisering vertaald worden en kunnen worden naar de verschillende projecten en bijbehorende aanbesteding.

3. Onderzoek zou gedaan kunnen worden naar de invoering van normen, zoals NEN- en ISO-normen, voor informatie management om digitalisering door de overheid verplicht te stellen.

Voor de praktijk worden de volgende aanbevelingen gedaan:

1. Formuleer voorafgaand aan de aanbesteding een breed gedragen visie, ten aanzien van data- en informatiemanagement op organisatieniveau.

2. Ondanks de technologische aard van gegevens- en informatiebeheer, wordt de doeltreffendheid ervan meestal bepaald door zachtere aspecten zoals mensen en organisatiestructuur. Dit zal in de toekomst het belangrijkste aandachtspunt zijn om de uitvoering te bevorderen.

3. Om dergelijke veranderingen mogelijk te maken, moeten ondersteunende factoren met betrekking tot het technologische en organisatorische aspect aanwezig zijn.

4. Als aanbestedende dienst is het van cruciaal belang dat de visie wordt vertaald in tastbare product- en proceseisen voor de opdracht die wordt aanbesteed.

5. Zorg ervoor dat je als aanbestedende dienst bewust de juiste mensen selecteert die een intrinsieke en doorleefde motivatie hebben en zorg ervoor dat ook degenen met minder ervaring met BIM en data gedreven werken worden meegenomen.

6. Referenties in de selectie fase kunnen nodig zijn om te waarborgen dat de visies van de partijen met bewijzen worden gestaafd.

7. Zorg ervoor dat technische en proces gerelateerde aspecten in de gunningsfase worden opgenomen.

Uiteindelijk moet de bouwsector toewerken naar een sector brede ILS volgens de ISO 19650-norm. Als er één ILS is, wordt de markt niet voortdurend geconfronteerd met veranderende eisen en kan zij zich voorbereiden. Aanbestedende diensten moeten daarom in co-creatie met marktpartijen komen tot de beste informatiespecificaties.

Glossary

Subject	Definition	Source
Asset management	The process through which organizations attempt to commission, operate, maintain, improve, or dispose of their assets in the most cost-effective way possible.	Own definition
Award criteria	The criteria are used to evaluate the candidates' tenders during the award phase.	Own definition
BIM Execution Plan (BEP) (*Dutch: BIM uitvoeringsplan*)	Plan prepared by the suppliers to explain how the information modeling aspects of a project will be carried out.	PAS 1192-2:2013
BIM Protocol	Document to make contractual BIM terminology more uniform across a project's design team.	Winfield & Rock, 2018
Building Information Management (BIM)	“An object-based and multidisciplinary approach aimed at facilitating collaboration between parties and the integration of object-related information over the entire life cycle of an asset. This function is supported by IT, through which building objects are often captured in 3D representations.”	Siebelink, Voordijk & Adriaanse, 2018
Common Data Environment (CDE)	“a platform for information collection, management, evaluation, and exchange.”	Preidel et al., 2018
Contracting authority	“The public body who launches a procurement procedure.”	Chao-Duivis, Bruggeman, Koning & Ubink, 2018
Construction 4.0	“The engineering and construction industry's shift towards increasing digitalization”	Winfield, 2020
Data drop	The moment when data is delivered.	Own definition
Digital twins (DT)	“A comprehensive digital representation of an individual product. It includes the properties, conditions, and behavior of the real-life object through models and data. The digital twin is a set of realistic models that can simulate its actual behavior in the deployment environment. The digital twin is developed alongside its physical twin and remains its virtual counterpart across the entire product lifecycle”.	Haag & Anderl, 2018
Employers Information Requirements (EIR) (*Dutch: Informatie Leverings Specificatie (ILS)*)	A document containing a list of requirements for the information that will be exchanged in a project.	Ransijn & Spekkink, 2019

Facility management	Facility Management (FM) involves the maintenance, improvement, and modification of an organization's facilities to foster a productive environment that supports the organization's main goals	(Pärn et al, 2017).
Internet of Things (IoT)	“Networking of sensory devices capable of transferring data across several platforms.”	Gubbi et al. 2013
Object Type Library (OTL)	A generic information model in which object types are organized, described and specified systematically.	Own definition
Open Standards	“Agreements about how data is captured and/or distributed to allow construction partners to store and interchange data regardless of the software they are using.”	Bruggeman, 2018a
Public procurement	“The purchase of products, goods, and services by public authorities to meet the requirements and expectations of public administration.”	Obwegeser & Müller, 2018
Selection criteria	The criteria on which the tenders of market parties are assessed in the selection phase.	Own definition
Smart Buildings	“a building that incorporates data collection, analysis, asset control, and action to respond to defined goals for a particular outcome. It supports the potential of emerging, cutting-edge digital technologies to promote a user-centric, sustainable, and continuously adaptable design for an optimized high performance with a responsive environment that is attractive and stimulating for the occupants”.	Olsen and Karlshøj, 2021

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1 Introduction

In this introductory chapter, the context of the research will be outlined. Thereby, the problem statement and reasoning that resulted in this research proposal, as well as the societal and scientific importance of the research, will be discussed in this section.

1.1 Research context

Over the last decade, digital information and digital technologies had a significant impact on both industries and our society. The Fourth Industrial Revolution is the driving force behind several of the products and services that are quickly becoming vital in today's world (Winfield, 2020). Consider voice-activated virtual assistants like Apple's Siri, customized Netflix suggestions, and Facebook's ability to recognize faces.

Also, the construction industry is undergoing a significant transformation towards greater digitalization. Construction 4.0 is the building industry's version of the Fourth Industrial Revolution. Over the last 15 years, the introduction of Building Information Modelling (BIM) has resulted in substantial changes in the construction industry (Adriaanse, Bruggeman, & Voordijk, 2020). This includes shifting from a 3D digital model comprising solely static building data to a digital model containing all sorts of measurement data collected over the life cycle of the building (Bruggeman & Hoogendoorn, 2021). With this shift, technologies such as Augmented and Virtual Reality (AR/VR), Cloud-based Common Data Environments (CDE) and digital twins are increasingly becoming part of the architecture, engineering, and construction (AEC) sector. The advantages of increased digitization are numerous according to scholars. Less waste of time, effort, and duplication; advancement of productivity, quality control, time, and costs; and more trustworthy data are only a few of the claimed advantages (Winfield, 2020).

However, digitization also adds a new dimension to the construction process, increasing its complexity (Adriaanse, et al., 2020). In addition to the physical building, there will be an extra flow of data that is gathered, analyzed, and exchanged. This can be in the form of a BIM model, but it can also include data from sensors used during construction or in the operation of a building, or data coming from technology integration and data analysis. Organizations and projects alike are frequently overloaded with too much data and information, mainly because technology has improved and data storage has gotten more affordable (EU BIM Task Group, 2017). Handling the massive amounts of data produced and shared regularly necessitates more robust and efficient approaches than ever before (Koutamanis, 2019). Working with data causes a greater emphasis on new abilities or a greater emphasis on existing skills, requires more cooperation from all parties, and, introduces new roles and responsibilities.

1.2 Problem statement

Exploiting the potential benefits of emerging digitalization is a significant challenge for contracting authorities (Osello, Rapetti, Semeraro, 2019). As the public sector is the largest customer in the construction sector, contracting authorities are considered vital drivers of innovation. For successful data exchange on the market, the preparation of relevant procurement documents is required (Popov et al., 2021). Therefore, tender documents will include a variety of new or modified documents or regulations relevant to digital construction and data management in addition to the standard documents regarding physical building work. A digital question that is improperly, incompletely, or unclearly formulated might cause the same issues as a similarly incomplete physical building demand specification. On the one hand, the market must be capable of meeting the established demand and criteria. The criteria, on the other hand, must match the needs and desires of the public sector. Furthermore, efficient project implementation necessitates that project participants be prepared before the start of the project. Understanding the data management capabilities of a contractor is an essential prerequisite for owners when selecting the most appropriate party to take on a project (Malla et al., 2022).

With the expanding influence of construction 4.0 in the industry, best practices and standards that apply to these new processes and obligations would be beneficial to parties' implementation (Winfield, 2020). Internationally, there are an increasing number of standards and guidelines for successful information management in the building industry. In the Netherlands, there are numerous bottom-up attempts to promote digitalization, with various industry organizations proposing methods and standards to make implementation easier. In the Netherlands, no national legal requirements are employed, and international standards have yet to be implemented. Standardization is complicated by the many purposes for which data is used and the many requirements placed on data, as well as by the many methods of cooperating and exchanging data in tenders and contracts. In the Netherlands, data exchange and related procurement still requires attention.

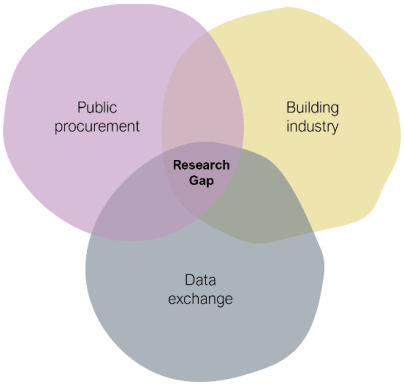


Figure 1.01: The gap of knowledge between public procurement, data exchange, and the building industry.

Also in research, the legal issues associated with BIM and data components have been identified as deserving of attention to achieve the potential positive outcomes (Kuiper and Holzer, 2013; Abd Jamil and Fathi, 2018). The small number of relevant articles found in the literature research (Chapter 2) confirms that data procurement has received limited attention in research thus far. There is a gap of knowledge in research connecting the management of data (and digitalization) to the procurement of it in the building industry (see figure 1.01). Comparative case studies, in particular, have received little attention in this area. The circumstances highlight the need to explore the position of contracting authorities concerning the procurement of data and therefore serve as the foundation for the research's problem formulation.

1.3 Relevance

1.3.1 Practical relevance

Research into the procurement of building projects with a data component can have the following practical relevance:

1 The purpose of this study is to provide contracting authorities and managers with knowledge as well as advice on how to procure to enhance successful data exchange in construction projects. The legal concerns concerning digitalization have been identified as important for research to achieve the benefits. Comparative case studies have hardly been discussed in this context. By conducting this study, it may be possible to incentivize the development of the procurement strategy of projects with a data component.

2 Building projects might be greatly improved as a result of obtaining information on data management for construction projects. By increasing the implementation of digital solutions and effective data management, overruns of time and budget may be avoided, and the overall quality of the project enhanced (Jones, 2014). The digitalization of the construction sector is an important element for the sustainable development of the sector (EC, 2012).

3 Contracting authorities and practitioners may be motivated to change their strategy and working methods as a result of this research. The construction industry is characterized by its fragmentation (Adriaanse, Bruggeman, & Voordijk, 2020; Aibinu, & Papadonikolaki, 2016), making it challenging to use knowledge from one project in the next projects, and project information generated and shared between phases often unreliable and difficult to obtain. By incentivizing them to alter parties' behavior, improve knowledge and information sharing, and promote work integration, the way people work will most probably change for the better.

1.3.2 Scientific relevance

Research into the procurement of building projects with a data component can have the following scientific relevance:

1 This study will contribute to the current body of knowledge in the area of data and information management and procurement in the construction sector. As indicated in the problem statement, there is a research gap combining data exchange and the procurement of building projects. This research aims to bridge this gap by providing more information on the procurement of a data component in construction projects. The existing body of knowledge will be expanded and updated with the latest by integrating literature on data management and procurement.

2 Methodology

The stated research aim and problem definition have led to the main question and several sub-questions. The purpose of these questions was to acquire a thorough understanding of successful data exchange in the tendering process and, as a result, to achieve the research goal.

2.1 Research questions

The following main question is central to the research:

"How can contracting authorities (re)design the procurement phases to enhance successful data exchange in construction projects?"

The main research question has been answered with the help of the following sub-questions (SQs). For each sub-question, a brief explanation is provided for how the sub-question will be addressed in the research.

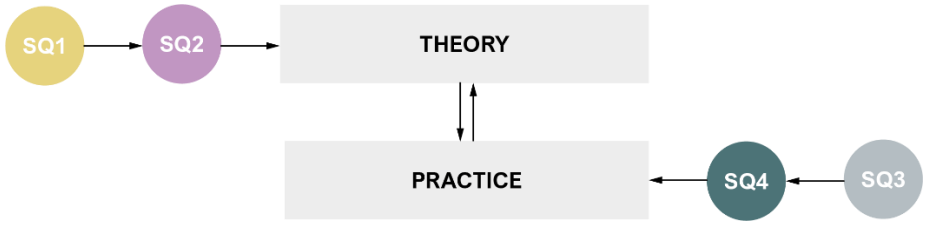


Figure 2.01: The relationship between the sub-research questions and theory and practice

SQ1 What does digitalization in the construction industry entail?

- What technologies are involved in the digitization of the construction sector?
- What are the implications of digital developments in construction projects and related processes?
- What are the implications of digital developments in the construction industry for public organizations?
- What data do contracting authorities need for asset management and facility management?

The purpose of the first sub-question was to get insight into what digitalization in the building industry entails and determine what changes it brings to the digital product as well as the process. In addition, the research examined how further digitalization affects the role of the contracting authority. Information was obtained through literature research.

SQ2 How can a contracting authority enhance data exchange within Dutch public procurement legislation?

- How is the Dutch Procurement Law structured?
- Which documents can be used in the procurement phase by a contracting authority for establishing project and process requirements to enhance data exchange?
- What selection and award criteria can be used to enhance the data exchange?

The goal of the second sub-question was to research the possibility to include a data component in the demands specification, as well as the award and selection criteria under Dutch procurement legislation. For this purpose, the relevant concepts from the Dutch Procurement Act and the process have been examined. An overview is given of the documents that can be used in the procurement process to record data agreements and the content described therein. Based on the existing literature, a conclusion was reached which provided an answer to SQ2 as well as a framework for the empirical part of the study.

SQ3 How do contracting authorities currently enhance data exchange throughout the procurement phase?

- What are the demand specifications used by the contracting authorities to enhance the data exchange?
- What are the selection criteria used by contracting authorities to enhance the data exchange?
- What are the award criteria used by contracting authorities to enhance the data exchange?
- What are stakeholders' experiences with the (re)design of the procurement phases to enhance data exchange?

The third sub-question was posed to investigate how contracting authorities currently demand and intend to demand digital technologies and related data in public procurement. The question was asked to gain insight into two important aspects of the tender: (I) the requirements of the product and process concerning data in the demand specification, and (II) the use of selection and award criteria. In doing so, it was essential to understand the client's and contractor's experiences with the requirements and criteria established. The question was answered through interviews and case studies.

SQ4 What organizational and legal conditions should be addressed to improve data exchange and accelerate digitization for the contracting authorities and their construction partners?

The fourth sub-question has been answered through validation interviews. The question aims to figure out what organizational and legal circumstances are necessary for efficient data exchange in public procurement.

2.2 Research method

The research made use of multimethod qualitative research through a combination of empirical and scientific literature research. Through the multimethod, a more detailed account, a deeper comprehension, and a higher level of trustworthiness is produced (Mik-Meyer, 2020). The research started with theoretical research, followed by an empirical study. The empirical study consisted of various case studies combined with in-depth interviews. Through the interviews, the study aimed to gain a deeper understanding of the concepts, perspectives, and experiences of the stakeholders involved. The research has been validated with the support of expert interviews. In figure 2.02 below, the relation between the research methods and answering the research questions is illustrated. The literature review (phase 1) and empirical research (phase 2) will be discussed in more detail in the following two paragraphs.

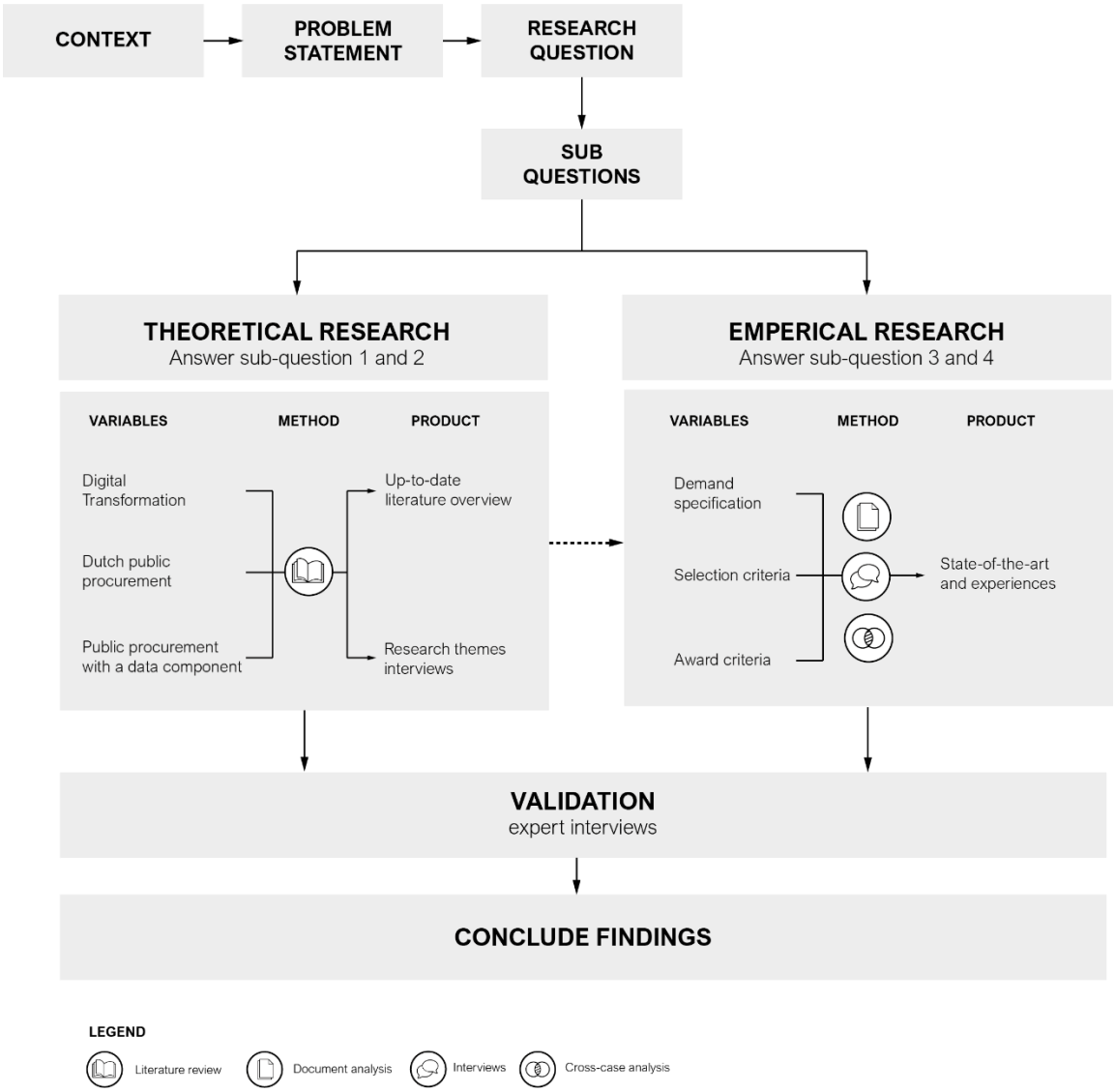


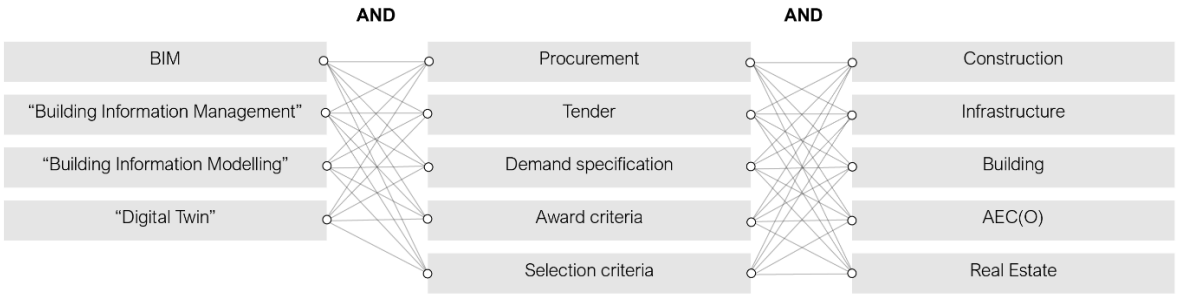
Figure 2.02: Conceptual model research methodology. Own illustration

2.2.1 Phase 1: Theoretical research

First, a literature review was conducted to investigate the current state of knowledge in the Dutch building domain regarding digitalization and associated data exchange. Thereby, it is considered how the data needs and related process requirements can be requested under current procurement legislation. Therefore a systematic literature review has been indicated as a method for summarizing existing findings and addressing research gaps (Brocke et al., 2009). This section outlines how the literature review was executed. The results are discussed in chapters 3 and 4 and provide the answers to the first two sub-questions.

To collect all relevant documents, two multidisciplinary search engines 'Scopus' and 'Web of Science' have been used. Several test searches were performed to identify the right keywords for the systematic literature review. Through the test searches, certain concepts could be refined. It was found the concept of "data" is broad and ambiguous. Therefore, the study focused on the two most significant technologies in the construction industry's data layer, namely "BIM" and "Digital Twins." Furthermore, a significant portion of the literature focuses on e-procurement in which BIM is used to support the electronic construction procurement process. E-procurement goes beyond the scope of this research and was therefore explicitly excluded.

The beginning point for each search is depicted in the figure below. Literature was only included if it was an international scientific journal concluding peer-reviewed articles, conference papers, master theses, or research reports of trusted organizations. Thereby, it had to be published in the year 2017 or later as BIM and Digital Twins are developing rapidly. The same search terms were used in the two search engines in November 2021, with the results of 227 papers.



TS= ((((BIM) OR ("Building Information Management") OR ("Building Information Modelling") OR ("Digital Twin")) AND ((Construction AND (Industry OR Project OR Sector)) OR (Infrastructure AND (Industry OR Project OR Sector)) OR (Building AND (Industry OR Project OR Sector)) OR (AEC) OR (AECO) OR (Real AND Estate)) AND ((Procurement) OR (Tender) OR ("demand specification") OR ("selection criteria") OR ("award criteria")) NOT ((e-procurement))))

Figure 2.03: Search strategy

These articles found form the initial database of the literature review. The literature was reviewed three times to eliminate any papers that aren't relevant. The titles of the papers were scanned first, followed by reading the abstract. The remaining papers were thoroughly read. The researcher applied the same qualifying criteria in each phase, as shown in table 2.01. As a consequence, three articles were produced for the analysis. The small number of relevant publications confirm that procurement of BIM/Digital twins has not gained much attention in the construction industry until now. Because this is such a small amount, background theories on the topics are required. Therefore, the snowball method and the citation searching have been applied.

Inclusion criteria	Exclusion criteria
Setting: Architecture, Engineering, and Construction industry	Setting: other environments
The study focuses on demand specification, award, and selection criteria	The study focuses on the project delivery method
The study makes use of BIM and/or Digital Twin	The study makes use of other digital tools such as VR
Type of research: empirical studies and systematic reviews	Type of research: theoretical papers, position, etc.
A clear description of methods and results	The data-collection process is unclear

Table 2.01: Qualifying criteria literature

A thematic literature review was then performed, and additional supporting articles on these themes were also explored. As a result, the review gave some significant insights into the conceptualization, implementation, and connection of various components involved in data procurement. The review's main points are addressed in chapters 3 and 4.

2.2.2 Phase 2: Empirical research

The second part of this research consists of case studies and in-depth interviews with stakeholders involved in construction projects. Case studies were chosen because they address the comprehensive nature of real-world situations and provide insights into undiscovered phenomena (Eisenhardt & Graebner, 2007). Multiple case studies have been conducted as findings from multiple case studies are often regarded to be more compelling and thus more robust. Furthermore, a multiple-case design was preferred over a single-case design because it minimizes vulnerability to uncertainties while maximizing analytical benefits (Yin, 2018). The process for a multiple case study is depicted in figure 2.04. First, cases were selected based on the theoretical research, and a data-gathering strategy was created. Whereafter, individual case studies were conducted and analyzed. To bring all the information together in a cross-case study to conclude. Finally, the discussion assessed the completed case study and theoretical research to see if there are any additions, changes, or inconsistencies that need to be addressed. The various steps for the case studies and interviews will be discussed in this chapter.

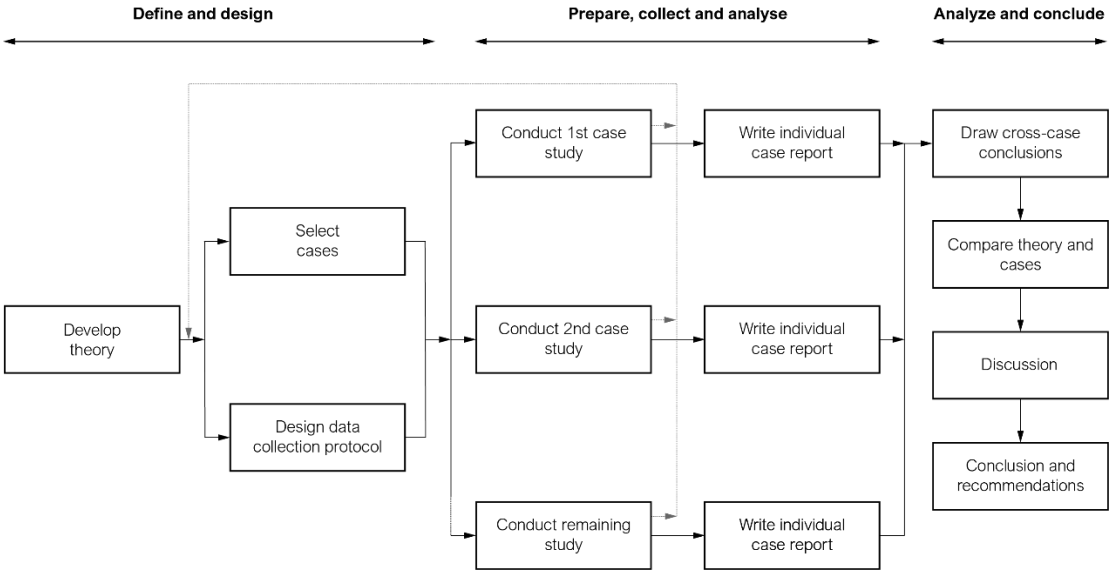


Figure 2.04: Multiple-case study procedure. Adapted from Yin (2018).

To be meaningful, the cases had to be comparable and therefore have a limited number of significant variables. The cases had to meet the following selection criteria to be considered relevant for this study:

.

Criterion	Motivation
There was a certain type of data exchange that took place.	Research is focused on data exchange between contracting authority and contractor.
The project needs to be executed in the architecture, engineering, and construction (AEC) industry.	Research is focused on the building industry.
The client must be a contracting authority.	Contracting authorities in the Netherlands are inherently constrained by the requirements outlined in procurement law principles.
The building has been completed. If not the tender should be completed and the contract awarded.	To find out the experiences of those involved, it is necessary that (part of) the process is been completed.
The project is executed within the last ten years.	Because digitalization is continually evolving, projects that are too long ago will become outdated.
The project is situated in the Netherlands.	Research is focused on the Dutch context.

Table 2.02: Case criteria and motivations. Own table.

The case studies started with project analysis. This analysis delved into the project's overall specifications, such as project objectives, project coalition, project planning, digital solutions, and procurement processes. Various documents on these topics were gathered to conduct this analysis (Bryman, 2016). Additionally, certain documents utilized throughout the procurement phase were examined. Documents such as the call demand specification and the tender instructions were carefully studied and analyzed.

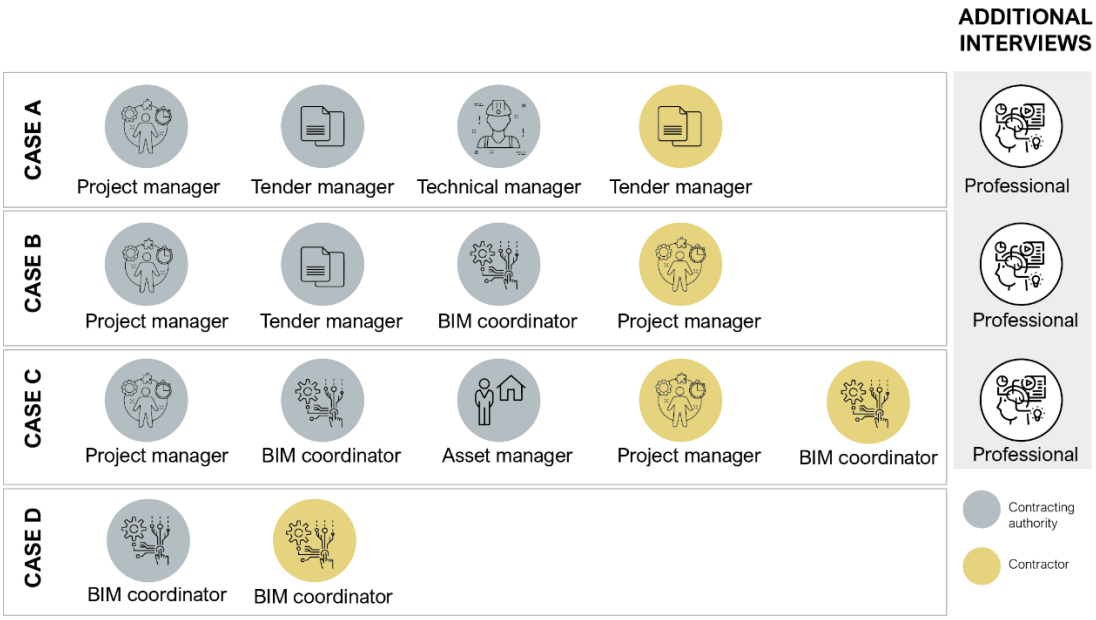


Figure 2.05: Conducted interviews. Own figure.

Following that, the project's involved stakeholders were interviewed. The interviews were conducted in a semi-structured approach. The semi-structured interviews allow for the perspective of the interviewees (Bryman, 20216). These interviews were intended to learn more about how the procurement approach being employed can help with data exchange success. Multiple interviews were conducted for each case study. First, project managers were interviewed because they are extensively involved in the process. Second, a representative participant or expert relevant to the procurement procedure was interviewed for each project. These experts were chosen based on their knowledge of procurement and the implementation of a data component in procurement. Other stakeholders, such as BIM coordinators, technical managers, and asset managers, were also questioned since they were important to the project's data exchange.

An interview protocol was created to set (flexible) boundaries and arrange the questions to some extent. Figure 2.06 demonstrates the procedures involved in creating the interview guide. The interview's protocol was dictated by leads found in the literature. Test interviews are done to ensure that the interview questions were correct and that no questions are redundant or absent.

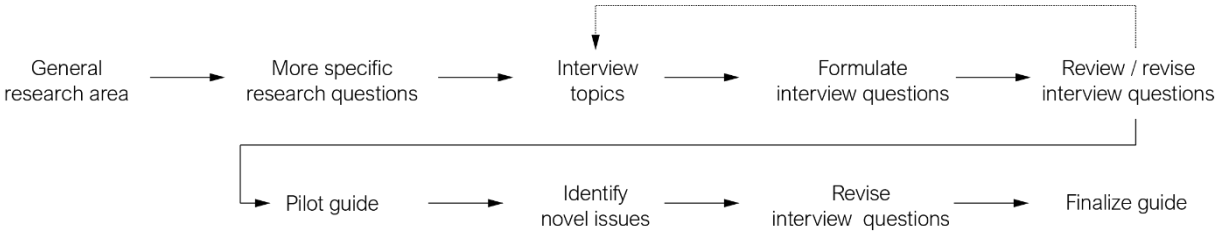


Figure 2.06: Formulating questions for the interview protocol. Adapted from Bryman (2016).

Data was acquired utilizing an audio recording device throughout the interviews. In addition, the interviewer took notes to serve as documentation of the conversation and as a guide for creating a summary of the information gathered. To maintain participant confidentiality, the interviews were transcribed anonymously and interviewees were assigned pseudonyms. The significant and relevant statements from the interviews were extracted and coded.

After the in-case studies, the cases were compared using cross-case analysis. Following, the data collected was presented to external experts to determine its external validity.

2.3 Ethical considerations and data plan

Ethical concerns, as well as in business in general, are becoming more critical. This is particularly crucial when research involves engagement with the business community from members of the general public who function as research participants (Polonsky & Waller, 2018). Participants should not experience any damage, discomfort, anxiety, or any other undesirable feelings as a result of the research (Oliver, 2010).

As this empirical research was done in the form of case studies, including data gathering through participant interviews and (internal) documentation, potentially sensitive, confidential, or even damaging information may be acquired (Creswell, 2014). Before agreeing to participate, participants should be thoroughly informed about all aspects of the study (Oliver, 2010). Potential participants should be informed about how the research findings will be disseminated. The extent of the confidentiality of the data submitted and the anonymity of the responses should be clarified with the participants.

Before the interview, participants were informed in writing about the research's purpose and process to guarantee that the interviewees understand exactly what they were committing to. The interviewee was requested to sign a consent form before the interview was conducted. The consent letter was prepared to clarify the research goals, how the data was used and processed, and the risks they may confront by participating in the research in this paper. The participant was asked if he or she consents to the interview being recorded so it could be transcribed and translated afterward. This document also included agreements about what will happen to the data once the study is conducted. The interviewee's participation cannot be traced if they decided to participate anonymously.

The FAIR data principles (Wilkinson et al., 2016) were respected when processing the data in this thesis, which prescribe the collected data should be findable, accessible, interoperable, and reusable. These principles will be implemented as follows:

- Findable: The final research thesis will be uploaded to the Delft University of Technology's educational repository.
- Accessible: Data not included in the final thesis can be requested by sending an email to the address listed in the colophon. Without the explicit permission of the person(s) involved, any (sensitive) personal information gathered during the interviews will not be disclosed. In the final thesis, the information will be censored or omitted as much as possible.
- Interoperable: The language utilized in this thesis is English to be easily interoperable. Likewise, Dutch data is translated into English, with the Dutch term in brackets if appropriate.
- Reusable: For the research's reusability, the methodology of the collected data is discussed in depth. All data is APA style referenced or cited and can be found in the reference chapter at the end of this report.

2.4 Research output

The objective of this research is twofold. The first goal is to create value for contracting authorities and practitioners by providing them with advice to develop and improve their procurement strategy regarding data exchange. Second, the purpose is to contribute significant knowledge to the academic literature on procuring data in (public) projects. The following objectives and deliverables have been established to help achieve the main goal:

- Literature review on the subjects of 'data exchange', 'Public commissioning', and 'procurement of data exchange by contracting authorities'. The purpose of the literature review is to provide an understanding of the current knowledge and to make an up-to-date well-structured literature overview of this topic.
- Interviews with practitioners who are already active in data procurement to provide specific and detailed information on their experiences.
- The in-case and cross-case analysis of data exchange in procurement. The objective of the case study is to integrate practical experience with scientific research. This research is aimed at the experiences of procuring data exchange in a variety of public projects.
- Recommended follow-up studies will be necessary because data exchange is still in the innovation phase.
- Insight into how the contracting authority is of influence on the data exchange and advise how the procurement strategy can contribute to a successful data exchange.

The outcome of this research can be used by contracting authorities in the Architecture, Engineering, and Construction (AEC) industry to revise and/or improve their current procurement strategy on data and information management. Hopefully, by adopting this advice, more successful projects will be completed, and data exchange in public building projects will become more effective. Furthermore, academics interested in data exchange and emerging technologies in the construction industry might find this paper valuable.

3
Digitalization

The central question in this chapter is: "*What does digitalization in the construction industry entail?"* (SQ1). This chapter aims to provide an overview of existing scientific knowledge on digitalization. It begins by exploring the sector's overall paradigm, construction 4.0, followed by an in-depth exploration of the most significant digital developments, as well as their implications for the construction process and product. Finally, focus on the influence in the specific context of contracting authorities.

3.1 Construction 4.0

In the latter half of the twentieth-century digital technologies in the manufacturing and production sector emerged, commonly referred to as the fourth industrial revolution (Karmaker & Delhi, 2021). This revolution of industrial processes enabled real-time data collection and analysis, allowing workflows to be more flexible and leading to faster and more efficient production (Newman et al., 2020). The concepts of industry fourth industrial revolution are increasingly being applied in the construction sector. However, the sector's shift to greater digitalization is unfolding more gradually than in other sectors (Karmaker & Delhi, 2021; Winfield 2020). This can be attributed to the complexity of the sector and its conservative nature in the face of disruptive change. Further, due to the substantial fragmentation in the sector, the transition from analog to digital processes is occurring at varying levels of maturity (Winfield, 2020; Adriaanse, 2014). While in the design phase the digitization process is developing rapidly, others phases, such as installation and construction are lagging.

However, identified as one of the least digitalized economic sectors (Barbosa et al., 2017), the construction sector has seen some technological innovations in the previous decade. With emerging technologies such as Digital Twins, Artificial Intelligence, Building Information Modeling (BIM), and Augmented and Virtual Reality (AR/VR) being implemented, the construction industry is currently at an interesting junction. These digital innovations are already affecting parties in the construction industry and will continue to do so in the coming decades. Due to the increasingly exponential development of computer power, the greater availability, and combinations of old and new digital developments, the speed of technological innovation will continue to accelerate (Adriaanse, Bruggeman, & Voordijk, 2020).

Construction 4.0 is the engineering and construction industry's shift towards increasing digitalization (Winfield, 2020). The associated dynamics of Construction 4.0 are visualized as a four-layered model by Karmaker & Delhi (2021) in Figure 3.01. The model consists of four layers: the physical layer, the digital tools layer, the data layer, and the control data management layer. Below, various digital developments in the construction sector will be briefly explored based on the different layers.

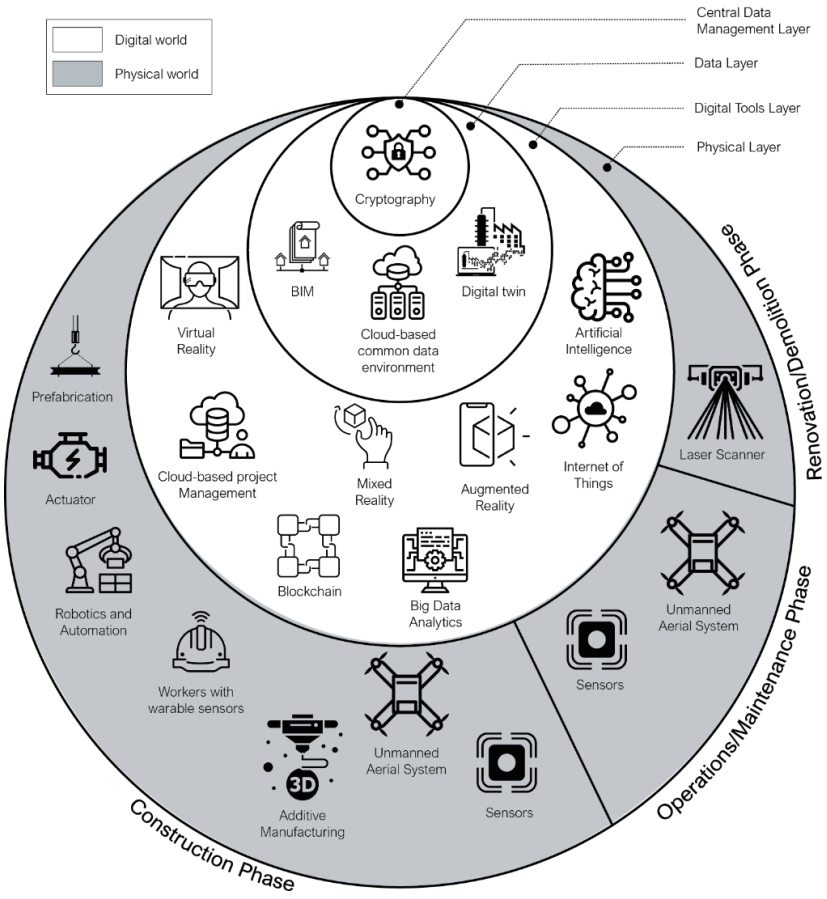


Figure 3.01: Four-layered model construction 4.0. Adapted from Karmaker & Delhi (2021)

Data layer

The data layer consists of the data models that correspond to the physical world. The fundamental drivers in this layer are the technologies as BIM, Digital Twin, and Common Data Environment (CDE). In which especially *BIM* plays a central role in the digitization of the construction sector. Already in the early 1990s, the term 'Building Information Model' was introduced (van Nederveen & Tolman, 1992). Ever since, Building Information Modelling (BIM) has received much attention and grown increasingly important for modern architecture, engineering, and construction (AEC) as it has the potential to offer multiple benefits. BIM is among others intended to result in enhanced collaboration, data integrity, intelligent documentation, dispersed access and retrieval of building data, and increased building performance and quality (Gu & London, 2010). Whether projects may effectively benefit from these promised benefits depends on how BIM is implemented in the project and organization.

During the previous two decades, BIM has evolved from Building Information Modelling to Building Information Management (Bruggeman & Hoogendoorn, 2021). This includes moving from a 3D digital model that just contains static building data to a digital model that includes all types of measurement data acquired throughout the building's life cycle. Initially, BIM was primarily used in the design phase of the construction process, with architects and engineers being the main users of this technological advancement. However, the use of BIM has gradually grown to include the integration of design and construction. BIM allows for the synchronization of design and planning (4D-BIM), as well as insight into the spatial orientation of construction activities and logistical processes on the construction site. The operation and maintenance phase of construction items now uses data from the BIM model's design and execution phases. BIM is

therefore more than just a technological shift; it's also a process transition based on a life-cycle approach and it encourages project participants to work together intensively (Bolpagni, Ciribini & Philp, 2016). However, further data integration across the full life cycle is still in its early stages (Adriaanse, Bruggeman, & Voordijk, 2020).

The use of BIM in combination with real-time data from the Internet of Things (IoT) provides a supplementary perspective on how to enhance construction efficiency and operations. BIM models can provide a highly accurate operational dataset that represents the specified building components, characteristics, and spatial organization as a collection of virtual assets by combining geometry, geographic position, and a scalable set of metadata values. IoT data extends to this set of data by providing real-time data on construction and operating activities (Tang et al., 2019). When it concerns BIM and IoT, several academics use the term "Digital Twins" (DT). Subsequently, Digital twins are frequently referred to as "enriched BIM," "IoT enabled BIM," or "Smart BIM" (Tijs, 2020). “The digital twin is a comprehensive digital representation of an individual product. It includes the properties, conditions, and behavior of the real-life object through models and data. The digital twin is a set of realistic models that can simulate its actual behavior in the deployment environment. The digital twin is developed alongside its physical twin and remains its virtual counterpart across the entire product lifecycle” (Haag & Anderl, 2018). Digital twins, like BIM models, come in a variety of sizes and shapes. Some common components that a digital twin may include: (1) Observing and monitoring the physical world by collecting useful information about physical objects and monitoring them throughout their life cycle using sensors; (2) Integrating and connecting BIM and other data and knowledge platforms; (3) Using artificial intelligence to perform simulations, predict and optimize processes (Boje, 2020). In the construction industry, the use of extended forms of digital twins is yet in the future but is promising. For example, digital twins can play an important role in the circularity of buildings. A digital twin can be used to gain insight into how the building components perform over time. It will then be possible to determine the extent to which they can still be reused. The knowledge about the material can subsequently be applied during the design process of future construction projects (Adriaanse, 2020).

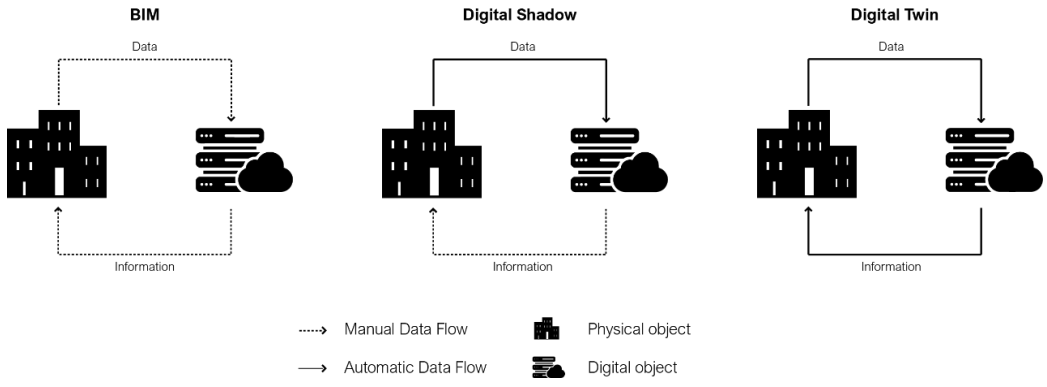


Figure 3.02: Data flows (adapted from Kritzinger et al. (2018)

Kritzinger et al. (2018) identified three primary sub-classes of the so-called Digital Twin. The first is the Digital Model, which corresponds to a digital representation without automatic data transfer and is quite similar to a BIM when utilized in the construction industry. In the Digital Shadow, data is conveyed in real-time from a physical asset to a digital asset solely. The Digital Twin is defined as a digital model that allows for the automatic interchange of physical assets with digital assets and vice versa (Figure 3.02).

Even though the two technologies seem to complement each other, there are some distinctions between BIM and Digital Twins (Khajavi et al., 2019). Firstly, BIM was developed to improve design and construction efficiency, whereas the digital twin was developed to increase building operational efficiency and deliver predictive maintenance. Secondly, BIM is not intended to deal with real-time data and it still does not necessitate real-time capabilities. The final distinction between the two concepts is the type of data necessary for each model. While BIM is useful for integrating cost estimates and schedule data to improve the efficiency of a construction project, the digital twin is intended to incorporate real-time sensor data to analyze and optimize the building's interaction with its surroundings and users.

The term 'Common Data Environment' (CDE) is frequently used while working with data and thus BIM and Digital Twins. The CDE serves as a platform for information collection, management, evaluation, and exchange (Preidel et al., 2018). A CDE could be an extranet, a cloud-based system, or a project server. The centralization of data storage decreases the possibility of data redundancy and ensures the availability of accurate data at all times. Furthermore, the CDE improves information reusability, simplifies model aggregation, and serves as a central repository for documentation (Preidel et al., 2018).

Digital Tools layer

Between the physical and data layers, *the Digital Tools layer* serves as a mediator that transfers information between these layers. This is done through technologies such as Artificial Intelligence (Ai), Big data analytics, Virtual Reality (VR), Augmented Reality (AR), Blockchain technologies, and Cloud-based project management technologies.

The Internet of Things (IoT) is widely regarded as one of the most crucial areas of future technology, and it is attracting a lot of interest from organizations. The Internet of Things can be described as the networking of sensory devices capable of transferring data across several platforms (Gubbi et al. 2013). Intelligent devices, single-board computers, smart mobile devices, and other sensors and actuators are examples of typical IoT devices (Tang et al., 2019). Regarding construction 4.0, five IoT technologies are identified: radio-frequency identification (RFID), wireless sensor networks (WSNs), middleware, cloud computing, and IoT application software (Forceal et al., 2020).

Thereby, Augmented and Virtual reality is already being used regularly in the sector. Augmented and Virtual realities (AR/VR) are computer-simulated environments in which the user interacts with mixed or virtual reality (Karmaker & Delhi, 2021). In virtual reality, the user encounters an alternate reality by immersing oneself in it. Via augmented reality virtual items are integrated into the natural environment. Visualization tools can be used, for example, in the design phase to represent the virtual design in its physical environment at full size, detect clashes, or support staff in carrying out complex repair and maintenance tasks (Adriaanse, Bruggeman, & Voordijk, 2020).

Physical layer

During the project lifecycle, *the physical layer* is where the tangible operations occur with the involvement of people. In the layer, technologies can be found that manipulate and/or capture physical reality into the digital world. Sensors, IoT-connected devices, Unmanned Aerial Vehicles (UAVs), and Light Detection and Ranging (LIDAR) are examples of these technologies. Various types of data, such as temperature, humidity, air velocity, light, and sound, can be collected through sensors and communicated to the building control system in a smart building to track the circumstances and human behavior (Arditi, Mangano, & De Marco, 2015). In the literature, various terms are used to describe smart building technology, such as 'intelligent building', 'smart building', and 'smart office'. According to Olsen and Karlshøj, (2021), smart buildings can be defined as "a building that incorporates data collection, analysis, asset control, and action to respond to defined goals for a particular outcome. It supports the potential of emerging, cutting-edge digital technologies to promote a user-centric, sustainable, and continuously adaptable design for optimized high performance with a responsive environment that is attractive and stimulating for the occupants".

Smart buildings may provide several benefits to the management and maintenance phase by combining data. Data can give objective insight into actual occupancy and use, allowing buildings to be used to their full potential. When a certain area is utilized infrequently, modifications can be made or the area can be assigned a new purpose. At the portfolio level, objective choices can be made to dispose of or purchase a building. The facilities department may prioritize cleaning by knowing which areas of the building are utilized the most. Combining occupancy and climate systems can help to reduce the energy consumption of a building. By using indoor climate data such as light, noise levels, heat, and air quality, the operator can steer the organization towards a healthy workplace. Technical building managers can get more insight into how installations operate and what issues may emerge. With accurate data, higher-quality long-term maintenance plans may be created, allowing maintenance to be organized as efficiently as feasible, resulting in fewer failures (Zeijl, & Drijfhout, 2021). However, there are some disadvantages to smart buildings. Hackers will have additional possibilities to gain access. Previously, smart building applications have been 'broken into' over the internet at various organizations (Ciholas et al, 2019). Thereby, social, organizational, and human variables are frequently overlooked, resulting in unsatisfactory performance. For example, allowing users to control their lighting, temperature, and location through an app may seem appealing, but in actuality, this type of project frequently fails. This frequently occurs because the user's requirements are unpredictable and liable to change. Working with the end-user to determine their specific requirements is critical (Zeijl, & Drijfhout, 2021).

Many data-generating systems are already present in modern buildings. It often contains a heating, ventilation, air-conditioning, and cooling (HVAC) system controlled by a building automation system (BAS), a lighting control system, and meters that monitor the use of various commodities such as energy and water (Burak Gunay et al., 2019). In addition to these established data sources, new data sources from different organizational sources are emerging, as can be seen in figure 3.03. This includes access and security systems to control access and provide protection through a.o. door sensors, movement sensors, and cameras. Data can be obtained through management systems, such as the computerized maintenance management system (CMMS), which is used to track the maintenance status and record defects and occupant satisfaction. The Wi-Fi network, for example, is one of the IT services that can be utilized to generate data. Thereby, HR can probably give information regarding people's performance, health, and satisfaction. However, it is difficult to get HR data, research employing HR data in building performance analytics is limited due to privacy considerations. Finally, systems such as networks of mobile devices and wearables are also emerging data sources to monitor thermal comfort, indoor air quality, and occupancy patterns (Burak Gunay et al., 2019).

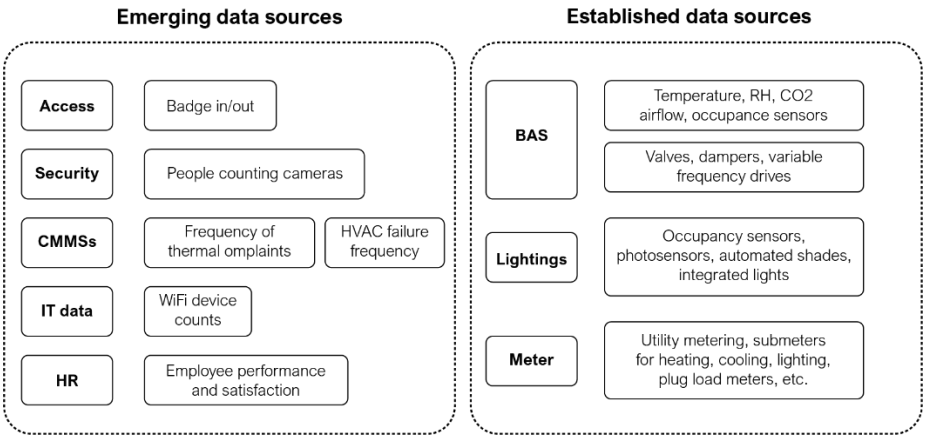


Figure 3.03: Emerging and established data sources in buildings. Adapted from Burak Gunay et al. (2019)

To analyze data from both established and emerging data sources, the ability to collect and combine data is essential. Even for the established sources, this can be challenging. These systems' data is only designed for their intended functions and not for analytics (Burak Gunay et al., 2019). This presents a number of issues for the data gathering phase, such as the fact that most data is only retained for a short period. It also presents issues for the combination phase, such as the lack of a common method of categorizing the data, which means that each building's categorization will most certainly be different. Other constraints include privacy and security considerations, which might arise, particularly when dealing with human resources or security data (Burak Gunay et al., 2019).

3.2 Product: data

With the digitization of the construction sector, there will be an extra flow of data in addition to the physical building. The volume of project data in the design and construction phases has expanded almost exponentially since the introduction of BIM (Boje et al., 2020). Whereas data was initially considered a by-product of digitalization, it is increasingly being considered a valuable asset that is critical to the success of a project. Given the growing relevance of data, it's worth considering the distinction established in research between data, information, and knowledge.

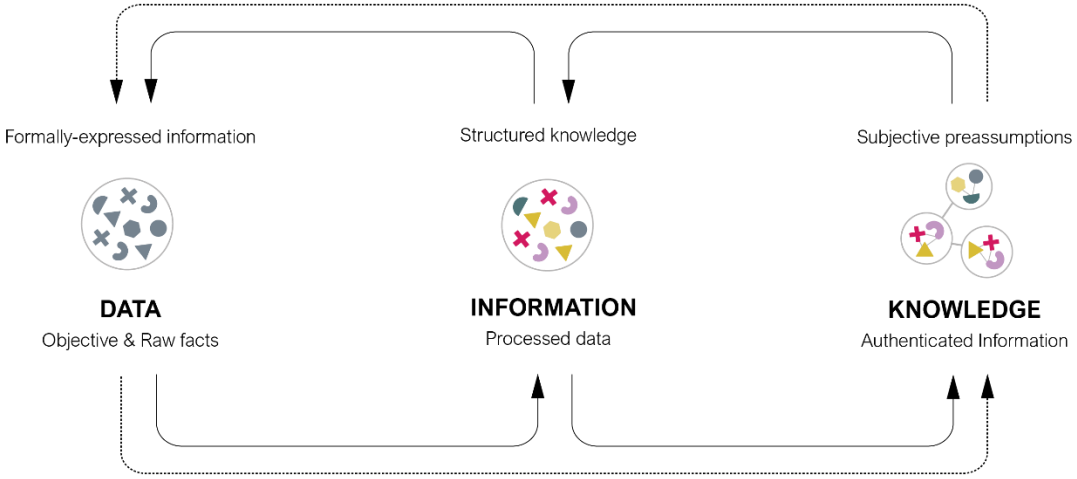


Figure 3.04: The cyclic model for the transformation of semantic levels (Parsanezhad, 2015)

Data is used to capture the actual representation by recording activities or situations. Data can be in the form of recorded symbols (including words, numbers, and images) and signals (including sensor and/or sensory readings of light, sound, smell, taste, and touch) (Liew, 2007). Most data unless utilized for explanatory purposes, such as forecasting, is considered historical. Data, in BIM terms, is the representation of data about the built environment. Thereby, a BIM model or a digital twin can collect (raw) data from an asset using for example sensors, signals, and measurements. 'Data' can be transformed into 'information' (Parsanezhad, 2019). Information, in this context, is referred to as a message containing relevant meaning, consequence, or input for a decision and/or action. It shows the connections between data elements. In BIM terms, consider the representation of the materials used, their size, their position in the building, their relationships with other components, and so on. By adding information to the dry data, it can be given significance. As the name implies, Building Information Modelling is concerned with assigning information to and creating information from elements and models. Subsequently, information can be validated against the organization's standards and values to create corporate 'knowledge'. Knowledge includes making connections and giving meaning to information. Knowledge's purpose in business is to produce or increase value for the organization and all of its stakeholders (Liew, 2007). In the case of BIM, information can be utilized to verify that the design meets the required schedule, as well as the results of calculations relating to energy efficiency, light, and cost estimations. Figure 3.04 presents a summary of the various theories in a cyclic model. Wherein, 'data' can be transformed into 'information,' which can then be validated against the organization's standards and values to create corporate 'knowledge'. Conversely, when structured, officially expressed, and documented, the subjective presumptions and tacit knowledge entrenched in the minds of disciplinary actors can be transformed into "information" and "data." (Parsanezhad, 2015).

The demand for detailed data increases during the life cycle of a building as illustrated in figure 3.05. 3D modeling systems are mainly used during the design phase to visualize the design. As the project progresses from conceptual to detailed design, more data on the materials, spaces, equipment and other elements will be incorporated into the design. Even more data and details are required throughout construction for calculations, coordination, and installation (Teichholz, 2013). Finally, the resulting "as-built" model must be maintained.

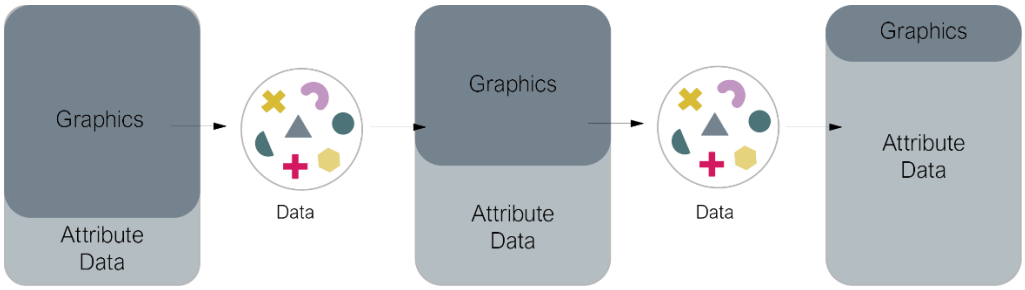


Figure 3.05: Mix of graphics and data changes over the building life cycle. Adapted from Teichholz (2013)

Data collected throughout a digital building's lifespan can be divided into active and passive data. Passive data, according to Halmetoja (2019), is information that does not have to be collected automatically. Passive data is permanent and is mostly generated during the implementation phase. According to its persistence, the study divides passive data into three categories: permanent, long-term, and short-term. Permanent data, such as the street address and geographic information system coordinates, remain constant throughout the building's life cycle.

Long-term data usually does not change. The short-term passive data consists of data that changes infrequently due to equipment refurbishment, maintenance, or replacement. BIM may be viewed as a passive data source. Active data is generated by operating and managing an asset and includes an automatic flow of data. Active data includes, for example, data generated by sensors and gauges, defect notifications, energy usage, service requests, indoor condition data, and alarms. A digital twin converts this data into information. This processed data or information is then returned to the asset in various ways, for example through stakeholder decisions or control signals.

3.3 Digital process

As noted in the introduction, working with new digital advances involves changes at the process level. Digital technologies profoundly alter organizational structures and procedures, as well as people's working styles, the responsibilities, and skills of everyone engaged will significantly change and new organizational roles will be developed. These changes will be briefly discussed in this section.

First of all, working with new technologies causes a greater emphasis on new abilities or a greater emphasis on existing skills (Bruggeman, 2020). It necessitates understanding from the building actors of digital design and construction, in addition to their typical activities of designing and/or developing. The usability of a new advanced digital technology feature is determined by how users understand and use it in practice (Liu, Van Nederveen, & Hertogh, 2017). Varying levels of BIM maturity between collaborating parties in a project, especially when it comes to BIM usage with significant data flows, can be a limiting factor to the extent to which ambitions and associated expectations can be realized (Siebelink, Voordijk, & Adriaanse, 2018). It can be difficult for old users to understand the potential and uses of existing systems. Therefore, for both practitioners and students, improved and up-to-date training programs are essential (Gu and London, 2010). It is vital to cultivate a culture of learning and innovation to create a learning organization (Liu et al., 2017).

Secondly, digitalization requires more cooperation from all parties and places a stronger emphasis on soft skills. Currently, the construction industry is facing a strong fragmentation. According to Adriaanse (2014), the construction industry is highly fragmented in at least three ways (see figure 3.06).

1 Vertical fragmentation*:* the construction process is divided into several phases with a clear division between them. This is primarily due to the traditional culture of collaboration in the building industry. The design is created by the client or the client contracts out the design operations to third parties. Once the design is finalized, the contractor becomes involved. The building is delivered to the client once the work is completed. As a result, there is limited information and knowledge transfer across phases. The division of the construction process into phases is called vertical fragmentation.

2 The increased complexity of construction and thus the necessity for specialized knowledge has resulted in a large number of parties per phase. This *horizontal fragmentation* has resulted in a network of an increasing number of parties involved in a construction project, each with its interests and experiences, as well as it's working methods and (digital) systems. Subsequently, parties focus on optimizing their respective contributions, with little knowledge and information exchange between them.

3 Longitudinal fragmentation: the construction sector primarily operates on a project-by-project basis. Cooperation is usually limited to the period of a single project, after which the relationship disintegrates. The industry's project-based orientation and evolving forms of collaboration make it difficult to transfer knowledge from one project to the next. Furthermore, it can be challenging to see a project in the context of the other projects that are running within that party at the time.

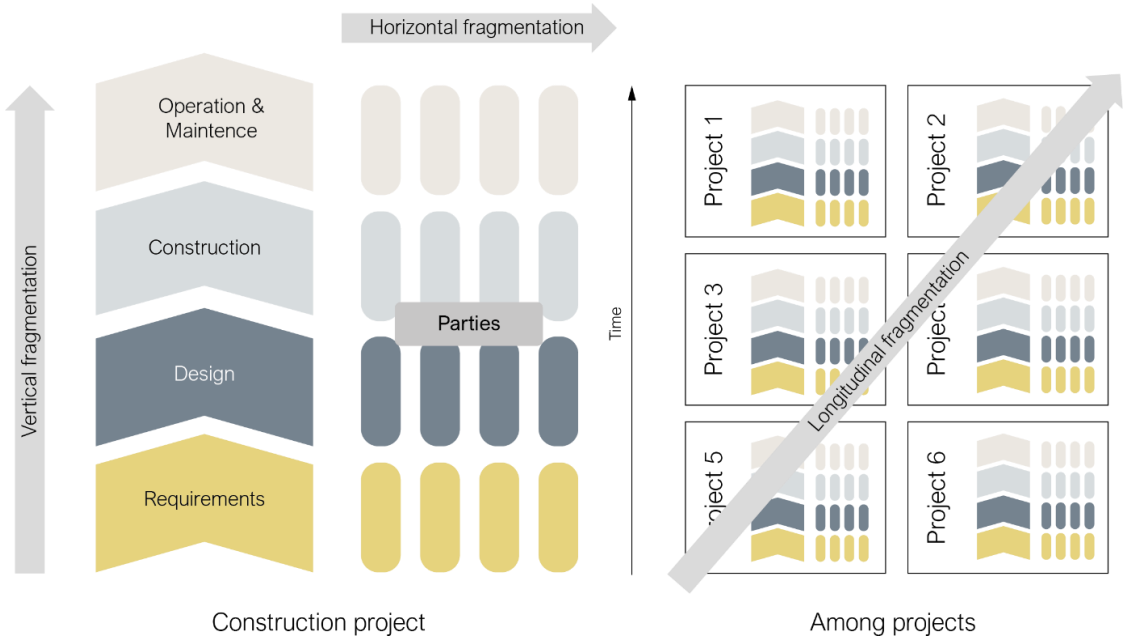


Figure 3.06: Three forms of fragmentation in construction (Adriaanse, 2014)

Working with digital technologies requires a transition from fragmented to more integrated practices (Miettinen and Paavola, 2014). To achieve the benefits of BIM, a cultural shift, a change in practices, and a change in working practices and competencies are required (Gu and London, 2010). The 'soft' aspects of collaboration are just as crucial as the 'hard' aspects of when it comes to effective cooperation using BIM (Papadonikolaki et al.,2019; Davies, McMeel, and Wilkinson, 2015). Communication, conflict management, negotiation, teamwork, and leadership are all necessary within a BIM project team to realize the potential for improved project information and increased efficiency (Davies et al., 2015). Soft talents require a combination of personality, experience, and training or education (Davies et al., 2015). As construction collaboration and integrated processes are tied to a contractual vision, it is critical to recognize the procurement approaches that might affect BIM adoption (Papadonikolaki et al., 2019).

Finally, it introduces new roles and responsibilities. Numerous BIM-related specialized functions have emerged and will continue to develop. If these numerous evolving BIM roles, such as BIM managers and BIM coordinators, are not properly managed and coordinated, they can further hinder cooperation (Papadonikolaki, van Oel, & Kagioglou, 2019). ICT innovations are simply becoming too complicated and crucial for construction projects to simply bolt on to project management (Adriaanse, 2014). Therefore, contracts should include roles, either in the form of a specific schedule of services or in the form of general responsibilities (ISO 19650). Especially, the coordinator of the digital project is an exceedingly significant function that demands special attention (Adriaanse et al., 2020).

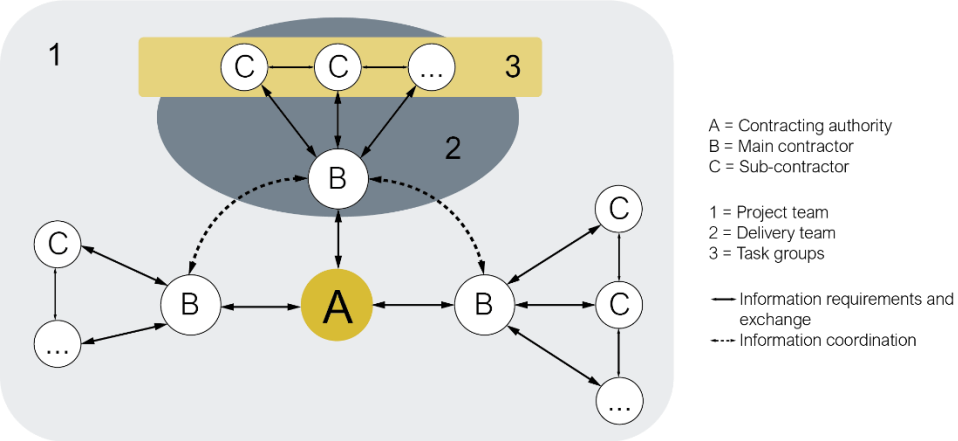


Figure 3.07: Roles in information management (Source: Bimloket)

3.4 Public organizations

Client requirements are regarded to be significant drivers of innovation and change in the construction sector (Ozorhon & Oral, 2017). In the context of digitization, it is also believed that client organizations are the stakeholders to encourage innovation in the industry. Porwal & Hewage (2013) even state that the degree of maturity and implementation of BIM in an industry is mostly determined by the client. However, research (Lindblad & Gustavsson, 2021) indicates that to bring about change in the industry, client organizations must first experience organizational development. Clients with technical expertise are more likely to become involved in projects and exercise influence on the project participants, and therefore encourage innovation. The findings highlight the necessity of initially building support within the client organization so that the client organization can influence the wider construction industry.

BIM has been required by public construction organizations for over a decade, mostly to enhance construction processes and create better buildings. However, clients are increasingly demanding greater control over the assets and systems they manage (Gurevich, & Sacks, 2020). BIM's dynamic, open-access digital environment makes it possible to store, share, and integrate data for building operations and management (O&M). The application of BIM at the O&M stage has been predominantly linked to facility management in recent years (Bosch, Volker & Koutamanis, 2015). Facility Management (FM) involves the maintenance, improvement, and modification of an organization's facilities to foster a productive environment that supports the organization's main goals (Pärn et al, 2017). The major focus of a facility manager is on the execution of the building's or facility's maintenance and operational plans. Asset managers integrate the strategy and direction for asset development with the organization's strategic goals. Their primary focus is on policy, planning, and evaluation to ensure asset value is realized. A building's life-cycle expenditures, according to Lee et al. (2012), might be five to seven times more than the initial investment expenses. According to Teicholz (2004), design and construction are thought to account for less than 15% of the total life-cycle cost for a standard building, whereas FM accounts for more than 85%. In any case, the operations and maintenance expenditures far surpass the initial construction costs. Due to the enormous investment made by clients and owners during the operation phase, it is important to consider the influence of BIM on FM.

BIM and FM integration can be classified as 7D modeling. The potential benefits of using BIM in FM appear to be considerable. Digital asset management can significantly increase the quality of data exchange between parties. Computerization makes asset information capture and retrieval

easier, however knowledge capture and automated data analysis are limited in computer-aided facilities management (CAFM) systems (Pärn et al, 2017). Currently, information is handed over to the FM phase mainly manually. Traditional manual data transfer frequently results in inaccuracies (or worse, data loss), limiting the operational data retained about a building throughout its existence (Roberts et al., 2018). In research (Kelly et al., 2013) it was shown that the benefit of BIM in FM originates mostly from (I) improving present manual information handover procedures and thereby improving the correctness of FM data; and (II) Increasing the efficiency of work orders execution, in terms of speed, data availability, and locating interventions. Thereby it can be used for energy and space management, emergency management, or retrofit planning (Volk et al., 2014).

Although BIM has the potential to assist FM in principle, there are yet to be compelling outcomes from the complete implementation of BIM-enabled FM in reality (Edirisinghe et al., 2017; Pärn et al, 2017). According to research (Pärn et al, 2017), identifying information needed to support operational decisions is crucial to setting data retrieval strategies during the post-construction stages, but this remains to be difficult. The usage of BIM models in the operations and maintenance stage is not as widespread as it is in the other phases. As far as possible, the criteria for each activity's area must be established. For example, work orders (for spare parts replacements), maintenance data (for maintenance management), asset rating (for condition assessment), core and supporting data from the assets (for asset inventory), or space data (for space management). Furthermore, precise specifics of these should be examined to offer the necessary information to operators and maintenance workers while dealing with the facilities' systems. These can include information from the manufacturer, the location and description of the components, systems, or assets, as well as asset performance ratings and maintenance levels (Liu and Gao, 2017, p. 140).

3.5 Conclusions digital transformation

The construction industry is gradually becoming more digitized. This is reflected in the construction sector by the various digital solutions discussed in this chapter, such as BIM, the Internet of Things, Virtual and Augmented reality, and digital twins. As a result, parties will have access to an increasing amount of digital data. Data can be obtained from external data sources, as well as information collected by parties during the life cycle and various sensors. The changes within the product layer also have consequences for companies and organizations in the sector. Processes evolve as digital information is progressively incorporated into activities and activities are supported or even taken over by digital technologies. Not only must organizational improvements be made to be able to use digital information from other parties, but also to be able to provide the needed digital information to others.

As a result, with the introduction of new digital solutions, parties' processes and products change. The above-mentioned organizational challenges that come with digitization are, of course, represented in the contractual framework of parties involved in the construction process of digitization. The following chapters will discuss this in more detail.

4

Data exchange within Dutch public procurement

This chapter discusses relevant concepts from The Dutch procurement law and the associated process. This knowledge will be used to further discover procurement with a data component. The literature review's purpose is to provide answers to sub-research question 2 and, as a result, provide significant input for the research framework for the empirical research.

4.1 Dutch public procurement

Public procurement is the purchase of products, goods, and services by public authorities to meet the requirements and expectations of public administration (Obwegeser & Müller, 2018). During a procurement, one or more companies are given the opportunity to submit offers for the execution of the public contract for works, supplies, or services (Essers & Lombert, 2017). The primary premise of procurement is to establish a procedure that is transparent and objective. The process leading up to the award and conclusion of a contract is covered by procurement law (Arrowsmit, 2014). Contracting authorities in the Netherlands are inherently constrained by the requirements outlined in procurement law principles. Contracting authorities are the State, regional, or local governments, bodies controlled by public law, or organizations created by one or more of these authorities or bodies governed by public law (Chao-Duivis, Bruggeman, Koning & Ubink, 2018).

4.1.1 Sources of procurement law

In the Netherlands, the 2012 Procurement Act (Aanbestedingswet 2012) applies to all procurements by public and semi-public institutions. With this national law, the Netherlands has implemented the European procurement directives. Especially, the Public Contracts Procurement Directive 2014/24/EU is relevant for the procurement of works, and hence for the area of construction law and construction contracts. It outlines the activities that must be conducted before awarding a contract to a supplier when the contract's value exceeds a certain threshold unless the contract qualifies for a specified exclusion (Chao-Duivis et al., 2018). The Act contains a distinct part (section 1.2.2) on the principles of European procurement law, which establishes the concepts of non-discrimination and equality (article 1.8 Aw), transparency (article 1.9 Aw), competition (articles 1.10a and 10b Aw), and proportionality.

The principles of non-discrimination and equality are inextricably linked. The first suggests that a contracting authority is not allowed to establish nationality-based distinctions. The latter is more comprehensive, requiring the contracting authority to ensure that similar cases are handled in the same manner. The transparency principle is composed of two parts that originate from the equality principle. First, the contracting body must publicize the tender at the beginning, and thereby the awarding must be motivated. The proportionality principle states that the contracting authority can only set requirements, prerequisites, and criteria that are proportional to the contract's objective throughout the tender preparation process. When a contractual authority violates these fundamental standards, a civil judge decides the consequences (Hofmeijer, 2019).

On a number of subjects, the Act also provides additional laws and policies. The Procurement decree (Aanbestedingsbesluit) has been issued to clarify several clauses of the 2012 Public Procurement Act (Pianoo, 2016a). The Proportionality Guide (Gids Proportionaliteit), the European Single Procurement Document (Uniform Europees Aanbestedingsdocument (UEA)), and the Works Procurement Regulations 2016 (Aanbestedingsreglement Werken 2016 (ARW 2016) are all included in the Procurement Decree (ARW 2016).

The Proportionality Guide provides regulations that further clarify the proportionality principle. The Guide lays out principles to ensure that contracting authorities implement requirements and criteria that are proportionate to the contract at all stages of a government tender. If a contracting authority declines to follow the rules established in the Guide, it must clarify why in the tender documents.

4.1.2 The procurement procedures

There are sixteen procurement procedures outlined in the Works Procurement Regulations 2016 (Chao-Duivis et al., 2018). Contracting authorities must apply one of the directive's specified procurement procedures. A contracting authority can always choose between the open and restricted procedures. Other procedures are dependent on a variety of preconditions. In this paragraph, four procedures will be introduced.

The open procedure

The open procedure is a formal tendering method in which the contract is announced in the EU's official journal and all interested bids are invited to submit their proposals (Chao-Duivis et al., 2018). The method is limited to a single round in which all tenderers can submit their proposals at the same moment. The tenderers and their bids (offers) are evaluated simultaneously by the contracting authority. There is no limit on the number of tenders in an open procedure, and the contracting authority may be required to evaluate a large number of tenders and tenders. The benefit of this approach is that it allows any firm in a specific sector to participate (Chao-Duivis et al., 2018).

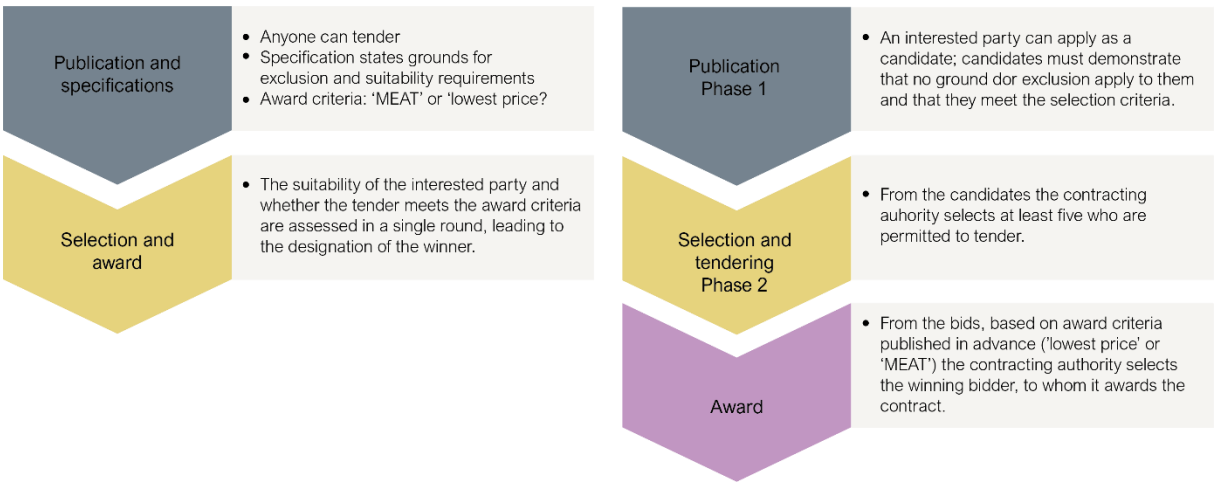


Figure 4.01: Open procedure (left) and restricted procedure (right), after (Chao-Duivis et al., 2018).

The restricted procedure

The restricted procedure is divided into two phases: selection and award. The restricted procedure starts with a contract notice in the EU Official Journal (via Tenderned). The tenderers are selected in the first round, the selection phase, based on the grounds for exclusion, the minimum demand, and the selection criteria. Based on the ranking, at least five tenderers must be invited to submit a tender. In the second round, the award phase, tenders are selected based on the award criteria. The advantage of this procedure is that the number of bidders can be minimized, resulting in a low administrative burden (Pianoo, 2016b). However, the procedure takes longer than the public procedure due to the prescribed minimum periods.

The competitive dialogue

The competitive dialogue (Public Procurement Act 2012 (2016) art. 2.28-2.29) is a European procurement procedure that allows the contracting authority and potential tenderers to enter into a dialogue. In accordance with the relevant requirements of Articles 56 to 66, the contracting authority shall engage in conversation with the selected participants to identify and specify the means best suited to achieving its needs and ambitions (2014/24/EU, article 30.3). This dialogue is particularly necessary when market participants' technical, financial, or legal knowledge can contribute to the specifications as the contracting authority is unable to ascertain what resources could be available to satisfy the requirement or evaluate what the market has to offer (Essers & Lombert, 2017). Following the dialogue, participants are invited to submit a tender, which is evaluated using established criteria. Only particularly complex public contracts are eligible for this approach (Chao-Duivis et al., 2018).

Negotiated procedure

There are two negotiated procedures: the negotiated procedure with a contract notice and the negotiated procedure without a contract notice. *The negotiated procedure with a contract notice* allows interested parties to submit a request to participate in response to a notice. The parties chosen by the contracting authority are eligible to make an initial tender after which negotiations with one or more of them will result in a final offer. Contracting authorities may only apply this procedure restrictively when special circumstances apply (Public Procurement Act 2012, Article 2.28). The procedure closely resembles the competitive dialogue, with the exception that an initial tender is only submitted after the dialogue phase (Pianoo, 2016b)

The *negotiated procedure without a contract notice* makes it possible to award contracts without an advertisement and generally without competition. This enables a contracting authority to award contracts to a preferred party directly. It can be applied in situations when there are no or insufficient tenderers, or if technical or artistic grounds necessitate the protection of exclusive rights (Chao-Duivis et al., 2018). Sections 2.32 to 2.37 of the Public Procurement Act 2012 include the precise provisions relevant to this procedure.

1.1.3 Procurement process

During the procurement process, several steps will be taken as described in Tendering Act 2012 (2016) art. 2.58 - 2.131 (see figure 4.02). For each tendering procedure, the process steps are structured the same way, however, the focus and length of each step are varied. In this subsection, all steps will be briefly explained.

Figure 4.02: Tendering roadmap, after Wolswinkel (2015, p.25)

Question

The contracting authority must first establish the needs before publishing any type of tender invitation.

Orientation

The proposed question is further defined in a statement of requirements during the orientation phase. The main purpose of the briefing process is to provide the contractor with the necessary information, directions, and inspiration to create a successful project (van Meel, & Størdal, 2017). Technical, functional, and performance-based specifications are the three types of requirements in the specification (Tendering Act 2012 (2016) article 2.76 lid 1 subs a & b). A technical description outlines how the contract will be carried out, such as by defining quantities, dimensions, etc. (Pianoo, 2016a). A *functional description* consists of a list of requirements that the work or solution must achieve, as well as the functions that the work or solution must fulfill (Pianoo, 2016b). The program of requirements (Programma van Eisen) usually comprises many criteria related to the physical building whereas the Employer's Information Requirement (EIR) contains the requirements for the digital building and/or data (Bruggeman, 2018a). The EIR will be discussed in more detail in section 3.3.

During this orientation phase, there are several options for determining the appropriate requirements. First, the client can decide whether the demand can be met by the market with the use of *market exploration*. This can be done by conducting desk research and/or field research, contacting knowledge institutes, and interviewing entrepreneurs (Hofmeijer, 2019). Secondly, a *market consultation* allows the contracting authority to bring a question to the market and see whether market participants can come up with creative solutions. Finally, the market can employ a *testing ground* to put new ideas to the test.

Tender invitation

The tender invitation (articles 2.58-2.74b of the Tendering Act 2012 (2016)) is an (electronic) document that invites market participants to apply for a tender (Hofmeijer, 2019). The contract notice, with the criteria for selection, as well as the award criteria must be published on TenderNed ahead of time, to conform to the principle of transparency (Chao-Duivis et al., 2018). Based on this information, market participants can determine whether or not to apply.

Selection of tenderers

Contracting authorities have a variety of criteria at their disposal for selecting tenderers. There are three types of criteria for participant selection: grounds for exclusion, minimum demands, and selection criteria (Essers & Lombert, 2017). The Public Procurement Act of 2012 includes both *forced and facultative grounds for exclusion* (Pianoo, 2016a). Contracting authorities are required by Article 2.86 of the 2012 Public Procurement Act to exclude a firm from further participation in

a procedure if that firm has been irreversibly convicted of one of the integrity-related criminal offenses outlined in that article. Article 2.87 contains an exhaustive list of facultative grounds for exclusion. The contracting authority has to select which of the optional grounds for exclusion will be implemented in the contract notice or the contract documents (Pianoo, 2016a).

With *the minimum demands/suitability requirements*, the participant must be able to demonstrate that the contracting authority's desired level of competence has been achieved to be accepted for the tendering procedure (Essers & Lombert, 2017). The minimum demands in a European tendering procedure must be related to a tenderer's economic and financial capability, technical and professional capacity, professional competence, or professional authority (Section 2.90 (2) of the AW). Asking tenderers to submit relevant reference works indicating their experience can be a way of testing professional or technical competence (Chao-Duivis et al., 2018). Awarding authorities may also request the bidder or its management employees to provide educational or professional qualifications, descriptions of technical equipment, samples or products, certification, and quality assurance or quality control procedures (Bruggeman, 2019). These requirements must be relevant to the procurement's subject matter and must not impose an artificial competitive barrier (Art 2.76 sub 3 Aw).

When utilizing an open procedure, the minimum demands are the only criteria used to evaluate the tender's competence. When using the restricted tender procedure, it is possible to distinguish between suitability requirements and selection criteria. A scoring methodology should be employed and specified ahead of time to determine if and how the selection criteria are met (Chao-Duivis et al., 2018).

Information exchange

During this phase, information about the project will be shared. The amount to which this occurs varies significantly between procedures (Hofmeijer, 2019). During the open procedure, an informative session is organized where all participants are given the opportunity to ask questions and receive information at the same moment. A competitive dialogue approach allows for several rounds of bilateral information sharing between the contracting authority and the contractor to talk about the contract's technical, financial, and legal implications (Wolswinkel, 2015).

Assessment

Following the assessment of the potential bidders against the selection criteria, the actual bids are evaluated using the award criteria. The contracting authority should award based on the Most Economically Advantageous Tender (MEAT) criterion, according to the European directive (Chao-Duivis et al., 2018). The best price-quality ratio, or either price or cost-effectiveness, is used to determine the most economically advantageous tender (Bruggeman, 2019). This criterion allows the contracting authority to consider criteria that represent the bid's quality, technical, and long-term viability, as well as price. Each criterion's relative weighting should be expressed in descending order of relevance while evaluating the submission. The contracting authority that decides the most economically advantageous tender based on price-quality ratio, must indicate in the contract notice which additional criteria it will apply to apply this assessment, according to Section 2.115 (1) of the Aw. The criteria may include a. quality, including technical merit b. aesthetic and functional characteristics; c. accessibility; d. design for all users; e. social, environmental, and innovative characteristics; f. trade, and the conditions under which trade takes place; g. the organization, qualification, and experience of the staff for the execution of the contract, where the quality of that staff can significantly affect the level of execution of the contract; h. customer service and technical assistance; i. terms of delivery, such as delivery date, delivery method, delivery period, or period of completion.

Award

The contracting authority presents the findings of the tender and declares which tender won the bid via a notice of contract after the selection and award phase. Contractors can object to the decision for a standstill period of 20 days, after which the actual award can take place if no objections are lodged or if the objections have been dealt with through summary proceedings pricing (Hofmeijer, 2019).

4.2 Public procurement with a data component

As the possibilities of working with data in buildings increase, so does the need for increasingly precise agreements regarding the procedures and tasks, as well as the requirements on the model or data. The tender documents will include several new or modified documents or provisions related to digital construction in addition to the traditional documentation. The documents or agreement frameworks that are commonly utilized in practice are discussed and briefly described in this chapter. When working with data, three documents are frequently involved: the Information Delivery Specification (ILS), the BIM protocol, and the BIM implementation plan. Furthermore, the several possibilities for a BIM tender's selection and award criteria are examined in this chapter.'

4.2.1 The Information Delivery Specification: ILS

The first document to be discussed in this section is the demand specification. As previously mentioned, the physical building standards and requirements are specified in the Statement of Requirements (SoR), which is part of the specifications. If the contracting authority requires a digital model or data, it must describe this in the tender specifications. This is often conducted through an Information Delivery Specification (*Dutch: Informatie Leverings Specificatie (ILS)*), which is then included in the tender documents. Technical specifications and basic agreements on starting points, as well as contract decision-making moments and data drops based, can all be incorporated into the ILS (Bruggeman, 2018a). The delivery specification should certainly describe how the parties will cooperate digitally, what the parties will deliver, and, specify when the parties have to provide data and information (Adriaanse, Bruggeman & Voordijk, 2020). An ILS ensures that information can be exchanged systematically and unambiguously between the contracting party and the contractor (Bim Loket, n.d.). In a sector that is still developing, the latter is not always guaranteed (Adriaanse, Bruggeman & Voordijk, 2020).

As with the specifications of a physical building, when tendering for a digital building, a distinction can be made between technical, functional, and mixed specifications (Bruggeman, 2018a). Clients who know exactly what they need will go for a technical description as they want data or models that are compatible with their maintenance or management system as well as with their database (Bruggeman, 2018a). Because BIM is still relatively new, it's possible that clients are unaware of exactly what they want and would rather leave the specification of the data or model to the market. Then the client may choose to specify functionally (Bruggeman, 2018a). Although the client may receive something greater than expected, the downside is that the result is difficult to evaluate and not always desired. The client will almost certainly end up with data that he cannot use, process, or access (Adriaanse, Bruggeman & Voordijk 2020). Uninformed clients can benefit from industry guidance in the form of recommendations and example projects.

The quantity and diversity of ILSs used in the Netherlands are enormous because of the lack of national standards and legislation, and standard contracts including data provisions (Ransijn & Spekkink, 2019). As a result, there are many diverse interpretations and methods used in practice, and the formats of an ILS produced by appointing parties vary significantly. According to the research of Ransijn and Spekkink (2019), there are now seven types of ILSs in operation. Only two types of ILSs are defined in the same way as the ISO 19650 standard (type 1 and 2). The

other five appear to have emerged from practice and do not adhere to this official guideline. ILSs are classified into the following groups (see figure 4.03):

- Type 1: ILS prepared by the employer (A) and delivered to the main contractors (B);
- Type 2: ILS including the employer's (A) requirements enhanced with the main contractor's information requirements. Handed on by the main contractor (B) and to his team of contractors (C).
- Type 3: ILS containing the main contractor's (B) requirements for the employer's (A) data to be provided to them (B) before the project is initiated;
- Type 4: information requirements imposed by the primary contractor (B) on the contractor(s) in his team (C), independent of the data requirements of the employer;
- Type 5: information requirements established by (sub or auxiliary) contractors (C) for the main contractor's (B) input;
- Type 6: Information requirements that contractors (C) can and do impose on each other;
- Type 7: requirements that primary contractors (B) specify for each other.

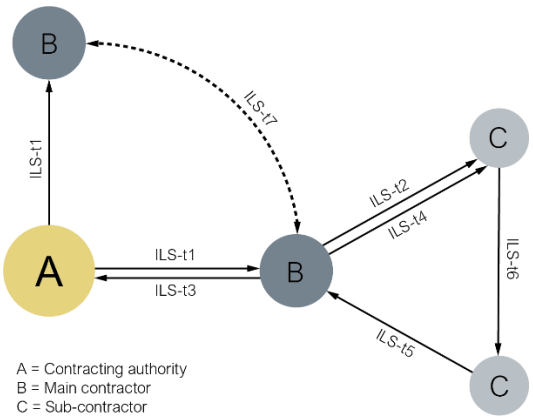


Figure 4.03: Various types of ILSs in the Dutch construction industry (Ransijn & Spekkink, 2019)

BIM Basis ILS

Subsequently, project contractors are constantly confronted with new information requests and are required to deliver customized solutions which make it challenging to standardize their digital processes (Ransijn & Spekkink, 2019). With the BIM Basis ILS, BIM loket is attempting to standardize ILS. The BIM Basis ILS was formed in dialogue with construction industry parties, in which a minimum level of agreement was developed on the delivery of information and the structure of (BIM) information models. Thereby, various software suppliers have developed manuals to make it easier for users of various software packages to comply with the requirements included in the BIM Basis ILS. Despite being adopted or endorsed by a wide number of organizations, the use of the BIM Basis ILS is still in its early stages. Long-term and widespread adoption by the industry may eventually make them conventional (Bruggeman, 2020).

The document is merely two pages long and mostly consists of graphics with limited description. In summary, three topics are covered: (1) how digital information is exchanged, (2) which structure the parties must follow, and (3) how future and other object information is coded. According to Bruggeman (2020), the BIM Basis ILS is primarily an agreement between BIM partners (architect, structural engineer, installer, and contractor), rather than a client's ILS. Practice shows, that many of the agreements covered in the BIM Basis ILS are commonly formalized in a BIM protocol or BIM implementation plan. Acknowledged by Ransijn and Spekkink (2019), the BIM Basis ILS can be classified as type 4 (information requirements set by the main contractor for the sub-contractor(s) in his team regardless of the client's information requirements) or type 7 (information requirements that main contractors (can) set among themselves).

In the United Kingdom, they are ahead of the curve in terms of developing an ILS, which is referred to as the Employer's information requirements (EIR). The fact that the UK is ahead in BIM development is due to government influence. The UK government announced in May 2011 that by 2016, it will demand completely collaborative 3D BIM (with all project and asset information, documentation, and data being digitized) as a minimum (Designing Buildings, 2020). PAS 1192-2:2013 was produced on behalf of CIC in response to the UK Government's construction strategy. Publicly Available Specifications (PAS) are accelerated standards, specifications, codes of practice, or guidelines. PAS 1192-2:2013 is the Specification for information management for the capital/delivery phase of construction projects using building information modeling. PAS 1192-2:2013 suggests that the employer's information requirements should include three types of information: technical, commercial, and management (Winfield & Rock, 2018). The technical part specifies requirements such as the software to be utilized open standards, the classification of elements, and the level of definition to which each model should be produced. The commercial includes information such as the objectives, key moments in the delivery, and BIM competency evaluations project members must complete. The management section describes the team's roles and responsibilities, the level of security required, the collaboration process to be followed, and the requirement for conflict detection and coordination.

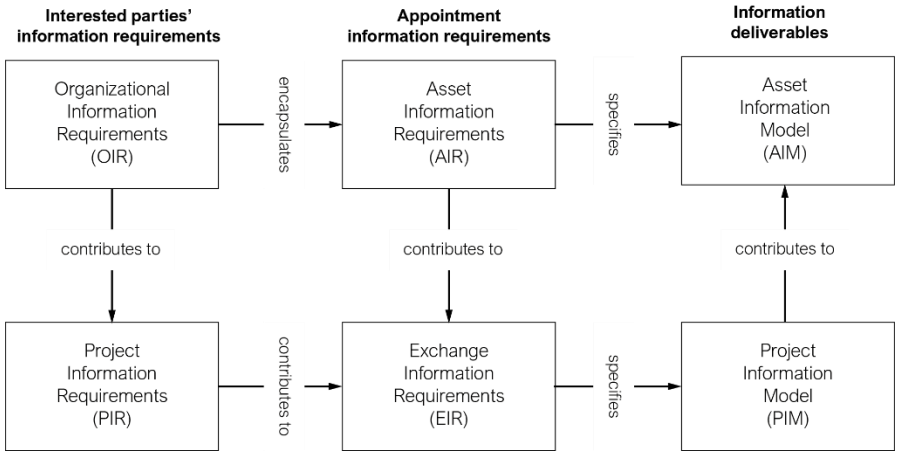


Figure 4.04: Hierarchy of information requirements (Source: EN-ISO 19650-1)

In December 2018, the ISO 19650-1 and ISO 19650-2 series of international standards were created to adopt the best practices of the PAS 1192 series of British standards and BIM normative documents, as well as other national standards (Popov et al., 2021). The formulation and exchange of Information Requirements is an important aspect of the standards. The first part of ISO 19650-1:2018 introduces general concepts and establishes the fundamental principles for how information should be obtained, provided, and maintained throughout the life cycle. Whereas, the second part of the standard, establishes particular guidelines for information management throughout the asset delivery phase (UK Framework, 2020). The ISO 19650 describes several files that precede the EIR (see figure 4.04). The Organizational information requirements (OIR) is the beginning point for all information management initiatives. The OIR enables the understanding of high-level information about assets throughout their lifespan. This enables the appointing party to manage their organization in an informed and efficient manner. Subsequently, the OIR is used to create the Asset information requirements (AIR). The AIR defines the specific details that the appointing party and their stakeholders will require to maintain physical assets throughout their existence. The Project information requirements (PIR) are derived in part from OIR. They allow the appointing party to comprehend the high-level information needed during a design and construction project. The PIR, once defined, becomes the high-level purpose that serves as the foundation for the more detailed EIR. This is where the project's information requirements are split down by appointment and combined with any project-specific AIR. The content of an EIR must

comprise at least the following components, according to EN ISO 19650 - Part 2 (Ransijn & Spekkink, 2019):

- *Project information* (project ID, project name, principal, location, nature of the project, etc.)
- *Structure of the project team* (composition of the client team, design team, main contractor, other contractors, etc., as far as known);
- *BIM objectives* for the project (measurable, achievable, and SMART);
- *Acceptance criteria*: Criteria against which it can be assessed whether the information requirements have been met;
- *The information standard for the project* (if the principal does not prescribe this, the contractor team must determine the information standard itself in the BIM Implementation Plan);
- *Information production methods and procedures* (again, if the client does not prescribe these, the contractor team must define them itself in the BIM Implementation Plan);
- *Reference information and shared information sources* for the project;
- *Data exchange schedule*: description of what information is needed and who is responsible for the delivery and in which form the information must be presented.

To allow construction partners to store and interchange data regardless of the software they are using, the adoption of *open standards* is encouraged in practice, both in the Netherlands and internationally. Open standards are agreements about how data is captured and/or distributed. In the Netherlands, there are eleven Dutch BIM standards listed by the BIM Loket. Currently, VISI and IFC open standards are the most widely utilized open standards, whereas COINS appears to be the open standard with the most long-term viability (Bruggeman, 2018a).

The open standards can be divided into three categories (Spekkink, 2022).

- Exchange standards: These mainly contribute to a smoother exchange of data;
- Semantic standards: These are mostly concerned with the definition and form of the various objects in construction drawings;
- Process standards: These are primarily concerned with streamlining the construction process.

The division between these categories is not always straightforward. IFC, for example, is not only an exchange standard but also contains many definitions of object types, properties, and relationships. NLCS is both a collection of layer definitions for CAD drawings, as well as an exchange standard.

Figure 4.05: Open standard categories. Own illustration

Exchange standards

In the B&U industry, IFC is becoming increasingly important for the exchange and coordination of 3D geometric models. IFC is a neutral and open file format for exchanging BIM-specific information between software applications. The BIM Basis ILS describes, among other things, the use of IFC as an exchange format. IFC is still little used in the GWW sector, mainly because the IFC version currently supported by software applications still contains few or no classes for infrastructure objects (Spekkink, 2022). COINS are being used more often in the GWW sector. COINS is recently replaced by the international standard ISO 21597 Information Container for Data Delivery (ICDD). An ICDD/COINS container is a zip file containing data files and/or documents as well as a metadata model that defines the relationships between the various items in the container.

Semantic standards

In the Netherlands, the NL/SfB classification is the most extensively used for building components. Building and installation companies code layers and objects in BIM and CAD systems with this open standard, and use NL/SfB for organizing information from suppliers (Spekkink, 2022). NL/SfB is also prescribed in the BIM Basis ILS. In the GWW industry, the 2D drawing should be done in NLCS. It is even mandatory for governments to employ NLCS for civil engineering projects above the €50,000 threshold. This open standard contains agreements on the handling of metadata, digital drawing, the appearance of the drawing, and - above all - the coding system and layer structure of CAD drawings. There is currently no system-independent standard for the interchange of 3D civil engineering drawings. When project partners use different 3D applications, they choose the most suitable exchange format for each combination (e.g. .dwg, .ndw, .dgn, .ifc). There are various ongoing initiatives to better integrate the 2D world of NLCS with the 3D world and semantic modeling (Spekkink, 2022).

Process standards

The process standards provided by the BIMLoket, among others, are VISI, DICO, the National Model BUP, and the National Model Information Protocol. DICO is the software-independent message standard for electronic communication between construction and installation companies. VISI is an open standard for digital communication. Using VISI, stakeholders determine when (process), who (role), what (information), and to whom (role) is delivered. However, the "entry threshold" for the use of VISI is fairly high, both for users and for software suppliers who make applications that support the standard. Initially, a specialist consultant is usually needed to set up a VISI framework for a project. Much has evolved in the domain of online collaboration and web architecture, interoperability, data, and applications since the creation of the VISI standard. Partly influenced by the NEN-EN-ISO 19650, however, the trend is for project partners to increasingly share data via Common Data Environments (CDEs) instead of sending documents/data files back and forth (Spekkink, 2022).

The other process standards will be discussed in detail in chapter 4.

4.2.2 BIM Protocol

In addition to the ILS, the BIM protocol can be created by the client. The BIM Protocol is designed to make contractual BIM terminology more uniform across a project's design team. It is supposed to be included in the construction contract, enabling the legal implementation of the processes and procedures necessary to create data that meets the EIR and BEP standards (Winfield & Rock, 2018).

The BIM Loket has prepared a document for the BIM Protocol that can be used to document BIM-related agreements. There are several chapters in the National Model BIM Protocol, starting with the provisions and definitions in the first chapter. In chapter 2, a priority rule is set out in the event of any contradiction or inconsistency between the provisions of this Protocol and any other document forming part of the Agreement. The clients' responsibilities are detailed in Chapter 3 which specifies, among other things, that the client must select a BIM director who will communicate with the contractor's BIM director. The contractor's obligations are outlined in Chapter 4 of the protocol, with a focus on the need to collaborate and coordinate. Chapters 5, 6, and 7 contain a series of extensive provisions on intellectual property, licenses, copyrights, ownership of the BIM, and liability for (the correctness of) the BIM data.

The rights to or ownership of the data and/or the model, are important to address when working with technologies. It is useful to lay this down in the tender documents since data is a new intermediate figure' that is not (or seldom) protected by intellectual property rights (Tjong Tjin Tai, 2018). Intellectual property rights refer to a variety of rights, including copyright, database law, trademark and design rights, and portrait rights (Bruggeman, 2020). According to the Copyright Act 1912 (Auteurs wet), every design for a building that contains a minimum of creativity and that has been given shape in any way as a drawing, model, or realized building, is a work of art and is therefore protected by copyright. Under Section 4 of the Aw, the creator of that work, the designer, is the copyright holder. Generally speaking, the creation of data does not involve creative human labor or the making of creative choices (Naves, 2018). The selection of data or the arrangement of the data may be such that there is the protection of work within the meaning of the Copyright Act, but the data themselves are not subject to copyright.

Because the law limits the parties' ability to control data, it's essential to create adequate agreements. There is a possibility that if this is not done, (Naves 2018):

- The party receiving the data may use it freely when it was not intended to;
- The party leaving the data continues to utilize the data even though it was not intended to do so;
- The party holding the data for another refuses to return it;
- Data generated during the execution of the agreement does not belong to the client.

The UK BIM Framework Information Protocol covers a wide range of difficulties concerning the usage of data and models. The protocol specifies the usage of 'Material,' which is considered to refer to data, models, and calculations. All intellectual property rights to the work or material should stay with the contractor, according to Article 8.3. The contractor or his subcontractors provide the client with a user license for the material they generate. The right to transmit, copy, and reuse the work is non-exclusive, royalty-free, and irreversible. The contractor must offer his written authorization if the parties want to do more with the content.

Contracting authorities can thus establish their user rights to data in their agreement, however, the nature and extent of the right must be carefully considered ahead of time (Ariaanse, Bruggeman, Voordijk, 2020).

4.2.3 The BIM Execution Plan: BEP

Following the BIM protocol and the ILS, a BIM Execution Plan (BEP) can be drawn up by the contractor in accordance with the project team. The BEP contains all of the agreements that the project team members make to complete the BIM project successfully. The BIR provides a framework for the Dutch BIM Implementation Plan (BIM Uitvoeringsplan), which is inspired by the UK's BEP. The authors of the BIM Implementation Plan aim to set out the planning for BIM work execution at an early stage in the process, which makes the model (partially) eligible for use in a tender (Bruggeman, 2018c). This allows the client to examine how the contractor plans to organize the (BIM) process before awarding the contract, ensuring that the client gets the relevant information in time to make decisions (KPCV, 2021). The NEN-EN-ISO 19650 series also describes this working method. In the British system, a pre-contract and post-contract BIM Execution Plan is distinguished. The pre-contract BEP contains the major milestones for information delivery, whereas the post-contract BEP contains a more detailed plan, a Master Information and Delivery Plan (MIDP). The MIDP is a comprehensive responsibility plan composed of several Task Information Delivery Plans (TIDP) that describe the milestones and data drops (Mosey, Howard, & Bahram, 2016). The BEP can also be part of the award criteria and integrated into an assessment procedure (Bruggeman, 2018c). This will be covered in more detail later in this section.

4.2.5 Selection phase

Recently, the BIM maturity and capability of organizations is an emerging prequalification and selection criterion (Mahamadu et al., 2017; Malla et al., 2022). Inconsistent BIM maturity levels among project stakeholders can limit the extent to which objectives and expectations can be achieved, especially when there is a considerable amount of data exchange between these stakeholders (Siebelink, Voordijk & Adriaanse, 2018). A BIM-capable firm minimizes both the chance of failure and the cost of the project, as less-capable organizations may cost the risk of failure and their lack of ability (Succar, 2010). Standards such as ISO 19650 and the British Standard Institute's PAS 91:2013 all demand a BIM capability assessment in terms of IT capabilities, roles and responsibilities, and experience from previous projects. In the United Kingdom, BIM execution plans must include a supply chain capability summary (SCCS), which details the BIM capabilities of all firms in the principal supplier and contractor supply chain (PAS1192:2, 2013). These standards, however, do not provide an assessment method (Mahamadu et al., 2019).

There are numerous BIM maturity measurement tools on the market, each with its own set of questions, framework, and evaluation procedures. However, minimal studies have looked into whether these criteria are genuinely indicative of a project's capacity to execute BIM successfully (Van Berlo et al., 2012). This is certainly relevant during the pre-qualification and selection process when such criteria are essential to anticipate which organizations are most likely to perform well (Mahamadu et al., 2019). Mahamadu et al. (2019) evaluated the post-selection performance of organizations on BIM construction projects (see figure 4.06). Whereas in most existing frameworks, the criteria used to measure BIM capabilities are frequently hard technology-focused, this study emphasizes the importance of collective information processing maturity, knowledge, skills, attitudes, and experience from former BIM implementation. Capacity and resources appeared as the most essential BIM capability criteria category for pre-qualification or selection assessments, followed by competence. Specific BIM modeling capacity (C6) was the most essential of the primary BIM capability assessment criterion areas, followed by the organization's experience (C3), then professional and academic qualifications (C1). The findings emphasize the need for historical and evidentiary demonstration of expertise in BIM delivery within organizations.

Critical BIM capability criteria			Survey – weighted importance of criteria – W_i (%) ($n = 64$)					
Capability criteria		Constituent attributes	Mean	Local	Global	Local	Global	
CC1 – competence	C1 – professional and academic qualifications	Key technical staff BIM qualification	2.938	23.95	3.22	36.48	13.43	36.82
		BIM staff availability for project	3.344	27.26	3.66			
		Organisation's BIM accreditations and certifications	2.391	19.49	2.62			
		Organisation's BIM training arrangements	3.594	29.3	3.94			
	C2 – staff experience	Managerial staff BIM experience	3.563	45.88	3.90	23.09	8.5	
		Key technical staff BIM experience	4.203	54.12	4.60			
	C3 – organisation experience	BIM software experience	3.656	26.90	4.00	40.43	14.89	
		Past BIM project experience	3.594	26.44	3.94			
		BIM experience on similar project	3.016	22.18	3.30			
		Internal use of collaborative IT systems	3.328	24.48	3.64			
CC2 – Capacity and resources	C4 – administrative and strategic capacity	IT vision and mission	3.156	31.56	3.46	25.51	10.95	42.93
		Quality of BIM implementation strategy	3.594	35.94	3.94			
		BIM research and development	3.250	32.50	3.56			
	C5 – technical (physical) resources	Software availability	3.500	38.03	3.83	23.48	10.08	
		Data storage (suitability and capacity)	2.828	30.73	3.10			
		Network infrastructure availability	2.875	31.24	3.15			
	C6 – specific BIM modelling capacity	BIM standards	3.625	26.45	3.97	34.95	15.01	
		Data classification and naming practices	3.500	25.54	3.83			
		Model maturity expertise/capacity	2.891	21.09	3.17			
		LOD/LOI expertise/capacity	3.688	26.91	4.04			
	C7 – proposed methodology	Suitability – BEPs for project	3.844	61.04	4.21	16.06	6.90	
		BIM vendor involvement and support	2.453	38.96	2.69			
CC3 – culture and attitude	C8 – reputation	Reputation – performance on past BIM projects	2.453	100.00	2.69	100.00	2.69	16.75
	C9 – technology readiness	Attitude towards new technology/willingness	3.359	33.39	3.68	65.75	11.02	
		Awareness of BIM benefits	3.734	37.11	4.09			
		Extent of IT support to core business and processes within firm	2.969	29.50	3.25			
	C1 – organisational structure	Organisational structure (level of decentralisation)	2.781	100.00	3.05	18.18	3.05	
CC3/C11 – cost		Cost/price of BIM service	3.188	100.00	3.49	100.00	3.49	3.49

Figure 4.06: Critical BIM capability criteria (Mahamadu et al., 2019).

Siebelink et al. (20218) constructed a BIM maturity model with six primary criteria: strategy, organizational structure, people and culture, processes and procedures, IT (infrastructure), and data (structure). Most criteria have multiple sub-criteria (Fig. 3.14). There are no specific weights assigned to the criterion, allowing for a consistent comparison of the criteria scores. The sub-criteria's maturity levels can be rated on a scale of 0 to 5, allowing for the evaluation of organizational BIM maturity.

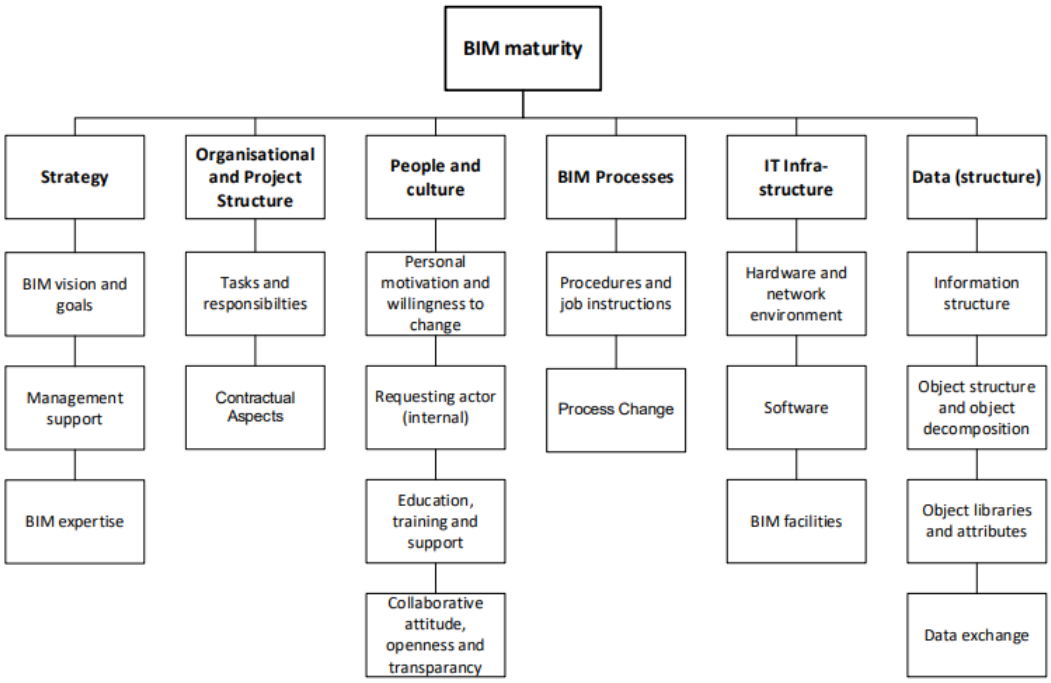


Figure 4.07: Criteria and subcriteria of the BIM maturity model (Siebelink et al., 2018)

As previously described in chapter 3.2 the Public Procurement Act specifies several mandatory and optional grounds for exclusion. While this is not yet the practice in the Netherlands, past performance is a potentially significant criterion for assessing when procuring work with a data component (Bruggeman, 2019). If a potential tenderer has demonstrated considerable or persistent inadequacies in the execution of any substantive requirements under a prior contract of comparable nature with the same contracting authority, past performance is an optional ground for exclusion. Various issues or forms of non-performance are possible, for example, data deliveries that are late or incomplete. The nature, content, and severity of the previous performance failure concerning the current procurement of the data component, must be examined in determining whether exclusion is reasonable (Bruggeman, 2019). Since the criterion of past performance is currently not or rarely invoked in the construction sector, it is questionable whether this ground for exclusion will be used in relation to data and/or BIM.

When it comes to the suitability requirements listed in Article 2.90 sub 2(b) Aw, the level of technical expertise can be especially relevant for the procurement of a data-related project (Bruggeman, 2019). As indicated in Article 2.92a Aw, these requirements cover the bidder's employees or technical resources, as well as the expertise they have. The level of technical competence can be measured or demonstrated utilizing reference works, certification, or other standards and by using performance indicators. The requested competency must be critical to the project or contracting authority to conform to the proportionality principle.

The suitability requirements may also include certification or educational qualifications. The responsibilities and qualifications of a data manager or coordinator, in particular, can be crucial. The bidder's management expertise and other similar qualities can ensure that the complex data exchange process and the activity of the people involved are well coordinated. It is only appropriate to require previous experience with specific software programs or technical open standards if it does not benefit specific manufacturers, producers, or companies.

Malla et al. (2022) found that in the short/medium term, the industry is more likely to incorporate desired BIM-specific prequalification requirements than in the long run. There appears to be a pressing need to include BIM-specific criteria into existing selection methods, showing a strong desire to embrace BIM. However, incorporating mandatory BIM criteria in the selection process at this time may result in fewer bids being chosen for project tendering.

4.2.6 Award criteria

Currently, various approaches are being used to select the best offer. First, the tenderer can demonstrate with the use of the execution plan, the quality he delivers in the context of BIM in his tender by providing insight into his work process, planning, and expertise. (Bruggeman, 2018c; Minderhoud, 2019). Following this approach, the contracting authority requires that the bidders develop an Execution Plan based on an Information Delivery Specification and a draft BIM Protocol. The bidder has to define in the BEP how they will meet the requirements and how they intend to collaborate. An assessment method can be linked to the execution plan which is compatible with the principles of equality and transparency. Weighting factors can be assigned to the various sub-award criteria, for example using a (weighting) matrix. In the context of data exchange, the criteria could include quality, including technical merit (under a of paragraph 2 Aw), aesthetic and functional characteristics (under b), suitable design for all users (d), innovative characteristics (under e), organization, qualification and experience of the employees assigned to performing the contract (under g), after-sales service and technical assistance (under h), and delivery terms, such as delivery date, delivery method, delivery period or period of completion (under i) (Bruggeman, 2018c). The contract may be awarded to the candidate with the highest score on the Execution Plan.

Using the Execution Plan when selecting a contract has been mandatory in the United Kingdom for some time. As mentioned earlier, a distinction is made between a pre-execution plan and a post-execution plan. Already in 2013, PAS 1192-2:2013 proposed the adoption of a pre-execution Plan to manage project delivery. The ISO 19650 series now replaces parts of the current British Standards and Publicly Available Specifications in the field of building information modeling and management (BIM).

According to the requirements of ISO 19650-2, the (pre-appointment) BEP should cover seven different key information management factors, according to ISO 19650-2 clause 5.3.2. These are as follows:

(a) Provide the details of individuals undertaking the information management function to ensure that the function will be carried out by a qualified delivery team.
(b) Proposed information delivery strategy.
(c) The proposed federation strategy is used by the delivery team.
(d) The delivery team's high-level responsibility matrix.
(e) Proposed changes/additions to the project's information production methods and procedures.
(f) Proposed changes/additions to the project's information standard.
(g) Proposed schedule of software, hardware, and IT infrastructure.

Second, the (BIM) model can be utilized to demonstrate that the tenderer can fulfill the BIM-related award criterion (Bruggeman, 2018c; Minderhoud, 2019). During the procurement procedure, the bidders are asked to prepare a model. The contracting authority may provide a model on which bidders can base their price and on which they can elaborate. The contracting authority must define beforehand at which point the model will be assessed to comply with the principle of transparency. Thereby, the principles of non-discrimination and fair competition, as well as the proportionality principle, will have to be considered here (Bruggeman, 2018b). If a contracting authority requests a very technically complex model, in a sector or market that lacks the experience or expertise to do so, this may limit the competition for the physical construction. The contracting authority must consider whether the requirement for a BIM is disproportionate, or whether it may be disproportionate if the additional demand of a BIM order hinders competition.

Subsequently, clients must assess the BIM model for compliance with the schedule of requirements or the requirements in the design. This can be done using model checking, whereby the model is assessed based on the configuration of objects, their relations, or attributes. However, it's possible that other properties can be extracted from the tenderer's BIM model. For example, quantities of building materials, cost calculation, and energy efficiency can be derived from a BIM model (Bruggeman, 2018c). All of these factors may then be given a weighting, enabling them to influence the award process. It is critical for clients to have the competence to check the model or assess the data provided about the model, as well as the technical ability to handle the model.

4.3 Conclusion on public procurement with a data component

This chapter has attempted to answer the following research question: “How can a contracting authority enhance data exchange within Dutch public procurement legislation?”

As the above explanation shows, there is currently a multitude of documents available on BIM, varying greatly in nature, content, detail, and level. There are generally three documents that can be used for this purpose: The Information Delivery Specification, a BIM protocol, and a BIM execution plan. Regardless of how contracting authorities wish to implement their wishes, it is important to think about this in advance and document everything properly. An unexpected request for information by the authority will have a detrimental impact on the way the contractor works, especially if project schedules are tight. Therefore, before the procurement procedure, several documents must be set up according to ISO 19650-2 (UK Framework, 2020). The OIR, the AIR, and the PIR, once defined, the more detailed EIR.

According to the ISO 19650 series, information can be described across four main facets:

(1) Content: required entities together with geometry and alphanumerical information. For example, a pump with the property FlowRateRange or the cost limit for the whole project.
(2) Function: performance and activity of the information. For example, a fire strategy or elemental cost plan.
(3) Container: how the data is packaged up and communicated. For example, a report or a drawing.
(4) Format: how the data is transported, physically or digitally. For instance, PDF or IFC.

In addition to the ILS, the BIM protocol can be created by the client to make contractual BIM terminology more uniform across a project's design team. Subsequently, the Execution Plan can be used by showing a potential contractor how to meet the award criteria. In the BEP, the bidder must explain how they will meet the requirements and how they plan to collaborate based on an Information Delivery Specification and a draft BIM Protocol. Alternatively, the (BIM) model can be used to demonstrate that the tenderer can fulfill the BIM-related award criterion

Selection criteria can be useful for selecting a bidder who is capable of not only constructing the building but also delivering the necessary data or model. As emphasized in de study of Mahamadu et al. (2019) the collective information processing maturity, knowledge, skills, attitudes, and experience from former BIM implementation are of high importance in the prequalification and selection phase. Suitability requirements could be particularly used as these requirements cover the bidder's employees or technical resources, as well as the expertise they have. The level of technical competence can be measured or demonstrated using reference works, certification, or other standards and by using performance indicators. The bidder's management expertise and other similar qualities can ensure that the complex data exchange process and the activity of the people involved are well coordinated.

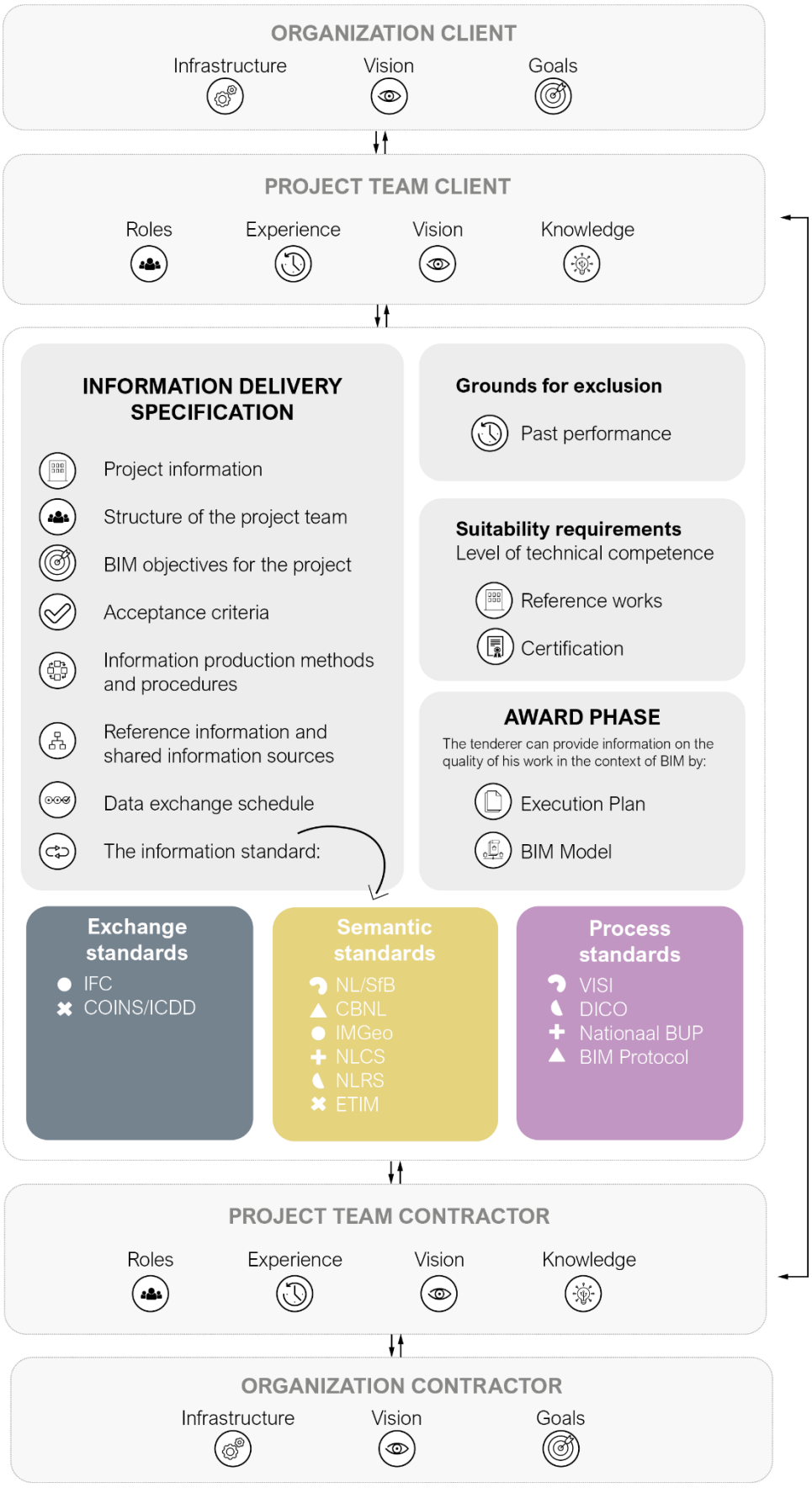


Figure 4.08: Theoretical framework

5 Empirical Research

The empirical research is presented in this chapter. The empirical research consists of case studies of four public projects. The selection of cases took place within the network of Rijksvastgoedbedrijf. All clients are Dutch contracting authorities striving to digitize their portfolios. In each project, digital building information was requested to a greater or lesser extent. Since the search was for recent projects, some of the projects are still in the design or construction phase. The procurement phase of each project has been completed.

For this study, two methods of data collection were utilized, as indicated in Chapter 2: (I) project document analysis and (II) semi-structured interviews. First, the project's general specifications, such as project objectives, project coalition, project planning, digital solutions, and procurement methods, were examined in the document analysis. Additionally, certain documents utilized throughout the procurement phase were examined. Documents such as the demand specification and the tender instructions were carefully studied and analyzed.

Thereby, data was collected through semi-structured interviews. An interview guideline with topics and questions was established before the interviews to structure these (appendix D). In total, 15 interviews with various project stakeholders were conducted (see figure 5.01).

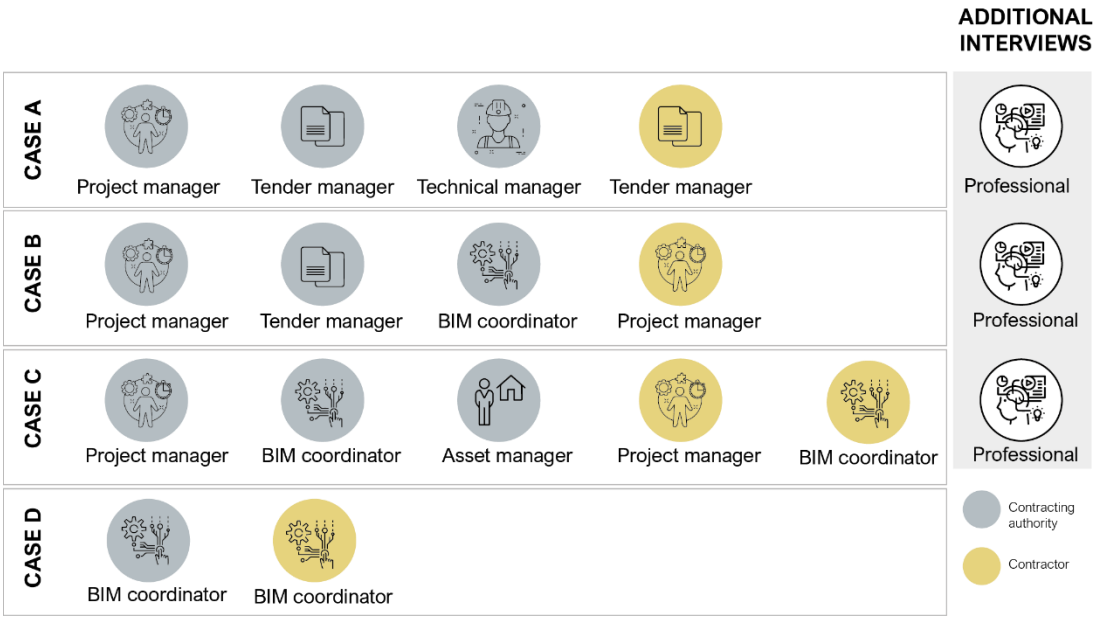


Figure 5.01: Conducted interviews. Own figure

5.1 case A – Herman Gorter Complex

Client	Rijksvastgoedbedrijf	**Awarded**	oktober 2019
Location	Utrecht	**Contract**	DBM&E
Size	37.248 m² bvo	**Procedure**	Competitive dialogue
Cost	€56.600.000	**Contractors**	Dura Vermeer, OTH, DWA & de Groot Installatiegroep
Published	July 2018		

The Rijksvastgoedbedrijf (RVB), Central Government Real Estate Agency, is the real estate organization of and for the central government. It is responsible for the management and maintenance of the largest and most diverse property portfolio in the Netherlands including prisons, law courts, barracks, airports, defense sites, ministries, ports, tax offices, monuments, museums, and palaces (Rijksvastgoedbedrijf, 2020). The enormous number of square meters of floor space and land gives the RVB the position to play a role in driving innovation and renewal in the built environment.

The Central Government Real Estate Agency is actively working on a number of projects to enhance digitization inside the organization. The Smart Real Estate (dutch: Slim vastgoed) program investigates which data must be generated in their buildings to derive added value from them, for owners and users at the building and portfolio level, and how the data can be converted into useful information.

Introduction

In the following years, the Herman Gorter complex in Utrecht will undergo extensive renovations. With this project, the Government Property Agency strives for the most sustainable and circular design possible. With the climate target for 2050 in mind, the Herman Gorter complex is the first government office to be renovated where the ambition of 'energy-neutral' was given to the market during the tendering process. A DBM&E contract was used to challenge the contracting partner to invest in energy-saving and energy-generating measures for a period of 15 years. The DBM&E contract was recently awarded to Dura Vermeer Bouw Hengelo in partnership with OTH, DWA and De Groot Installatiegroep. The building will be completed in 2023 after which it will accommodate about 2,000 employees mainly from the Ministry of Justice and Security (RVB, 2020).

Initiation phase

The complex consists of a property and two rental properties. The RVB owned the drawings and the revision of the property. On the rental properties, the drawings were incomplete, and alterations to the property had not been carefully updated since construction. Interviewee A1 (2022) mentioned: "*We had ten drawings for one floor and eight or seven of those were different*". As it takes a lot of time and money to figure out which drawings are correct, the technical manager decided to digitize the buildings utilizing laser scanning. The complex was measured both inside and out in 3D where the point clouds were then used to create an as-built BIM model. This strategy would allow parties to have a strong understanding of reality throughout the procurement procedure since any divergence would be instantly expensive (interviewee A1, 2022). As explained by interviewee A2 (2022): "*The price is heavily influenced by the level of risk involved. The more risk there is for the contractor or the architect the more expensive it becomes. They have a much higher risk if they don't know what the status of the current building is*" and therefore, "*We made a special effort at the beginning to make sure the information regarding the properties was correct. But each time we just didn't get there. As a result, we made a number of assumptions and now you see that after the contract was awarded we have to do a lot of extra work*".

To work with the scanned 3D model like a BIM did not have any value after the tender a the scans were not accurate enough. The objective was primarily to determine how the inner walls were positioned (Interviewee A4, 2022), whereby important components such as the construction and installations were not scanned (Interviewee A1, 2022). "*So you have to imagine that the ceilings were still there, and the wall coverings were still on them. So we didn't have a model of the bare structure*" (Interviewee A3, 2022). As a result, once the contract was awarded, the contractor collected its own measurements, created a model, and is currently working on it.

Demand specification and scope

For the Herman Gorter complex, the BIM models must be developed in conformance with the Rijksvastgoedbedrijf BIM Norm. In 2013, the RVB published the 'BIM Norm version 1.1' describing how IFC models, CAD extracts, and additional extracts as measurement data, calculations, and pull-out lists should be delivered. In 2019, the CAD specifications have been separated from the RVB BIM Norm, and are covered in the RVB CAD Specification. The specifications of BIM 3D extracts are now recorded in the 'RVB BIM Specificatie'. The RVB BIM Specification (RBS) outlines the technical starting points and requirements, as well as the open standards (IFC and NL-SFB) and the data it wants to receive and in what format. The authority does not work with an OTL or a central database. The criteria concentrate on the fundamentals of the BIM model design.

The BIM specification consists of four chapters. Chapter 1 concerns the definitions. Chapter 2 is the most comprehensive part of the specification and prescribes requirements for the end products to be delivered, the BIM-3D extracts, to guarantee the mutual consistency of BIM-3D extracts in terms of design, structure, and naming. Chapter 3 deals with the files to be supplied with the BIM-3D extracts. The appendices are discussed in Chapter 4. The RBS does not define the procedure or the technical details required to obtain the desired output. It is only about the data that the organizations desire to receive, as well as the method or format in which they wish to get it. When compared to EN ISO 19650, it is apparent that the ILS initiative merely regulates a part of the content. The (B)IM objectives of the project are not defined, the information milestones are not specified and a description of non-geometric data is for example missing. The specification of the process and product information to be delivered is determined each time per project and still included in the contract if there is enough ambition and knowledge among project managers or other people involved. Specification of the information to be delivered can be included, depending on the form of contract, in a separate information delivery specification (ILS). However, an organization-wide information demand specification (ILS) is a work in progress. In addition to the RBS, the contractor must provide CAD drawings. These drawings are necessary for the management and maintenance phase because the State Property Agency does not yet fully work according to the BIM principle. Ultimately, the files must be usable by RVB during the operation and maintenance phase. "*Sure you can provide 3D drawings, but if you can't read them, can't manage them then they're no use to you. That's a waste of money. Certainly, creating a 3D takes a lot of time and effort*" (interviewee A1).

According to interviewee A4 (2022), there is a need for improvement to identify the organization's information requirements. "*The inclusion of requirements in the BIM standard is still ad hoc. I have the feeling that a real battle is needed to adequately involve all disciplines. What do you want with it? What are its potentials? What do you hope to get out of it?"* This was also addressed by interviewee A2 (2022). "*I think it's good that there is a standard, but we also need to consider what each project requires. I believe there is a genuine need to align what you ask for in a tender with what we can process in our systems. I feel there is a discrepancy between the two. If we ask for complete BIM models and don't do anything with them other than read out the floor plans, it's still inefficient."* Interviewee A1 (2022) points out that the departments Property Management (Vastgoed Beheer) and Property Information (Vastgoed informatie) are responsible for initiating the next steps.

The contractor (interviewee A3, 2022) also believes that the client is now unable to do anything with the requested models. "*The question is whether they can really do anything with them at that point in time. A client often takes a different perspective on a building; they consider it from the standpoint of use* ". The models that are currently being created are mostly technical, with a lot of information put into them. The contractor has been working with BIM for years for the design and realization phases and, as a large party, has all the software and hardware at its disposal. The current specifications of the RBS are workable for the main contractor. According to interviewee A3 (2022): "*The protocols that are made available are fine for us to work with. Our BIM execution plan fits within those protocols, as standard. As a result, no changes to our working methods are required. We can just use our normal working methods*".

Since the RBS is limited, specifications can be added to the output (OS) specification, also called the performance or product delivery specification, in the form of a specification, a schedule of requirements, or a functional (output) specification, which describes which performance and information products must be delivered. For the Herman Gorter complex, some additional requirements have been set in the process requirements concerning BIM. Firstly, the contractor must provide the source file of several Building Information Models at the time of acceptance (DO and completion). These include one integral coordination model of the project consisting of the models of all disciplines and three coordination models of the three buildings and the air bridges between the buildings. The following models, in the following Levels of Development (LOD), must be included in the BIM coordination models:

- Structural model, LOD 300
- An architectural model with walls, floors, facades, and finishing, LOD 300
- Installation model, LOD 300
- Interior model (with all loose fittings), LOD 300
- Infra model, LOD 300

Production models are supplied in LOD400 if the supplier concerned works in 3D. The contractor has complete freedom in selecting modeling and control software.

The Level of Development were specified with the help of an architectural consultant at the time. The consultant had worked with BIM on prior projects and believed that using the Level of Development to express how detailed the model had to be was favorable (interviewee A4, 2022). "*However, in the elaboration of the requirements, everyone works in their own manner and not quite following the way we have in mind*" highlights interviewee A4 (2022). The contractor was unable to meet the LOD at the appointed milestone. The commissioning party, for example, had originally requested a final detailing of the building during the DO. This is only feasible for the contractor once the supplier model is delivered. Therefore, there have been a few refinements during the process (interviewee A4, 2022).

It is not surprising that the LOD was the subject of discussion as it is no longer required and applied by most parties in the construction industry. LOD is an ambiguous term and in practice often not smart and specific enough. There are two LOD standards: LOD combined with the hundreds (100, 200, 300, 400, and 500) and LOD combined with single numbers (1, 2, 3, and 4). Presently, the LOD has been replaced by a European standard. The European standard, 'Levels of Information Need', indicates how you should specify the information levels of data deliveries depending on the intended use. The standard is fully in line with the NEN-EN-ISO 19650.

Milestones were not specifically specified in the demand specification, yet two evaluation moments were built in the process. The first evaluation moment was included in the DO. The second, after 15 years of maintenance. The contractor must deliver an up-to-date state of the digital building where they have to keep the BIM model up to date in the meantime. Interviewee A4 (2022): "*But whether they do that every year or every five years, I don't think we have any requirements for*

that". "*There is no BIM plan or information management plan, I don't think that is requested as a product. Then you realize that the need side of the RVB is not sufficiently clear, what exactly are we trying to accomplish with it? If we are going to use it very actively, I can imagine that we will ask very specifically what we want at that moment, but for now, it appears that if we still have it at completion and then again at final delivery, it will be enough. Because we don't do anything with it in the meantime*".

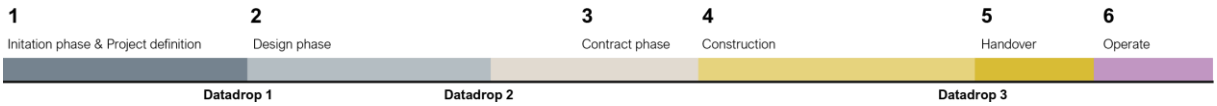


Figure 5.02: Datadrops Herman Gorter complex. Own illustration

This is a problem that does not only occur in this project or is specifically related to BIM, but a problem in information management of the RVB in general. The project phases are not completed accurately. The as-built information of the building, whether in PDFs or BIM, is not collected properly, resulting in information that is not or less relevant throughout the following phases. As highlighted by interviewee A2 (2022): "*What we frequently encounter at the moment of delivery, that's a major problem…the completion file is often incomplete and not at all in line with how it was actually built and we often can't get it right again because the contractor has already left and gone to another project and they no longer consider the completion file to be relevant. That's usually a difficult point to get right*".

Selection phase

The grounds for exclusion and suitability requirements do not relate to the contractor's competency to work with BIM and/or a data component. The level to which the candidate can demonstrate their competence to work with BIM is not specified in the selection criteria. Special selection criteria for BIM, according to the interviewees, are not required or the benefits are not yet seen. "*You see that engineering firms and architects are often already quite advanced in digitization. When it comes to building data, it is quite standard for architects and engineering firms to work in BIM models*" (interviewee A2, 2022). For the design and engineering process, BIM is used as the standard by the contractor to work with its subcontractors. As the contractor (interviewee A3, 2022) explains: *"We have a BIM protocol in which we describe exactly how we want to do this. We make that geographical model available to subcontractors and suppliers and they create their own product model in it, ensuring that they have a model with which to operate their machines and factories. This is used as a check to see if it fits. It is part of our standard operating procedure. You also see this with other contractors. There are quite a few parties who work in 2D or who think along two lines, but I don't think all the major construction companies do this anymore".* Yet Interviewee A4 (2022) also sees an advantage of implementing selection criteria: *"The projects of the State Property Agency are generally quite large. They are not one-man businesses or small companies that we come across. These large companies generally have it well under control and they already work with BIM on their projects daily. However, I do still see a point for development in bringing them together. That if you have different parties, a structural engineer, or an architect, they can work together properly. Of course, a part of the corporate culture has to fit together, but also the way of working. If all kinds of different systems are used that communicate poorly or not at all with each other, no one benefits. So you could also ask them for some kind of vision on how they approach their information structure in a project".*

Award phase

The most economically advantageous tender is determined based on the best price-quality ratio. Additional financial and qualitative criteria were used to decide this. No award criteria have been set for information management. BIM is not utilized as an award criterion anywhere in the RVB, as far is known. In PPP agreements, the contractor is required to produce plans such as a Quality Management Plan or a Services Implementation Plan which indicates how it will comply with the requirements set. Conceptually, this is comparable to a BIM Implementation Plan. However, these plans are only submitted after the contract is awarded, not as part of the tender (Personal communication, A5).

Summary findings

Case A concerns the renovation of the Herman Gorter Complex in Utrecht. How the BIM model needed to be delivered by the contractor was specified by employing the 'RVB BIM Specification'. The document primarily specifies requirements for the final products to be delivered, the BIM-3D extracts. The RVB does not define the procedure or the technical details required to obtain the desired output. The document lacks among others a description of the goals and objectives, a description of milestones, and guidance on non-geometric data. As a result, the project team decided on a few additional requirements regarding the model. LODs were requested, which are now hardly used and have become outdated.

Data and digitalization are not enforced by the State Property Agency. As interviewee A1 (2022) explains: "*We always work with the AutoCAD version which is at least four versions behind what is usual on the market, and that's the way it is with all ICT things*". There are a few early adopters inside the organization who see the benefits of digitization, but the majority have yet to do so. As a result, nothing is done with the models after delivery.

Concerning digitization and data, the market has more knowledge. Many measures must yet be taken by the contracting authority to get there. Systems must be put in place to store the data and allow for collaboration with partners. At the moment, the models are requested, but cannot be opened and end up in an archive somewhere. As the technical manager (interviewee A4, 2022) describes it, "*I have Solibri installed on my PC, as I am unable to view BIM models received from the contractor in the RVB system. Then I put it down locally and I go through it myself, but obviously, this is not how you want to work within the organization*".

In addition, new roles will have to be deployed within the organization. Information managers and directors will have to play an active role in the project. The link between the project organization and the management organization must be established. Currently, property management and even object managers are not involved in the projects (interviewee A4, 2022). The organization needs to gain insight into what information is needed.

5.2 Case B - A12 IJsselbruggen

Client	Rijkswaterstaat	**Awarded**	March 2021
Location	Rheden	**Contract**	E&C-contract
Size		**Procedure**	Competitive dialogue
Cost	€ 42,000,000	**Contractors**	Savera IJsselbruggen (Dura Vermeer & Hollandia Services)
Published	September 2020		

The Dutch National Road and Waterways Authority, Rijkswaterstaat (RWS), is the executive organization of the Ministry of Infrastructure and Water Management and works daily to ensure that the Netherlands is safe, livable, and accessible. RWS has been working on implementing BIM into their working processes and databases for some time. RWS is standardizing and making uniform the way it describes, collects, stores manages, and exchanges data on its acreage through the AIRBIM program (Rijkswaterstaat, 2020).

Introduction

The A12 IJssel bridges are being renovated as part of Rijkswaterstaat's Replacement and Renovation program. Many bridges, tunnels, locks, and viaducts date back to the 1950s and 1960s and have been subjected to heavy use over the years by more and heavier traffic. After 60 years, the steel bridges of the A12 motorway over the IJssel near Arnhem are also in need of renovation and strengthening. In 2017, it became evident that the two steel IJssel bridges were at risk of developing fatigue fractures and that short-term renovation was necessary. Savera IJsselbruggen, a joint venture between Dura Vermeer and Hollandia Services, has been granted the contract by Rijkswaterstaat.

This project is one of the pilot projects for the application of a two-phase approach by Rijkswaterstaat, which aims to reduce risk as much as possible. In phase 1, Rijkswaterstaat and Savera IJsselbruggen will jointly produce the design, whereby uncertainties will be removed by for example additional research. Based on the design, the definitive price is agreed upon with a risk profile that is acceptable to both parties. Subsequently, the project is carried out collaboratively in phase two. The approach to the project is based on the DOEN philosophy, which strives for optimal cooperation among the project's numerous stakeholders.

Initiation phase

Initially, the a12 IJsselbruggen project was designated as an AIRBIM project. With the AIRBIM program, Rijkswaterstaat wants to improve the quality of areal data by standardizing the way data is stored and exchanged. This also concerns improving the exchange of areal data with market parties. The program started at the beginning of 2019. The experiences from the earlier programs, AIR2020 and BIM, prompted changes in the steering line and approach.

The original goal of the Rijkswaterstaat's AIRBIM initiative was to build a data room for the A12 IJsselbruggen project. The data room is a virtual environment in which all existing and new information relating to the project to be realized is available. The BIM data room can contain documents, data, or links that are relevant to the tender for a project and the subsequent contract phase. In the end, it turned out that the room could not be realized before the start of the project. As explained by interviewee B2 (2022): "*There was supposed to be a working data room at the start of the tender, but that milestone was not achieved. Then the goal was adjusted so that it would be there at the end of the tender. Finally, the goal was to look at what we can learn from*

each other about delivery and transfer and how that can help us to do something with AIRBIM in the future". Due to the time pressure of the project, the organization was forced to continue without a data room. Currently, the program looks in particular at how the asset management organization can be connected to the project (interviewee B1, 2022).

Demand specification

In recent years, the contracting authority developed an extensive OTL and an extremely comprehensive ILS, containing more than 72 pages. In its ILS, the client prescribed the usage of two open standards: COINS and VISI. The definition, properties, and reciprocal relationships of various object types were all recorded in an OTL. In the end, the OTL system proved to be extremely complex, and research on AIRBIM by the ICT Assessment Agency in 2020 led to RWS making significant changes and streamlining the present program (Rijkswaterstaat, n.d.). "*The asset managers did not feel heard. They couldn't find what had been entered into the system. The AIR development was overly technical, the OTL was overly complicated, and the COINS mechanism for supplying the information containers was insufficient. It required too much of the contractors because they had to set up their systems following the requirements. As a result, the decision was made to put the present OTL on hold and create a new one*" (Interviewee B3, 2022). The program's attention has shifted to what asset managers require to directly utilize the areal data. Thereby, priority will be given to cleaning up the existing application landscape, while the design and intended added value of the AIR system are reviewed. *"It necessitates much more than a new system, a new contract, but also a new way of working among the Rijkswaterstaat employees*", explains interviewee B3 (2022), "*This is the challenge that AIRBIM now faces: not only making products but also ensuring that these products, such as an ILS, are managed and that the latest version is always available. that it is included in the contract and that the process around it is also regulated. We have spent a long time creating the technology. Now that we've been tapped on the shoulder, we need to pay much closer attention to the process*."

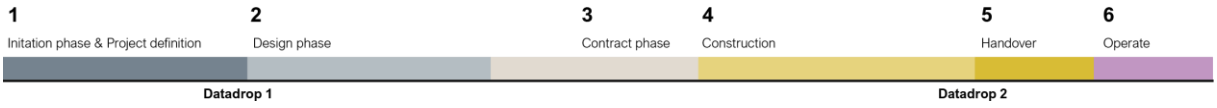


Figure 5.03: Datadrops A12 IJsselbruggen. Own illustration

The contracting authority does not yet have a general information delivery specification (ILS). It is currently being developed and the planning is to have a generic ILS ready in the course of this year (2022). The demand specification process for the A12 IJsselbruggen does include generic contract requirements for the "Geodetic Activities and Area Data" in the appendix. This is a standard annex which is the same requirements for (almost) all projects. During the project's preparation, the area information list and the documentation type tables are made specifically to the type of area of the contract and attached to the contract as an appendix. This document indicates which data and documents the client needs to properly manage its acreage and in which systems the data must be stored. In addition to the requirements for the documents, some requirements are set for the process and delivery. First, before updating the data in the management applications, particularly in the case of adjustments to the decomposition and GIS data, the contractor must agree with the contracting authority on a date on which the update will take place. In addition, a delivery plan is requested in which the contractor specifies which information will be sent when, in what sequence, and how the testing process will go throughout the project (interviewees B2 & B3, 2022). Aside from agreeing on a delivery plan and a date for data delivery, there are no further criteria for the procedure.

The contractor is required to provide the as-built files and drawings in word/excel, dwg, pdf, and/or GIS. "*There is currently no obvious need for 3D models. The 3d models are only used in projects since the contractor creates them. The client does not yet ask for them, because Rijkswaterstaat has not yet paid any attention to them or has no place to store them. There are no rules yet with which they must comply, and there is no idea what they can be used for at all*" (interviewee B3, 2022). Client and contractor worlds are widely apart in this regard, as explained by the interviewees. Contractors have been using BIM to collect and create project information for years, while client primarily uses PDFs. "*The Rijkswaterstaat's systems are incapable of handling 3D objects; they can only handle 2D and, preferably, PDF. In terms of time, those worlds are so far apart. We are 15 years behind each other in terms of time. We are behind as an organization, whereas contractors are simply up to date and employ the most up-to-date technology*" (interviewee B2, 2022). In practice, the information from the models is frequently flattened and printed out, rather than the benefits of BIM being utilized (interviewee B1, 2022).

Because the organization has not yet chosen a system, there is a continuous discussion between the asset manager and the contractor of the A12 IJsselbruggen about where and how the information should be stored. As highlighted by interviewee B1 (2022): "*They keep circling each other. The contractor advises that the asset managers select a system so that they have something to base their decisions on. The asset management organization, on the other hand, tells me the exact opposite. They ask the contractors 'What projects do you use, what does the contractor use, and how can we connect the two?' Each project will have a somewhat different response to the asset manager's request. Because one contractor may work with one system and another with another. This results in a very fluid discussion in which all variables are slightly different, making it extremely difficult to reach a consensus*".

Following that, the contractor (interviewee B4, 2022) explained that this project would indeed initially learn from the AIRBIM Program. In practice, Savera was mainly advising Rijkswaterstaat on how they should digitize. The contractor continued: "*I see fantastic opportunities for an asset management organization. In light of the whole replacement and reconstruction work that RWS and even more public commissions authorities face in the future years, this is both huge potential and a huge challenge*". The contractor points out that to do so, the client must understand and standardize its asset management requirements. Currently, the contractor must constantly strive to integrate with the client's systems. "*There are different systems, we can all connect to them because you work with different clients who all have their systems*" (interviewee B4, 2022). The contractor emphasizes the importance of chain collaboration to standardize. To accomplish so, the client must collaborate with the contractors to decide what information they require and can provide.

Selection and award phase

In the selection phase, the first step was to see which applicants had the right technical knowledge and experience. There are no grounds for exclusion, eligibility requirements, or selection criteria specific to the data component. Subsequently, the goal of the tendering phase was to choose the best cooperation partner from the three most eligible parties that emerged from the selection phase for the project's effective execution. The proposals were evaluated in the tendering phase based on four criteria, mainly focused on collaboration. No award was made on the data component.

As interviewee B2 (2022) points out, they, the contracting authority, is far less advanced with digitization than the contracting parties. First and foremost, the organization must be clear on the path it wishes to go and what it will take to get there. Interviewee B1 (2022), on the other hand, indicates that they can select parties who can help with the further development of BIM. "*However, you must be extremely mindful of whatever component is being asked, whether it is content,*

process management, or something else". However, also states as soon as the organization has a clear (or substantially clear) notion of what a contracting is required to accomplish concerning the data component, it can be included as a contract requirement instead of selection criteria." *If you want to make this as normal as possible, then you will have to move as rapidly as feasible towards standard contract requirements in the form of, for example, an ILS that clearly states that we as the Rijkswaterstaat want to do it this way and this way how we want you to connect to it. I would certainly do this together with market parties or with sector associations to ensure that you have a shared starting point. But make it clear that those parties can organize and invest in their procedures. Especially if you start doing something new with every project, it only becomes more complex*".

The contractor (interviewee B4, 2022) agrees: "*For me, the investment is essentially on the part of the client to further professionalize, and the contractors will subsequently follow*". A major contractor may put more money into it and will probably develop faster than a small contractor. However, the contractor believes that in the end, the small contractors will keep up with developments. The interviewee notes that when tendering, contracting authorities have to estimate what kind of contractors will respond. If the contracting authority expects a significant number of larger construction businesses to tender, the standards might be set a little higher because they are frequently more advanced in their procedures and understanding.

Summary findings

The case study of the A12 IJsselbruggen shows that Rijkswaterstaat has a pressing need to get the asset data organized. A lot of data is already known but kept in multiple systems, as there is no consistent manner of keeping track of data. The various systems' layouts are neither consistent nor standardized. The organization is already aware of this, as described by one of the interviewees as‘ consciously incompetent’. Eventually, the goal is that the seven regions work in the same way and store information in the same way. For this, the organization seeks to minimize the number of systems and to map out the information needs on the one hand. On the other hand, it wants to implement projects step by step and involve the region in them. However, putting BIM into practice still appears to be extremely difficult and causes many obstacles. The ambition is great to tackle the problems and improve, but because the organization is so unwieldy, it is difficult to make the transition.

In 2020, the OTL and accompanying ILS proved to be too complex for asset managers and contractors, thus it was decided to concentrate on the process A new ILS is currently being developed. For the time being, the standard request in projects is for pdf, excel/word, dwg or GIS. This means that, in practice, the information from the models is often flattened because contractors can already work according to the new technologies. It is time that Rijkswaterstaat identifies how they want to receive, store and exchange information so that contractors can organize their processes accordingly.

5.3 Case C – E-Pier Schiphol

Schiphol Nederland B.V. (SNBV) is part of N.V. Luchthaven Schiphol. N.V. Luchthaven Schiphol carries out its activities under the name Schiphol Group. Schiphol Group is the operator of Amsterdam Airport Schiphol, the largest airport in the Netherlands. It is the ambition of Amsterdam Airport Schiphol to be and remain Europe's Preferred Airport; the airport that is valued for its quality, capacity, and extensive network of destinations. Furthermore, Schiphol aspires to be the world's leading 'digital airport.' Schiphol uses BIM to achieve these goals. In addition to information about the building products via BIM, a great deal of information about the project management processes is also collected and processed.

Client	Schiphol Nederland BV	**Awarded**	February 2018
Location	Schiphol	**Contract**	Build
Size	20.000 m2 BVO	**Procedure**	Retricted procedure
Cost	€ 15.350.000,-	**Contractors**	Strukton
Published	November 2017		

Introduction

Case C concerns the execution of construction and installation works on the E-Pier. Thereby, the work includes the realization of new retail and catering clusters, the replacement of lighting, and sanitary facilities, and the redesign of the seating areas. The goal is to enhance the quality experience of travelers on the piers and to give the piers a commercial impulse with products and services. The upgrade of Pier E is part of the larger Upgrade Piers project. This project realizes the redevelopment of the 1st floor of the four non-Schengen piers, the D-, E-, F-, and G-piers. Due to the introduction of central security in 2015, the security arrangements at the gates are no longer necessary, allowing for open gates. Pier E is the final project in the upgrade of the piers. Before this project, piers F and G and pier D have already been tendered and/or executed. Lessons learned from previous tenders have been incorporated into the renovation of Pier E. The architectural design and master plan were created by Benthem Crouwel and NACO, and the interior design by Kossmanndejong.

Initiation phase

Asset information management at Schiphol is increasingly embedded in the organization due to a group of early adopters who began spreading the benefits of BIM for construction and management throughout the Schiphol organization a few years ago. At the time, digitalization was initiated by the project organization. The transition started with the large projects as they could afford to incorporate the existing situation of the terminal into BIM (Interviewee C1, 2022). Gradually, data-driven work is becoming more significant in the organization. In 2019, a highly active and large program was executed, demonstrating the added value of BIM across the whole supply chain. Since then, the goal has been to create that digital twin (interviewee C2, 2022). Nowadays, all projects must use BIM. There are a few exceptions, but only if just one asset is affected or if the project is an inspection, in which case BIM is not required. All projects must adhere to the ILS even if no BIM models are delivered. In principle, all employees in the organization have the same vision, but there are project managers who are more and less interested. Some project managers are primarily concerned with the financial element of the project (interviewee C2, 2022).

Demand specification

The specifications include an AIM protocol as-engineered and as-built, an Information Delivery Specification Schiphol (ILS), an overview of IFC models, and a BIM reference. The BIM reference was written for the project Upgrade Piers, E-pier. The reference provides insight into the considerations and choices made by the BIM partners Benthem Crouwel NACO (BCN), HaskoningDHV Nederland B.V. (Construction) and HaskoningDHV Nederland B.v. (Installation Technology Consultant). When the model is checked and/or utilized again after delivery, the document will reveal the exact starting points, the ILS and procedure employed, and how the information must be interpreted (interviewee C2, 2022).

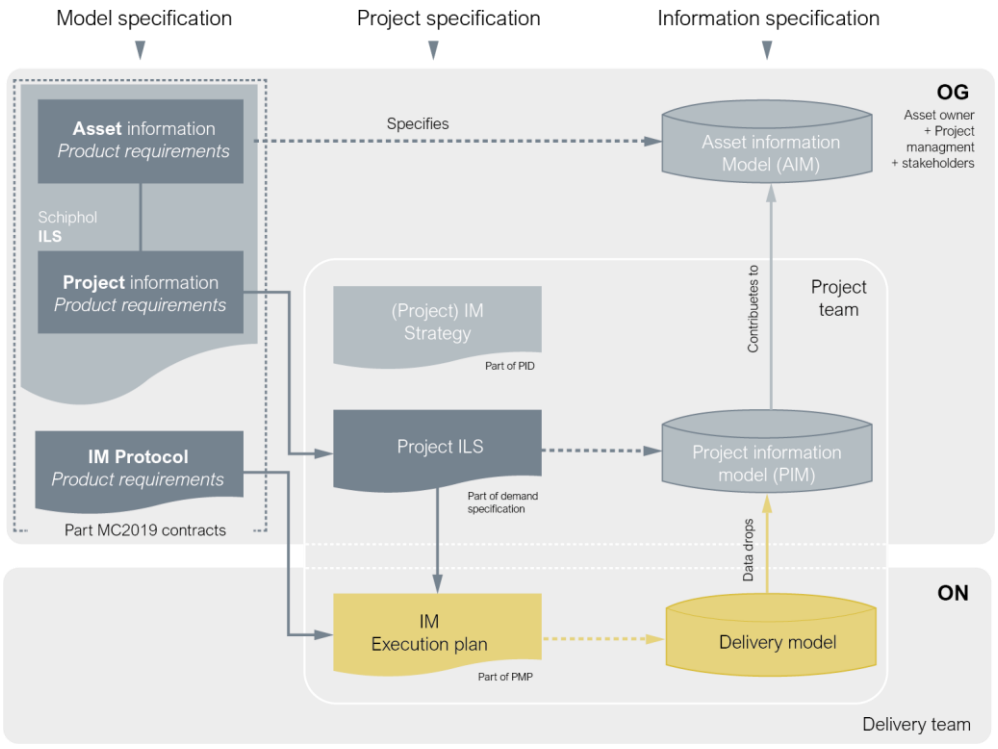


Figure 5.04: Coherence of ILS, IM protocol, and IM execution plan Schiphol

At the time the E pier was awarded, AIM Protocol 3.0 and ILS 3.1 were in force. Meanwhile, the organization is already working with version 4.0. The separation of Product Requirements (ILS) and Process Requirements is the most significant shift (IM Protocol) since the third version. It remains a major challenge for the organization to request the correct information in the ILS. The ILS must fulfill the demands of the organization, but it must also be compliant with the market. C3 interviewee (2022): "*What is in the ILS is not only for us but also for the architect who ultimately has to make a design or the contractor who ultimately has to build with it. How do you bring the whole chain together so that they can all find something in it and have something to say? That is a big challenge. You also want to give them the freedom to apply their expertise, but on the other hand, you have to prescribe something, because you know that you will be reusing the data at a later stage and that there will be other needs*."

Version 3.1 of the ILS is divided into four chapters. Chapter 1 describes Schiphol's objective of the Information Delivery Specification (ILS) and gives a short description of the delivery process. Chapter 2 focuses on the information delivery process (how should the data and information be delivered). The delivery moments and expectations concerning content are highlighted. This chapter also contains an explanation of the roles and responsibilities and the method of delivery.

Chapter 3 describes the norms and standards that apply. The various underlying agreements of both the models and the objects are described. A new chapter, 'Terms and Definitions,' has been added to the most recent edition. Every project has an ILS table that specifies which information products per asset type must be produced. This is always done on a project-by-project basis.

Chapter 1 contains a description of the objectives, scope, and application, the Information Delivery Cycle, the relationship between the ILS, AIM protocol, and (BIM) implementation plan, and the relationship between ILS documents and the reader's guide. The objective of the Information Delivery Specification (ILS) is multiple:

1. Information for ASM processes: during the entire duration of the project/work, Asset management (ASM) needs information for its tasks, such as assessing designs and deviations on design grounds, verification of set requirements, the commissioning and management of assets, but also processes like Terminal Allocation, scaling up/down of facilities or issuing codes.
2. Creating and enriching the Asset Information Model: Asset information is organized in an object-oriented manner, with characteristics, geometric data, documents, and other asset-related information provided in connection to the object.
3. Accurate and efficient processing of information: the capacity to process the information in the appropriate information systems, to increase automation.

Chapter 2 describes the information delivery process. The information delivery is characterized by two types: Information coordination moments during the design and engineering process as recorded in the IM implementation plan and formal information delivery moments per project phase referred to as data drops. The data drops in the design phase are related to the design phases of the DNR-STB 2014. The construction, handover, and operation phases are following NEN 2574 (see figure 5.05). In the ILS for the renovation of the E-pier, the data drops have not been made project-specific. The general seven different data drops are described, while ultimately only a few data drops will be applicable. The drops in the initiation phase and design phase are not applicable because these have already taken place before the tender of the E -pier.

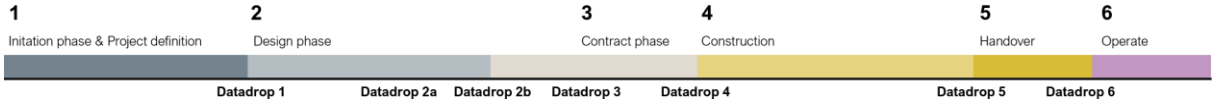


Figure 5.05: Project phases and data drops as defined in the Schiphol ILS

In ILS 3.1, the data drops are briefly explained. In the latest version (4.0), this has been moved to the IM protocol. The following paragraphs outline the responsibilities and tasks of the roles in the information supply process. In the most recent version, this has likewise been relocated to the IM protocol. Following that, the method of delivery is described by setting requirements for file format and file name structure, folder structure, and transfer media. In protocol 3.1 the files had to be delivered via a secured USB storage medium or WeTransfer. Currently, Schiphol has a Data Room where the files must be delivered.

Chapter 3 focuses on the principles and standards that Schiphol uses for information delivery. information supply. These guidelines guarantee that the information provided meets the demands of stakeholders as well as the information structure of Schiphol's systems. This chapter describes the principles and standards concerning (1) The structure and standards used for information products; (2) The geography of objects; and (3) The classification and attributes of objects. The contractor will use IFC to exchange and deliver models. For the decomposition and classification and coding of items, the official version of the Schiphol Technical Decomposition (STD) is in force at the start of the project. The STD is mostly based on the NL-SfB, and where necessary

supplemented with airport-specific objects, with corresponding codes. Nowadays, the Data Dictionary Schiphol (DDS) contains the specifications of all information products: the content, the standards with which the products must comply, and the format of delivery. Comparable with an OTL.

In ILS 3.1, references are made to the PAS1192 and in ILS 4.0 to the industry standard ISO 19650-1. The organization is closely involved in the development of international and national standards. Interviewee C3 (2022): "*We try to adhere to that standard as much as possible because we also want our work methods and our data to be recognizable to the outside world. That we are not reinventing the wheel or asking for strange things. So that parties working for us can connect as easily as possible*".

As abovementioned, BIM was initiated and set up from within the project organization. As a result, the various stakeholders involved in the project noticed that asset management is still lagging (Interviewee C1, C4 & C5, 2022). "*You see that asset management is not yet able to cope with these data deliveries. They are still trying to figure out how to set up their systems, how to build them, and what information they need exactly*" (interviewee C1, 2022). BIM coordinator from Strukton (interviewee C5, 2022) also noted that none of the employees of the asset management organization was present during the meetings. The contractor's project manager (interviewee C4, 2022) thinks that Schiphol should research what sort of information they require for what kinds of components to do effective maintenance. "*Otherwise, it is just occupational therapy and a nice tool that you use and never look back".*

The asset management organization's lack of vision is manifested in a variety of barriers that stakeholders from both the commissioning and contracting parties encounter. The project manager (interviewee C1, 2022) explains that the ILS was initially set up by the projects and then supplemented and modified by asset management. As a result, the project manager observed, that the later data drops do not properly match the projects' working methods. The interviewee explains that most projects at Schiphol, 80 to 90 percent, take place in an existing building, which means that you have an existing process and they want to disrupt that existing process as little as possible. As soon as renovations have been completed, Schiphol intends to make the new data available to the operation again. In practice, phases collide with one another. In the ILS, a strict distinction is made between asset management and operation. Conversely, certain schedules are only requested at handover, while the management organization needs the schedules at the data drop for the operation to be able to solve failures. "*These are differences in insights to which we should pay much more attention to allow that process to run more smoothly*".

The contractor pointed out that the ILS requests a lot of information. According to interviewee C5 (2022), "*The AIM protocol, as well as the specific data needs, astounded me. A realistic project could not include 25 to 30 features for a door ", and continues "We focused with the modelers and stakeholders to deliver information that was useful for further maintenance of the projects within Schiphol* ".

The model that the contractors initially received from Schiphol was very inaccurate. "*We tossed the model aside and started to build a new model ourselves to be able to make work drawings*" (interviewee C4, 2022). Following then, there were several conversations concerning the information that needed to be returned. The ILS stated that contractors only had to submit new data concerning the alphanumeric data and documents. It was not necessary to deliver the updated geometry. Schiphol's project manager explained that the organization wishes to stick to the philosophy of passing on and enriching one model. "*We have seen this before in Autocad; if each succeeding party starts developing their own model, you will never reach the principle of working together in one model*". On the other hand, the contractor (interviewee, C5, 2022) finds

it remarkable that Schiphol has the ambition to create digital twins, but does not take into account that there are also mutations and changes to the geometry during the construction process. Interviewee C1 (2022) explains: "*Do you need to know exactly where everything is, or will a 1-meter margin suffice? Because asset management is still unable to adequately deal with models, there have never been any good discussions about the degree of accuracy in models to this day*".

The stakeholders in the project did a round after the pier was completed to see if the models matched reality, which was done for the first time for the E-Pier. Interviewee C2 (2022): "*With the supervisors, we went to verify if what had been planned had been carried out and if the models matched reality. It was quite instructive for me and all stakeholders involved to do so. You can examine whether the geometry that we have in the models is correct, but also whether the information that is linked to it is correct*". That is a lesson they are now applying to several projects.

Selection phase

To be awarded, the candidate must be technically and organizationally capable of performing the contract within the preconditions set by the contracting authority concerning time, quality, and costs. In total for the E-Pier project are four core competencies. The candidate shall submit one reference project that satisfies the following criteria for the BIM core competency:

- The reference project relates to the execution of construction work, including implementation coordination of Mechanical and Electrical Engineering work, of a non-residential construction project, whereby a BIM model forms the basis of the design.
- The reference project concerns a new building or renovation and has an order value of at least € 1,000,000, excluding VAT;
- The reference project was completed within five years of the registration deadline.
- The reference project concerns an existing building with complex construction logistics in a densely populated environment with intensive traffic flows, which is operational 24 hours a day, 7 days a week, and 365 days a year, whereby the candidate carries out the work in multiple shifts. Examples include airports, prisons, hospitals, shopping centers, and railway stations with high numbers of visitors.

If more than five candidates were found suitable based on the assessment of the grounds for exclusion and minimum suitability requirements, the contracting authority would rank the candidates found suitable as referred to in Article 12 of the ARN201. The further selection consists of the contracting authority's assessment of the proposed construction task, based on an in-depth assessment of several minimum requirements concerning technical and organizational expertise. In total, there are five selection criteria (S1, S2, S3, S4, S5,) relating to technical and professional competence. For point S5, the candidate must show through a project that it has directed the BIM design to a minimum of LOD 400 for execution and a minimum of LOD 500 for revision. The candidate's fulfillment of their role as manager is important for a higher score, at the highest possible Level of Development.

The project manager of Schiphol (interviewee C1, 2022) believes that BIM is a basic skill. "*That ultimately you do not get the local installer or the plumber but rather an installer or a contractor who knows how to deal with this*". According to the contractor (interviewee C4, 2022), contractors and installers are typically more advanced than the client, " *We can write all kinds of things down, but if the client does not provide the right information, the process will come to a halt*."

Award phase

The Upgrade E pier was realized by the tenderer with the best Price-Quality Ratio. There were no award criteria related to information management.

However, during the tendering process, the contractor was asked to submit an execution plan. This was not assessed when the contract was awarded. When the contract was awarded, the contractor did continue to modify the strategy in conjunction with the contracting authority. Project manager C1 (2022) is convinced that any contractor can make a proper plan, but in the end, it's all about execution. That's why they chose to include BIM as a selection criterion, rather than the execution plan as an award criterion. According to the contractor (interviewee C4, 2022), the execution plans the contractor usually writes down are quite standard. The contractor argues that contractors can currently distinguish themselves by entering into a dialogue with the client about the 7D aspect. Building managers and owners can use 7D BIM to manage operations and facilities. "*That 4D and 5D are of no use to the client. I believe that 7D is where the client and the contractor have to find each other. If you have that conversation with each other beforehand, then you are one step further than 3D modeling*".

Summary findings

Case C comprises the upgrade of Pier E which concerns the execution of construction and installation works on the E-Pier. Due to a group of early adopters employed by Schiphol who began spreading the benefits of BIM for construction and management throughout the organization a few years ago, asset information management is becoming increasingly integrated into the organization. Schiphol has made significant progress in terms of information management and associated documentation. There is a standard ILS and a standard IM protocol in which information is requested. The organization strives to adhere to the standards to the greatest extent feasible. As a result, the ILS and IM protocol, as defined by ISO-19650, are used in every project.

However, BIM was initiated and set up from within the project organization, as a result, the various stakeholders involved in the project noticed that asset management is still lagging. Asset management requirements and how they might be integrated with the project organization and contractors will be examined more carefully in the future.

5.4 Case D – A326

The Province of Gelderland is responsible for 1160 kilometers of roads and related objects such as public lighting, civil engineering projects, and roadside trees. This infrastructure is intensively used and forms an important connection between national roads and municipal infrastructure. Sustainable spatial development and accessibility are among the province of Gelderland's highest priorities. Some innovators who are responsible for the management of provincial buildings and the maintenance of the provincial road network saw that BIM could provide significant added value here. Meanwhile, the Province of Gelderland has gained expertise with BIM and is implementing it in a growing number of projects.

Client	Provincie Gelderland	**Awarded**	October 2021
Location	Wijchen	**Contract**	RAW + D&C contract
Size	10km	**Procedure**	Restricted procedure
Cost	€ 4.236.000	**Contractors**	BAM infra
Published	April 2021		

Introduction

In the summer of 2022, major maintenance will be carried out on the A326 from the Bankhoef junction to the Palkerplein. The current top layer construction is at the end of its life span and needs to be replaced. With this project, the Province of Gelderland is challenging the market to further develop circular asphalt with an optimal lifespan. In this way, the Province of Gelderland is contributing to the higher goals of reducing CO2 emissions and stimulating the circular economy. In addition, other maintenance measures need to be carried out on and around the A326. This varies includes the replacement of signposts, signs, and crash barriers to minor maintenance of engineering structures and miscellaneous minor maintenance.

Initiation phase

For the maintenance work, a RAW contract form was adopted. A Design and Construct (D&C) contract has been followed for the replacement of the top layer and the intermediate layer. This hybrid form was chosen on the one hand to stimulate the market to offer an optimal sustainable solution for asphalt construction. On the other hand, to limit the efforts of the design work of the contractor that can be fully specified.

During initiation, the BIM coordinators of the province of Gelderland decided that this project should be delivered in BIM. The initiative from the province is mainly with a small group of BIM coordinators. Currently, the project managers in the organization have very limited knowledge of information management and do not yet attach much value to this information (interviewee D1, 2022). Together with the contractor and the BIM coordinator of the province, expertise and information are exchanged. D1 (2022) interviewee: " *You may need to take them by the hand at times because they have a low level of maturity*". At the moment, not every project is working with BIM. The medium-sized projects are chosen because BIM knowledge is still low among small contractors.

Demand specification

The demand specification, as defined by the UAV-GC 2005 and the Basic Agreement, is divided into two parts: demand specification requirements (VS1) and demand specification process (VS2). The contract also includes the Basic Agreement, the stipulations, the RAW specifications for maintenance work, and the annexes.

In the demand specification VS2 process, activities are considered by the client to be of such importance for the realization of the work or its activities. This document also establishes certain requirements regarding the building information. The requirements set for the building information refer mainly to annex XV, the Information Delivery Specification (ILS). The VS2 Demand specification also contains requirements that are not further discussed in the ILS. Firstly, requirements relating to the systems. The contractor must create its own Project Management System (PMS), which will allow for the export and import of BIM information delivery in compliance with Annex XV ILS. The BIM sub-management plan should provide insight into how the contractor's project management system is set up and how the contractor demonstrates that the requirements from the ILS can be met. In the PMP Project Management Plan, a description of how the as-built file is prepared should be worked out.

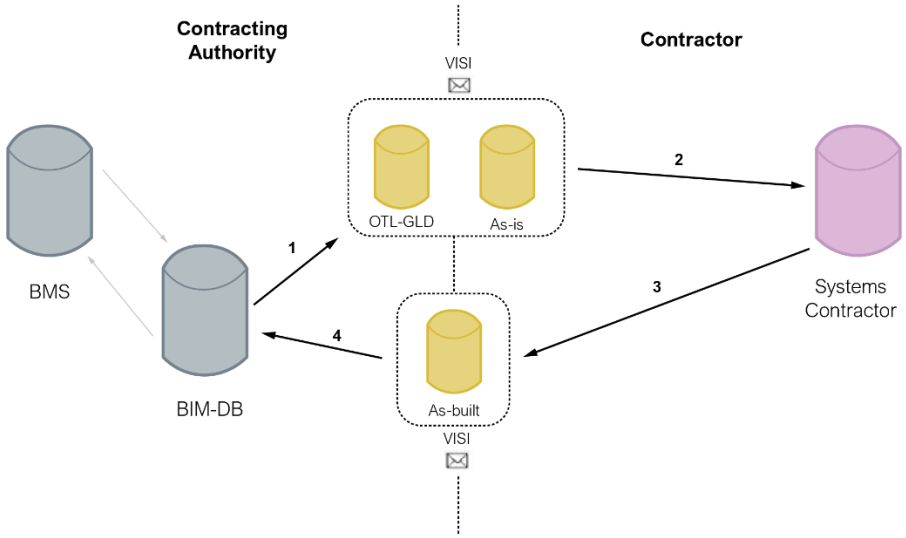


Figure 5.06: BIM information delivery Provincie Gelderland

Second, requirements for roles in the information exchange are established. To supervise the digital information exchange, the contractor must designate an information manager. The contractor must also appoint an information manager to facilitate communication with the contracting authority. Thirdly, there is a requirement for the process. The contractor must organize a BIM start-up meeting within one month of the start date. Thereafter, monthly meetings between the contractor and the Province must be scheduled to track the BIM process' progress and resolve any issues.

Annex XV "As-built instructions Province" consists of Information Delivery Specification (ILS), VISI format, and drawing regulations. The ILS is a general delivery specification that is not specified for the A326 project. The ILS is used to set requirements for information deliveries concerning BIM. Chapter 2 sets out the requirements for information packages (COINS container, data, geometry, and documents). Chapter 3 sets out the requirements for the information delivery process (VISI messages and COINS viewer). Other chapters include the introduction (Chapter 1) and appendices (Chapter 4), which include a glossary, document list, and measurement instructions. The ILS is fairly compact as most of the information on structure and construction is contained in the Object Type Library (OTL).

The OTL is a generic information model in which object types are organized, described, and specified systematically. This OTL provides a template for the manager's information requirements. The OTL contains the information needs of the Province. For each object type, the OTL comprises the following:

- Definitions;
- Images (if available);
- Position in the taxonomy and decomposition;
- Properties to be delivered by the Contractor;
- Geometry (information to be provided by the Contractor).

The OTL does not remain still and is constantly evolving. This ensures that there can be a gap between what is requested in the OTL and what the organization currently manages in terms of information (interviewee D1, 2022). The OTL's preliminary design is created by the BIM coordinators following the information needs of the management organization of the province of Gelderland (BOW department). The structure is made up of a variety of standards, but the foundation is IMBOR. The open standard IMBOR (Information Model for Management of Public Space) contains agreements about the names of types of objects in the public space and management data that can be recorded for each type of object. With IMBOR, CROW wants to offer the field of public space management a standard ontology to standardize the registration of data so that parties can better share their data in the entire asset management process. Interviewee D1 (2022): "*So actually to make it recognizable instead of having your own structure of how things are fitted in*". The open standard IMBOR is compared with the internal management systems.

During the tendering process, the OTL is provided as a viewer for the contractor to see what information is requested. After the tender, the second, more comprehensive version is provided (interviewed D1, 2022).

Requirements for information packages

The requirements for the information packages consist of the requirements for the COINS container (2.1), the data (2.2), the geometry (2.3), and the documents (2.4). Each component will be briefly discussed.

Several years ago, the Provincial Executive decided to work with the open standard COINS. COINS (Constructive Objects and the Integration of Processes and Systems) enables construction parties to exchange digital information between various IT platforms and environments (BIMLoket). In the meantime, COINS 2.0 has been further developed at an international level. Currently, ICDD (Information Container for linked Document Delivery) is the international successor to the COINS 'container'.

Until recently, the province used COINS as a way of exchanging data in all projects but recently abandoned it. As interviewee D1 (2022) explains: "*It was a very difficult principle to exchange data with. It turned out to be almost impossible in practice, so we were forced to say, "let's exchange in a way that enables us to do that"*. The province then decided to exchange data based on a File Geodatabase (FGDB) format. "*That was truly a thorn in our side*" the contracting party (interviewee D2, 2022) mentions, referring to the usage of COINS. "*Also because there are ultimately only 3 or 4 companies that can generate a COINS container. It is something very specific and it costs a lot of money. The switch to FGDB has saved us a lot of time and money*". Due to the recent switch, the contract documents for the A326 were still requested in COINS. After the contract was awarded, the province met with the contractor to discuss the possibility of using FGDB instead of COINS. Coincidentally, they had a previous project with BAM. BAM has already hired a third party to assist with the COINS deliveries of the two projects. Therefore, they chose to examine the difference between COINS and FGDB in the other project. The A326 project then opted for FGDB

exchange, not COINS (interviewee D1, 2022). One difference is that COINS can link geometry, information, and documents. With the GIS format, it is only possible to link geometry and information. The documents must therefore be delivered separately in the transfer file (interviewee D1, 2022). Subsequently, the asset specialists link the documents to the geometry in the management system.

For the project Sustainable Asphalt Maintenance A326, four information deliveries and thus four information packages are required. The first information delivery is after awarding (IP0). The province will supply the data for the existing area as far as is known in its management system. The information delivery includes the objects in the current area (within the project area) and all related object data, such as filled-in object properties and geometry according to the OTL-Gelderland. The province delivers the OTL-Gelderland, which contains all of the required object information. The information requirement consists of an overview of:

- Object types;
- Properties associated with these object types;
- Values lists with standard values belonging to these properties.

The province delivers the folder structure to be filled with the documents requested in the appendix to the document list. The documents must be distributed according to the numbering of the folder structure.

The second delivery, IP1 Trial delivery as-designed, concerns a part of the Final Design by the Contractor. At a mutually agreed-upon time, the contractor must send a trial delivery of the area data with the DO. Through this delivery, the Contractor demonstrates its ability to deliver data in accordance with the open standard and OTL-Gelderland. The trial delivery includes an object decomposition of the area representative of a part of the area of all disciplines and all related object data: filled-in object properties, four related documents, and geometry according to the OTL-Gelderland.

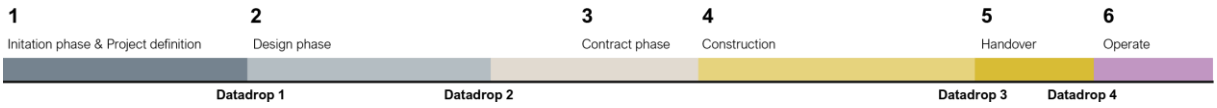


Figure 5.07: Data drops as defined in the ILS of Province Gelderland

Subsequently, no later than two weeks after the opening of (part of) the project, the Contractor must provide a total delivery of the data for that area (IP 3 contract delivery as-built). The information delivery includes an object breakdown of the area within the project zone and all related object data except for the requested linked documents. The delivery contains completed object properties and geometry according to the OTL-Gelderland. Because specified geometry must be given by the province to national institutions, the geometry takes precedence. So that's where the most importance is found within the organization (interviewee D1).

Ultimately, the contractor must make a total delivery of the area data at the same time as submitting the Project Delivery File (IP4 contract delivery as-built transfer file). The information delivery includes an object decomposition of the area and all related object data: completed object properties, all related documents, and geometry according to the OTL-Gelderland.

In delivery IP1/3/4, the Contractor must fill in the properties for the objects following the information required from the OTL-Gelderland. For each property, it is indicated whether this property must be delivered (yes/no). Properties with a yes response must always be supplied, whereas those with a no answer must only be delivered if the property is relevant to the object instance. In

addition, for the items that appear in the 'Product Specification Digital Terrain Model,' the Contractor must produce geometric representations in the form of GML files in delivery IP1/3/4. When obtaining the geometry, the Contractor must adhere to the accuracy and precision standards outlined in the 'Product Specification Digital Terrain Model.' The basis for the measurement instruction is the IMGEO information model from the BGT Act. The Contractor must supply drawings and documents of the work it has carried out following the appendix containing an overview of the documents. This list has been recently drawn up with numbering and folder structure. Nothing had been arranged to get documents from the project organization to the management organization. Interviewee D1: "*That generated a great deal of annoyance. What an asset manager had to do was to look in the folders of projects on the network drive to retrieve things*". With the new folder structure, it is still sometimes difficult to exchange documents internally because they are not used to it.

Chapter 3 briefly discusses the process of information delivery. VISI must be used to deliver the information (version 1.6). VISI is an open standard for digital communication. The Province provides an interaction framework available for this purpose. Using VISI, the Province determines when (process), who (role), what (information), and to whom (role) is delivered.

In general, contractor BAM has great experience with the Province of Gelderland's information delivery specifications. As both parties had worked together before, the contractor was already familiar with the delivery procedure before the start of project A326. Interviewee D2 (2022) states that the provinces' ILS is fairly straightforward. It explains step by step how they want the information delivery done. The document remains very basic, but on the other hand, interviewee D2 believes that it does not have to be more than it is. If anything does turn out to be ambiguous, the organization's lines are short. Communication with the three persons in the Province of Gelderland who are in charge of information delivery is accessible. Interviewee D2 (2022): "*What I think is positive about Gelderland is that they always use the same people for information exchange. The contract always states that there is one person at the client's side and one person at the contractor's side that whom they have contact. It leads to good conversations. Things are becoming increasingly clear about information exchange*". Thanks to the good contact with the client's contact persons, the contractor is always able to find a good solution to the question. The contractor does think, however, that Gelderland needs to establish one method at a certain point in time on how they want the data to be delivered. In this respect, they are still innovating and developing, which makes it more difficult for the contractor to apply this standardization.

In general, interviewee D2 believes that the public commissioners should include more specific contractual provisions in the field of information and data. " *Commissioning parties, in my opinion, should take a more active role. RWS, RVB, and various provinces have to make certain things compulsory to get them adopted on a national level in the Netherlands. If you look at the ILS and the OTL, you'll notice that they could be more stringent and explicit There could be a more of a request for information*". Contractors, according to the interviewee, are already well ahead of the public sector in terms of digitalization. "*We contractors come up with the most wonderful things with 3D models, 4D, 5D connections, and integrations, all to promote and improve our work process. In the end, the client asks for a flattened digital drawing that you can't do anything with*".

Selection and -award phase

The award criterion is the Most Economically Advantageous Tender (EMVI) based on the Best Price-Quality Ratio (BPKV). The province has not established any particular data component selection and/or award criteria. This is not done on any project within the organization. As interviewee D1 (2022) indicates: "*Those are things we are working towards in the future. We also want to move towards a BIM execution plan in the future. First and foremost, we want to ensure that the entire chain is operational* ".

Interviewee D2 (2022) indicated that currently, the major contractors are on the same level. All large contractors and engineering firms are ISO-19650 certified and work according to the standard's guidelines. This also trickles down to subcontractors and suppliers. According to the ISO, the main contractor is accountable for the data they receive as well as all project-related information exchanged. As a result, Contractor D2 finds that more and more people are becoming credentialed, as well as an increase in contract demand. "*The small companies also work with BIM, everyone works in 3D, everyone works with data, everyone works with information, with information parameters and deliveries. Only we think it's a shame that not much happens with it in the end. If the client does not utilize it, we just place it in the refrigerator and call it a day, so to speak*". However, not every contractor that the province comes into contact with will be able to meet the requirements concerning the data component. "*If you ask, say, the local concrete farmer around the corner to do something and have to replace three tiles, then you have a completely different type of information delivery and expectation. A local asphalt farmer does not have the power to make that COINS delivery. In that case, you are pricing certain contractors out of the market*". So if the province chooses to specifically select on BIM or has it included in the contract, it will preselect certain companies that are capable of doing so or have the option to outsource.

Conclusion

For several years, the province of Gelderland has been gathering expertise using BIM. Pioneers in the province embark on a journey of exploration, together with contractors, to see what works best. The province of Gelderland has more and more projects where BIM is requested utilizing the OTL. Ultimately, the province of Gelderland wants to collect accurate data from all projects in the organization. The province of Gelderland makes extensive use of standards. Among other things, the organization uses the IMBOR standard so that data is recognizable to the parties with whom they work. The province seeks to learn from other parties who are facing similar problems.

The province's strategy is working. The contractor can work successfully with the OTL and ILS, and interaction with the province is easy if any needs are unclear. In the future, the contractor does hope that Gelderland will at some point establish one method in which they will safeguard everything so that the contractor can apply standardization. To this end, interviewee D1 (2022) wants to standardize more and more. The more you standardize, the more projects you can serve. Eventually, the BIM coordinators only need to check that the information is incorporated in the OTL in the right way. The organization will gradually evolve toward a standard that also includes an execution plan.

6

Cross-case analysis

In this part, a cross-case method is used to analyze the differences and similarities between the four case studies. This comparison allows a more general conclusion to be drawn regarding the present situation of the procurement process in terms of data. These conclusions will be discussed in greater depth in the next sections, but first, the contexts of the case studies will be compared.

Context

When comparing the context of the four projects, there are several contrasts as well as parallels. First of all, all four projects are renovations of an existing building, building part, or infrastructure. This ensured that data and information on the assets were previously available to some extent. As these are renovation projects, special attention throughout the selection and awarding of cases B and C was devoted to maintaining the operational procedures going throughout the process. Whereas cases A and C belong to the building and utility construction sector (B&U sector), cases B and D are in the civil engineering sector (GWW sector).

The nature of the contracting authority, and hence the type of contractor, is another contextual distinction between the cases. The public organization of case A contains 11.7 million m2 of gross floor space of national government and Ministry of Defense buildings with a total of 82,615 ha of land. The organization employs 2,313 people (2,223 fte). The organization of case B is significantly larger, employing some 10,000 people across national and regional organizational divisions. The organization of case C is smaller than case A and has over 2,000 employees, some of whom work on developing, managing, and maintaining the property. Case D organization employs 1,500 people, with some of them in charge of infrastructure. As a result, the project sizes vary significantly, with expenses projected at € 56,600,000 for Case A, € 42,000,000 for Case B, € 15,350,000 for Case C, and € 4,236,000 for Case D. The size of the project may determine the size and type of the contractor. In these case studies, all the contractor companies are fairly large.

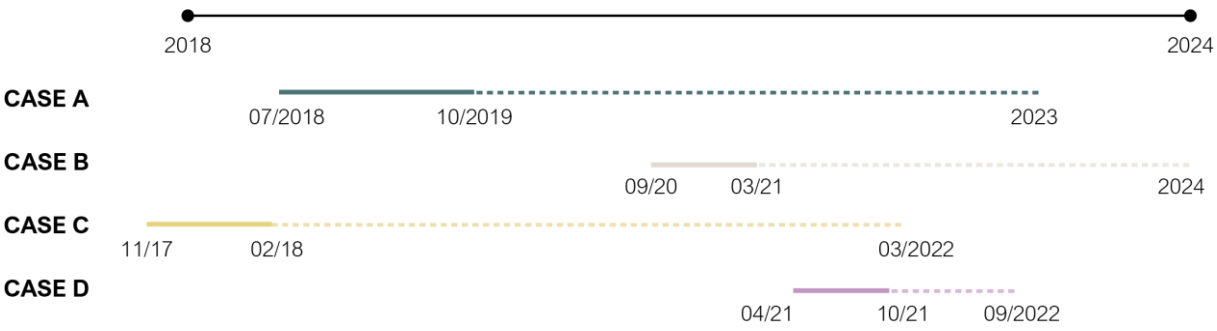


Figure 6.01: Start procurement phase, award, and finalization dates of cases. Own illustration

The procurement phase for all projects has been completed. Tenders have been invited from the end of 2017 to the end of 2021. Meanwhile, the construction of case C has been completed. Cases A, B, and D are still in progress. There was a considerable urgency behind the renovation in Case B because the load-bearing capability of the two steel bridges was rapidly decreasing. This necessitated a fast tendering procedure, which had an impact on the use of the data demands.

Contract

In all four cases, different types of contracts were used. There were several reasons for using these types of contracts, however, in none of the cases the choice of contract type was related to data or information management.

Open standards

The use of open standards is compared according to three categories, as defined in chapter 4.

	Case A	Case B	Case C	Case D
Exchange standards	IFC	FGDB	IFC	FGDB
Semantic standards	NL/SfB	NLCS IMGeo	NL/SfB	NLCS IMBOR IMGeo
Process standards	-	-	-	VISI

Table 6.01: Open standards per case.

Exchange standards

In both cases A and C, the open standard IFC is applied. As already mentioned in the literature research, IFC is becoming increasingly important for the exchange and coordination of 3D geometric models in the B&U industry. The BIM Basis ILS describes, among other things, the use of IFC as an exchange format. IFC is still little used in the GWW sector, mainly because the IFC version currently supported by software applications still contains few or no classes for infrastructure objects. This can also be seen in the two cases from the GWW sector (B and D). COINS was previously used by both organizations as an open standard. Both organizations have (temporarily) abandoned this standard. The File Geodatabase (FGDB) is currently the exchange standard of the contracting authority of case D. The OpenFileGDB driver provides read access to vector layers of File Geodatabases (.gdb directories) created by ArcGIS 9 and above. This standard is therefore not software independent. Client in case B is experimenting with data rooms, often known as Common Data Environments (CDEs). It is unclear whether the organization will exchange data files and documents via ICDD containers (new COINS standard) or share them via CDEs in the future.

Semantic standards

Cases A and C employ the same semantic standard as well. As explained in chapter 4, the NL/SfB classification is the most extensively used for building components in the Netherlands. NL/SfB is also prescribed in the BIM Basis ILS. The OTL of case D is based on IMBOR. The Information Model for Management of Public Space (IMBOR) is an open standard for the uniform naming of all types of objects in public space and the management data that can be recorded for each type of object. In addition, while obtaining the geometry, the contractor must adhere to the 'Product Specification Digital Terrain Model' criteria for accuracy and precision. The measuring instruction is based on the BGT Act's IMGEO information model. IMGEO is also prescribed by case B.

Process standards

Case D uses the open standard VISI for formal transaction communication based on standardized e-mail traffic. Both the client and the contractor are capable of working with this open standard. DICO, the National Model BUP, and the National Model Information Protocol are not used for cooperation and communication in the investigated cases. In cases A and B, hardly any or no process requirements are set. This will be discussed further on. Case C has its own developed BIM protocol, an ILS, and requires the contractor to provide an execution plan. The IM protocol and ILS are based on the industry-standard ISO 19650-1. A number of process criteria are specified in the ILS for Case D.

In the following section, the requirements in the demand specification, selection, and award criteria relating to the data component of each will be discussed and compared. An overview of the documents and criteria can be found in the table below.

	Case A	Case B	Case C	Case D
Demand specification	RBS + RCS + Inventory list of management and archive documents	Annex Geodetic Activities and Area Data	ILS + IM Protocol	ILS
Selection criteria	None	None	Key competence: BIM	None
Award criteria	None	None	None	None

Table 6.02: Demand specification and criteria cases

Demand specification

The table below (Table 6.03) compares the demand specifications of the researched cases and contracting authorities. The comparison is based on the criteria that an ILS must meet following EN ISO 19650 (see chapter 3). The comparison shows that most ILS initiatives provide regulations for only part of the content of an ILS in accordance with EN ISO 19650. None of the ILSs cover the full spectrum. The incompleteness of the initiatives is mainly because they are project-independent guidelines or templates. While many of the criteria from EN ISO 19650 relate to the project-specific content of an ILS. In all cases, information about the project and the project structure is missing. In addition, the public procurers fail to meet some additional requirements outlined in the standard.

First of all, the BIM objectives of the project must be established in the ILS. According to the ISO, the client will already have defined the asset-related objectives as part of the AIR. Any project-related objectives should be derived from the PIR. In practice, it appears that only the information delivery specification of case C has defined the objectives. Multiple objectives have been set for the organization. These objectives are not project-specific. In the other researched cases, no objectives have been defined and recorded in the specification. This can be explained by the fact that the overarching vision of BIM is currently lacking or limited in organizations of cases A and B. The value of BIM and the information needs have yet to be defined throughout the organization. As a result, the objectives per project have not yet been formulated. For case D, the objective is mainly to implement asset management for the infrastructure. However, this objective is not specifically defined in the ILS.

A PIM and an AIM contain, according to the '19650', three types of information: (1) Geometric; (2) Alphanumeric (non-geometric, structured information); (3) Documentation. Half of the inventoried ILS initiatives focus only on non-geometric, structured information. Case A only asks

for 3D extracts. The contractor is responsible for ensuring that the external appearance and associated alphanumeric information of IFC objects correspond to that of the BIM objects in the BIM source file. The present models only provide basic geometry and title items, which are insufficient for effective asset management. In practice, this means that the CAD drawings are used, which are always requested as a backup. Case B also limits the request to geographical data in GIS, whereby the documents remain leading. These cases demonstrate that BIM is still often associated with 3D geometric building models. However, working with 3D models improves construction quality significantly, but data must be added to BIM for it to be useful to the public commissioning authority.

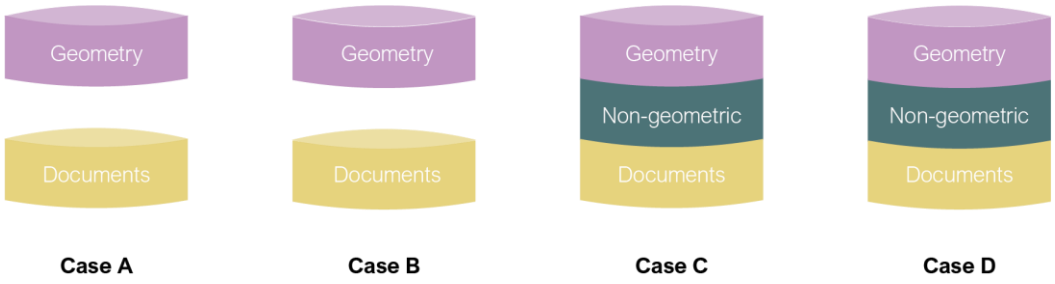


Figure 6.02: Information management products per case. Own illustration.

The ILS of cases C and D require all the characteristics of a transition stage from a traditional working method to a data-driven BIM working method. The ILS of cases C and D focus on both geometric and non-geometric data and documents and aims to bring them together. In case C, all these information products are requested using a comprehensive but also complex ILS with extensive appendices. Concerning BIM files, all source files and all associated extracts such as drawings, parts lists, IFC extracts, model documentation, etc., are transferred completely. To structure the data, an OTL is requested by both parties. The Schiphol Technical Decomposition (STD) is mainly based on the NL-SfB, and where necessary supplemented with airport-specific objects. The OTL of case D is based on the IMBOR standard.

Thirdly, the ILS should define the moments of information delivery to determine when data will be exchanged from contractor to client and/or between subcontractors. This refers to the public commissioning party's consideration of the information they need for their purposes plus their obligations. Case C sets out several coordination moments per project phase, during which information is exchanged, in the ILS. Each project phase is concluded with a formal information delivery, a so-called data drop. In principle, the contractor provides information to Asset Management, but there are also times when ASM provides information to the contractor. The data drops in the design phase are related to the design phases of the DNR-STB 2014. Construction, handover, and operation are in accordance with NEN 2574. There are a total of six data drops defined in the ILS of case C, to which they can still be adjusted per project. However, in practice, it appears that these data drops are not made project-specific as in case C. Case D requires four information deliveries and thus four information packages. After the award, the client delivers the data of the existing area as far as this is known in its management systems. Subsequently, the contractor will make a trial delivery of the as-designed part of the DO. The contractor must make a total delivery of the data for the area no later than two weeks after the project ends. The information delivery includes an object breakdown of the area and all related object data, apart from the requested linked documents. The contractor must then make an overall delivery of the area data at the same time as submitting the Project Delivery Dossier. The information deliveries are not further specified in both cases A and B. An overview of de data drops as defined in each ILS can be found in figure 6.03.

Figure 6.03: Data drops as defined in the ILS. Own illustration.

Fourthly, only some of the ILSs describe the methods and procedures for the exchange of information. The ILS of case D describes that the information supplies must be offered via VISI. The contracting authority provides an interaction framework for this purpose. An information manager is appointed by the contracting authority to oversee the digital information exchange. The contracted party must also appoint an information manager to facilitate communication with the client. Within one month of the start date, the contracted party must organize a BIM kick-off meeting. Following that, bi-monthly discussions between the contractor and the client are required to track the development of the BIM process and resolve any issues. The ILS of case C includes a detailed description of how the asset list must be filled. An IM execution plan must be drawn up by the primary contractor. The purpose of this document is to secure the successful application of BIM within the project and to record the agreements that the project partners have made and will make. The BIM management team consists of the project manager(s) of the project, who are advised and supported by the Project Information Manager (PLuS) for BIM-related matters. The contractor is expected to appoint one point of contact in the role of IM manager, whereby the client recommends the use of the BIM roles ((central) IM manager and BIM coordinators). Cases A and B do not describe any procedures for the exchange of information.

To exchange information products unambiguously, the client must set up a common data environment (CDE). In both the case of A and B, no special CDE has been set up. For some trial projects, the contracting authority of case B has set up a data room where the contractor may store documents and data. To exchange information products, the client of case C has made a Data Room available for each project. This platform provides an environment for exchanging information and has been set up with a template according to the ILS structure. Case D does not impose any requirements on the systems used by the contractor for the construction and management of the requested building information. The contractor must set up its own Project Management System (PMS), which makes it possible to export and import BIM information deliveries following the ILS.

	Case A	Case B	Case C	Case D
Project information	The document is not adapted specifically to the project.	The document is not adapted specifically to the project.	The document is not adapted specifically to the project.	The document is not adapted specifically to the project.
Structure project team	The document is not adapted specifically to the project.	The document is not adapted specifically to the project.	The document is not adapted specifically to the project.	The document is not adapted specifically to the project.
BIM objectives	BIM objectives are not defined in the ILS.	BIM objectives are not defined by the client.	The objective of the (ILS) is multiple: (1) Information for Asset Management processes; (2) Building and enriching the Asset Information Model; (3) Proper and efficient processing of information.	BIM objectives are not defined by the client
Acceptation criteria	The requirements for the information standard cover the acceptance criteria.		The quality of documents, and geometric and non-geometric data are described.	It defines what the information packages have to fulfill.
Information standard	In the ILS, the two open standards IFC for the structure of information in 3D models and NL/SfB for the ordering/filtering of information based on functional building elements.	The Contracted Party must provide the areal information of the Work in GIS, Excel, PDF, word, or DWG.	3D extracts are requested in IFC. The Schiphol Technical Decomposition (STD) is mainly based on the NL-SfB.	Until recently, the provinces used COINS as a way of exchanging data. Currently, data is exchanged based on a File Geodatabase format.
Production methods and procedures	The ILS describes neither the process nor the step-by-step technical details to achieve the result according to the prescribed specifications.	The process requirements do not describe the process to achieve the result according to the prescribed specifications.	The Information Management protocol describes the process.	The Province of Gelderland makes use of VISI. Using VISI, the Province determines when (process), who (role), what (information), and to whom (role) it delivers.
Reference information	The designating party does not take into account existing reference information and shared resources in the ILS to support the tendering process of all designated parties. Information is shared with all parties in Relatics.	The client will grant the contracted party access to the necessary management applications of the client's management system.	All documentation relating to the ILS is available on the Asset Management Knowledge Base and in the Data Dictionary Schiphol (DDS). The Knowledge Base and the DDS always contain the current version of the aforementioned files.	The Province will provide the Contractor with its Object Type Library (OTL) after the award of the contract. A draft version of this is already shared during the tendering procedure.
Data exchange schedule	No description of what information is needed when, who is responsible for the delivery, and in what form the information should be presented.	The Contractor must guarantee that the file to be delivered by him is constructed following the version applicable at the time of delivery.	Describes information during the design and engineering process and formal information supply moments per project phase, so-called data drops.	The Province of Gelderland wants to exchange the information digitally at four moments during the project and therefore requires four information packages.

Table 6.03: Comparison of information delivery specifications cases using ISO 19650

Selection phase

The contracting authorities can use several criteria for selecting tenderers. First, the public authority may exclude a potential tenderer if the latter has shown significant or persistent deficiencies in the performance of essential requirements in the context of a previous contract of a similar nature with the same contracting authority. In none of the cases, past performance is a key evaluation criterion when tendering for work with a data component.

Among the suitability requirements referred to in Article 2.90 (2)(b) of the Act, the level of technical expertise may be particularly relevant to the tendering of a data-related project. The level of technical competence can be measured or demonstrated utilizing references, certification, or other standards and through performance indicators. The tenderer's expertise and other similar qualities can ensure that the complex data exchange process and the activities of the persons involved are adequately coordinated. In terms of technical and professional competence, only case C applied a BIM selection criterion. A recent reference project of a non-residential construction project in which a BIM model forms the foundation of the design must be submitted by the candidate. The level of technical competence does not have to be demonstrated utilizing certification or other standards. In the other cases, the level of technical competence in relation to information management is not measured or demonstrated. In these cases, data does not yet have such a priority that a selection criterion needs to be set up for it.

Award phase

The execution plan can be considered to provide insight into the work process, planning, and expertise of the potential contractor in the context of BIM. The contracting authority expects bidders to produce an execution plan based on the information delivery specification and a draft BIM protocol in this method. The execution plan might be connected to an evaluation system that adheres to the equity and transparency criteria. Weighting factors may be assigned to the various sub-award criteria, for example using a (weighting) matrix.

Only in case C, the main contractor is asked to prepare an Execution Plan before awarding the contract. Before the contract is signed, the IM Execution Plan is reviewed and approved by the Project Manager (PLUS), ASM Developer, and Project Information Manager (PLuS). The execution plan, on the other hand, has no weighting considerations and hence is not included in the award phase. In the other cases, the client did not prescribe an execution plan at all.

Secondly, the (BIM) model can be used by showing a potential contractor how to meet the award criteria. During the tender procedure, bidders are asked to prepare a model. The contracting authority must determine in advance at which point the model will be assessed to comply with the transparency principle. In none of the cases is a (B)IM model requested during the award process.

BIM Maturity

The maturity scores for each case for the six primary criteria of the BIM maturity model are shown in Figure 6.04. This contributes to the understanding of how the average BIM maturity is developed and how much variation there is across cases and criteria. The research revealed one case (case C) that scored above average and two cases (cases A and B) that scored below average based on the average BIM maturity. In all situations, the BIM maturity scores for data infrastructure are rather high, as seen in the figure. Second, the cases indicate that organizations have not devoted serious attention to both the organizational structure criterion and the processes and procedures criterion. The formalization of duties and responsibilities, as well as processes and procedures connected to BIM, still has a lot of potential in cases A, B, and D. These findings suggest that in recent years, these features have lagged behind the fast growth of BIM in other areas. As a result, BIM procedures become increasingly reliant on individual skills, potentially resulting in disparities in BIM performance between projects or between departments.

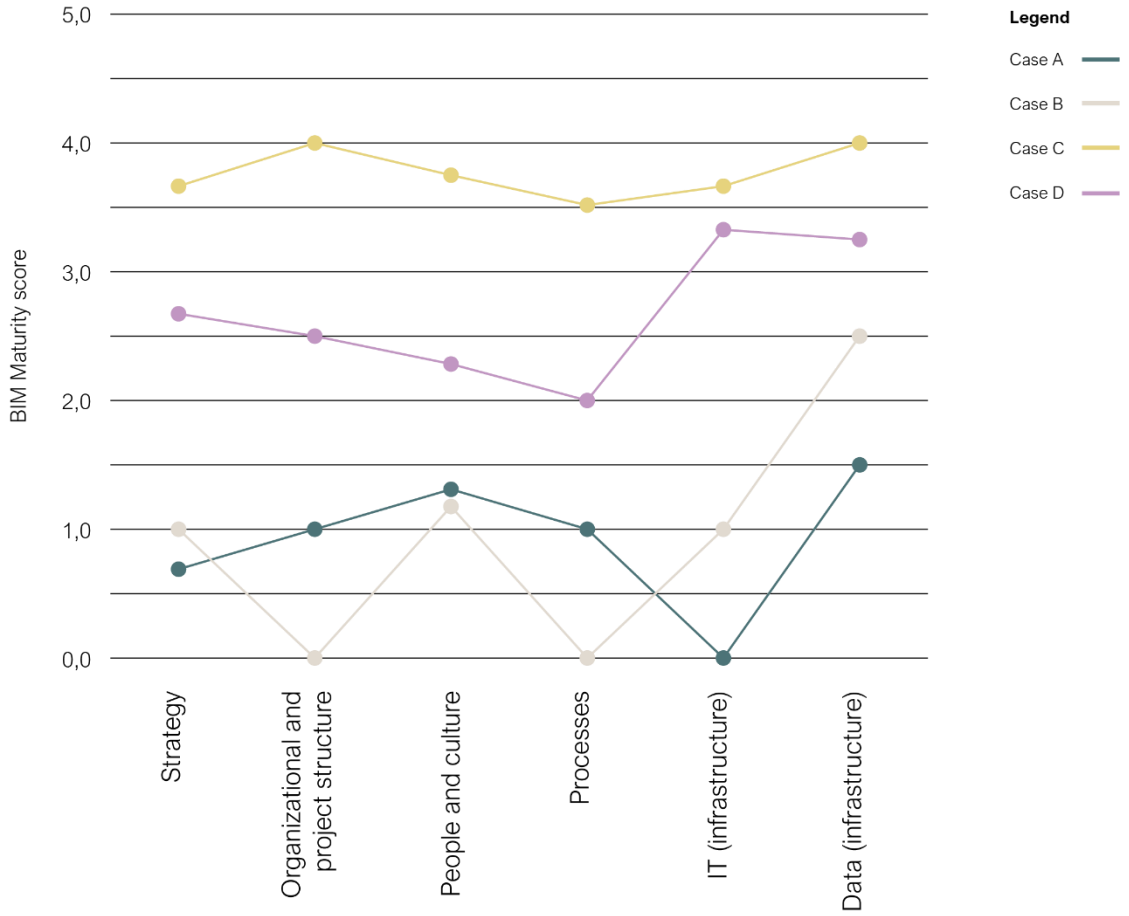


Figure 6.04: Maturity scores cases

Experience contractors

All four case studies show that contractors can operate with BIM without difficulty. The contractors have been using BIM in the design and construction phases for years, and the entire organization is set up for it. The contractor in case A thinks the current specification drawn up by the contracting authority is workable. The ILS is compliant with the organization's protocols, thus no changes to the working approach are required. However, the contractor wonders whether the models will be used by the client after delivery. The models are highly technical and are primarily intended for design and construction. Also in cases B and C, the contractor indicates that the contracting authority has not yet clearly established what the information needs are in the management and maintenance phases. This results in case C in many specific data requirements with for example 25 to 30 characteristics for a door. The contractor makes it obvious that the client should consider carefully what kind of data they intend to use in the future. Otherwise, contractors' time and effort will be wasted. Also the contractor in case D, highlights, that in general most of the data and information they provide in a model is flattened into a digital drawing. Clients of cases A and B and other provinces, according to the contractor, should take a more active role and make certain specifications necessary for them to be implemented at a national level in the Netherlands. In general, the contractor has good experience with the information process of the contracting authority in case D. The province's ILS is fairly straightforward, explaining step by step how they want the information to be provided. The contractor does believe, however, that the client should establish a unified way for data deliveries some time. They are still innovating and expanding, making it more difficult for the contractor to implement standardization.

7

External Validation

The organization and results of the expert interviews will be discussed in this section. Three professionals from the construction sector who already had worked on projects with a data component formed the external validation. Experts were chosen based on the criteria in table 7.01 to ensure that input on the findings was derived from professionals with sufficient expertise on the topic.

Criteria
1. The expert has working experience in the Dutch public construction sector.
2. The expert has experience in the procurement of a data component.
3. The expert is not interviewed or involved in one of the four case studies.

Table 7.01: Selection criteria expert interviews.

This resulted in the following three experts:

Expert	Company	Role
1	BIM Loket, KPCV	Consultant and researcher
2	Rijksvastgoedbedrijf	Manager
3	TNO, University of Twente	Director and professor

In advance, an email with the statements was forwarded to the experts to enable them to prepare. On the day of the expert interview, the experts were presented a summary of the research in a concise presentation. Following the introduction, the expert was provided with statements based on findings in the literature and the empirical research. Hereafter, the experts could provide feedback on each statement. The expertise is utilized to validate the findings and generate practice recommendations. A summary of the discussions is provided below.

Statement I: Data is becoming increasingly important in the asset management of the public sector. Although there is a small group of frontrunners, the majority of contracting authorities are insufficiently mature in data and information management. They still do not know enough about what they want and can do with it.

All experts agreed with the statement, noting that clients do not know what to ask for and still have little idea of what information they need to manage their assets effectively. Expert 2 adds that all public sector clients are just now realizing that the benefits from digitization are actually in the asset management phase. During the last ten years, they have mostly concentrated on the design and construction phases. According to expert 2, the asset management phase is set up in a traditional way to share and use documentary information and not to share data. "*In practice, you'll find that throughout the asset management phase, parties such as maintenance parties or facility*

service providers have far more data on the property in their systems than we have. This is a challenge that all public commissioning bodies face" (Expert 2, 2022).

Statement II: Contracting authorities must formulate higher data and information product and process criteria following NEN-EN-ISO 19650.

The experts all agreed with the above statement, however, they added that it all starts with analyzing the information needs of asset management. "*They should, in my opinion, base their product and process requirements on their information needs. Subsequently, they could produce specifications conform to the ISO-19650*" (Expert 3, 2022). Most commissioning parties have to start or are working on understanding the required information for effective asset management. Expert 2 says that the BIMLoket and 'opdrachtgeversforum', are attempting to link information specifications to the NEN-EN-ISO 19650 in the asset management phase. However, they are unsure of where to begin. Worldwide, no example has already succeeded in doing so. It is probably a very long process before the contracting authorities can comply with the NEN-EN-ISO 19650 in asset management. "*I can see opportunities for this in the short term for the design and realization phase, but for the asset management phase, it will take a very long time before we reach that point* (Expert 2, 2022).

Statement III: Contracting authorities need to cooperate more to achieve a uniform information delivery specification.

All experts agreed with the statement. "*If you have one system for specifying the demand, the market is not constantly confronted with new demands and knows what to expect*" (Expert 1, 2022). As mentioned in the previous statement, clients are currently working on a collective ILS and Object-Type Library. Expert 1, however, emphasized that this has been discussed for already a long time, getting organizations to that position requires a lot of effort. Experts 2 and 3 immediately pointed out that clients should not be the only ones to collaborate, but should also cooperate with contractors. Contracting authorities must work in co-creation with market parties to come up with the best information specifications that can be standardized. "*Imagine that clients decide on extremely ambitious information delivery specifications and the market is unable to meet them, then they have a problem too*" (Expert 3, 2022). Contractors are presented with a variety of information delivery criteria, according to the expert, but they receive the information from clients in the most traditional format. There should be specifications regarding what the client must provide.

Statement IV: Many contractors can fulfill (higher) data-related product and process requirements, as well as criteria for selection and award.

The experts agree with this statement to a certain extent. Many contractors, according to Expert 1, can provide good information, but they tend to focus on what they require for their processes. They still have too little eye for what information is needed by the asset and facility manager. This is why, according to the expert, it is critical for the contracting authority to formulate a clear data demand. If the client does formulate that need, the contractor could technically do it. "*However, I believe there is also a cultural issue here. There must be the mindset to accomplish it, as well as the understanding that it is critical*" (Expert 1, 2022). Expert 2 emphasizes the importance of developing these product and process criteria in collaboration with the market. If the requirements do not fit in with the contractors' systems, they will not do anything. They will not be able to distribute it correctly if it does not fit into their databases. Expert 3 adds that contractors should also take into account in the tender what kind of contractors will respond. According to the expert, many larger contractors will be able to fulfill higher criteria, but this will not always be the case with smaller contractors.

Statement V: The use of selection and award criteria will help to achieve better data deliveries and accelerate digitalization in the construction industry.

All experts agreed that, in the end, selection and award criteria may help improve data delivery and drive digitalization in the construction industry. "*In that sense, public sector clients hold the key*" (Expert 2, 2022). Expert 3 (2022) continues: "*If large parties, large commissioning parties, become more ambitious, it will ultimately result in movement and innovation in the sector. Certainly, if the clients take actions in line with those of the contractors, it can help enormously*". Expert 1 references the ISO-19650, which prescribes the use of an execution plan in the award phase. First of all, give the client the confidence that the contractor can deliver what they ask for. Secondly, the client may also have unfulfillable requirements or make excessive demands. In that case, a contractor can submit alternatives. If according to expert 1, selection criteria are applied, there will undoubtedly be parties who can do this excellently, but mainly the frontrunners in the sector. The vast majority of market actors in the contracting industry are SMEs who find it quite difficult to implement data and information management. A certain standardization is important.

Expert 2 emphasizes once again that the public commissioning authority must also find much more of a connection with the market. Thereby, the commissioning party itself will have to establish what it requires for the management phase.

Summary validation

In general, the experts agreed with all five statements and provided a wide variety of examples from their experience that supported these statements. The first statement captured the main problem that the contracting authority is currently facing to achieve higher product and process requirements, uniformity, and certain selection and award criteria. Only recently public commissioning parties realized the importance of data in the operation and maintenance phase. The first efforts in mapping out this information requirement are already being performed. Clients are currently working on a collective ILS and Object Type Library, but this still has a long way to go. In co-creation with market parties, clients must decide which information specifications can best be standardized. If the requirements do not match the contractors' systems, they will not deliver properly either. During the procurement process of a project, the execution plan can help to achieve a plan that satisfies both the client and the contractor.

8

Discussion and limitations

8.1 Discussion

This chapter discusses the findings of the research twofold. First, the relationship between the findings and the problem statement is discussed in this section (I). Secondly, the contrasts and similarities between the case study and the literature review are discussed (II).

8.1.1 Findings and problem statement

The problem statement focuses on gaining more insight into the management of data by Dutch public sector clients during the procurement phase. This research focuses on two important aspects of the tender: (I) the product and process requirements concerning data in the demand specification, and (II) the use of selection and award criteria. This research formulated answers to all (sub)questions. However, not all aspects could be answered extensively (enough).

It has become evident which data-related product and process requirements may and should be specified in the demand specification. However, two case studies lacked an organization-wide vision and approach for data and information management in projects. The absence of a baseline made it difficult to translate the organization's ambitions into projects. As a result, the data component and the associated contractual agreements in projects received limited attention in the execution of the project, and not all stakeholders had sufficient knowledge in this area. Limited learning lessons may be converted into practice due to a lack of demand and expertise. However, the literature study and other case studies provided enough insight for a successful data request.

Thereby, the extent to which the case studies provide a definitive answer to the problem definition is greatly limited by time constraints. One method of carrying out case studies to include all activities and bottlenecks of a project would be where the research starts and ends in parallel with the project. However, the empirical data collection of this graduation project lasted only four months, while the projects studied have existed, or will exist for a long time. As a result, important parts of the process were not included in this research and certain bottlenecks were not encountered. This is partially solved by using semi-structured interviews, which allow for historical information to be requested. For future research, it is recommended to carry out case studies in which aligned with the initiation phase to the award to accurately map out all activities and bottlenecks.

The case studies revealed that award and selection criteria related to data deliveries are not or hardly applied in the procurement phase of projects. Due to the lack of criteria found in the case studies, it is not possible to determine what the consequences are in practice and whether applying them is desirable. The findings are limited to the literature study and assumptions and claims made by participants involved in the interviews. To provide a definitive answer to the problem definition, the analysis of other case studies where selection and award criteria have been applied is strongly suggested for further (future) research. This could be combined with a survey

of all public contracting authorities and their contractors to find out to what extent selection and award criteria are applied and what the experiences are with this.

8.1.2 Findings literature review and case studies

The findings of the case studies are substantially comparable with the previously established literature study. Similarities are found concerning the application of selection and award criteria and the diversity of information delivery specifications.

The literature already showed that there is a great diversity in information delivery specifications in the Netherlands due to the lack of national standards and legislation. The case studies likewise demonstrated that the formats of an ILS drawn up by commissioning parties vary widely. Where one commissioning party works (almost) completely under NEN-ISO-19650, the other commissioning party does not (yet) have a generic ILS. However, the literature study revealed limited differences in the content of the various specifications. In the case studies and cross-case analysis, an attempt was made to look more closely at the various process and product requirements provided by the clients. In this research, the experiences of the stakeholders involved in the projects were also taken into consideration. In the literature, it was unclear how the contracting parties and contractors experienced the criteria in the project.

The theoretical research already revealed that the possible selection and award criteria are hardly ever applied in practice. This was also discovered in the empirical research. There were no particular award criteria in any of the projects studied, and only one case imposed selection criteria.

The literature, on the other hand, demonstrates that much is possible in terms of digitization and information management and that the benefits are substantial. However, implementation in practice sometimes proves difficult. In the transition to a data-driven organization, various process-related steps must be taken before contractual requirements can be set. Many factors influence an organization's data and information maturity. In the interviews, it emerged that culture and education play a major role in this. The definition of (B)IM appears to be a point of contention among the many parties concerned. Data and information are broad concepts, resulting in a wide range of inquiry and knowledge among individuals who deal with them. The role of the 3D representation of a building model often differs in this respect. Whereas some people are more concerned with the 'Building Information Model,' others are more concerned with 'Building Information Management,' in which the information (from 3D to 7D) is central.

8.2 Limitations

The research, as well as the findings' reliability, validity, and transferability may be susceptible to several limitations. These limitations will be explored in the following sub-sections.

The first limitation of this research is the fact that there was a limited number of case studies. Only a few case studies were possible due to the time constraints of the research. Understanding the projects and conducting in-depth research requires a considerable amount of time. If more case studies had been examined within the same period, the amount of in-depth study may have been reduced. In the future, more case studies could provide more insights to generalize certain findings. Thereby, follow-up research can have a broader scope, including other clients, so that results can also be validated more broadly. The study demonstrated that we are at the very beginning of a transition, with demand specifications and the selection and award criteria related to data still being relatively limited. As a result, public parties may have varying ambitions in the area of data-driven work and BIM development, resulting in data exchange that varies greatly between projects and contracting authorities. This diversity made it difficult to properly select and compare projects for case studies. Various methods, such as a questionnaire, might be explored to gain a wide picture of the public commissioner's usage of the procurement phase and their experiences with it. Thereby, projects involving small contractors need to be considered. In all four cases, the projects are carried out by considerably large contractors who had already largely mastered the information management and related processes. For public sector customers working with small contractors who are not yet as mature in data and information management, this might create a distorted picture. Thereby, only a small number of stakeholders involved in the projects were interviewed because of time constraints. Particularly the public commissioner's and contractor's employees were interviewed and thereby excluded other stakeholders such as suppliers, subcontractors, and architects.

Secondly, the projects are chosen in consultation with certain people in the organization. In some cases, it was a large organization where there is not always a total overview/database of exactly which projects are running in the organization. It can be possible that some of the projects are not representative projects of the organization.

The third limitation is related to the theoretical research. Because the literature review will be limited to a few databases, useful sources can be overlooked. Despite the time invested in creating and testing search phrases, other studies may use different terms for keywords.

The fourth limitation of the study is the qualitative aspect. For this research, in-depth interviews were conducted with professionals, contracting authorities, and awarded parties. To ensure that the interview questions were accurate and that no questions were missing or unnecessary, pilot interviews were conducted. However, the use of interviews to acquire data may still be limited by ‘demand characteristics’. Demand characteristics occur when participants grasp the purpose of the study and begin to act differently as a result. Thereby, the involvement of interviews can be a limitation related to reliability. As construction projects often involve long processes, the representation of the stakeholders involved may change during the project and the stakeholder involved may not remember every detail. As the activities explained were asked utilizing an open question and were situated in time, it is possible that certain activities were not mentioned. Thereby answers to the questions reflect the expert's perceptions, memories, intentions, and ideas at a certain point in time (Verschuren & Doorewaard, 2007). Over time, more needs could have emerged, based on new insights or convictions. Thereby, events and circumstances can influence the experience. As a result, the same expert could have responded differently at different moments and other participants could have given different responses at the same time. Therefore at least two practitioners working on the same project were questioned, and the researcher purposefully

sought stakeholders involved throughout the process and picked current rebuilding projects to prevent this as much as feasible.

Thereby, to guarantee adequate validation, the intention was to interview an equal number of people from the project for each case study. However, from a practical standpoint, this proved to be a difficulty. In the case of D, it was indicated that certain people involved had little or no knowledge of the procurement of a data component. Also in cases A and B, it became evident that several participants had little experience with data-driven work and, more importantly, the related procurement. Nevertheless, interviews were conducted with these participants. Discussing BIM or data-driven work without the participants having experience or limited experience with it made it difficult to discuss the effects and possibilities. However, it does enable them to think outside the box and consider the needs within their current work process.

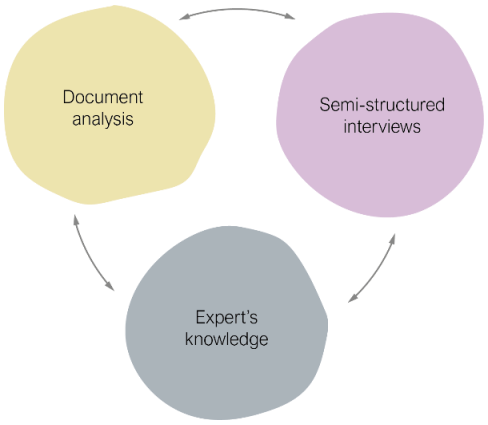


Figure 8.01: Triangulation of the research (Yin, 2018)

In addition to participant bias, the researcher's subjective viewpoint or attitude might impact the interpretation of participants' responses and the study's conclusions (Saunders et al., 2016). The interviewer's particular expectations may also cause the interviewer to perceive a certain direction during the interview, and as a result, direct the conversation in that direction to obtain the desired research results. When a researcher has particular expectations and it impacts the evaluation of the participants' responses, it is known as 'observer bias'. To limit this, explanations during interviews were formed before the interview, and interviews were structured so that the questions, and explanations given, would be consistent throughout the interviews. In addition, to make the synthesis more constructively valid, triangulation was used in this research. Triangulation took place through document analysis, and semi-structured interviews and finally the study was validated by external experts (see figure 8.01). By gathering data via several methods, data triangulation improves the validity of the study (Yin, 2018). For follow-up research, the interviews could be distributed among several interviewers. Because one researcher performed 15 interviews for this study, the interviewer may have been more biased due to the large number of interviews. As a result, there may be fewer in-depth and follow-up inquiries.

In addition, the interviews were conducted in Dutch, and the interview quotes were afterward translated into English. This may result in a translation that differs slightly from the original statements.

9

Conclusion and Recommendations

In this chapter, the research questions will be answered and conclusions will be formed. Following recommendations for future research and practice will be discussed.

9.1 Conclusion

The sub-questions have been addressed in the various chapters of this study. In this section, each research question will be answered briefly. By establishing a relationship between the answers to the various sub-questions, the main question of this study is answered: *"How can contracting authorities (re)design the procurement phases to enhance successful data exchange in construction projects?"*

SQ1 What does digitalization in the construction industry entail?

Construction 4.0 is the engineering and construction industry's shift towards increasing digitalization. Examples of Construction 4.0 include BIM, Virtual and augmented reality (VR/AR) Internet of Things (IoT), wireless sensors, 3D printing, and Digital Twins. BIM, in particular, plays a critical role in the construction industry's digitalization. In the early 1990s, the term 'Building Information Model' was first used. Building Information Modelling (BIM) has gotten a lot of attention since then and has become increasingly significant in modern architecture, engineering, and construction (AEC). Initially, BIM was employed in the design phase of building projects, with architects and engineers being the primary users. Gradually, the application of BIM is extended to the construction phase as well as the management and maintenance phase of construction objects. In doing so, it is making a transition from a 3D digital model comprising only static building data to a digital model that incorporated all types of data collected during the building's life cycle.

With the emergence of BIM, the volume of project data has increased enormously (Boje et al., 2020). Previously seen as a by-product of digitization, data is increasingly seen as a valuable asset. The usage of data translated into information and knowledge can significantly improve the efficiency of construction and maintenance processes.

Working with new technology and data necessitates a larger emphasis on either new or current abilities. It necessitates comprehension of data in addition to their usual design and/or development operations. Second, digitalization necessitates more collaboration from all parties involved and places a greater focus on soft skills. To realize the potential for enhanced project information and efficiency, the project team must practice communication, conflict management, negotiation, teamwork, and leadership. Thereby, new roles and responsibilities are introduced. ICT developments have become much too complicated and important to building projects to be merely tied to project management.

Client organizations are thought to be crucial in the context of digitization. As the public sector is the largest customer in the construction sector, contracting authorities are considered vital drivers

of innovation. The literature emphasizes the need to first create support within the client organization to bring about change in the sector. Clients with technical competencies are more likely to participate in initiatives and influence project members, which leads to more innovation.

SQ2 How can a contracting authority enhance data exchange within Dutch public procurement legislation?

The process leading up to the award and conclusion of a contract is covered by procurement law. In the Netherlands, the 2012 Procurement Act (Aanbestedingswet 2012) applies to all procurements by public and semi-public institutions. The Procurement Act is namely aimed at ensuring that a tender is carried out in an equal, non-discriminatory, transparent, and proportionate manner. During the procurement process, several steps will be taken as described in Tendering Act 2012 (2016) art. 2.58 - 2.131. The phases relevant to this research will be briefly discussed below.

First, the briefing process is to provide the contractor with the necessary information, directions, and inspiration. As contractors and public commissioning authorities do have different interests, the public commissioner needs to indicate their information requirements. Data-related requirements, as well as contract decision-making moments and data drops, can all be implemented with the Exchange Information Requirement (EIR), also known as the Information Delivery Specification (ILS) in the Netherlands. The delivery specification should certainly describe how the parties will cooperate digitally, what the parties will deliver, and, specify when the parties have to provide data and information. An ILS ensures that information can be exchanged systematically and unambiguously between the contracting party and the contractor. The content of an EIR must comprise at least the following components, according to EN ISO 19650:

- Project information
- Structure of the project team
- BIM objectives for the project
- Acceptance criteria
- The information standard for the project
- Information production methods and procedures
- Reference information and shared information sources for the project
- Data exchange schedule

For the selection phase, contracting authorities have a variety of criteria at their disposal. There are three types of criteria for participant selection: grounds for exclusion, minimum demands, and selection criteria. If a potential tenderer has demonstrated serious or chronic shortcomings in the fulfillment of essential requirements in the context of a previous contract of a comparable character with the same contracting authority, the public authority may exclude them. With the minimum demands/suitability requirements, the participant must be able to demonstrate that the contracting authority's desired level of competence has been achieved to be accepted into the tendering procedure. Tenderers may be asked to produce relevant reference works demonstrating their BIM experience as a means of determining professional or technical competence. The bidder may also be asked to provide educational qualifications or certification in information management.

Also for the awarding phase, contracting authorities can define different criteria for effective information and data management. First, the execution plan can be used to demonstrate the tenderer to provide insight into his work process, planning, and expertise in the context of BIM. The plan contains all of the agreements that the project team members make to complete the BIM project successfully. The execution plan could be linked to an evaluation system that meets the standards for equity and transparency. A (weighting) matrix can be used to assign weighting

elements to the various sub-award criteria. Second, the (BIM) model can be utilized to demonstrate that the tenderer can fulfill the BIM-related award criterion.

SQ3 How do contracting authorities currently enhance data exchange throughout the procurement phase?

It was discovered through interviews and case studies that contracting authorities still have a limited understanding of the information they need to manage their assets efficiently. They have mostly focused on the design and construction stages throughout the previous ten years. Clients in the public sector are just now seeing the value of digitization in the asset management phase. This has an impact on how contracting parties presently request data throughout the procurement phase.

First, there was no correlation found between data exchange and procurement methods in the case studies. Other factors influenced the choice of procurement method. According to literature, BIM is more advantageous with integrated delivery processes, such as IPD (Holzer, 2015). However, Aibinu and Papadonikolaki (2016) demonstrated that other procurement strategies, such as Design-Build, may enable integrated BIM implementation procedures. For this purpose, it was discovered that project coordination mechanisms, particularly structures and procedures, are affected not only by procurement but also by the selection of various involved tendered firms.

However, award and selection criteria concerning data and information management were hardly applied in the case studies. The case studies revealed that only in one case a selection criterion had been set concerning BIM. Contractors seldom create pre-contractual BIM Implementation Plans in response to the principal's information requests (ILS).

Thereby, only a limited number of clients already include an ILS in their contracts with contractors. There is considerable overlap in the specifications, as the same advisors are frequently engaged. On the other hand, there is still a lot of variety as each client tries to give it its twist and does not always describe it under the NEN-ISO 19650. The structure and terminology used by the various clients vary, resulting in clients being frequently presented with varied (contractual) information requirements. Clients that know exactly what they need, will opt for a more technical description because they want data or models that are compatible with their maintenance or management system and with their database. For most organizations, a wide vision of information management is still lacking. The clients are unaware of exactly what they want and would rather leave the specification of the data to the market. Although the client may receive something greater than expected, the downside is that the result is difficult to evaluate and not always desired. The client will almost certainly end up with data that he cannot use, process, or access. It is striking that in all cases the majority of the information products requested are still document-based. This is illustrative of the current state of digitization in the construction industry. We are in a transitional phase from full document-based information exchange to data exchange and sharing.

SQ4 What organizational and legal conditions should be addressed to improve data exchange and accelerate digitization for the contracting authorities and their construction partners?

Traditionally, the construction industry is set up for exchanging and exploiting documentary information rather than data exchange. The usage of unstructured and incomplete two-dimensional documentation handed over throughout the building's phases is often inefficient and ineffective. In practice, instead of receiving comprehensive information from all preceding steps, the information flow is frequently fragmented and incomplete. As a result of the fragmented information, it is unclear whether decisions were taken in prior phases if the information is up to date, and whether the documents are comprehensive. The data obtained during the planning, design, and construction phases are frequently not or insufficiently utilized during the operating phase. These issues cause disagreement, increased financial costs, and delays. The inefficiencies

associated with the poor transition between the project and operation phases might be overcome now that BIM is transforming the way people operate across the whole building life cycle. In practice, however, there is currently no seamless information interchange between the project and operation phases, despite the usage of BIM. BIM is a technology that can help, but it is not a stand-alone solution to the structural issues facing the construction industry.

To overcome the fragmentation of the construction industry and the associated loss of data and information, market participants will have to work together more and place a stronger emphasis on soft skills (Adriaanse, 2014). When it comes to effective collaboration with data, the 'soft' aspects of collaboration are equally as important as the 'hard' aspects (Papadonikolaki et al.,2019; Davies, McMeel, and Wilkinson, 2015). A project team must include communication, conflict management, negotiation, teamwork, and leadership (Davies et al., 2015). Looking at the dimensions of Siebelink (2018), clients score low on the soft criteria such as management support, personal motivation, and willingness to change, as well as procedures and work instructions. The contractual aspect also lags in this development. Within each organization, there are a few early adopters inside the organizations who see the advantages, but the majority of the employees from the large contracting authorities continue to think in traditional ways. Contracting authorities will have to work on the softer, cultural, and organizational factors to realize the benefits of greater digitalization.

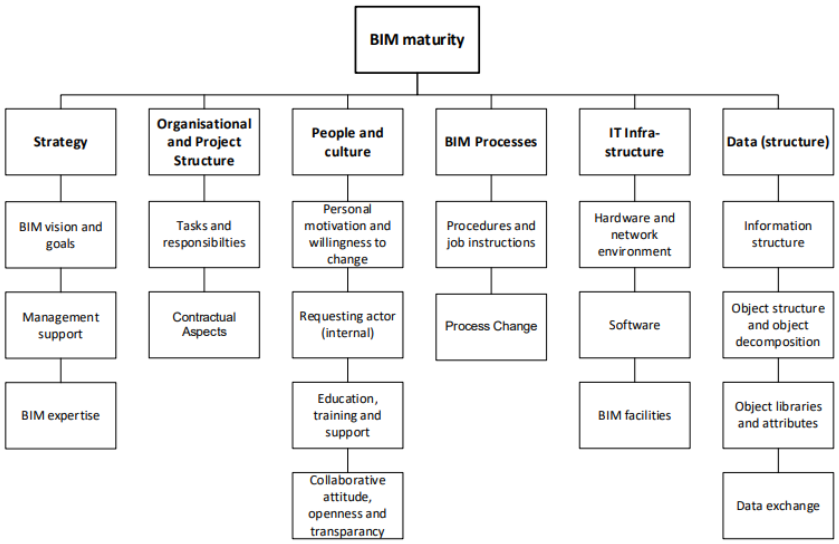


Figure 9.01: Criteria and subcriteria of the BIM maturity model (Siebelink et al., 2018)

Thereby, contracting authorities will need to cooperate more to achieve a uniform information delivery specification. Contracting parties will have to determine, in co-creation with market parties, which information specifications can best be standardized. If the requirements do not match the systems of the commissioning parties, they will not deliver properly either.

RQ How can contracting authorities (re)design the procurement phases to enhance successful data exchange in construction projects

By establishing a relationship between the answers to the sub-questions and the insights gained during the various phases of the study, the main question can be answered. The conclusion concentrates on two important aspects of the tender: (I) the requirements of the product and process concerning data in the demand specification, and (II) the use of selection and award criteria.

(I) The requirements of the demand specification

As the results in this case studies on digitization demonstrate, public organizations prioritize data in different ways across the organization and hence the preparation of tenders. Due to the developing and unexplored nature of the new initiative, there are many different definitions used by stakeholders in the construction industry. According to the findings, it is critical for a contracting authority to first develop an organization-wide vision for data and information management. In this way, data is focused on the organization as a whole, and it becomes a component of the strategic goals. Based on the vision, it then turns out to be important to draw up a generic information delivery specification. Digitalization is complex and without support, the objectives cannot be realized. By formulating unambiguous process and product requirements under NEN-EN-ISO 19650, and in line with the vision, it will be clear to market parties what the assignment entails and what is expected of them. Clients should operate less like 'independent silos' and collaborate with each other and contractors to achieve a uniform information delivery specification.

(II) the use of selection and award criteria.

The case studies indicated that in the procurement phase of projects, award and selection criteria relating to data deliveries are not or seldom used. First and foremost, it is recommended to ask for a reference to BIM as selection criteria. Even though BIM is a relatively new concept, it is recommended to ask for references in respect of information management in the selection phase. The references are used to judge experience with BIM rather than proof. They should not be considered as a minimum requirement, but rather an assessment aspect. In this way, market players who have experience with BIM are rewarded, but market players without such experience still have a fair chance of participating. Since the BIM maturity of the Dutch construction sector is considerably high, most contractors should be able to meet this requirement.

The study shows that data and information management should be an integral part of the contract, and therefore also of the award criteria. Concerning award criteria, the study shows that criteria must in any case be formulated that deal with technical and process aspects of information management. It is not enough to simply define the technical aspects of data delivery; process agreements must also be established to ensure that the data quality is guaranteed. It is recommended that an execution plan for data management be requested by the contracting authority. By requesting an execution plan, the candidates are encouraged to think carefully about the process-oriented aspects of BIM and what they can contribute. As a result, improved process agreements may be created at a later stage, resulting in enhanced data deliveries. An execution plan also illustrated the extent to which it is practically feasible and how (labor) intensive the process is to secure the data. Thereby, contractors can help with developing and mapping out client information needs for asset and facilities management. An assessment approach that is compatible with the principles of equality and transparency can be linked to the execution plan. However, it appears that a uniform measurement method does not yet exist.

9.2 Recommendations

Based on the research, some recommendations can be made. First of all, recommendations can be made for future research, highlighting noteworthy topics that have evolved throughout this study. In addition, practice recommendations are offered.

9.2.1 Recommendations for future research

Because the research of data and information management in project procurement is still in its early stages, there are several research opportunities for future research.

First, further research could broaden the scope, beyond the limitations of this thesis project. For example, the research could be done into contracting authorities outside the Dutch context, subcontractors or suppliers may be included, and emphasis could be placed on groups outside the context of construction projects in other industries and sectors. For further research, it would be interesting to find out how contracting authorities in different countries approach data management in construction projects. The BIM strategy of a country is frequently discussed in general terms in current research, but comparative case studies focusing on the demand specification and award criteria are lacking in the literature. It is important to note that BIM is a relatively new concept; therefore, not many countries have already implemented BIM (Popov et al., 2021). The development of BIM among public commissioning parties, as well as the associated procurement process, should be examined in detail to see whether there are any lessons to be learned for Dutch practice. In the literature and interviews, countries such as Norway and England are mentioned. In Norway, almost all large-scale public projects are supervised by the government agency Statsbygg, which has imposed the use of BIM on every project since 2010. The United Kingdom has mandated the use of 'BIM level 2' for government buildings since 2016.

The emphasis in this research was on the contracting party and the main contractor. For further research, it is recommended that a wider variety of parties involved in construction projects be involved in the research. After all, the requirements imposed on the main contractor also affect chain cooperation with suppliers and subcontractors. Further research can examine, among other things, how the contractors translate the requirements to their subcontractors. Extra attention can be paid to how the contracting authority acquires ownership of all its data and information. The interviews revealed that at the moment there is also a lot of data that contracting authorities cannot access because it belongs to a subcontractor with whom they have no communication. This research can lead to new insights or support existing findings.

This research focused on four public commissioning authorities in the Dutch construction sector. For future research, it would be interesting to investigate how the procurement phase is used by other public commissioning parties. By conducting additional case studies, the implementation of information management in the procurement process and the related strategies can be optimized. More information (on different projects) will be obtained on the relationship between procurement and contextual factors, which is helpful to learn what should be applied for digitalization. In addition, it is possible to generalize the results at a higher level and consequently use this information in other projects to determine the most appropriate procurement strategy. For example, one could look at how provinces and other municipalities implement BIM. Three of the four interviewed contracting authorities mainly work with large contractors. In follow-up research, the demand specifications and award and selection criteria set by smaller commissioning parties such as municipalities could be examined more specifically to see how they affect small contractors. Thereby, case studies within housing corporations can be further investigated. The Dutch housing corporations are likewise constructing ILSs to keep track of the data they require about their properties. In addition, the European Commission has again pointed out to the

Netherlands that it believes that housing corporations should fall under the European obligation to tender. Perhaps it can be examined how the request for information can be processed in this.

In this study, research is done at the project level, however, it is also valuable to consider this research at the organization level. For this purpose, research can be done into the inclusion of data management in relation to portfolio program management. It would be interesting to gain insight into what the vision and policy is on how ambitions concerning digitization are and should be translated into the various projects. Specifically for the contracting authority, it will be necessary to examine what information is needed for effective asset and facility management.

Finally, the research could be carried out into the introduction of standards, such as NEN and ISO standards, for information management to make digitization compulsory on the part of the government. In a number of European countries, the implementation of BIM according to certain norms and standards is already mandatory. In some interviews, it emerged that this should also be done in the Netherlands to promote digitization. Research can help policymakers gain insight into the extent and investment of proposed policy changes in response to BIM.

9.2.2 Recommendations for practice

In addition to the recommendations for future research, some practical recommendations can also be made based on the study. The study has produced a set of recommendations that, at a higher level of abstraction, deal with aspects that a contracting authority should consider throughout a tender process. Subsequently, it will have to do the actual implementation of those aspects itself.

1. Formulating a vision
   Before the tendering procedure, formulate a widely supported vision, regarding data and information management at the organization level. According to the research, this guarantees that both the contractual authority and the market participants are aware of the higher purpose and the project's eventual contribution.

2. Invest in people and culture
   Despite the fact that data and information management has a technical connotation, its performance is mostly determined by softer factors such as people and organizational structure. To achieve an integrated and interdisciplinary data strategy, organizations will need a collaborative environment and culture. Thereby, investments in training, education, and support systems, among others, will be required.

3. Invest in technology and systems
   To facilitate such changes, supporting factors relating to the technological aspects and systems must be in place. It will be necessary to focus on establishing a common data environment, ensuring that employees have the appropriate software and hardware, and facilitating exchange with the contractor.

4. Create specifications based on the vision.
   As a contracting authority, the vision must be translated into tangible product and process requirements for the contract being tendered. Data then does not remain abstract but is concretized at the contract level. This makes it clear to both the contracting authority and the market parties what the conditions are for the contract and what attention needs to be paid to the execution of the contract.

5. Spend time selecting the right people for the project team.
   As a contracting authority, be aware of the impact of the project team on the tender. The success of tenders depends on the people involved. This includes those involved from the client's side. Make sure that as a contracting authority, you consciously select the right people who have an intrinsic and lived motivation. In addition, ensure that those with less experience with BIM and data-driven work be included as well, to broaden the organization's knowledge and competence.

6. Ask for references in the selection phase.
   References might be required to ensure that the parties' visions are supported by evidence. It is important here as a contracting authority to make a distinction between the minimum requirements and the assessment aspects that are imposed on the references. It is advisable at this stage of development not to set BIM as a minimum requirement for references but as one of the assessment aspects. In this way, parties without prior experience are not automatically excluded, but those with prior experience are rewarded.

7. Make sure that technical and process-related aspects are included in the award phase.
   By including at least the technical and process-related aspects in the award framework, as a contracting authority, you may ensure that the data is safeguarded to some extent. In any case, it ensures that market parties will think carefully about the process-related consequences and prepare themselves accordingly. BIM adoption may become a formality or an extra burden in completing contractual commitments if the BIM suitability assessment is not applied and selection is made primarily on traditional financial, technical, and legal grounds (Malla et al., 2022). Because asset and facility management has been underrepresented in BIM to this point, more focus may be dedicated to the 7D part of BIM. Contractors can contribute to further development and mapping out client information requirements. A standardized measurement method for information management has yet to be devised, according to the case study. The execution plan could be used as a basis for awarding the contract.

Clients are still searching for the information they need for adequate asset management. For the most part, they are probably looking for the same data. It is preferable to join forces here for the purpose of efficiency and standardization. It must be prevented that market parties are confronted with different information requests for each client, which reduces their own possibilities to standardize their digital processes. Contracting authorities must therefore work in co-creation with market parties to come up with the best information specifications. At the various delivery points, the needed content and format of the information/data (formats) can already be specified. Thereby, the development of uniform database structures can be developed along with it.

10
Reflection

In this chapter, the final product, process, and planning of this graduation research will be discussed and reflected on, as well as the researcher's personal experience.

10. 1 Product

At the beginning of the study, the research gap had to be identified within the research topic. First, a systematic approach was selected to accurately define the research gap and assure the literature study's sufficient validity. A thorough review of the literature revealed a scarcity of research on the topic of procurement in (re)construction with a data component. A broader searching method with a wider variety of sources was also used to properly understand the context of the research topic. Various sources were used for the literature review, including, journal articles, conference proceedings, books, and internet sites to provide an accurate overview. This in-depth search combined with a broader search resulted in a comprehensive overview of the knowledge on digitalization and procurement. The theories collected in the conceptual framework proved to be valuable for understanding the findings. In retrospect, I found that the theories on digitalization can provide an important context for my research, but that they are very extensive compared to what was experienced in the case studies. More focus in the literature research could have been specifically on the digitization of the contracting authorities.

Throughout the first part of my research process, it was unclear what the final result would be. I expected a thorough and tangible decision model to emerge from this research. However, after a few months of research, it became apparent that this was an unrealistic goal. Because the digital transition is still in its early stages, there is a lack of understanding and clarity among public and private stakeholders on what selection and award criteria a tender should include. I expect that once the public authorities have explicitly established the information requirements for the operation and maintenance phase, specific procurement criteria may be developed. Ultimately, the four case studies performed in-depth explorations into the topic by interviewing 21 stakeholders, resulting in thorough conclusions that extend previous research on the subject. With the research, a new perspective is provided for scholars researching digitalization in the industry. If I had more time for this research, I would have liked to do more research on the vision and needs of asset management.

10.1.1 Relevance

The relevance of this research stems from the purpose to fill a knowledge gap in research that connects digitalization with project procurement in the construction industry. Insights and recommendations are presented to public commissioners and practitioners on how to better procure data exchange in construction projects. Second, academics researching the relationship between data exchange and procurement in construction projects will be provided with new perspectives and research directions.

10.1.2 Position within the MSc track

This thesis is part of the TU Delft's Management in the Built Environment track, which is part of the Architecture, Urbanism, and Building Sciences program. The research is part of the Design and Construction Management domain. The focus of this domain is on challenges relating to the development and realization of buildings with a specific focus on construction process innovation. This research concentrates on the procurement phase of the construction process, connecting it to the future in which digitization becomes more crucial, and attempts to provide insights on how contracting authorities can shape the procurement phase in data-driven construction projects. By describing, analyzing, and further developing legal possibilities and preconditions for building process innovation, the research contributes directly to the chair of building law. Through its application to public procurement law, the research helps in the scientific development of the field that belongs to the interaction of (semi-)public players with market players.

Examining the potential for this research topic to be used in MBE's educational program, it would be Interesting for future students to learn more about digitization in the construction industry and which technologies can be applied during the process. The existing educational curriculum has limited depth in the domain of BIM. The current BIM course mainly focuses on the structure of information and the development of 3D models. In the building industry, digital technology will become increasingly significant. Students should be given more insight into the culture and organizational change that comes with further digitalization. By confronting students during their studies with the fact that further digitalization of construction has consequences for project management and organizational changes, awareness can be created, even before students encounter it in practice. If this is addressed early in their studies, they may be able to understand the importance of data and the related process early in their careers, supporting the acceleration of digitization in the construction industry.

10.2 Process and planning

The research made use of multimethod qualitative research through a combination of empirical and scientific literature research. The planning of this research was designed around the different presentation moments of the master. The process planning was outlined in the P1 presentation. This planning has been followed throughout the process with just minor deviations.

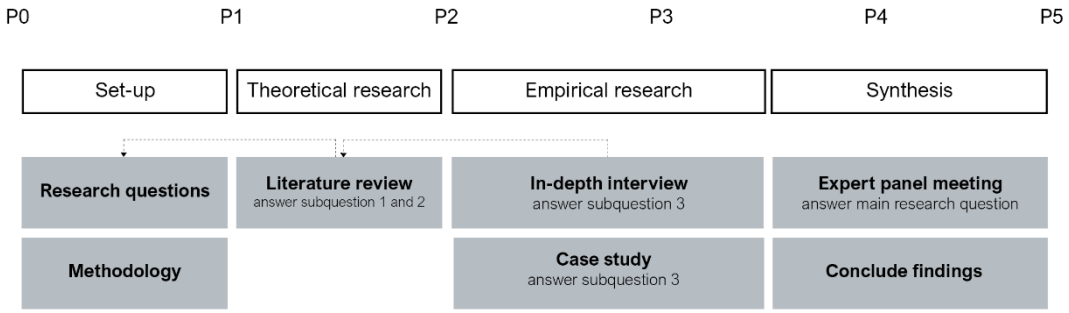


Figure 10.01: Planning of research

At first, the literature review was conducted to gain knowledge about the topic. Sometimes it proved difficult to find the right literature. Much research in construction digitization is focused on BIM. Less has been written about data in construction, especially with a focus on procurement. This sometimes made it difficult to find the right literature. It was also easy for me to get sidetracked and search too broadly because my expertise in digitization was restricted.

Finding relevant projects and interviews proved to be challenging. First of all, the use and procurement of data is quite new and not yet widely deployed in Dutch (re)construction projects.

This necessitated the adoption of recent (re)construction projects. One of the selected cases seemed to meet the criteria for case selection. However, the case ultimately proved unsuitable after the document analyses and two interviews had been conducted. The data component was very limited in the project and several stakeholders were involved during the process. The interviewers had little to no knowledge of the data involved, and the project's management was overloaded by other challenges. As a result, this case had to be excluded. Thereby, several cases appeared to be highly promising in the document analysis, but the stakeholders involved did not have time for interviews. It took some time, patience, and commitment, but I was eventually able to identify four suitable projects with 15 willing participants to cooperate in this research.

A test interview had been scheduled before the formal interviews. This test interview was quite useful in ensuring that the questions were well-formulated, asked in the correct order, and covered the full research. When I started conducting the interviews, I found that I underestimated the task of interviewing more than 21 stakeholders. It took a long time to transcribe and analyze the interviews. But it was also incredibly beneficial because particular statements made during the interview could not be remembered. Each interviewee continued to surprise me with new information and examples that supported what the others had stated. The ethical considerations in this study, as outlined in Chapter 2, were addressed by providing information before conducting the interview and by removing the respondents' identities from the transcripts to ensure their privacy.

Just before the P4, the results were validated by conducting expert interviews. Due to a shortage of time, the expert discussions were done separately. The experts were unable to discuss the statements with one another because these meetings were conducted separately, yet they were able to communicate their own experiences and perspectives. The expert interviews were beneficial to my research. The experts added many relevant details to the statements I provided and contributed relevant examples from their backgrounds. This information gave me a new perspective and encouraged me to refine my recommendations for practice and further research.

10.3 Personal experience

This graduating procedure took a total of ten months, during which time I developed myself significantly. In general, working on my graduation research has been a really rewarding experience for me. Learning about my graduation subject and discovering links between literature and practice was instructive. I was interested to learn more about digitization in the construction industry as it was a relatively new topic for me. However, looking back on the whole process, it was also an intensive period.

The graduation process started smoothly as I already decided on a topic and found a supervisor during the summer. This ensured a relaxed start to the semester compared to fellow students who experienced the first week as very stressful. Throughout this process, my planning abilities and perseverance have proven to be important strengths. Despite the lockdown during the first semester, I was able to complete the research proposal and literature review on time. I realized that maintaining a work-life balance was critical throughout this period. I needed some brain space to comprehend all of the material between reading literature and writing paragraphs.

Selecting relevant cases and contacting the corresponding stakeholders took more time than expected. It was often difficult to connect with public organizations other than my graduation firm. Because of the time, it took to search for relevant cases and consult, I was still conducting interviews much later than planned. In the end, I was able to interview a large number of stakeholders for each case, as well as speak with several specialists who were not involved in the cases. The professionals were very involved and eager to help me with my research by sharing their knowledge. It was encouraging to see that some people were deeply committed to digitizing

the construction industry and had invested a significant amount of time in doing so. It was fascinating to observe how the knowledge I learned improved my understanding of the literature. Linking the empirical investigation to the literature review was both intriguing and enjoyable.

My mentors at the Government Property Agency were really helpful and tried to help me get in touch with the right people. I was also warmly welcomed by other colleagues, and I was able to easily schedule meetings with them, allowing me to rapidly acquire a great deal of knowledge. The experience of conversing with employees and gaining a sense of what they do provided me with a lot of background knowledge that was supported in the interpretation of the materials from the interviews. The Government Property Agency has been an enjoyable and ideal location to work on my thesis and learn about practice because of the openness of the employees, their desire to participate, and their curiosity about the findings.

During this process, my TU Delft mentors were supportive. Every few weeks I met with my supervisors and discussed my findings and questions accumulated over the weeks. The extensive experience in the legal and digital aspects of the building industry of Evelien Bruggeman was quite helpful in the early stages of my research where she could provide me with a plethora of references and information. Also during the process, she made me feel that I could contact her at any time if I did not understand something or needed help. Ad Straub, as an experienced researcher, has assisted me in developing the methodological approach with corresponding research questions. He was also extremely helpful when it came to conducting interviews and case studies and provided me with valuable feedback.

The last few months have taught me a lot. From performing systematic literature reviews to conducting interviews, and from analyzing interviewee input to reaching a definite conclusion. Altogether, I am satisfied with the process and the result.

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A

List of Interviewees

Case studies

Case	Organisation	Interviewee	Role	Date	Way
A	Rijksvastgoedbedrijf	A1	Project manager	11/03/22	Video call
A	Rijksvastgoedbedrijf	A2	Tender manager	18/03/22	Video call
A	Rijksvastgoedbedrijf	A3	Technical manager	28/03/22	Video call
A	Dura Vermeer	A4	Tender manager	23/03/22	Video call
B	Rijkswaterstaat	B1	Project manager	30/03/22	Phone call
B	Rijkswaterstaat	B2	Tender manager	30/03/22	Video call
B	Rijkswaterstaat	B3	BIM Coordinator	02/05/22	Video call
B	Dura Vermeer	B4	Project manager	09/05/22	Phone call
C	Schiphol	C1	Project manager	04/05/22	Video call
C	Schiphol	C2	BIM coordinator	25/04/22	Video call
C	Schiphol	C3	Asset manager	23/03/22	Video call
C	Spie	C4	Project manager	03/05/22	Video call
C	Spie	C5	BIM Coordinator	03/05/22	Video call
D	Provincie Gelderland	D1	BIM Coordinator	30/03/22	Video call
D	BAM	D2	BIM Coordinator	25/04/22	Video call

Additional interview

Organization	Interviewee	Role	Date	Way
Waternet	E1	Asset manager	21/03/22	Video call
BIMLoket	E2	Management	16/03/22	Phone call
Spie	E3	BIM manager	01/04/22	Video call

B

Information sheet interview

Geachte heer/mevrouw,

In dit informatieblad worden alle aspecten van deelname aan dit onderzoek voor u als ondervraagde toegelicht. Na het lezen hiervan wordt u vriendelijk verzocht het toestemmingsverklaringsformulier in te vullen. Mocht u nog vragen of zorgen hebben, dan hoor ik dat graag.

Deelname aan het onderzoek

Dit onderzoek wordt verricht ter afronding van de MSc track Management in the Built Environment aan de TU Delft. Door deel te nemen aan dit onderzoek draagt u bij aan de kennis over aanbesteden met een datacomponent. Een literatuurstudie en het analyseren van praktijkcases zijn belangrijke methoden voor dataverzameling. U hebt gewerkt aan een bouwproject (een casus) waarover ik graag meer te weten zou komen via een interview met u. Tijdens het interview, zal ik u vragen stellen die betrekking hebben op de volgende onderwerpen:

1. Uw professionele achtergrond, rol binnen het bouwproject en het projectteam;
2. Uw ervaringen met het aanbesteden van bouwprojecten met een datacomponent;
3. Uw visie op de digitalisering binnen uw organisatie.

Het interview zal worden opgenomen. Houd er rekening mee dat er geen goede of foute antwoorden zijn, en u niet verplicht bent alle vragen te beantwoorden. Als u zich op enig moment wilt terugtrekken uit dit onderzoek tijdens het interview of nadat het interview is afgenomen, kunt u dat doen. Mocht dit het geval zijn, gelieve mij dan zo snel mogelijk te informeren.

Gebruik van gegevens tijdens het onderzoek

Na afloop van het interview wordt de geluidsopname getranscribeerd. De uitwerking hiervan zal naar u gestuurd worden ter controle. Informatie over uw rol binnen het bouwproject zal expliciet moeten blijven omdat dit van belang is binnen het casus onderzoek. Alle andere persoonlijke informatie zullen worden geanonimiseerd. Persoonlijke informatie die u zou kunnen identificeren, zoals uw naam, zal niet worden gedeeld buiten het onderzoek en begeleiders.

Toekomstig gebruik en hergebruik van gegevens door anderen

Nadat het onderzoek is uitgevoerd en de scriptie is afgerond en ingeleverd, zal deze worden gepubliceerd en gearchiveerd in de repository van de TU Delft, zodat deze kan worden gebruikt voor toekomstig onderzoek. Gegevens uit het interview zullen deel uitmaken van deze publicatie. Als deelnemer heeft u het recht om rectificatie. Neem contact met mij op via de hieronder als u hierover vragen of opmerkingen heeft.

Hartelijk dank voor uw medewerking en bijdrage aan dit onderzoek!

I.S. (Ilse) van Milaan

C

Informed consent form interview

Dit formulier zal aan alle ondervraagden worden toegezonden, zij moeten alle passende vakjes "ja" aankruisen voordat ik hen mag ondervragen.

Onderzoek: Msc scriptie over de aanbesteding van data in publieke bouwprojecten.
Onderwijsinstelling: Technische Universiteit Delft
Interviewer: Ilse van Milaan
Geïnterviewde: ……..
Datum van interview: [dd/mm/JJJJ]

Gelieve de vakjes aan te kruisen	Ja	Nee
Deelname aan het onderzoek		
1. Ik heb het informatieblad gelezen en begrepen of het is mij voorgelezen [aan het begin van het interview]. Ik heb vragen kunnen stellen over het onderzoek en mijn vragen zijn naar mijn tevredenheid beantwoord.	☐	☐
2. Ik geef vrijwillig mijn toestemming om deel te nemen aan dit onderzoek en begrijp dat ik kan weigeren vragen te beantwoorden en dat ik me op elk moment uit het onderzoek kan terugtrekken, zonder dat ik daarvoor een reden moet opgeven.	☐	☐
3. Ik begrijp dat deelname aan het onderzoek een interview inhoudt dat audio- of video opgenomen, getranscribeerd en later geanalyseerd zal worden. Alle opnames zullen één jaar na de indiening van het eindverslag van de scriptie worden gewist.	☐	☐
4. Ik begrijp dat de onderzoeker zal vragen om bedrijfsdocumenten te gebruiken als secundaire en ondersteunende bronnen na de interviews.	☐	☐
Gebruik van data tijdens dit onderzoek		
5. Ik begrijp dat de door mij verstrekte informatie gebruikt zal worden voor academische doeleinden, zoals de afstudeerscriptie, voor de MSc Management in the Built Environment, onderzoekspaper en scriptiepresentatie. Ik geef toestemming aan de onderzoeker om de verzamelde gegevens te gebruiken voor toekomstige onderzoek publicaties en lezingen, tenzij anders vermeld dat specifieke informatie vertrouwelijk is.	☐	☐
6. Ik geef toestemming om deze scriptie - met de door mij verstrekte informatie - te publiceren en te archiveren in de educational repository van de TU Delft, zodat deze gebruikt kan worden voor toekomstig onderzoek en onderwijs.	☐	☐
7. Ik begrijp dat, als ik ervoor kies, mijn bedrijf en persoonlijke identiteit anoniem zullen blijven gedurende het onderzoekspaper en andere output.	☐	☐

8. Ik begrijp dat persoonlijke informatie die over mij is verzameld en die mij kan identificeren, [bv. mijn naam of waar ik woon], niet buiten het onderzoeksteam zal worden gedeeld als ik dat expliciet heb aangegeven.	☐	☐
9. Ik stem ermee in dat mijn informatie mag worden geciteerd in de onderzoeksresultaten.	☐	☐

Handtekening

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _	_ _ _ _ _ _ _ _ _ _ _ _
Naam deelnemer	Handtekening	Datum

Ik heb het informatieblad nauwkeurig voorgelezen aan de potentiële deelnemer en naar mijn beste kunnen, van vergewist dat de deelnemer begrijpt waarmee hij/zij vrijwillig instemt.

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _	_ _ _ _ _ _ _ _ _ _ _ _
Naam Onderzoeker	Handtekening	Datum

Voor vragen, details van het onderzoek of nadere informatie kunt u een e-mail sturen naar l.S.vanMilaan@student.tudelft.nl

D

Interview guide

Opdrachtgever

Introductie praatje

Hartelijk dank voor uw deelname aan dit onderzoek naar de aanbesteding van opdrachten met een datacomponent. Dit onderzoek is onderdeel van mijn afstudeeronderzoek voor de mastertrack Management in the Built Environment aan de TU Delft. Het doel van dit onderzoek is om aanbestedende diensten en mensen uit de praktijk te helpen bij het ontwikkelen en verbeteren van hun aanbestedingsstrategie met betrekking tot de digitalisering. En daarbij kennis bij te dragen aan de academische literatuur over het aanbesteden van een datacomponent in bouwprojecten. Om hier inzicht in te krijgen ga ik verschillende partijen interviewen die betrokken zijn geweest bij bouwprojecten met een datacomponent.

Uw rol binnen dit project in het bijzonder en uw ervaring met digitalisering van de bouw in het algemeen zijn van grote waarde voor dit onderzoek. Er zijn geen goede of foute antwoorden, uw persoonlijke visie is wat telt. De gegevens die u verstrekt zullen niet worden gebruikt voor andere doeleinden dan dit onderzoek. Daarbij zullen alle resultaten anoniem worden verwerkt. U heeft vooraf aan het interview het toestemmingsformulier ingevuld. Ik wil u echter nogmaals vragen of u het goed vindt dat dit interview wordt opgenomen.

Inleidende vragen

1. Kunt u uzelf introduceren en uw rol in het ….. (RVB/RWS/Prorail/Schiphol) toelichten?
2. Wat was uw rol en werkzaamheden binnen dit bouwproject?

Techniek

3. Wat zijn uw ervaringen met de digitalisering van de bouwsector?
4. Wat is uw visie op de digitalisering?
5. Wat denkt u dat de organisatie moet veranderen om een snellere digitalisering de bevorderen?
6. Kunt u mij vertellen wat voor datacomponent er is uitgevraagd in dit project?
7. Wat was de belangrijkste drijfveer om een datacomponent toe te passen binnen dit project?
8. In welke projectfase wordt er data verzameld en uitgewisseld?

Proces

9. Kunt u mij vertellen hoe de aanbesteding van dit bouwproject is verlopen?

<u>Voorbereiden opdracht</u>

10. Hoe zag de oriëntatiefase eruit?
11. Is er een ILS of andersoortige data-vraagspecificatie opgesteld door de opdrachtgever als onderdeel van de data-vraag?

12. Was dit ILS een standaard/reeds beschikbaar ILS of daarop gebaseerd, of was het volledig project specifiek gemaakt?
13. Welke partijen waren betrokken bij het opstellen van de informatiebehoefte?
14. Hoe hebben de specificaties met betrekking tot de datacomponent effect gehad op de inschrijving(en)?
15. Zijn alle data aspecten die in de specificaties worden aangegeven, volledig in de inschrijving(en) verwerkt?

Selectie

16. Kunt u mij vertellen hoe de uitsluitingsgronden, de geschiktheidseisen en selectiecriteria met betrekking tot data hebben geholpen om de juiste opdrachtnemer te selecteren?

Informatie-uitwisseling

17. Hoe was de communicatie tussen opdrachtgever en opdrachtnemers bij (mogelijke) onduidelijkheden over de dat aspecten van de specificaties?
18. Was voor de opdracht nemende partij duidelijk wat er gevraagd werd met betrekking tot de data?
19. Kunt u mij vertellen of er knelpunten waren waar door de markt niet aan voldaan kon worden met betrekking tot de data?
20. Zijn er door de opdracht nemende partij suggesties gedaan met betrekking tot de data?

Gunnen

21. Kunt u mij vertellen hoe de gunningcriteria met betrekking tot de data hebben geholpen om de juiste opdracht te selecteren?
22. Schiep de datacomponent in de opdracht ruimte voor opdrachtnemers om een 'concurrentievoordeel' te behalen?
23. Maakte het opstellen van een uitvoeringsplan (o.i.d.) deel van het gunningsproces? Dus werd de wijze waarop de opdrachtnemer voorstelde zijn proces rond data leveringen vorm te geven meegenomen in de gunning/beoordeling. En zo ja, hoe?

Contract

24. Wat is er na de gunning van het contract nog besproken met betrekking tot de datacomponent?
25. Heeft de opdracht nemende partij nog documenten moeten opstellen voor verdere uitwerking van de datalevering?

26. Zou u achteraf gezien iets veranderen in uw aanbestedingsaanpak met betrekking tot de datacomponent van het project? En wat zijn de leerlessen voor volgende projecten?

Organisatie

27. Kunt u mij vertellen in hoeverre u en uw organisatie voldoende achtergrondkennis had om het datacomponent te begrijpen en aan te besteden?
28. In hoeverre wordt het model en/of de data up-to-date gehouden?

Afsluiting interview

Is er nog iets overgeslagen met betrekking tot de aanbesteding van een datacomponent of de digitalisering wat u nog wilt delen? Dan waren dit alle vragen, nogmaals ontzettend bedankt dat u wilde meewerken aan het interview, dit helpt mij weer vooruit met mijn onderzoek. Als u wilt, kan ik u wanneer mijn afstudeeronderzoek is afgerond, de resultaten opsturen?

Opdrachtnemer

Introductie praatje

Hartelijk dank voor uw deelname aan dit onderzoek naar de aanbesteding van opdrachten met een datacomponent. Dit onderzoek is onderdeel van mijn afstudeeronderzoek voor de mastertrack Management in the Built Environment aan de TU Delft. Het doel van dit onderzoek is om aanbestedende diensten en mensen uit de praktijk te helpen bij het ontwikkelen en verbeteren van hun aanbestedingsstrategie met betrekking tot de digitalisering. En daarbij kennis bij te dragen aan de academische literatuur over het aanbesteden van een datacomponent in bouwprojecten. Om hier inzicht in te krijgen ga ik verschillende partijen interviewen die betrokken zijn geweest bij bouwprojecten met een datacomponent.

Uw rol binnen dit project in het bijzonder en uw ervaring met digitalisering van de bouw in het algemeen zijn van grote waarde voor dit onderzoek. Er zijn geen goede of foute antwoorden, uw persoonlijke visie is wat telt. De gegevens die u verstrekt zullen niet worden gebruikt voor andere doeleinden dan dit onderzoek. Daarbij zullen alle resultaten anoniem worden verwerkt.

U heeft vooraf aan het interview het toestemmingsformulier ingevuld. Ik wil u echter nogmaals vragen of u het goed vindt dat dit interview wordt opgenomen.

Inleidende vragen

1. Kunt u uzelf introduceren en uw rol in het ….. (bedrijf) toelichten?
2. Wat was uw rol en werkzaamheden binnen dit bouwproject?

Techniek

3. Wat zijn uw ervaringen met de digitalisering van de bouwsector?
4. Wat is uw visie op de digitalisering?
5. Wat denkt u dat uw organisatie moet veranderen om een snellere digitalisering de bevorderen?

6. Kunt u mij vertellen wat voor datacomponent er is uitgevraagd?
7. In welke projectfase werd er data verzameld en uitgewisseld?
8. Wat betekent de data component voor de samenwerking met toeleveranciers?

Proces

9. Kunt u mij vertellen hoe de aanbesteding van dit bouwproject is verlopen?

<u>Voorbereiden opdracht</u>

10. Wat was de reden was om een inschrijving te doen?
11. Is er een ILS of andersoortige data-vraagspecificatie opgesteld door de opdrachtgever als onderdeel van de data-vraag?
12. Was dit ILS een standaard/reeds beschikbaar ILS of daarop gebaseerd, of was het volledig project specifiek gemaakt?
13. Zijn alle data aspecten die in de specificaties worden aangegeven, volledig in de inschrijving(en) verwerkt?

<u>Selectie</u>

14. Kunt u mij vertellen hoe de selectie criteria met betrekking tot data hebben geholpen dat uw inschrijving werd gegund?

Informatie-uitwisseling

15. Kunt u mij vertellen in hoeverre de informatiebehoefte en de eisen in betrekking tot de datacomponent duidelijk was?
16. Hoe was de communicatie tussen opdrachtgever en opdrachtnemers bij (mogelijke) onduidelijkheden over de aspecten met betrekking tot data van de specificaties?
17. Kunt u mij vertellen of er knelpunten waren waar uw organisatie niet aan kon voldoen met betrekking tot data?
18. Zijn er door uw organisatie suggesties gedaan met betrekking tot data?

Gunnen

19. Kunt u mij vertellen hoe de gunningcriteria met betrekking tot data hebben geholpen dat uw inschrijving werd gegund?
20. Schiep de datacomponent in de opdracht ruimte voor uw organisatie om een 'concurrentievoordeel' te behalen?
21. Maakte het opstellen van een uitvoeringsplan (o.i.d.) deel van het gunningsproces? Dus werd de wijze waarop de opdrachtnemer voorstelde zijn proces rond data leveringen vorm te geven meegenomen in de gunning/beoordeling. En zo ja, hoe?

Contract

22. Wat is er na de gunning van het contract nog besproken met betrekking tot de datacomponent?
23. Heeft uw organisatie nog documenten moeten opstellen voor verdere uitwerking van de datalevering?

24. Zou u achteraf gezien iets veranderen in uw aanbestedingsaanpak met betrekking tot de datacomponent van het project? En wat zijn de leerlessen voor volgende projecten?

25. Hoe denkt u dat de opdrachtgever de aanbestedingsaanpak veranderen om digitalisering te bevorderen?

Organisatie

26. Kunt u mij vertellen in hoeverre u en uw organisatie voldoende achtergrondkennis had om het datacomponent te begrijpen en mee te doen met de opdracht?
27. In hoeverre wordt het model en/of de data up-to-date gehouden?

Afsluiting interview

Is er nog iets overgeslagen met betrekking tot de aanbesteding van een datacomponent of de digitalisering wat u nog wilt delen?

Dan waren dit alle vragen, nogmaals ontzettend bedankt dat u wilde meewerken aan het interview, dit helpt mij weer vooruit met mijn onderzoek. Als u wilt, kan ik u wanneer mijn afstudeeronderzoek is afgerond, de resultaten opsturen?