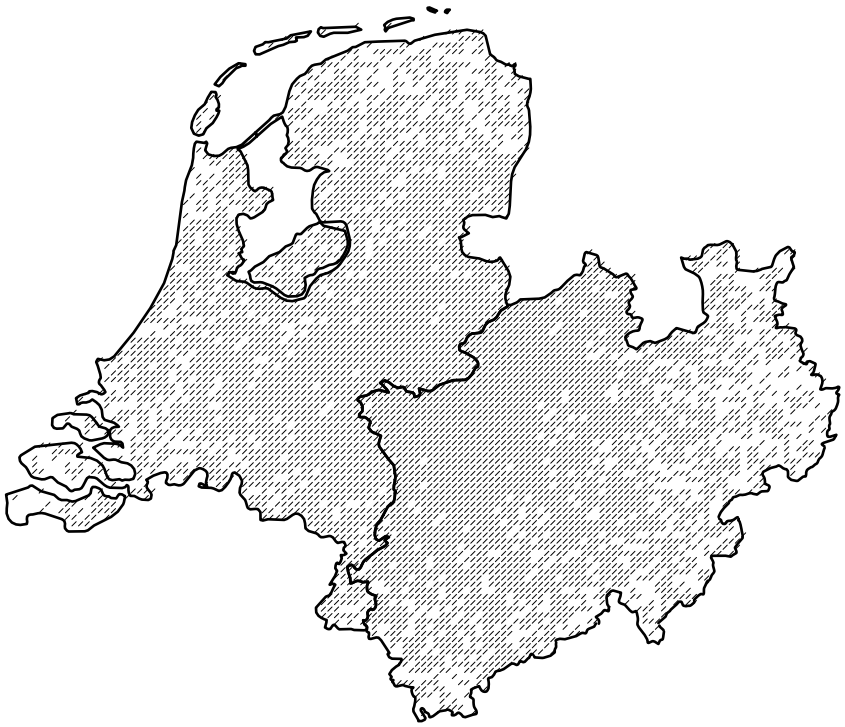
TU Delft Department of Management in the Built Environment
BK Bouwkunde

# Towards comprehensive data demands: A long-term strategy for public clients' asset life cycle data needs

**An exploration of a continuous improvement approach for the formulation of comprehensive data demands in the Bau- und Liegenschaftsbetrieb NRW (BLB NRW) of Germany**



Leonardo Fred Micolta Diaz

MSc. Thesis Report P5
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# Colophon


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# Abstract

The Recent advancements in digital transformation within the Architecture, Engineering, Construction, Owner, and Operator (AECOO) sector emphasize the potential for creating public value through strategic IT implementation, particularly when driven by public clients. Public clients play a pivotal role in driving digital adoption across the AECOO industry, leveraging procurement practices to encourage sustainable and innovative outcomes. Digitalization, exemplified by tools such as Digital Twins (DT) and Building Information Modelling (BIM), offers the means to achieve long-term sustainability goals, including real-time energy monitoring, lifecycle asset management, and circular economy transitions. However, the transition remains complex due to inherent industry fragmentation and limited integration of digital systems, particularly in the Operations and Maintenance (O&M) phases.

While BIM has demonstrated efficiency improvements during the design and construction phases, its benefits are less pronounced in O&M, where information continuity and integration remain challenging. A socio-technical approach, integrating people, processes, and policies, is essential for effective digital adoption, especially to address organizational silos, behavioural barriers, and knowledge gaps that hinder technological integration. Public clients, positioned as agents of change, must adopt tailored, holistic data management strategies that align with life cycle needs and public values. This research focuses on enhancing BIM's role across the AECOO lifecycle by formulating a comprehensive framework to bridge existing gaps between data requirements, project phases, and client expectations.

Through theoretical research and a case study, this study develops a multi-level framework incorporating hierarchical policy alignment, knowledge management, and information exchange protocols to address the “practical-knowledge gap” seen in digital implementations. Findings suggest that a client-led approach with strong social integration mechanisms is crucial for overcoming industry fragmentation and driving sustainable digital transformation in the AECOO sector.

## Research methods

The research employs a mixed-method exploratory sequential design, incorporating semi-structured interviews, internal document analysis, and both internal and external validation in focus group settings, gathering both qualitative and quantitative data.



## Key words

Digitalization in AECOO, Building Information Modelling (BIM), asset life cycle management, public clients, socio-technical approach, data demand formulation.

# Executive Summary

Recent research into digital transformation within the Architecture, Engineering, Construction, Owner, and Operator (AECOO) sector reveals an evolving narrative. Moving away from a sole emphasis on cost reduction and efficiency gains, digitalization is increasingly seen as an enabler for broader public values. Among these values, sustainability is paramount, especially for public clients tasked with addressing climate challenges while delivering high-quality built environments. This research outlines the potential of digital transformation to reshape the AECOO sector, focusing on public clients as key agents of change. It discusses the role of emerging technologies like Building Information Modelling (BIM) and Digital Twins (DT) while analysing the socio-technical complexities involved in digital adoption. This summary also provides insights into overcoming key barriers, particularly those that arise from fragmentation, knowledge gaps, and a lack of cohesive digital strategies.

## The Need for Digital Transformation in AECOO

The AECOO sector has long been characterized by its fragmented nature, where different stakeholders operate within "silos," resulting in inefficiencies and information losses. This sector's traditional, project-based approach often leads to significant challenges related to budget overruns, schedule delays, and poor information management. Digitalization, in this context, presents a unique opportunity to address these issues by enabling more integrated project delivery models that streamline information flows and improve collaboration among stakeholders. However, recent research highlights that achieving these benefits is not solely a matter of technological implementation. Digital transformation requires public clients to play a proactive role in setting standards, defining requirements, and using their procurement influence to drive market-wide changes.

## Public Clients as Drivers of Change

Public clients are in a unique position to act as drivers of digital transformation, primarily because of their influential role in commissioning projects and managing assets. As major players in the AECOO market, public entities can establish procurement requirements that encourage the adoption of digital tools and sustainable practices. Moreover, public clients are responsible for managing and operating public assets throughout their life cycle. This gives them a vested interest in ensuring that data generated during the design and construction (D&C) phases are effectively utilized during the Operations and Maintenance (O&M) phases to achieve long-term value. The integration of these processes is crucial for addressing sustainability goals and reducing the carbon footprint of the built environment.

## Key Technologies Enabling Digital Transformation

Technologies like Building Information Modelling (BIM), Digital Twins (DT), and digital ledgers are key enablers of digital transformation. BIM serves as a shared digital representation of an asset, enabling stakeholders to collaboratively manage information throughout the asset's life cycle. BIM's benefits are well-documented for the D&C phases, including improved productivity, coordination, and reduced costs. However, its use in O&M remains limited, partly due to the challenges of transferring comprehensive and usable data between different project stages.

Digital Twins (DT) further expand the potential for digital integration by enabling real-time monitoring of an asset's performance, which helps optimize energy use, manage maintenance activities, and reduce environmental impacts. DTs create dynamic digital replicas of physical assets, providing valuable insights into how an asset operates over time. This capability is

particularly valuable for public clients aiming to achieve sustainability targets, as DTs support energy efficiency and facilitate data-driven decision-making across the asset's life cycle.

Moreover, exploring the use of digital ledgers and Digital Records (DR) of assets enables a more effective way to trace construction materials, contributing to the circular economy. By integrating these technologies, public clients can create a unified database for managing material stocks throughout an asset’s life cycle, thereby supporting sustainable procurement and effective resource use.

## Challenges in Digital Adoption

Despite the potential of BIM, DT, and related technologies, adoption within the AECOO sector remains inconsistent, particularly among public clients. One of the major barriers is the sector’s fragmented and project-based nature, which makes information transfer challenging. Typically, project data lose value at each handover stage due to poor documentation, lack of standardization, and inadequate communication between stakeholders. This issue is particularly pronounced during transitions from D&C to O&M, where valuable information generated during the design and construction stages is often not carried over in a usable form for facilities management.

Furthermore, the principles of "vertical integration" or "beginning with the end in mind"—which emphasize considering downstream needs during early project phases—are underutilized in current practices. Public clients, in particular, struggle to establish clear data requirements that ensure BIM's usefulness across the asset's life cycle. A lack of contractual models focusing on data requirements and insufficient participation from Facilities Management (FM) and Asset Management (AM) professionals during the design phases contribute to these challenges.

## Socio-Technical Considerations and Practical-Knowledge Gaps

Effective digital transformation requires addressing both the technological and social aspects of adoption. One significant challenge is the "practical-knowledge gap," which refers to the discrepancy between the intended use of digital tools and their actual implementation in practice. This gap often results from organizational inertia, where stakeholders revert to familiar practices rather than fully embracing new technologies. Additionally, there is a disconnect between the knowledge required to use digital tools effectively and the existing skills within organizations, particularly among public clients.

A socio-technical approach is crucial to overcome these challenges. This approach emphasizes the interplay between people, processes, and technology and the importance of creating an environment that supports change at both individual and organizational levels. It also highlights the need for effective change management strategies, focusing on individual behaviours, organizational culture, and the provision of adequate support for stakeholders transitioning to digital workflows.

## The Role of Public Clients in Promoting Innovation

Public clients, as key stakeholders in the AECOO sector, can play a crucial role in promoting innovation and driving change. They can adopt a client-led or supplier-led role in fostering innovation, depending on whether competition or collaboration is the primary driver. In a client-led role, public clients act as system integrators, coordinating various actors involved in the project and ensuring that innovations are implemented effectively. This approach is

particularly beneficial for fostering systemic changes that go beyond individual projects and have a lasting impact on industry practices.

By setting clear and consistent data requirements, public clients can provide a foundation for the broader adoption of digital tools, thereby improving data interoperability and enhancing the efficiency of information exchange across the asset's life cycle. Additionally, by focusing on sustainability and the circular economy, public clients can use digital tools to drive positive environmental outcomes, ensuring that projects not only meet budgetary and time constraints but also contribute to broader societal goals.

## A Comprehensive Framework for Digital Transformation

To address these challenges and fully harness the potential of digital transformation, a comprehensive framework is needed—one that aligns an organization's goals with its data needs while considering the barriers it faces. This framework should facilitate a holistic approach to capturing and managing data across the asset life cycle, thereby enhancing the value of facility data and enabling better decision-making throughout the life cycle of the built asset.

The proposed framework builds on a socio-technical model that integrates policy across hierarchical levels—micro (individual and team), meso (organizational), and macro (industry and regulatory). It also incorporates principles that address system complexity, which connects BIM processes with broader enterprise-level digital strategies. This alignment ensures that digital practices are not isolated but rather contribute to an organization's overall goals, particularly those related to sustainability and long-term asset management.

The framework also emphasizes the need for tailored data management processes that align with life cycle phases, ensuring that data generated during D&C is appropriately captured, transferred, and utilized during O&M. Public clients must consider both tacit and explicit knowledge—understanding that informal, experience-based knowledge is just as critical as formal documentation for effective digital adoption. By integrating different forms of knowledge, public clients can create a more complete picture of their data needs and align these with their sustainability and operational goals.

## Case Study: BLB NRW, Germany

The research incorporates a case study—the Bau- und Liegenschaftsbetrieb NRW (BLB NRW) in Germany. The case study provide insights into how public clients can implement digital transformation strategies in practice. The organization has undertaken digital initiatives, but face challenges related to information fragmentation, inadequate data integration, and the practical-knowledge gap.

The case study reveals that successful digital transformation requires not only a well-defined strategy but also strong intra-organizational support mechanisms. These mechanisms help ensure that individual project managers and team members are equipped to engage with digital processes and contribute to the organization's broader goals. The findings highlight the importance of clear communication, comprehensive guidelines, and ongoing support for stakeholders at all levels of the organization.

The empirical analysis of the BLB NRW case study reveals critical insights through a SWOT analysis, summarized as follows:

**Strengths**

- **Strong Coordination and Teamwork -** Effective inter-departmental collaboration is supported by regular communication mechanisms, such as team meetings and workshops, fostering knowledge sharing and collective learning.

- **Knowledge Sharing and Stakeholder Relations -** A culture of knowledge exchange enhances goal alignment and productivity through workshops, direct interactions, and collaborative efforts.

- **Technological Tools for Collaboration -** Platforms like the BLB Portal, ECM, and BLB-Kompass streamline knowledge sharing, project management, and operational efficiency.

- **Data Quality Initiatives -** Ongoing efforts aim to improve data governance, addressing information quality challenges.

**Weaknesses**

- **Reliance on Informal Networks:** Knowledge dissemination depends heavily on personal expertise and ad-hoc interactions, leading to inconsistencies and inefficiencies.

- **Complexity in Information Retrieval -** Multiple tools and systems complicate data searches, underscoring a need for simplified pathways.

- **Role Clarity and Delegation Challenges -** Ambiguity in roles and responsibilities disrupts efficient delegation and hampers productivity.

- **Manual Data Processing -** Dependence on manual processes creates inefficiencies and elevates the risk of errors.

**Opportunities**

- **Enhanced Training for Data Governance -** Investing in best practices training can boost data quality and operational consistency.

- **Centralized Knowledge Repository -** A unified repository would reduce reliance on informal networks and improve information accessibility.

- **Standardized Data Structuring -** Streamlining data management practices would enhance operational efficiency and reliability.

- **Integrated Data Systems -** Improved usability and integration can facilitate better collaboration and informed decision-making.

**Threats**

- **Dependency on Key Individuals -** Over-reliance on specific individuals risks creating knowledge silos and operational disruptions.

- **Data Fragmentation and Relevance Issues -** Inconsistent and outdated data structures impair decision-making and operational effectiveness.

- **Resistance to Change -** Cultural resistance to standardized processes hinders the adoption of more efficient practices.

- **Legacy Systems -** Outdated software and systems reduce efficiency and exacerbate data management challenges.

These findings underscore the need for strategic initiatives to address weaknesses and threats while leveraging strengths and opportunities to enhance BLB NRW's operational and data governance capabilities

## Recommendations for Public Clients

The research provides detailed recommendations aimed at enhancing the adoption of digital transformation and Building Information Modelling (BIM) within complex public sector organizations, particularly those navigating socio-technical challenges. These recommendations address organizational, technological, and policy-level strategies for improved outcomes. The generalized recommendations for public clients are as follows:

### Adopt a Holistic Socio-Technical Framework

Organizations should implement frameworks like the PPP complex system model, which integrates policy, process, and product dimensions across hierarchical levels and asset life cycles. This approach ensures that data needs, barriers, and demands are addressed comprehensively, aligning strategic objectives with actionable processes and technological capabilities. It is crucial to tailor this framework to the unique characteristics of the organization and its regional policy environment to maximize its effectiveness.

### Enhance Coordination and Knowledge Sharing

Effective coordination and communication across departments and stakeholders are pivotal for overcoming socio-technical barriers. Organizations should:

- **Standardize Knowledge-Sharing Platforms** - Develop centralized repositories or intranet systems to facilitate access to shared resources, including project data, guidelines, and lessons learned.

- **Foster Interdepartmental Collaboration -** Schedule regular cross-departmental meetings and workshops to ensure alignment on goals and operational strategies.

- **Encourage Informal Knowledge Exchange -** Create opportunities for informal interactions, such as brainstorming sessions or workshops, to enhance tacit knowledge transfer.

### Focus on Customized BIM Implementation

Organizations should tailor their BIM adoption strategies to reflect specific goals, project needs, and stakeholder requirements. Recommended steps include:

- **Develop Clear and Specific Exchange Information Requirements (EIRs) -** Customize EIRs to the project's unique objectives, ensuring compliance with ISO 19650 guidelines.

- **Leverage Pilot Projects -** Use small-scale pilot projects to test BIM strategies and refine processes based on feedback before full-scale implementation.

- **Address Interoperability Challenges** - Invest in open data standards and protocols that enable seamless data exchange between systems and stakeholders.

**Invest in Organizational Maturity and Training**

Building organizational maturity is critical for the successful implementation of digital transformation initiatives. Recommendations include:

- **Establish Structured Training Programs** - Develop comprehensive training initiatives for employees to enhance their technical competencies and understanding of BIM and digital transformation.

- **Promote Leadership Development** - Train leaders to act as system integrators, capable of managing cross-disciplinary teams and aligning organizational efforts with strategic goals.

- **Use Maturity Models** - Employ maturity assessment frameworks to evaluate and incrementally improve processes, policies, and technological infrastructure.

**Prioritize Data Governance and Quality**

Ensuring data interoperability, quality, and security is foundational to effective digital transformation. Recommendations include:

- **Develop Robust Data Governance Policies** - Define clear guidelines for data ownership, access rights, and security measures.

- **Improve Data Interoperability** - Adopt and enforce standards that facilitate seamless data exchange, such as the Industry Foundation Classes (IFC) format for BIM.

- **Monitor Data Quality** - Regularly assess data accuracy, relevance, and completeness to prevent errors and inefficiencies.

**Strengthen Leadership and Change Management**

Organizations must recognize the pivotal role of leadership in driving digital transformation. Recommendations include:

- **Define Leadership Roles Clearly -** Assign roles such as BIM champions or digital transformation leaders to oversee the integration of new technologies and practices.

- **Promote Proactive Change Management** - Develop strategies to address resistance to change, emphasizing the benefits of new systems and processes.

- **Encourage Accountability** - Ensure leaders and teams are accountable for achieving milestones in digital transformation projects.

**Leverage Feedback Loops for Continuous Improvement**

Integrating feedback mechanisms into digital transformation processes ensures that strategies remain adaptive and effective. Recommendations include:

- **Regularly Review Pilot Project Outcomes -** Analyze successes and challenges from pilot projects to inform broader implementation strategies.
- **Incorporate Stakeholder Feedback** - Actively involve clients, tenants, and external partners in evaluating the effectiveness of BIM and digitalization initiatives.
- **Document Lessons Learned** - Create a structured system for recording and sharing lessons learned across projects to build organizational memory.

**Promote Innovation through Public Procurement**

As public clients are significant drivers of innovation in the construction industry, they should:

- **Set Clear Expectations for Suppliers -** Develop procurement policies that prioritize innovation and require the adoption of BIM and digital solutions.
- **Support Market Development -** Partner with private sector stakeholders to co-develop technologies and practices that enhance digital transformation.
- **Balance Client-Led and Supplier-Led Approaches -** Choose between active client involvement or supplier-driven innovation based on the organization's internal capabilities and project requirements.

**Strengthen Policy Integration Across Hierarchical Levels**

Organizations must ensure that policies align across different levels—micro (individual/departmental), meso (organizational/project), and macro (regional/national). Recommendations include:

- **Tailor Policies to Organizational Needs** - Avoid one-size-fits-all policies by considering localized needs and operational contexts.
- **Encourage Flexibility in Implementation -** Allow policies to adapt to the complexities of specific projects while maintaining alignment with overarching strategic objectives.
- **Collaborate with Policymakers -** Engage in dialogue with regional and national policymakers to align organizational goals with broader public values.

**Address Long-Term Sustainability Goals**

Organizations should integrate sustainability considerations into their digital transformation strategies. Recommendations include:

- **Adopt Sustainable Practices** - Align digital initiatives with environmental and social sustainability goals, such as reducing resource consumption or enhancing building efficiency.
- **Use BIM for Sustainable Design** - Leverage BIM tools to model and analyze the environmental impact of construction and operational decisions.

- **Measure Long-Term Value Creation -** Evaluate how digital transformation contributes to broader public values, such as economic, social, and environmental improvements.

By implementing these recommendations, organizations can address the socio-technical challenges of digital transformation and BIM adoption, ensuring that their strategies are aligned with both organizational goals and public sector values. These steps can help enhance efficiency, foster innovation, and deliver long-term value across projects and stakeholders.

## Conclusion

The digital transformation of the AECOO sector offers significant opportunities for improving efficiency, reducing costs, and achieving public value, particularly in terms of sustainability. However, realizing these benefits requires a comprehensive approach that addresses the socio-technical complexities of digital adoption. Public clients, as key drivers of change, must play a proactive role in defining data requirements, setting procurement standards, and fostering an environment that supports innovation.

This research provides a comprehensive examination of digital transformation and Building Information Modelling (BIM) within public sector organizations, highlighting critical socio-technical dimensions and their implications for organizational efficiency and innovation. By integrating theoretical insights with empirical findings from BLB NRW, the study underscores the importance of aligning policy, processes, and data needs to achieve strategic objectives. It identifies key barriers, such as interoperability challenges, fragmented knowledge sharing, and resistance to change, while emphasizing the role of leadership, stakeholder collaboration, and tailored BIM implementation strategies in overcoming these obstacles. Practical recommendations focus on adopting holistic frameworks, enhancing organizational maturity, and fostering innovation through public procurement. The research also identifies promising areas for further exploration, including longitudinal studies, emerging technologies, and sustainability-focused initiatives. Ultimately, this study serves as a valuable resource for decision-makers seeking to navigate the complexities of digital transformation, offering actionable insights to drive sustainable value creation and industry-wide innovation.

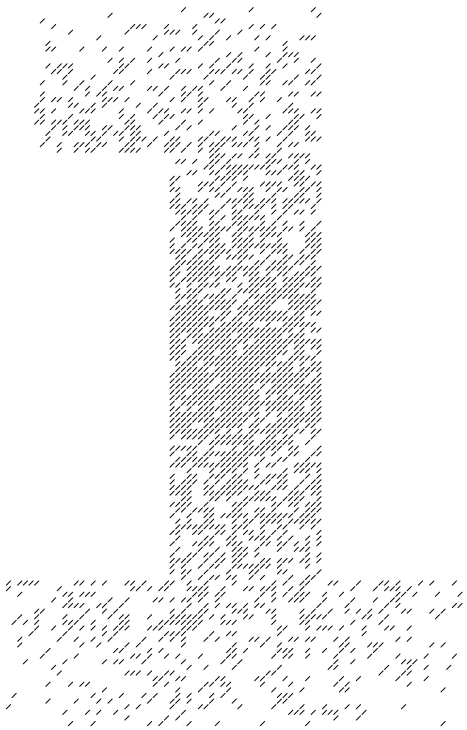
# Contents

# List of figures

## List of tables

## List of terms and acronyms

| | |
|---|---|
| AEC | Architecture, Engineering and Construction |
| AECOO | Architecture, Engineering, Construction, Owner, and Operator |
| AIM | Asset Information Model |
| AIR | Asset Information Requirements |
| ALCM | Asset Life Cycle Management |
| AM | Asset Management |
| BEP | BIM Execution Plan |
| BIM | Building Information Modelling |
| BLB NRW | Bau- und Liegenschaftsbetrieb NRW |
| CDE | Common Data Environment |
| CREM | Corporate Real Estate Management |
| D&C | Design and Construction |
| DR | Digital Record |
| DT | Digital Twin |
| EIR | Exchange Information Requirements |
| FM | Facilities Management |
| IFC | Industry Foundation Classes |
| IoT | Internet of Things |
| LOIN | Level of Information Need |
| NRW | Nordrhein-Westfalen |
| O&M | Operations & Maintenance |
| OIR | Organization Information Requirements |
| PIM | Project Information Model |
| PIR | Project Information Requirements |
| RVB | Rijksvastgoedbedrijf |



# 1 Introduction

## 1.1 Research context

Recent research on digitalization in the Architecture, Engineering, Construction, Owner, and Operator (AECOO) sector has shifted focus beyond identifying cost savings and improved efficiencies. Instead, digital transformation now emphasizes that organizations can achieve significant public value through the implementation of information technology (Godager et al., 2021; M. May et al., 2023). This perspective effectively places public clients in a leadership role, as their influence in procurement and ability to set requirements are key drivers of industry-wide adoption of information technology (Lee & Borrmann, 2020; Lindblad & Guerrero, 2020). Furthermore, public clients not only commission construction projects but also manage and operate building assets from a long-term perspective.

Sustainability in the built environment is a key public value that guides public clients' efforts to address climate change. Digitalization is seen as an essential enabler for attaining sustainability goals, effectively acting as a vehicle to achieve these ends. For example, exploring the traceability of construction materials using digital ledgers and Digital Records (DR) of assets contributes to creating a unified database for managing material stocks throughout an asset's life cycle, aiding the transition to a circular economy (Bargavi & Mathivathanan, 2024; Potting et al., 2017; Watson et al., 2019). Digital Twins (DT), another example, enable real-time monitoring of energy use and thermal comfort, optimizing a building's performance and contributing to global CO2 reduction targets (Lu et al., 2021; UN, 2015). Additionally, integrating Building Information Modelling (BIM) with Computer-Aided Facility Management (CAFM) systems improves repair and maintenance processes, including defect management and service scheduling, thereby prolonging asset life and reducing the need for new construction (Benn & Stoy, 2022; Potting et al., 2017)

Various data repositories and information management systems exist in the built environment to manage assets (Godager et al., 2021; M. May et al., 2023). At the core of digitalization in the AECOO sector, BIM is the most common link connecting information across an asset's life cycle (Bryde et al., 2013; Siebelink et al., 2021; Wong et al., 2018). While BIM is not the only method for delivering information models, it serves as an essential data conduit and repository for supporting Operations & Maintenance (O&M) and Corporate Real Estate Management (CREM) activities (Benn & Stoy, 2022; S. T. Matarneh et al., 2019).

BIM literature predominantly focuses on overcoming technical and procedural barriers to the adoption of information technologies in organizational and project settings (Siebelink, 2021; Wildenauer, 2023). Common research topics include developing standardized technical guidelines, identifying data use cases, and defining general implementation procedures (Khudhair et al., 2021; Olawumi et al., 2017). Despite the availability of guidelines and standards, most public clients across Europe are still in the early stages of their digitalization strategies and struggle to define comprehensive ways to utilize BIM throughout a building's life cycle (Charef et al., 2019; Godager et al., 2021; Meins-Becker & Kaufhold, 2021).

BIM, promoted as a digitalization solution in the AECOO sector, has not yet fully addressed the entire project life cycle. Issues related to inadequate information capture and transfer between the Design & Construction (D&C) phase and the Operations & Maintenance (O&M) phases remain prevalent (Dixit et al., 2019; S. Matarneh et al., 2019). The principles of "vertical integration" or "beginning with the end in mind" are still under-realized. Setting requirements based on downstream needs necessitates new contractual models focused on data, or increased participation from supply chains, Facilities Management (FM), and Asset Management (AM)

during the design phase (Dixit et al., 2019; S. T. Matarneh et al., 2019; Pilanawithana & Sandanayake, 2017; Schriefer & Ganesh, 2002; Wildenauer, 2023).

Kuiper (2021) emphasizes that, while accurate and timely information is essential for AEC projects, procuring physical assets differs from procuring public data or digital infrastructure. This challenge often leads decision-makers to settle for “good enough” due to incomplete information and cognitive limitations. Figure 1 illustrates the challenges, practices, and proposed solutions for addressing information transfer gaps between D&C and O&M phases.

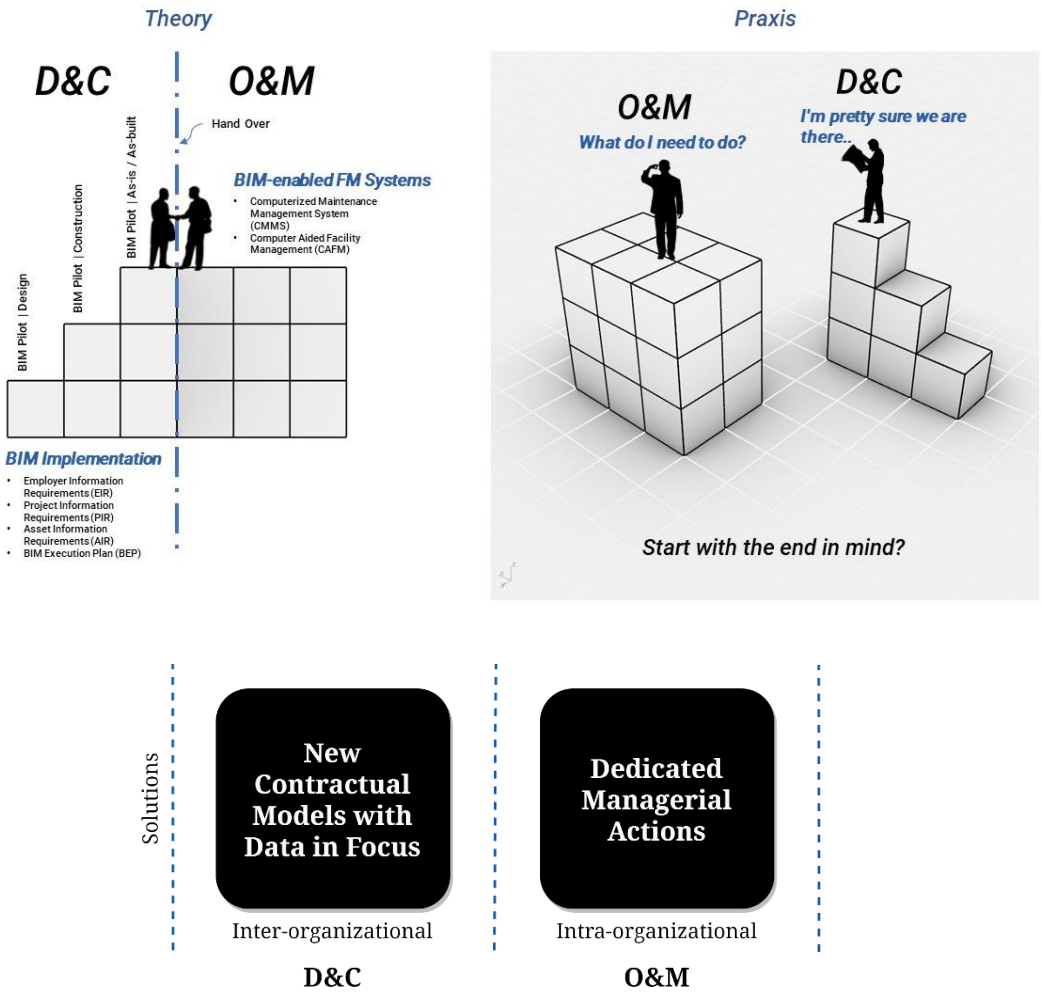



Figure 01 | Theory, praxis, and solutions to BIM D&C / O&M information transfer mismatch (by author)

BIM implementation has demonstrated benefits in D&C, such as improved productivity and collaboration among stakeholders, reduced construction costs, minimized waste, enhanced communication, efficient report production, and easier creation of design variants (Dixit et al., 2019; Lee & Borrmann, 2020; Ullah et al., 2019). However, its advantages for O&M remain less evident (Benn & Stoy, 2022; Dixit et al., 2019). These benefits primarily address the construction phase, as BIM workflows have been predominantly developed to manage design, construction, coordination, and communication during early project phases (S. Matarneh et al., 2019). While there is currently limited evidence supporting BIM's benefits for O&M, interest in this area is growing. This interest arises from estimates that 60% to 80% of a building's life cycle costs are incurred during the operational phase (see Figure 2), alongside the need to address various societal challenges while balancing organizational goals (Ashworth & May, 2023; Benn & Stoy, 2022; Wong et al., 2018).

Thus, academic discourse on BIM implementation by public clients has expanded beyond digitalization in D&C, which focuses on delivering Project Information Models (PIM), to include O&M through digital transformation initiatives that emphasize the need for improved Asset Information Models (AIM) (Benn & Stoy, 2022; Chan, 2020; Kuiper, 2021; Li et al., 2020; S. T. Matarneh et al., 2019; Watson et al., 2019). This involves leveraging a broader ecosystem of information technologies beyond BIM to effectively capture valuable information throughout the entire building life cycle, thereby enhancing the value of facility data.

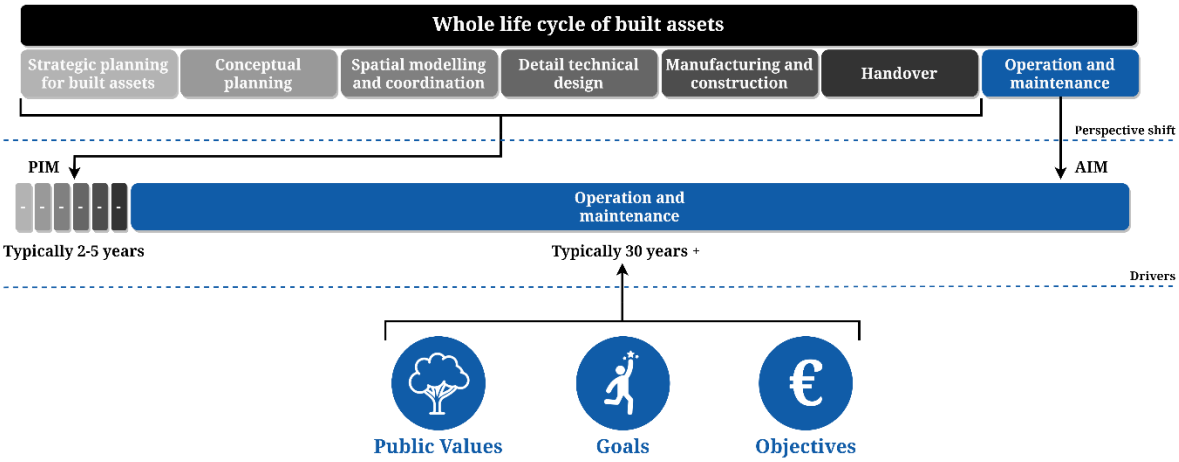



Figure 02 | The importance of the operating phase within the life cycle of a built asset
adapted from (Ashworth & May, 2023)

## 1.2 Problem statement

Surveys consistently show that the Architecture, Engineering, and Construction (AEC) sector lags behind other industries in implementing information technologies (Chan, 2020). Authors Ejohwomu et al. (2021) and Chan (2020) attribute this lag to the fragmented nature of the construction industry rather than a lack of technological capability. The AEC sector is often described as fragmented, project-based, and prone to significant budget overruns and scheduling issues (Chan, 2020; Lee & Borrmann, 2020; Siebelink, 2021; Wildenauer & Basl, 2021). Typically, construction projects are large, complex, and long-term, involving temporary project organizations composed of numerous disciplines and stakeholders (Lindblad & Guerrero, 2020; Winch, 2010). Traditionally, these collaborative project organizations operate in "silos," characterized by piecemeal information sharing and unclear task divisions among actors and stakeholders (Siebelink, 2021). This fragmentation is further exacerbated by the one-off nature of construction projects, which limits the broader application of innovative solutions since there are few incentives for market participants to share their competitive advantages (Lindblad & Guerrero, 2020).

The project-based mindset, combined with the declining value of project information at each handover stage in the project's life cycle (Eastman, 2011), leads to a loss of information value during phase transitions, as illustrated by the 'Traditional' path A shown in Figure 3. Consequently, the negative aspects of fragmentation extend beyond the AEC sector to affect O&M, as they are inherently interconnected. Furthermore, given the emerging value of facility data, Eastman's assumption that the value of information levels off during the O&M phase is no longer applicable.

In addition to the loss of information value due to compartmentalized information transfers throughout the asset life cycle, the AECOO sector has been notably resistant to technological

change and reluctant to adopt knowledge from other industries (Chan, 2020; Ejohwomu et al., 2021; Wildenauer, 2023). This resistance is often attributed to social factors, such as individual behavior, self-efficacy for change, and organizational support for change (Shirish & Batuekueno, 2021). Research by Shirish and Batuekueno (2021) found that in the cost-benefit analysis of technology adoption, an individual's behavioral intention to use the technology mediates the relationship between IT adoption and IT resistance. Therefore, they argue that addressing individual behavior is a key component of effective change management strategies and interventions. Capturing facility data throughout the asset life cycle is influenced by these individual behaviors, further complicated by the fact that information capture spans up to 30 years, during which both technology and personnel are likely to change. Currently, a long-term strategy for capturing and managing emerging facility data is not well established within the AECOO sector.

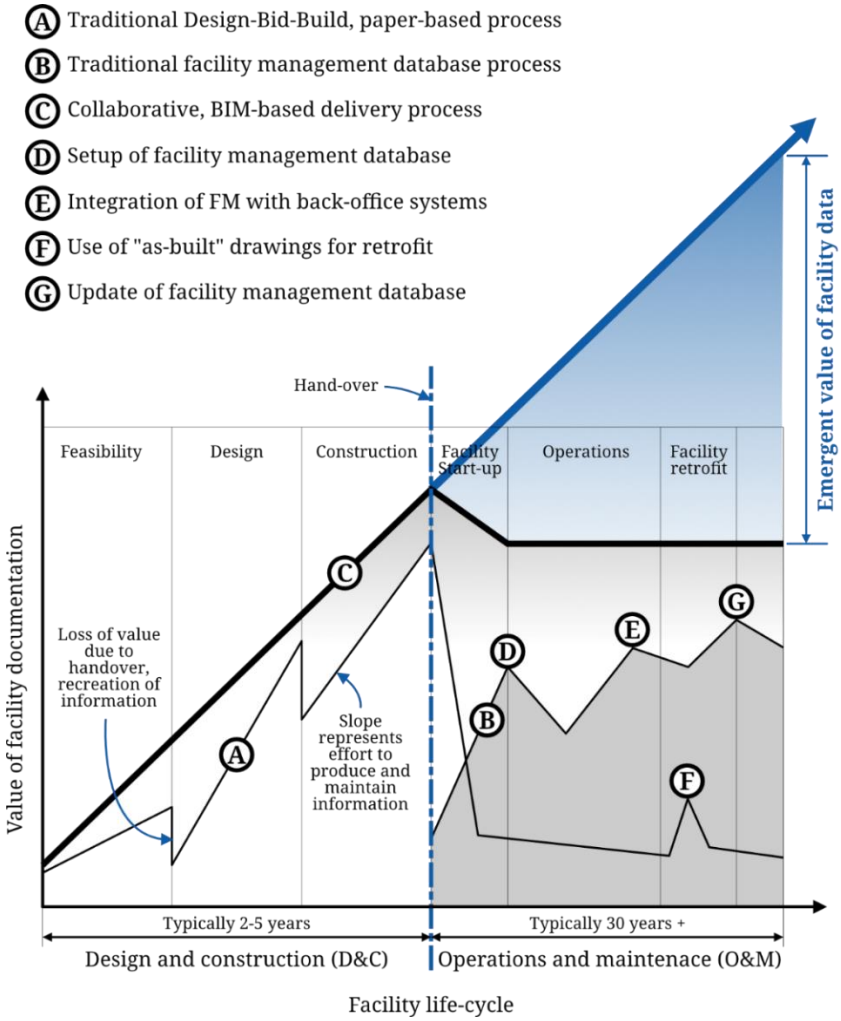



Figure 03 | Conceptual diagram of information flow
adapted from (Eastman, 2011)

Moreover, individual behavior is not always consistent when it comes to implementing new technologies, as hybrid approaches that combine new practices with old habits are common (Chan, 2020; Lindblad, 2019). Therefore, it is important to periodically evaluate the actual use of information technologies in relation to their perceived future value (Shirish & Batuekueno, 2021). This evaluation helps determine whether individual behavior aligns with the intended use of the technology, which is crucial for successful adoption. The gap between intended and actual behavior is described by Miles (2017) as a "practical-knowledge gap." This gap occurs

when professionals' actions do not align with their advocated practices (Miles, 2017). Kuitert et al. (2019) illustrate this gap in the public sector, noting that while procedural obligations are formally well-defined in public construction organizations, clients often revert to old patterns and behaviors. Unfortunately, this practical-knowledge gap hinders public clients' ability to fully leverage digitalization in the AECOO sector (Kuiper, 2021; Wildenauer & Basl, 2021).

In response, an increasing number of authors argue that a socio-technical approach is essential for successful technological adoption in the AECOO sector, including BIM. Some even suggest that greater emphasis on social factors may be needed to bridge the practical-knowledge gap (Abbasnejad et al., 2021; Chan, 2020; Ejohwomu et al., 2021; Lee & Borrmann, 2020; Lindblad & Karrbom Gustavsson, 2021; Siebelink, 2021; Wildenauer, 2023). While previous foundational research focused on defining technical standards, such as the ISO 19650 series, addressing the practical-knowledge gap requires developing explicit "game plans" tailored to meet specific client data needs (Wildenauer, 2023). Historically, research emphasized generalized concepts and standards to expand the use of information technology capabilities—a process-driven technological approach. However, many public clients across Europe are still struggling with their initial digitalization efforts, despite the availability of guidelines and standards (Charef et al., 2019; Fiamma & Biagi, 2023; Meins-Becker & Kaufhold, 2021). Additional research focusing on practical managerial aspects is needed to address these current challenges.

There is limited research on explicit BIM implementation guidelines that envision a comprehensive and holistic utilization of Project Information Models (PIM) in conjunction with Asset Information Models (AIM) throughout a building’s life cycle (Abbasnejad et al., 2021; Godager et al., 2021; Siebelink, 2021; Wildenauer, 2023)—in other words, deploying "winning game plans." Therefore, this research shifts focus from an industry-wide perspective to an inward, intra-organizational approach. The goal is to develop a method that considers an organization's goals, identifies its specific data needs, accounts for the barriers it faces, and aligns these factors to formulate comprehensive and holistic data demands. Thus, the research problem statement is:

> The lack of a well-defined, long-term strategy for capturing and managing facility data across the asset life cycle in the AECOO sector impedes public clients from formulating comprehensive and holistic data demands, limiting the impact of digital transformation efforts.

## 1.3 Research questions

To address the research problem, specific managerial actions are explored. This exploration aligns with suggestions by Kuitert et al. (2019), as these actions can be integrated into a continuous improvement approach that aims to break down information "silos" while addressing prevailing social factors. Therefore, the main research question derived is as follows:

> RQ: How can public clients develop a comprehensive and holistic framework for data demand formulation that aligns with their asset life cycle needs, organisational goals, and desired public values?

To answer the main research questions, the following sub-questions will be answered:

> SQ1: How do digitization, digitalization, and digital transformation relate to BIM implementation, and what strategies do public clients employ to manage these interconnected initiatives effectively?

SQ2: What theoretical framework can be used to evaluate an organization's current state in relation to its desired state in digital transformation adoption efforts?

SQ3: What are the organization's data needs, and how do they relate to its short- and long-term goals?

SQ4: What internal barriers, shortcomings, or peculiarities should be considered when formulating demands in accordance with the needs?

SQ5: What are the organization's data demands, and how are they communicated to market parties?

SQ6: What are the (mis)alignments between the needs, barriers, and demands in relation to the organization's short- and long-term goals?

SQ7: What are the essential elements needed to align organizational needs and barriers into effective data demands for public clients?

## 1.4 Relevance

### 1.4.1 Professional relevance

This research explores how public clients can improve intra-organizational information flow and knowledge transfer, aiming for a more comprehensive and holistic understanding of their information needs. The goal is to develop a management process that can be activated when formulating demands for procuring construction works and services. The practical relevance of this research lies in optimizing internal processes for public clients. This optimization results in more transparent communication, reduces redundant efforts in sourcing building data, saves time, and improves the quality of outcomes. It aims to break down intra-organizational communication "silos" and serves as a tool to set a vision for using information models throughout a building's life cycle.

Managers in public client organizations, at both strategic and operational levels within projects and CRM teams, can benefit from the findings of this research by highlighting their data needs early in the process. They can engage in a process that ensures information delivery meets their expectations and standards. Additionally, this research is relevant for policymakers looking to enhance digitalization and address the challenges associated with Industry 4.0 technologies in the built environment. While much has been written about BIM implementation in client organizations, limited knowledge exists about how the Industry 4.0 paradigm impacts the established BIM paradigm and its related policies. Understanding the interaction between these two paradigms from a public client perspective may offer new insights for policymakers aiming to advance digitalization in the built environment.

### 1.4.2 Societal relevance

The quality of our built environment plays a crucial role in mitigating the effects of climate change, as highlighted by the United Nations' 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) (UN, 2015). Notably, SDG 11 focuses on sustainable cities and communities. To achieve these SDGs, the concept of a Circular Economy (CE) has been proposed, which is defined as "an economic system based on the reusability of product components, recycling of materials, and the conservation of natural resources while creating added value in every link of the system" (Potting et al., 2017).

A foundational element of transitioning to a circular built environment is sustainable procurement, often referred to as Green Public Procurement (GPP). The European Commission defines GPP as "a process by which public authorities seek to procure goods, services, and works with a reduced environmental impact throughout their life cycle compared to alternatives with the same primary function" (Bidin et al., 2022; Finamore & Oltean-Dumbrava, 2022). GPP requires public clients to formulate demands that include information on the desired sustainability aspects. This information is essential for quality control, validation, and effective asset life cycle management (Bougrain, 2020; Finamore & Oltean-Dumbrava, 2022).

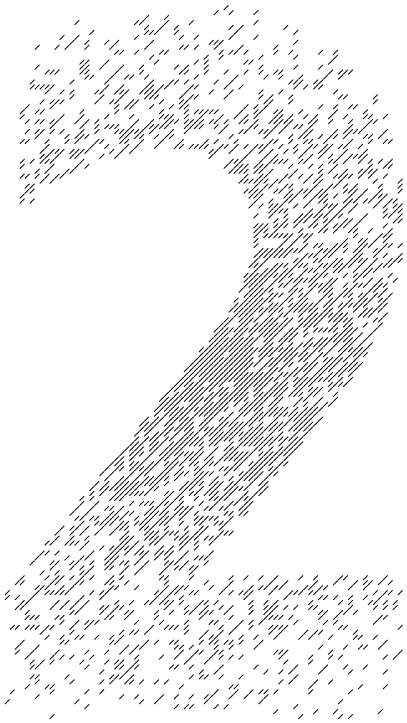
The societal relevance of this research lies in its contribution to improving the demand formulation process, which enables more effective delivery of public values, including fostering a sustainable built environment.

### 1.4.3 Scientific relevance

Despite the extensive literature on the slow and challenging adoption of digitalization in the AECOO sector, the emphasis on digitalization in the built environment, particularly within the public sector, remains an important research focus. The role of public clients in driving industry change is widely regarded in the literature as a key strategy to address fragmentation in the construction industry (Al Ahbabi & Alshawi, 2015; Kuitert et al., 2019; Lee & Borrmann, 2020; Lindblad & Guerrero, 2020). Kuitert et al. (2019) further elaborate on this by stating that "[public] clients have no tools, except stimulation or dedicated managerial actions, to actively implement new [public] values" in the delivery of public services such as construction projects. Since the industry is already highly regulated and mature, there are limited alternative avenues for exploring solutions.

This research contributes to the academic discourse on the significance of the role and policy positioning of public clients when promoting initiatives that realize public values.

—End of Chapter—



# 2 Methodology

## 2.1 Research methods

### 2.1.1 Research design

This research examines a case study: the Bau- und Liegenschaftsbetrieb NRW (BLB NRW) in Germany. Three key factors guided the selection of the case. First, the organization needed to have undertaken digitalization efforts to ensure the availability of relevant data and individuals with experience in digital processes and methods. Second, access to the organization was crucial, with mentors playing a key role in leveraging their networks to secure access. Third, given the scope of a master's graduation project, time constraints limited the analysis to one case.

The research employs a mixed-method exploratory sequential design, incorporating semi-structured interviews, document analysis, and both internal and external validation through focus groups to gather qualitative and quantitative data. Figure 4 illustrates the sequence of research methods, applying retroductive logic to uncover underlying structures or mechanisms that explain observed patterns (Blaikie & Priest, 2019). The ontological assumption aligns with depth realism, while the epistemological assumption follows a neo-realist perspective. The research paradigm is based on critical realism, which Blaikie and Priest (2019) define as:

> *"Reality consists not only of events that are experienced but also of events that occur whether experienced or not, and of the underlying structures and mechanisms that produce these events. The aim of science is to discover these structures and mechanisms, some of which may be reasonably accessible using instruments that extend the sense. This is done by building hypothetical models of them and then searching for evidence of their existence."*

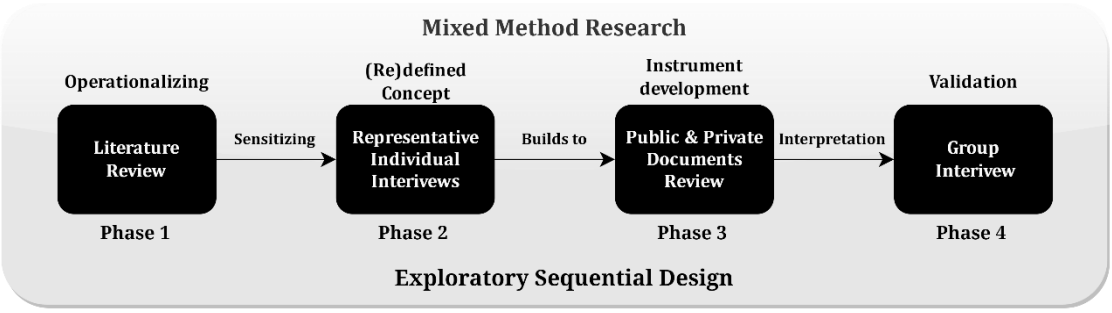



Figure 04 | Visualization of research methods, exploratory sequential design (by author)

### 2.1.2 Conceptual model

Figure 5 presents the research conceptual model, which shows the relationship between the research methods and the research questions. The first phase of the research involves a literature review, which was used to develop the theoretical framework, operationalize research concepts, and create the research instrument for data analysis. Phase 1 addresses Sub-question 1 (SQ1): "How do digitization, digitalization, and digital transformation relate to BIM implementation, and what strategies do public clients employ to manage these interconnected initiatives effectively?" and Sub-question 2 (SQ2): "What theoretical framework can be used to evaluate an organization's current state in relation to its desired state in digital transformation adoption efforts?"

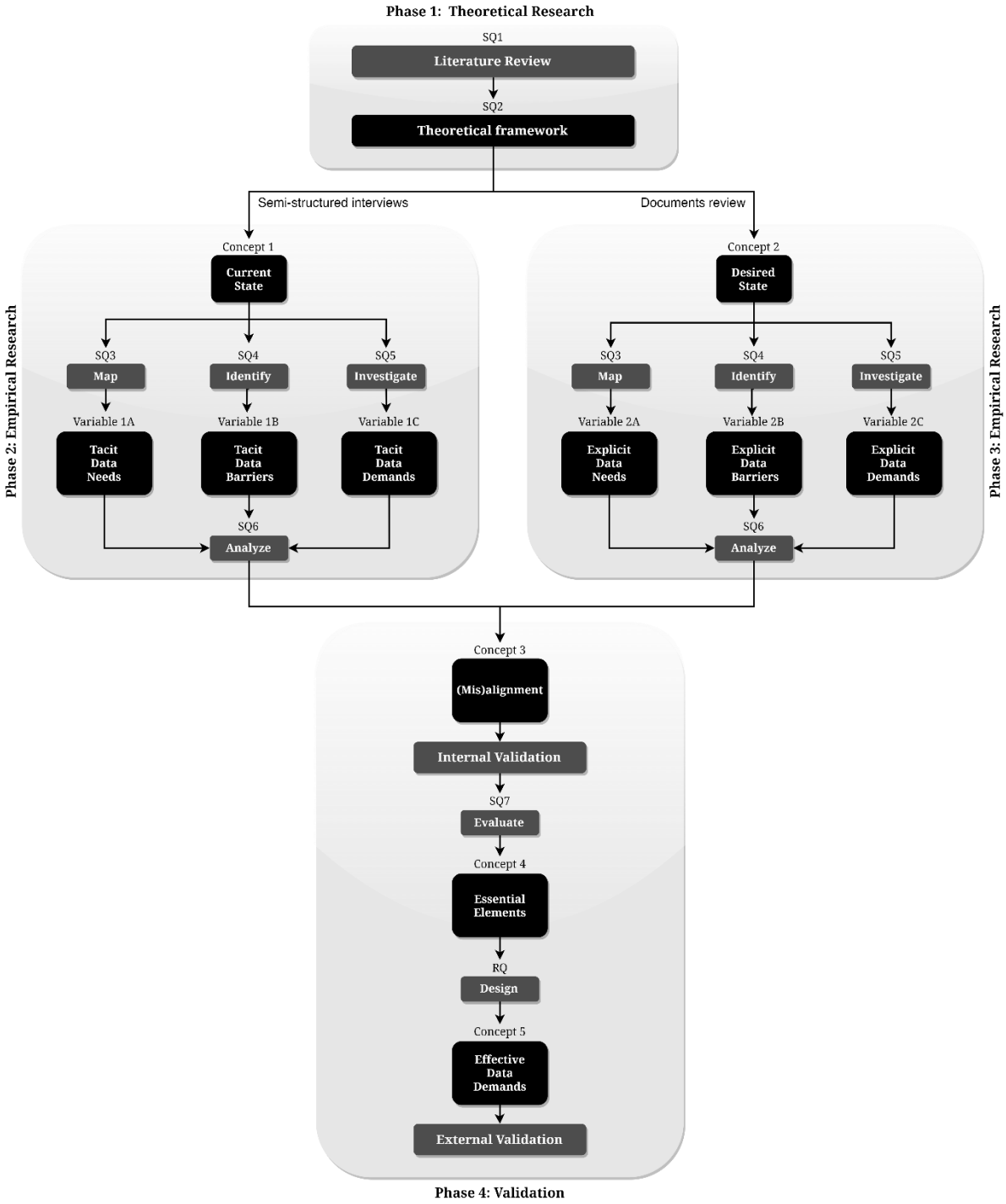



Figure 05 | Conceptual model
(by author)

The empirical research in Phases 2 and 3 aims to establish two constructs for digital transformation adoption efforts that can be contrasted and evaluated: the *current state* (Concept 1) and the *desired state* (Concept 2). This approach is commonly used to assess both enterprise activities and project-based outcomes, such as the adoption of information technology (Godager et al., 2021; Shirish & Batuekueno, 2021). Kuiper (2021) supports this notion, noting that an organization's awareness of a policy often differs from actual adoption or implementation, highlighting a gap between the "should" and "is" situations. Kuiper (2021) further argues that, while policy may set the "right path," implementation often falls short of being "perfect," which

aligns with Kuitert et al.'s (2019) observations of public clients reverting to old patterns and behaviors. Therefore, establishing these two constructs—current and desired states—is an important first step in evaluating an organization's process.

The *current state* (Concept 1) is based on the organization's tacit knowledge. Tacit (implicit) knowledge, gained through experience, is deeply rooted in action, commitment, and context, and is often held by individuals or specific groups, making it inherently challenging to document, formalize, and communicate at the organizational level (Dossick & Neff, 2011; Nonaka, 1994). Since this type of information is rarely or only partially documented, qualitative data was collected through semi-structured interviews with key organizational actors involved in operational information management across asset life cycle phases, departments, and branches, as well as individuals responsible for strategic planning in digitalization and digital transformation efforts. By engaging diverse perspectives from various roles across the organization, the most prominent and overlapping *tacit data needs* (Variable 1A), *tacit data barriers* (Variable 1B), and *tacit data demands* (Variable 1C) were identified.

The *desired state* (Concept 2) is based on the organization's explicit knowledge. Explicit knowledge is formal, codified, and can be readily documented and communicated at the organizational level (Dossick & Neff, 2011; Nonaka, 1994). (Dossick & Neff, 2011; Nonaka, 1994). Since this information is formal and documented, quantitative data was collected through reviews of policies, guidelines, internal process audits, and project demand formulations. By analyzing various documents related to different aspects of an asset's life cycle, *explicit data needs* (Variable 2A), *explicit data barriers* (Variable 2B), and *explicit data demands* (Variable 2C) were identified.

Phases 2 and 3 collectively address sub-questions 3 to 6. Sub-question 3 (SQ3), "What are the organization's data needs, and how do they relate to its short- and long-term goals?" is a compound question with two parts: Part 1 is addressed in both Phases 1 and 2 through Variables 1A (*tacit data needs*) and 2A (*explicit data needs*). To align data needs with the organization's goals, these needs are mapped to the relevant asset life cycle phase for each goal.

Sub-question 4 (SQ4), "What internal barriers, shortcomings, or peculiarities should be considered when formulating demands in accordance with the needs?" aims to identify BLB NRW's current implementation barriers and shortcomings, represented by Variables 1B (*tacit data barriers*) and 2B (*explicit data barriers*). Sub-question 5 (SQ5), "What are the organization's data demands, and how are they communicated to market parties?" investigates how BLB NRW's informal and formal data demands are expressed, represented by Variables 1C (*tacit data demands*) and 2C (*explicit data demands*).

Sub-question 6 (SQ6), "What are the (mis)alignments between the needs, barriers, and demands in relation to the organization's short- and long-term goals?" serves as the analysis phase for the findings from SQ3, SQ4, and SQ5. Its purpose is to highlight the *(mis)alignments* (Concept 3) between the tacit and explicit data needs, barriers, and demands currently present in BLB NRW. This is done by comparing each corresponding variable across the two phases (e.g., Variable 1A to 1B) as well as analysing differences between variables within each phase (e.g., Variable 1A, 2A, and 2C).

The results of the analysis from SQ6 mark the beginning of the validation phase (Phase 4). This phase starts with internal validation in a focus group setting, where the session prioritizes the (mis)alignments identified in the analysis. Based on these priorities, the topics from the (mis)alignment analysis are distilled into a set of *essential elements* (Concept 4), which addresses

Sub-question 7 (SQ7): "What are the essential elements needed to align organizational needs and barriers into effective data demands for public clients?"

Finally, the main research question (RQ), "How can public clients develop a comprehensive and holistic framework for data demand formulation that aligns with their asset life cycle needs, organizational goals, and desired public values?" is addressed by first applying the essential elements to the theoretical framework. This process yields a set of critical paths that identify required managerial solutions for achieving *effective data demands* (Concept 5). To illustrate the application of the theoretical framework, managerial solutions were designed to address the highest-priority essential elements. Lastly, the designed solutions and the theoretical framework's application were reviewed in an external validation focus group to assess their utility.

## 2.2 Ethical considerations and data management

### 2.2.1 Protecting participants

As the host organization, BLB NRW provided the author with data access through an internship agreement. Throughout the research, it was crucial to protect respondent anonymity to prevent potential workplace repercussions, such as a loss of trust with the host organization, which could lead to job loss or other negative consequences. To encourage honest responses, a safe environment was fostered through timely communication and clear, accessible explanations of the research objectives. Each participant received an informed consent form detailing the consent points and an information letter outlining the research scope and their role (see Appendices 2 and 3). Additional protective measures included pseudonymizing identifiable attributes and appointing an Organization Data Manager to review pseudonymized data before dissemination.

During the internal document analysis phase, no personal information, competitive details, or identifiers of specific projects, such as project names or locations, were made publicly available. Additionally, the internal documents themselves were not included in the research publication. Data collected from these documents was pseudonymized during the analysis phase, and only pseudonymized data was used in this study. Appendix 6 provides a comprehensive Data Management Plan, detailing the data descriptions, collection methods, storage practices, any collected personally identifiable information, and protection measures for sensitive data. Figure 6 illustrates this data management plan.

### 2.2.2 Data collection

The research was conducted from early February to the end of April 2024 at the host organization's headquarters in Düsseldorf, Germany. The internship took place within the Department of Planning, Construction, and Instruments, specifically in the Construction Management Division, which oversees the strategic development and implementation of digital methods for managing construction processes. Data collected during the internship included transcribed audio recordings of semi-structured interviews with key individuals from both the headquarters and nearby branch offices, notes from focus group interviews with selected individuals for internal validation of preliminary findings, and excerpts from policy and project-related documents that explicitly addressed data requirements. A final focus group interview for external validation was conducted as the concluding step.

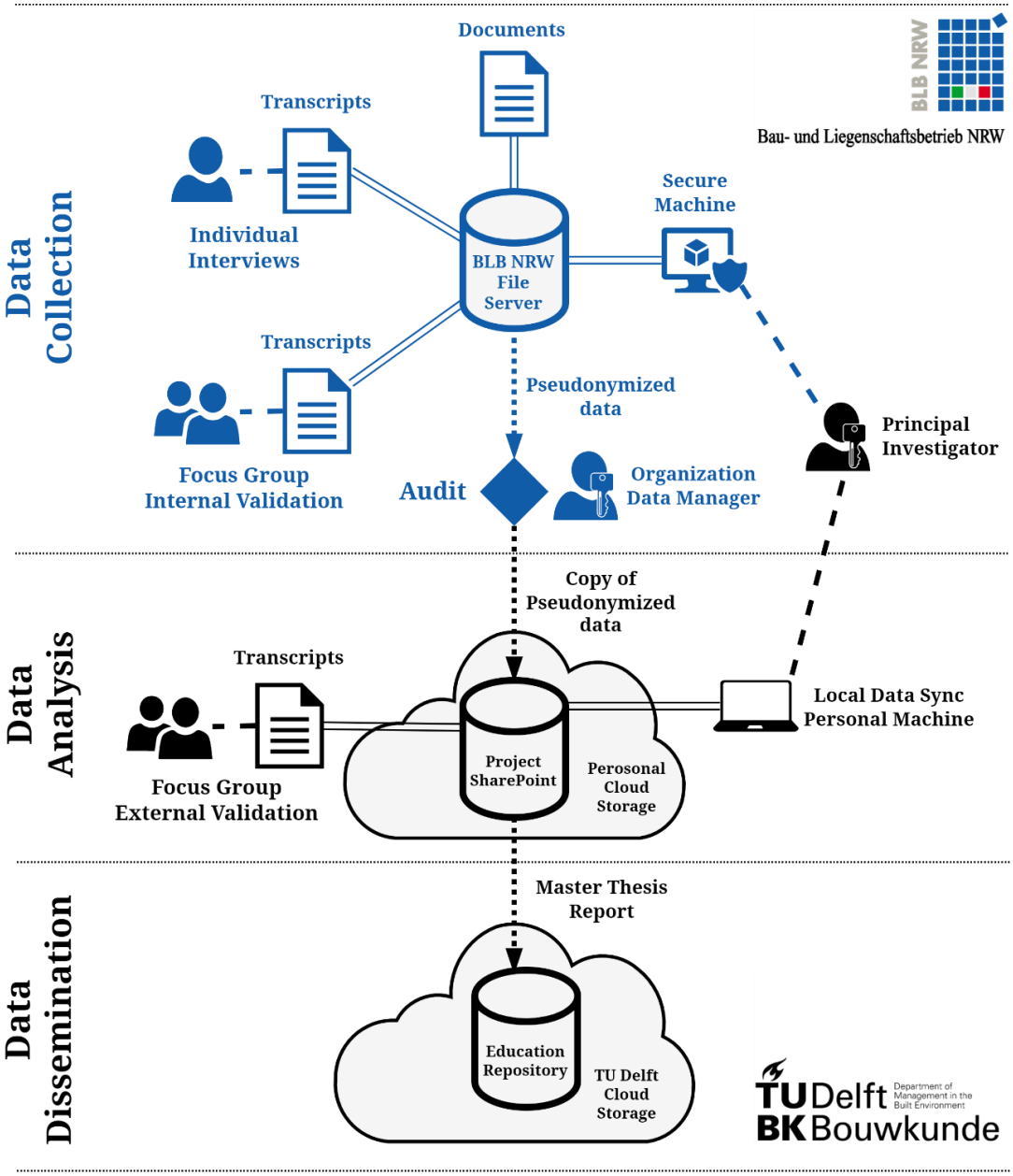



Figure 06 | Data storage of research phases
(by author)

### 2.2.3 Data storage

As a public organization, BLB NRW adhered to strict data security and storage protocols. Access to the organization's documents and other collected data was restricted to the BLB NRW server, where it was stored locally. The author (Principal Investigator) was granted access to the server via a user account created as part of the internship, allowing log-in to networked machines within the BLB NRW premises. This access enabled the author to work directly with the relevant research data. Raw audio recordings from interviews and their transcriptions were saved locally on the BLB NRW server. Collected data was pseudonymized and shared with each participant for review and approval. To ensure compliance with internal data protection protocols, the organization's Data Manager was consulted. Once approved, the pseudonymized data was downloaded to the author's personal storage for further formatting, analysis, and presentation. Due to data privacy policies, the raw pseudonymized data is not part of the

publicly accessible research publication; however, it may be made available upon request with the host organization's approval.

### 2.2.4 Data dissemination

This report will be publicly accessible in the TU Delft Education Repository. All relevant data that does not compromise participant anonymity or violate data protection policies will be included in the appendices. As stipulated in the internship agreement between the author and the host organization, ownership rights to the findings from the graduation project are retained by Bau- und Liegenschaftsbetrieb NRW. Any third-party use of information contained in this report requires approval from the host organization. For related inquiries, please contact the Principal Investigator (the author).

—End of Chapter—

# 3 Theoretical research

## 3.1 Digitization, digitalization, and digital transformation

A clear distinction between the terms digitization, digitalization, and digital transformation is needed, as their definitions and usage vary across languages and sectors (Vrana & Singh, 2021). In this research the following definitions are used:

| | | |
|---|---|---|
| Digitization: | The conversion of analogue (physical) information into digital (binary) data formats. | (Koutamanis, 2022; Vrana & Singh, 2021) |
| Digitalization: | The process by which digital data is used by information technology (IT) to simplify specific operations. | (M. May et al., 2023; Vrana & Singh, 2021) |
| Digital transformation: | The concepts and methods used to deploy and implement information technology to create added value for an organization. | (M. May et al., 2023; Vrana & Singh, 2021) |

### 3.1.1 Data, information, knowledge semantic levels

The relationship between data, information, and knowledge has been described in the context of knowledge management as a "learning ladder," where data serves as the foundation of objective facts, progressively building up to subjective models (Ford, 2024; Parsanezhad, 2015). Ford (2024) links the knowledge ladder to complexity, information management, actions, knowledge types, political influences, and practice type to illustrate how data impacts the decision-making effectiveness (see Figure 7).

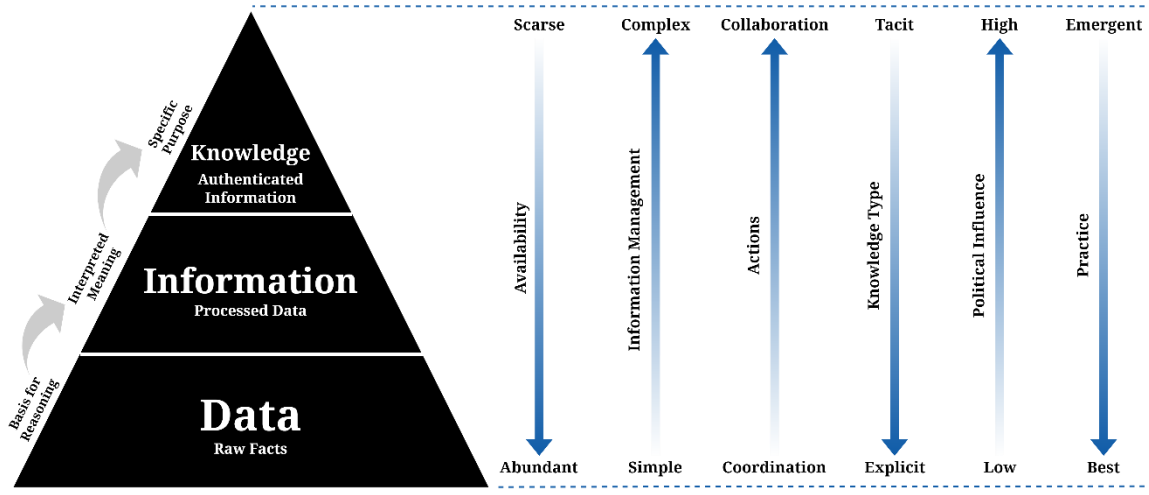



Figure 07 | Knowledge semantic levels and relationships to domains
Adapted from (Ford, 2024; Parsanezhad, 2015)

In discussing the domain of actions, Ford (2024) emphasizes that as individuals transition from coordination settings to collaborative settings, decision-making effectiveness improves

significantly. Furthermore, political influence tends to increase with complexity, while the mediator between tacit and explicit knowledge directly correlates with the abundance of data. Finally, emergent practices are associated with tacit knowledge, whereas best practices are aligned with explicit knowledge. In the context of knowledge management, where various interpretations and definitions of data, information, and knowledge exist, this research adopts the following definitions:

| | | |
|---|---|---|
| Data: | Raw, numeric, and basic facts used as basis for reasoning, discussion, or calculation. | (Koutamanis, 2022; Parsanezhad, 2015) |
| Information: | One or more data that have interpreted meaning, relevance, and context. | (Koutamanis, 2022; Parsanezhad, 2015) |
| Knowledge: | Information that is authenticated against specific purpose of an organization or actor. | (Parsanezhad, 2015) |
| Tacit knowledge: | Personal, experience-based knowledge that is difficult to articulate or share, often involving skills, intuition, and insights. | (Ford, 2024; Nonaka, 1994) |
| Explicit knowledge: | Formalized knowledge that is easily documented, communicated, and shared, such as manuals, databases, or written instructions. | (Ford, 2024; Nonaka, 1994) |

Based on the selected definition of "data," no reference is made to its format, which can be either analogue (physical) or digital (Vrana & Singh, 2021). While analogue data formats remain prevalent in both D&C and O&M, digitization efforts explicitly aim to address this challenge. This research recognizes digitization as a distinct process that falls outside its scope, focusing instead on the transition from digitalization to digital transformation. Consequently, the term “data” in this research refers exclusively to digital formats.

Digital data formats can be categorized into three types: structured, semi-structured, and unstructured data, with BIM classified as structured data (Koutamanis, 2022). The definitions of the three data formats are as follows:

| | | |
|---|---|---|
| Structured data: | Data organized in a precise and predefined format, making it easy to store, search, and analyse, such as relational databases. | (Koutamanis, 2022) |
| Semi-structured data: | Data with some organizational structure, such as tags or metadata, but without a fixed schema, such as XML files. | (Koutamanis, 2022) |

| | | |
|---|---|---|
| Unstructured data: | Data without a defined format or organization, often complex and harder to analyse, such as text, images, or videos. | (Koutamanis, 2022) |

## 3.2 Building information modelling

Building Information Modelling (BIM) is a collaborative working method used by participants in construction projects and asset management to create information models throughout both the design and operational phases of a project's life cycle (ISO, 2018). Building information models consist of model elements interlinked through a spatial and logical scheme, based on an object-oriented data structure that integrates alphanumeric attributes with graphical geometric data (VDI, 2020). Whereas, information models are composed of “information containers,” each containing retrievable information stored within a file, system, or application storage hierarchy (ISO, 2018). Building information models represents only a subset of the broader information model created during a specific life cycle phase, which also includes documents, spreadsheets, schedules, and other related data. The ISO 19650 series classifies information models into Project Information Models (PIM), created during the D&C phase, and Asset Information Models (AIM), created during the O&M phase. The primary terms related to BIM in this research are defined as follows:

| | | |
|---|---|---|
| Building Information Modelling: | Use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions. | (ISO, 2018) |
| Building Information Model: | Data model consisting of model elements interlinked through a spatial and logical scheme, based on an object-oriented data structure that integrates alphanumeric attributes with graphical geometric data. | (VDI, 2020) |
| Information Models | Set of structured and unstructured information containers | (ISO, 2018) |
| Asset Information Model: | Information model relating to the operational phase | (ISO, 2018) |
| Project Information Model: | Information model relating to the delivery phase | (ISO, 2018) |
| Alphanumeric Data: | Data type consisting of letters, numbers, symbols or spaces. | (Vrana & Singh, 2021) |
| Graphical Data: | Data type visually representing spatial elements such as surface and geometric objects. | (Vrana & Singh, 2021) |

The ISO 19650 series describes PIM a nested system of information models; however, it does not provide illustrations to clarify these relationships. This omission is due to the variability in how information models relate to each other, depending on the available information technology and the use cases selected for modeling.

Figure 8 offers an interpretation of the relationship between the building information model, information models, and project information models during the “spatial modeling and coordination” phase of the project life cycle. In this context, multiple use cases generate information models grouped by discipline. Each of these models contains at least one distinct building information model that satisfies the requirements of its respective use case. Collectively, these various information models constitute the PIM for this phase. At the beginning of the next phase, a new set of use cases generates a fresh set of information models, forming the PIM for that phase.

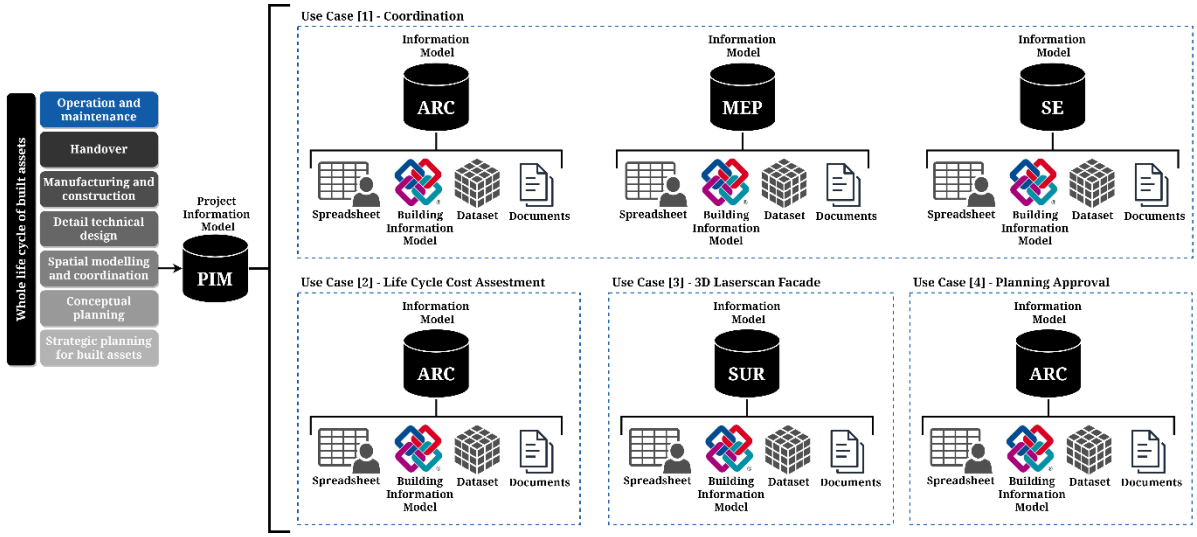



Figure 08 | Information models hierarchy
(by author)

### 3.2.1 Converging Paradigms

We are currently experiencing the Fourth Industrial Revolution, known as Industry 4.0, a term introduced in Germany by Wolf-Dieter Lukas in the April 2011 article, "Industry 4.0: With the Internet of Things Toward the 4th Industrial Revolution" (Chan, 2020; Kagermann & Wahlster, 2022). Industry 4.0 refers to the vertical integration of digital technologies that enable automation, data exchange, and other "smart solutions." It encompasses technologies and principles such as the Internet of Things (IoT), Big Data Analytics, Artificial Intelligence (AI), Cloud Computing, Augmented Reality (AR), Digital Twins (DT), and advancements in Cybersecurity, among others (Kagermann & Wahlster, 2022).

Yet, Industry 4.0 is often misunderstood as simply "automation replacing people." The core concept is to enhance human productivity through advanced systems and collaborative robots, making it inherently focused on human-centred development (Kagermann & Wahlster, 2022). Chan (2020) describes Industry 4.0 as having "manufactured the (re-)imagination of a brave new mass-personalized and self-configured world deemed to become more efficient and flexible." Efficiency and flexibility are key values that reflect the top societal priorities of the digital age.

Around the time of Industry 4.0's introduction, early BIM-adopter nations such as the USA, UK, Norway, Sweden, and Finland began publishing national standards and guidelines for BIM

implementation (Stange, 2020). Table 1 highlights some of these notable publications. Of particular importance for the European public sector is the European Commission directive 2014/24/EU, which recommends that member states use BIM for public construction works and design purposes (Ullah et al., 2019). As a result, the EUBIM Task Group was formed to develop more specific recommendations (EUBIM Task Group, 2017; Stange, 2020). The EUBIM Handbook, published in 2017, endorsed the adoption of vendor-neutral data exchange formats with open standards, specifically recommending the ISO 16736 Industry Foundation Classes (IFC) file format (EUBIM Task Group, 2017). To this day, BIM has primarily focused on delivering information models in file formats, particularly the IFC file format for the European public sector.

| | Pioneering | | | | Independent Developments | | | | | | Standardized | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ISO | | | | | | | 16736 | | | | | 19650-1<br>19650-2 |
| EU | | | | | | | | 2014/24/<br>EU | | | EUBIM<br>Handbook | |
| USA | NBIMS<br>v1.0 | | GSA 3-5 | | GSA 8 | NBIMS<br>v2.0 | | | NBIMS<br>v3.0 | | | |
| Australia | | | CRC | | NATSPEC | | | | | | | |
| UK | 1192-1 | | | | 8541-2 | 8541-1<br>8541-3 | 1192-2 | 1192-3<br>1192-4 | 7000-4 | | | |
| Denmark | | Bips<br>v1.0 | | | | Bips v.1.1 | | | | | | |
| Norway | | Statsbyg<br>v1.0 | Statsbyg<br>v1.1 | | Statsbyg<br>v1.2 | | Statsbyg<br>v1.2.1 | | | | | |
| Finland | Senate<br>v1.0 | | | | | COBIM<br>v1.0<br>Senate<br>v2.0 | | | Senate<br>v3.0 | | | |
| Sweden | | | Bygg 90 | | | | | | | | | |
| Netherlands | | | | | | Rgd v1.0 | Rgd v1.1 | | | | | |
| Germany | | | | | | | | Guidelines | Step-<br>by-step<br>plan | | VDI 2552 | |
| Singapore | | | | | | BIM<br>Guide<br>v1.0 | BIM<br>Guide<br>v2.0 | | | | | |
| Hong Kong | | | BIM<br>Manual | | HKBIMS<br>Specs | | | HKBIMS<br>ExecPlan | CIC<br>v1.0 | | | |
| Japan | | | | | | JIA BIM<br>Guideline | | | | | | |
| China | | | | | | | BIM<br>Civil | CIBSDR | BIM-<br>Guide | | | |
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |

Table 01 | Overview of the adoption of BIM Standards
adapted from (Stange, 2020)

However, Industry 4.0 goes beyond file-based data types, emphasizing data formats that enable seamless data exchange (Kagermann & Wahlster, 2022). This paradigm shift has sparked new research aimed at expanding the application of BIM under Industry 4.0 principles. Terms such as "BIM to Digital Twin (BIM2DT)," "BIM for Facilities Management (BIM4FM)," and "BIM for Corporate Real Estate Management (BIM4CRM)" are now commonly found in literature exploring this new paradigm (Benn & Stoy, 2022; Deng et al., 2021; S. T. Matarneh et al., 2019; Tsay et al., 2022). Thus, incorporating the concepts of Industry 4.0 into the AECOO sector is highly relevant to today's academic discourse.

The gradual development of the BIM paradigm has been too slow in comparison to Industry 4.0, making it challenging to consolidate the two paradigms and thereby negatively impacting BIM's relevance. Current research on expanding BIM applications frequently highlights issues such as interoperability challenges, data loss during file conversion, incompatibility with both new and

existing computerized management systems, and, most critically, the omission of essential data needed for the O&M phase (Benn & Stoy, 2022; Deng et al., 2021; S. T. Matarneh et al., 2019; Tsay et al., 2022).

There remains considerable uncertainty about how to effectively integrate the BIM and Industry 4.0 paradigms, a gap that has significantly hindered BIM adoption, particularly within public client organizations. The AEC sector is already well known for its resistance to change and the slow adoption of new technologies. Meanwhile, public clients are often seen as "agents of change" who are expected to drive innovation in the construction industry (Lindblad & Guerrero, 2020). This creates a challenging balancing act for public clients: they must manage the internal organizational aspects of BIM adoption while also attempting to influence external stakeholders across the broader construction industry. As a result, many public clients struggle to determine where to begin.

Compounding these challenges, Industry 4.0 solutions are often touted as being more efficient and flexible, leading organizations to consider an expanding range of technological tools. This has created confusion among policymakers, who may mistakenly equate BIM with all aspects of Industry 4.0 (Kuiper, 2021). The fragmented approach to data in the built environment further complicates the use of the term BIM. BIM is often misconstrued to include all matters related to the "digital," "data-related," or "data-oriented" aspects of the built environment, or vice versa (Kuiper, 2021). For example, government documents often use the term "BIM implementation" as synonymous with the broader goal of digitalizing the built environment. This confusion is compounded by the lack of consensus in the literature regarding the definition of BIM, as interpretations range from a technological tool to a methodology and/or a process-oriented approach (Abbasnejad et al., 2021; Kuiper, 2021). The relationship between BIM and the overall data repository of a built asset remains a topic of ongoing research. Regardless of the medium, the focus of this study is data in the built environment. Figure 9 illustrates the convergence of these paradigms, driven by digitalization efforts.

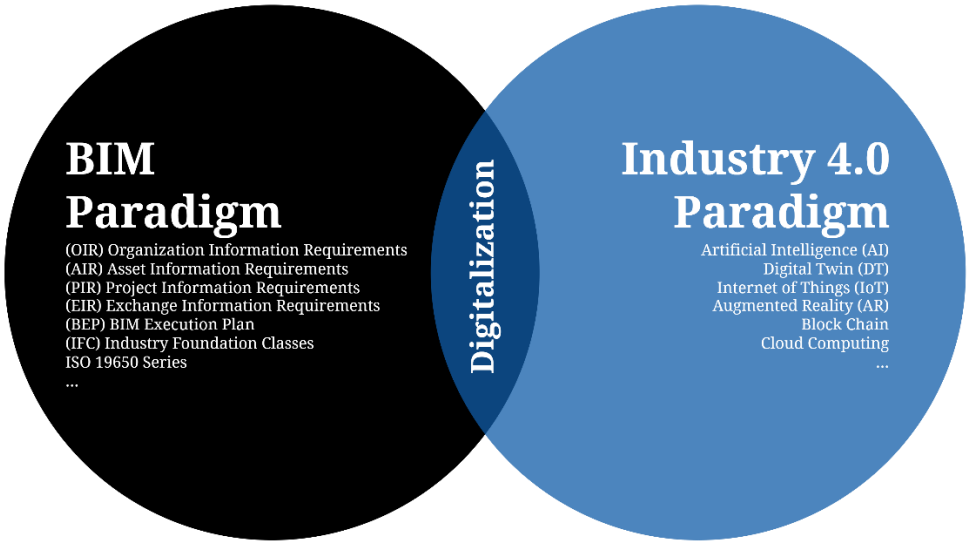



Figure 09 | Converging paradigm
(by author)

### 3.2.2 Information exchange protocols and guidelines

Public clients aiming to digitalize must first consider regional guidelines and standards, such as the ISO 19650 series (Meins-Becker & Kaufhold, 2021). The ISO 19650 series represents a significant milestone in digitalization efforts within the AECOO sector, offering guidance on

information management. However, its practical implementation is not yet widespread or standardized (Siebelink, 2021; Wildenauer, 2023).

Currently, an organization's data demands are documented within the Exchange Information Requirements (EIR). Figure 10 illustrates the hierarchy of information requirements in relation to an organization's needs and demands in accordance with the ISO 19650 series. The EIR serves as the legal framework for public procurement of BIM and should align with an organization's BIM goals while specifying the relevant BIM use-cases (ISO, 2018).

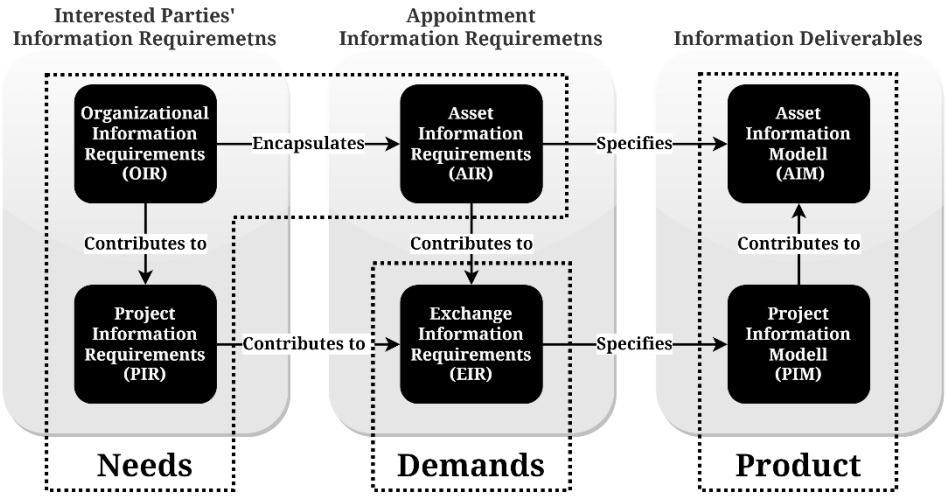



Figure 10 | Hierarchy of information requirements
adapted from (ISO, 2018)

Due to a history of uncoordinated development and slow BIM adoption (Stange, 2020), multiple EIR templates have been developed independently, resulting in a variety of approaches: top-down (client-driven), middle-out (project-driven), and bottom-up (consultant/market-driven) (Kuiper, 2021). Recognizing this complexity, ISO 19650 renamed "Employer Information Requirements" to "Exchange Information Requirements" to better reflect the diverse roles involved. Despite this adoption, many EIR templates today still do not conform to ISO 19650 guidelines.

In the Netherlands, research by Dutch BIM Loket identified seven types of EIR templates in use, with only two complying with the ISO 19650 guidelines (Bruggeman, 2020). Furthermore, an EIR can be developed for BIM use-cases focusing on either the realization of construction works, the delivery of digital building assets, or both. Inexperienced clients often lack the in-house expertise needed to define BIM goals and effectively manage the derived BIM use-cases (Charef et al., 2019; Kuiper, 2021). Consequently, this leads to situations where the EIR is underdeveloped for some use cases and overdeveloped for others (Bruggeman, 2020; Kuiper, 2021).

Simply adopting a nationally developed or commercially available EIR template does not solve this issue. Each organization has different goals and underlying strategies to achieve them (Kämpf-Dern & Pfnür, 2014). Adopting an external EIR template requires a process of adaptation to ensure it meets the specific needs of the organization. In her dissertation, Kuiper (2022) emphasizes that "references to BIM-based examples from different jurisdictions and organizations can assist but addressing local or localized needs may be necessary for application." Therefore, when it comes to EIR templates, there is no one-size-fits-all solution, nor are there shortcuts.

### 3.2.3 Status quo of BIM Implementation in public client organizations

In the European construction sector, recent research has highlighted a significant gap in the adoption of BIM across the 28 EU countries. Charef et al. (2019) reports that over a quarter of member states do not have any BIM mandates in place, while 25% have implemented mandates, and the remainder have announced future adoption plans that have not yet come into effect. According to a survey conducted as part of this research, 63% of respondents believe this disparity negatively affects the EU economy, while 88% feel that a unified EU-wide approach would have a positive economic impact.

The current EU-wide BIM strategy is described in the EUBIM Handbook and was heavily influenced by the UK's PAS 1192 series, the predecessor of the ISO 19650 series (Lee & Borrmann, 2020; Stange, 2020). The The PAS 1192 series detailed the BIM implementation process within client organizations, emphasizing a continuous improvement approach and identifying key components such as Employer Information Requirements (EIR) and the BIM Execution Plan (BEP) (Al Ahbabi & Alshawi, 2015).

The continuous improvement approach was defined as a step-by-step methodology in which a client's BIM maturity level advances with each completed phase (Al Ahbabi & Alshawi, 2015). BIM maturity capabilities are developed by gradually increasing the complexity of BIM requirements at each stage, typically using pilot projects to test and enhance these capabilities. Lessons learned from pilot projects help refine the BIM implementation process, as feedback from external actors can be incorporated into the broader strategy. This approach also enables clients to monitor and improve their performance over time (Al Ahbabi & Alshawi, 2015).

In the UK, the components of maturity levels are explicitly defined in the BSI B/555 norm (Al Ahbabi & Alshawi, 2015). In contrast, the ISO 19650 series does not provide specific descriptions, leaving each client organization to define the requirements that constitute its maturity level, while only offering general principles about what should be included (ISO, 2018). Figure 11 illustrates the continuous improvement approach to BIM implementation according to the PAS 1192 series.

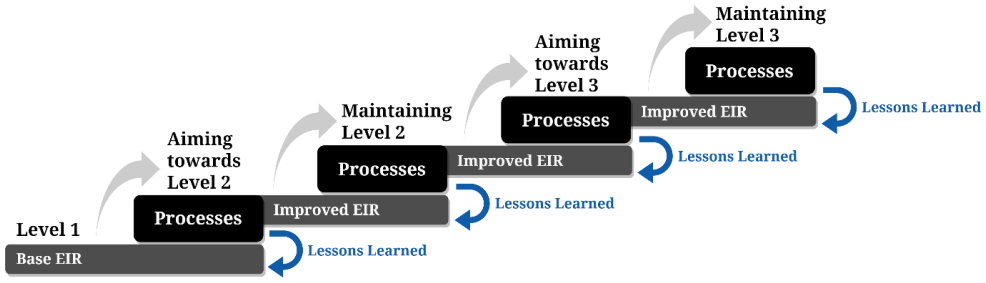



Figure 11 | A continuous improvement approach to BIM implementation process adapted from (Al Ahbabi & Alshawi, 2015)

However, recent observations have raised concerns regarding the current state of BIM adoption in the AEC sector. Lee and Borrmann (2020) highlighted that two decades of BIM projects have produced mixed results, with outcomes varying depending on how these technologies are deployed and by whom. They note that merely adopting BIM technologies does not guarantee project success; excessive focus on technological adoption has overshadowed crucial non-technical aspects of BIM implementation. Important non-technical considerations include legal and contractual issues, collaboration strategies, team management, education and training, organizational dependencies, social interactions, policies, and BIM service fee structures (Lee & Borrmann, 2020).

To illustrate these concepts, Lee and Borrmann (2020) selected three studies for analysis. First, Aibinu and Papadonikolaki (2020) explored economically efficient BIM strategies, noting that inefficiencies in BIM often stem from delays in data provision and emphasizing the need for early involvement of key participants. Second, Akintola et al. (2020) identified a lack of theoretical perspectives to explain the gradual transformation of work practices resulting from BIM adoption, underscoring the challenges of implementing processes in constantly changing environments. Third, Lindblad and Guerrero (2020) examined the role of clients in promoting BIM, finding that competing policies in a case study involving Sweden's largest transportation client led to tensions among project managers.

Sweden, an early BIM adopter and considered one of the most advanced EU countries in BIM implementation, has provided several case studies on its approach (Stange, 2020). One notable study followed the Swedish Transport Administration's (STA) BIM initiative from 2013 to 2016 (Lindblad, 2019). Using Actor-Network Theory (ANT) and the Sociology of Translation, BIM implementation was analysed as the creation of an actor-network, allowing Lindblad (2019) to map activities that linked actors to the network and describe their needs and motivations.

According to Lindblad (2019), the STA's BIM implementation strategy was initially driven by an informal network of early adopters and BIM enthusiasts within the organization. Although these actors initiated the process, they lacked the influence needed to ensure its success. As new participants joined, they influenced the network dynamics, adapting it to their own preferences. This shift introduced competing policy initiatives, ultimately limiting BIM's application to procurement rather than management processes. Consequently, BIM became a "Black Box"—included as a procurement requirement but not actively managed—leaving its implementation open to interpretation and reducing its overall effectiveness.

The case study findings highlight that BIM implementation requires the involvement of multiple actors, each playing a role that influences the process. Aligning the diverse agendas of these actors is essential for successful implementation. Figure 12 illustrates the BIM actor-network as described by Lindblad (2019).

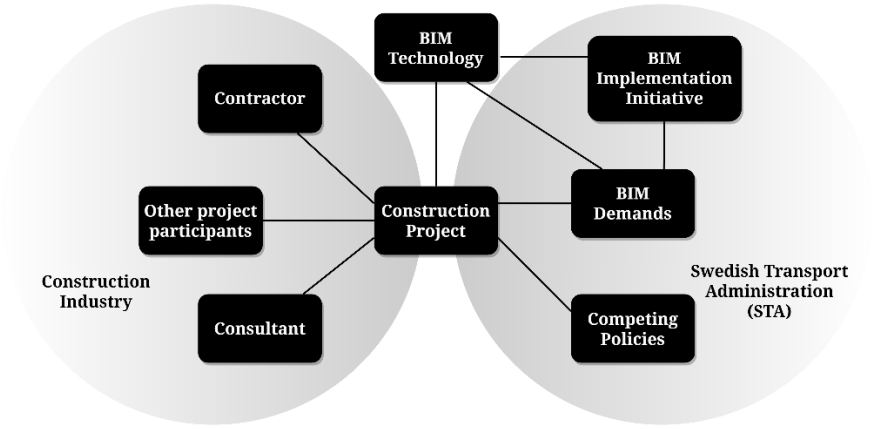



Figure 12 | BIM Actor-Network
adapted from (Lindblad, 2019)

BIM adoption across the EU remains low, and although the continuous improvement approach described by PAS 1192 and ISO 19650 aims to enhance an organization's BIM maturity over time, it does not guarantee project success. Research shows that non-technical factors, such as people and policy, must be addressed alongside technical considerations. Actor-Network Theory's concept of relative boundedness reinforces the idea that actors are defined by their

relationships with other network elements, meaning the actor influences the process, and the process, in turn, influences the actor.

### 3.2.4 Regional policy, public values, and organizational goals

Public clients, such as the BLB NRW, are public organizations that respond to regional policies established by higher levels of governance, including municipal, state, and federal bodies (Kuiper, 2021). These public clients must formulate their organizational goals based on the policy principles set by these higher levels. Nieboer (2011) describes the challenge of aligning public organizational goals related to business operations with those derived from policy principles as a strategic planning process (see Figure 13). This strategic planning process means that public clients incorporate regional policy principles into their strategy formulation during a project's program development, aiming to create public value through the successful realization of the project (Kuitert et al., 2019; Nieboer, 2011).

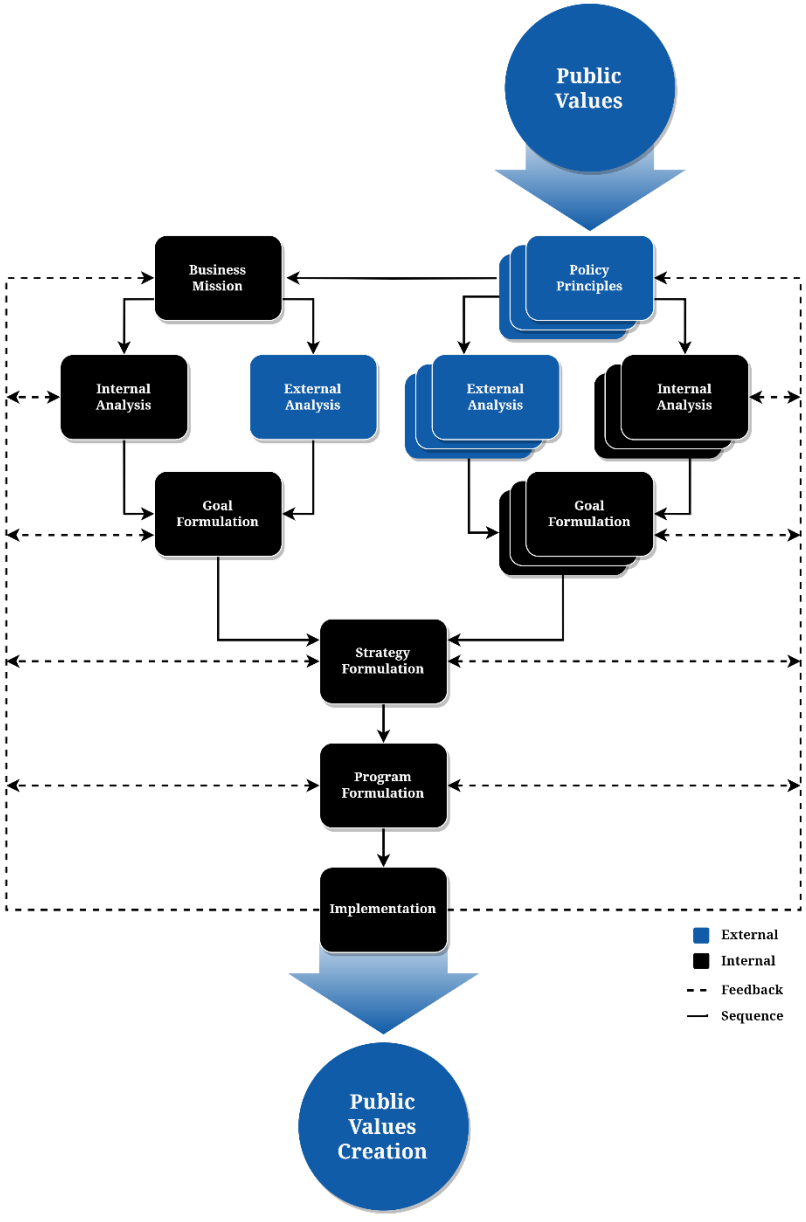



Figure 13 | Strategic planning process with several policy actors
adapted from (Nieboer, 2011)

Mendez et al. (2024) examine the relationship between regional policy and public value creation by categorizing public values into four types: goal attainment, institutional performance, democratic value, and socio-political value. These categories are defined by Mendez et al. (2024) as follows:

*Goal attainment value* relates to how effectively public organizations achieve and enhance outcomes valued by the public, such as economic, social, and environmental improvements. In regional policy, programmatic goals often distinguish between outcomes and outputs. Outcomes refer to the direct or indirect effects resulting from cause-and-effect dynamics, while outputs are the immediate results produced by the resources dedicated to an intervention.

*Institutional performance value* refers to the effectiveness of policies in addressing technical problems and ensuring successful implementation. This value emphasizes the principles that guide an organization and its administration in converting policy into outputs and outcomes, with a focus on cost-effectiveness and minimizing bureaucratic inefficiencies.

*Democratic value* pertains to the connection between the state and its citizens, highlighting how policies are formulated and how effectively they respond to citizens' preferences.

*Socio-political value* influences society broadly, holds civic importance, and reflects the collective experience of public policy. Regional policies provide citizens with opportunities, resources, and a shared identity, fostering coexistence and helping communities address differences when facing common challenges.

The extent to which public clients create these public values through the delivery of construction works depends on the effectiveness of their strategic formulation (Nieboer, 2011). Although this process is highly influential, the formulation of organizational goals and the strategic formulation are beyond the scope of this research. Instead, the focus is on addressing the pragmatic issues public clients currently face in program formulation, particularly in identifying their data needs. The strategic formulations are accepted as a given; however, their implementation and the feedback loops needed for continuous improvement form the foundation for the managerial actions explored in this research.

### 3.2.5 Public client’s role in promoting innovation and change

Thus far, there has been limited attention to how digitalization policies intersect with the broader concept of public clients promoting market innovation (Kuitert et al., 2019; Lindblad & Guerrero, 2020). The importance of the client's role in driving change in the construction sector is well recognized in the literature (Al Ahbabi & Alshawi, 2015; Lindblad & Karrbom Gustavsson, 2021). Several authors argue that, due to their power to set requirements, contracting authorities can stimulate market innovation through public procurement by advancing public values while nudging the market towards greater integration (Finamore & Oltean-Dumbrava, 2022; Hobma & Jong, 2022; Kuiper, 2021; Kuitert et al., 2019; Lindblad & Guerrero, 2020). This aligns with a recent shift in policy, which favors a market-driven approach to delivering public services (Chan, 2020; Lindblad & Guerrero, 2020; Lindblad & Karrbom Gustavsson, 2021).

To illustrate the role of public clients in BIM implementation and innovation in construction, as well as their ability to drive industry change, two papers related to a case study of the Swedish Transport Association (STA) will be discussed. First, an analysis by Lindblad & Gerrero (2020) of the role played by the STA during BIM implementation identified two distinct client positions influenced by policy. In the research, it is assumed that public clients play a role in stimulating innovation in the AEC sector. However, the nature of this role depends on whether the primary driver of innovation is competition or collaboration. When collaboration drives innovation, the

client's role is to establish a cooperative network of actors. Conversely, when competition drives innovation, the client's role is to manage the innovation process to achieve commercial success and competitive advantage from entrepreneurial investments. These two perspectives effectively define two types of client roles in promoting innovation: client-led and supplier-led.

A client-led role requires active participation from the client's project managers, acting in a system integrator capacity. This system integrator function involves interpreting the context set by the various actors involved in the innovation process and translating it into a project network that includes the innovation infrastructure (i.e., suppliers, contractors, and consultants). On the other hand, a supplier-led role takes a more hands-off approach, emphasizing market forces to develop the innovation infrastructure, allowing suppliers to build competitive advantages by adopting new solutions (Lindblad & Guerrero, 2020).

The case study findings indicate that supplier-led innovation tends to promote modular innovations, which are primarily beneficial to the direct supplier. While such innovations help build competitive advantage, they do little to foster industry-wide technological adoption. Additionally, the study found that the two client roles are inherently contradictory when applied simultaneously. Therefore, it is crucial for clients to decide on which position to adopt for each project. If a client possesses the necessary internal capabilities for implementation, a client-led role is recommended. This approach adds additional responsibilities to the client's project managers, who must act as system integrators (Lindblad & Guerrero, 2020).

Lindblad & Karrbom Gustavsson (2021) provide further insights on the public client's ability to drive industry change with the STA case study. The literature review in this paper reiterates that public clients can influence the construction industry, particularly when promoting innovation or technological adoption. This ability is analyzed through the concept of absorptive capacity, which refers to an organization's ability to recognize related knowledge, absorb it, and apply it. Although absorptive capacity is contingent on internal organizational structures, it cannot be developed in isolation (Lindblad & Karrbom Gustavsson, 2021).

In the context of BIM, understood as a "systemic innovation," policies must be kept flexible to suit the unique circumstances of each project. BIM technologies do not simplify complex projects; instead, policies should embrace project complexities to support creative solutions. The case study findings indicate that clients must first achieve internal acceptance of change before exerting influence on external actors. When there is insufficient client demand for BIM, from an absorptive capacity perspective, it means there are not enough triggers for clients to absorb BIM knowledge. Because BIM is systemic in nature, coordination between industry actors is also required, as external knowledge influences the BIM implementation process. Additionally, a process called bisociation, which involves integrating external knowledge with existing project work practices, is necessary. Furthermore, knowledge absorption must extend beyond a limited group of early adopters.

Thus, a public client's ability to drive industry change depends on several factors, including the capacity to absorb new knowledge, the coordination among actors, and a commitment to widespread adoption. Furthermore, public clients must first consider intra-organizational process changes before exerting influence on external actors. This can be achieved by ensuring that internal process changes are accepted, and that the absorption of external knowledge is supported through strong social integration mechanisms. Furthermore, the decision on which role to adopt—client-led or supplier-led—should be carefully evaluated for each project. However, if a public client has the necessary capabilities for implementation, a client-led role is recommended.

## 3.3 Socio-technical approach

One of the key challenges facing the AEC industry during the digital revolution is not only the technological change but also the necessary social transformation, as noted by Ejohwomu et al. (2021). Regarding the implementation of BIM, Abbasnejad et al. (2021) and Siebelink (2021) emphasize that successful adoption requires a socio-technical systems approach. Similarly, Lee and Borrmann (2020) argue that an effective BIM adoption process needs a comprehensive framework that integrates people, processes, and policies

While standards like the PAS 1192 series and ISO 19650 provide valuable guidelines for processes, successful implementation also demands a deep understanding of social factors. This includes the roles of users and stakeholders, as well as relevant policies, standards, regulations, and initiatives. Kuiper (2021) further asserts that the impact of BIM should not be viewed as a standalone artifact. Instead, it must be understood as intrinsically linked to technology (both software and hardware), processes, people, and policies, all of which are interconnected with product terminology.

In his dissertation, Siebelink (2021) relates BIM implementation barriers to an organization's BIM maturity level, identifying that the primary challenges are non-technological in nature. Among Siebelink's propositions, one stands out as highly relevant: "The core group of barriers to BIM implementation and use, which cross all organizational levels, is formed by people-related aspects linked to motivation, competence, and capacity to switch to BIM." This highlights the need to address socio-technical barriers, especially those related to human factors, to facilitate successful BIM adoption.

Furthermore, Dossick and Neff (2011) highlight the importance of integrating actors' tacit knowledge when adopting BIM. In multidisciplinary collaborative efforts, tacit knowledge is often exchanged through "messy talk" formats, such as brainstorming sessions or informal discussions. In contrast, explicit knowledge, which is easier to document through "clean technology" like BIM tools, often falls short in capturing the subtleties required for cross-disciplinary collaboration. According to Dossick and Neff (2011), "messy talk" helps to find solutions that are "distributed across disciplinary boundaries and require the exchange and discovery of tacit knowledge."

These perspectives collectively underscore the importance of considering people at all levels of BIM adoption—from the broader, industry-wide digital transformation to the specific collaborative needs at the project level. Building on these insights, the present research adopts a socio-technical approach to address the challenges in BIM implementation. The following sections explore various theoretical frameworks that incorporate socio-technical analysis, ultimately identifying the most suitable framework for the research design.

### 3.3.1 People, process, technology (PPT) framework variants

The People, Process, Technology (PPT) framework is a foundational model that emphasizes the interconnectedness of these three dimensions in driving organizational efficiency and effectiveness (Karmakar & Delhi, 2021; Lee & Borrmann, 2020). Originally introduced by Harold Leavitt in the 1960s, the framework has evolved to address contemporary challenges, including digital transformation and knowledge management (Lee & Borrmann, 2020). The PPT framework is widely utilized as it effectively illustrates how people and technologies interact, facilitating information flow across organizational layers through defined processes (Karmakar & Delhi, 2021).

Karmakar and Delhi (2021) extended the PPT framework by categorizing elements based on their relevant asset life cycle phases and linking them to three distinct data layers: physical, cyber-physical, and digital (see Figure 14). The physical data layer encompasses unstructured digital data formats, which may include digitized versions of analogue media (e.g., scanned documents) or digital content originally created for physical output (e.g., documents, drawings, and visualizations). The cyber-physical layer represents semi-structured digital data captured through sensors and stored in formats such as XML files or point clouds. Lastly, the digital layer refers to structured data formats, such as Building Information Modelling (BIM) files and relational databases.

While this adaptation offers valuable insights for mapping the ecosystem of actors and technological interactions throughout the asset life cycle, it also has notable limitations. Specifically, it does not address the challenges involved in information flow processes, nor does it consider public values, overarching goals, or specific objectives.

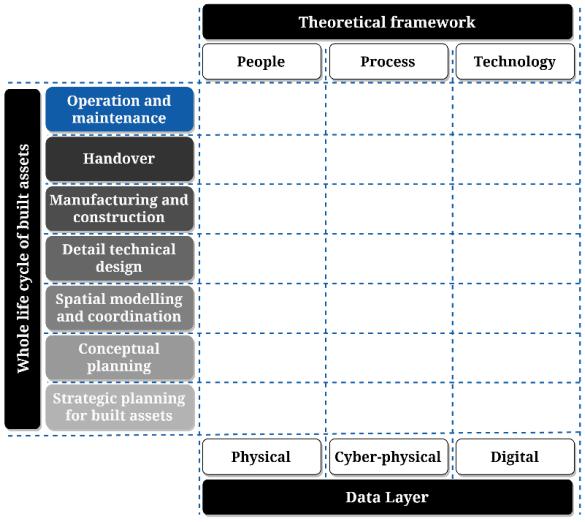



Figure 14 | The project life cycle vs. people-process-technology framework adapted from (Karmakar & Delhi, 2021)

Lee and Borrmann (2020) also highlight these gaps in the PPT framework. In an editorial, they argue that Building Information Modeling (BIM), as a technology, should be evaluated through the lens of its actors (people), the best practices adopted by the industry (processes), and the policies that facilitate its adoption (see Figure 15). However, this perspective primarily focuses on the D&C phase of BIM adoption, rather than encompassing the entire asset life cycle as Karmakar and Delhi's (2021) variant does. This narrower focus limits its applicability to broader asset management contexts.

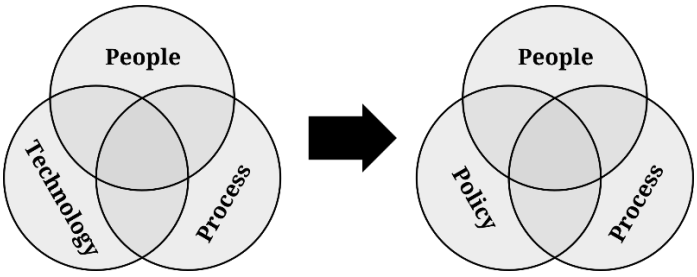



Figure 15 | From PPT to PPP (people-process-policy) framework (by author)

### 3.3.2 Fitting BIM into information systems

To position Building Information Modeling (BIM) comprehensively across the entire asset life cycle, Godager et al. (2021) introduced the concept of Enterprise BIM (EBIM), see Figure 16. EBIM is defined as "a virtual holistic representation of the life cycle of the built environment, adapted for optimized enterprise management, knowledge sharing, and collaboration." The key innovation of this concept lies in the integration of EBIM strategy with an organization's overall Enterprise Modelling (EM).

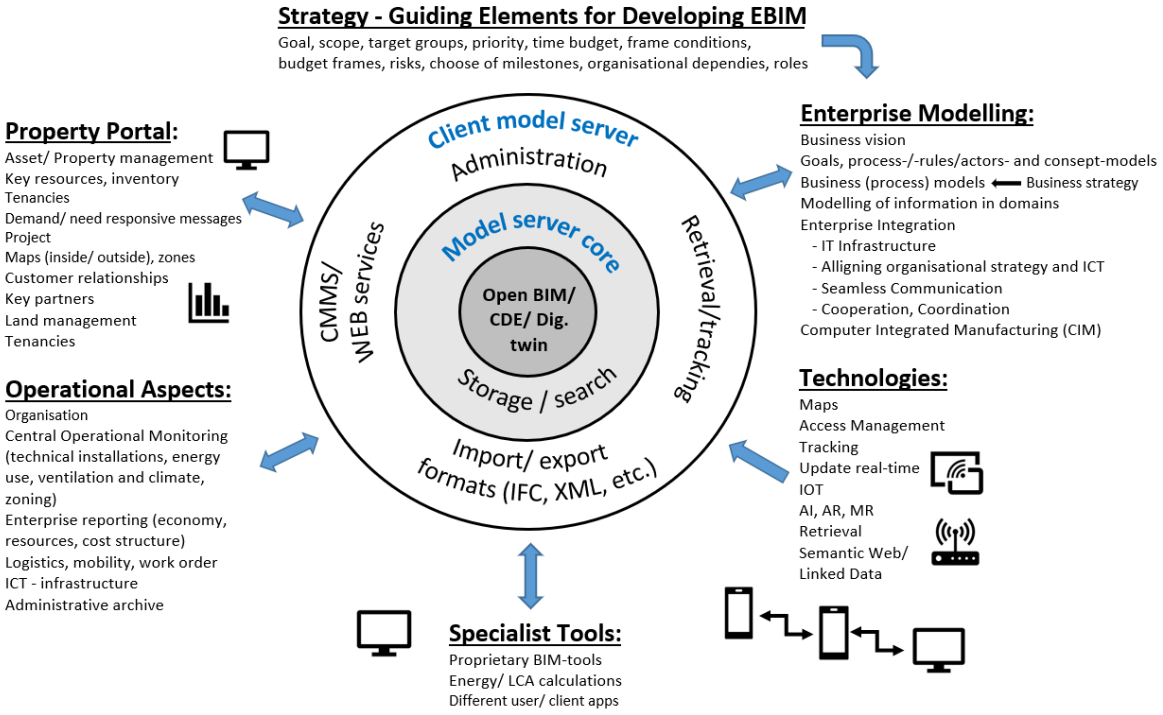



Figure 16 | The principle of the digital collaboration model in EBIM (Godager et al., 2021)

Enterprise Modelling encompasses the organization's structure, activities, processes, information, people, behaviors, goals, constraints, and relationships with external stakeholders (Godager et al., 2021). While EM serves as a computational representation of the organization, supporting a high-level understanding, control, and evaluation of its fundamental components and environment, EBIM enhances EM by embedding BIM into a holistic structure that spans the entire life cycle of a building asset.

Despite the promising potential of EBIM, Godager et al. (2021) do not provide a specific modelling solution to integrate EBIM with EM. They acknowledge the need for methods that clarify stakeholder requirements, as well as the dependencies between different business processes and procedures throughout the asset life cycle.

### 3.3.3 Process modelling with the PPP framework

While exploring modeling methods for Enterprise BIM (EBIM), Godager et al. (2021) point to the IDEFØ method (see Figure 17). The Integration Definition for Function Modeling (IDEFØ) is one of five standard modeling methods developed by the United States National Institute of Standards and Technology. This method comprehensively and consistently models the activities, processes, or operations (functions) required by an enterprise, along with the

relationships and data that support the integration of those functions (National Institute of Standards and Technology, 1993).

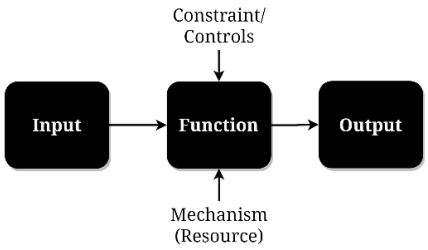



Figure 17 | Integrated definition methods IDEFØ
Adapted from (National Institute of Standards and Technology, 1993)

However, when relating the IDEFØ model to Lee and Borrmann's (2020) People-Process-Policy (PPP) framework, it becomes apparent that in the context of asset life cycle management, people are not considered an input, and policy is not treated as an output. Instead, Godager et al. (2021) explain that people and technology serve as mechanisms, while standards, templates, and checklists function as forms of control. According to the IDEFØ manual, controls are conditions necessary to produce the correct output (National Institute of Standards and Technology, 1993). Using this definition, innovations can be considered a form of process control. Thus, policies, which are intended as statements of intent, become inputs to the process. The product of this process can encompass both tangible outputs, such as Exchange Information Requirements (EIR) documents, and broader outcomes, such as the successful delivery of a built asset. Figure 18 illustrates the integration of the PPP framework with the modeling concepts of IDEFØ to create a Policy-Process-Product (PPP) model.

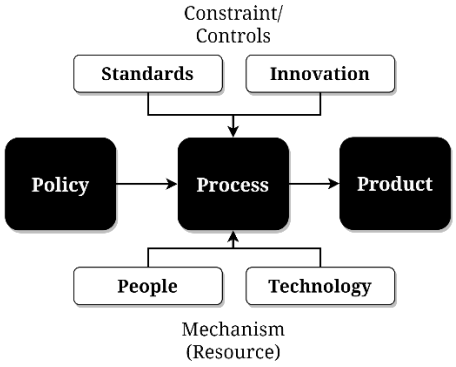



Figure 18 | PPP (policy-process-product) model
(by author)

### 3.3.4 Addressing policy levels and complexity

Godager et al. (2021) note that the IDEFØ method is likely unsuitable for modeling EBIM due to the complexity of the objects that need to be interconnected, which implies that the PPP model (Figure 18) may also be inadequate. Recognizing the need to effectively model complexity within dynamic systems, Sundstrom et al. (2023) and C.K. May (2022) apply the panarchy framework to address the hierarchical nature of these systems. This framework underlines the need to define emergent issues, identify the scales of key processes, highlight critical feedback loops, and pinpoint thresholds within those processes (Sundstrom et al., 2023).

When applied to organizations, the panarchy framework reveals that goals become more formal and authoritative as they ascend the hierarchy (C. K. May, 2022; Sundstrom et al., 2023).

However, these higher-level goals also tend to be more abstract and have slower adoption rates. At the organizational level, operational policies define the operative goals, specifying the means, resources, and prioritization required to achieve official objectives. At lower levels, such as the team or individual level, unofficial goals evolve more rapidly (see Figure 19). These goals are shaped by individual preferences, interpretations, capabilities, and power dynamics as personnel engage in daily problem-solving and fulfill their roles (C. K. May, 2022).

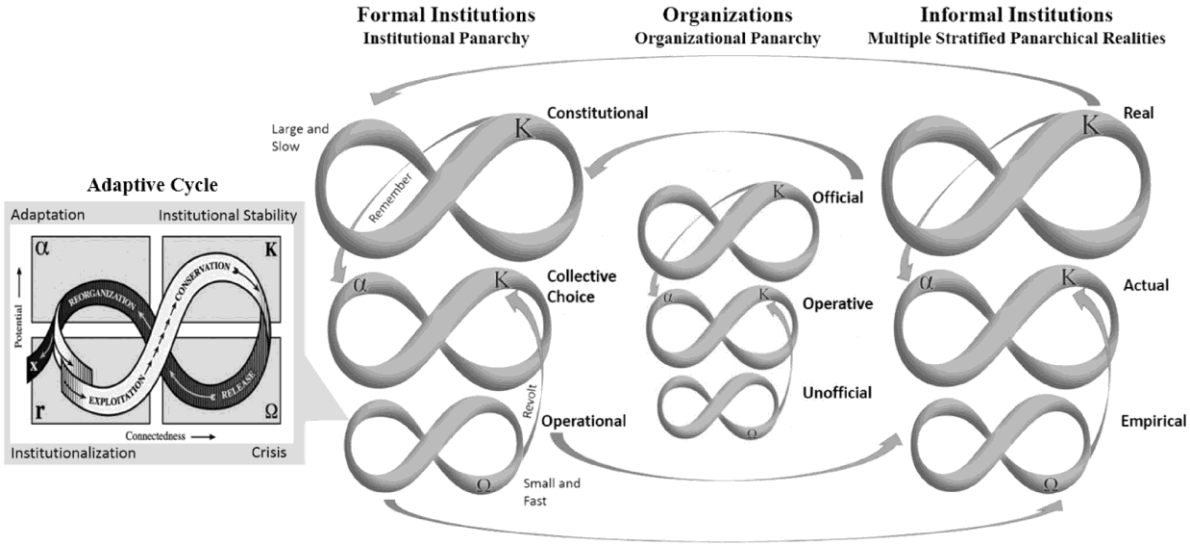



Figure 19 | Complex adaptive governance systems framework
(C. K. May, 2022)

A key feature of the panarchy framework is its ability to trace how unresolved issues grow and escalate to higher levels—a process known as "revolt connections." At these higher levels, solutions are then developed and incorporated into policies that provide guidance for addressing the issues, referred to as "remember connections" (see Figure 20).

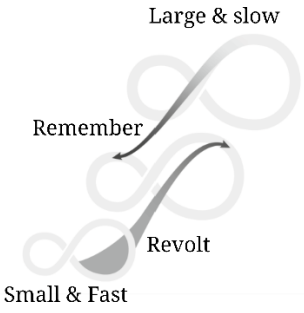



Figure 20 | Panarchy figure
Adapted from (Sundstrom et al., 2023)

Kuiper (2021) emphasizes the importance of considering policy across hierarchical levels, associating issues across different policy scales—micro, meso, and macro—to tailor more effective responses. The micro level includes perspectives from individuals, firms, and organizations; the meso level involves project organizations, supply chains, and industries; and the macro level encompasses broader institutional entities such as municipal, state, and federal governments, as well as society at large.

While simplifying hierarchical levels into three dimensions (micro, meso, macro) can be effective for policy development, a more nuanced approach for this research is necessary. The panarchy framework, for instance, highlights the importance of identifying key processes

across multiple scales within a system. Sundstrom et al. (2023) illustrate this by applying the framework to two examples across five levels: individual, local, regional, national, and global.

In the context of developing managerial actions within an organization, a more granular approach than the three-level model proposed by Kuiper (2021) is needed to ensure that actions are tailored effectively at each distinct level of operation.

### 3.3.5 PPP (policy-process-product) complex system model

The PPP model represents complex systems by integrating key domains of complexity: policy hierarchy levels, data layers, individual behaviour toward change, and phases of the asset life cycle (see Figure 21). This model is a two-dimensional representation of a multi-level framework that maps the alignment of data needs—driven by public values—to an organization's goals within specific phases of the asset life cycle. The framework serves as a mapping mechanism that is not only valuable as a tool for the strategic alignment of a project's program formulation and implementation but also functions as a means of organizational remembrance. It achieves this by documenting the interconnected network of data, actors, technologies, processes, and managerial actions undertaken throughout the asset life cycle. This documentation, in turn, supports continuous improvement efforts, enabling organizations to fully leverage the added value of digital transformation initiatives.

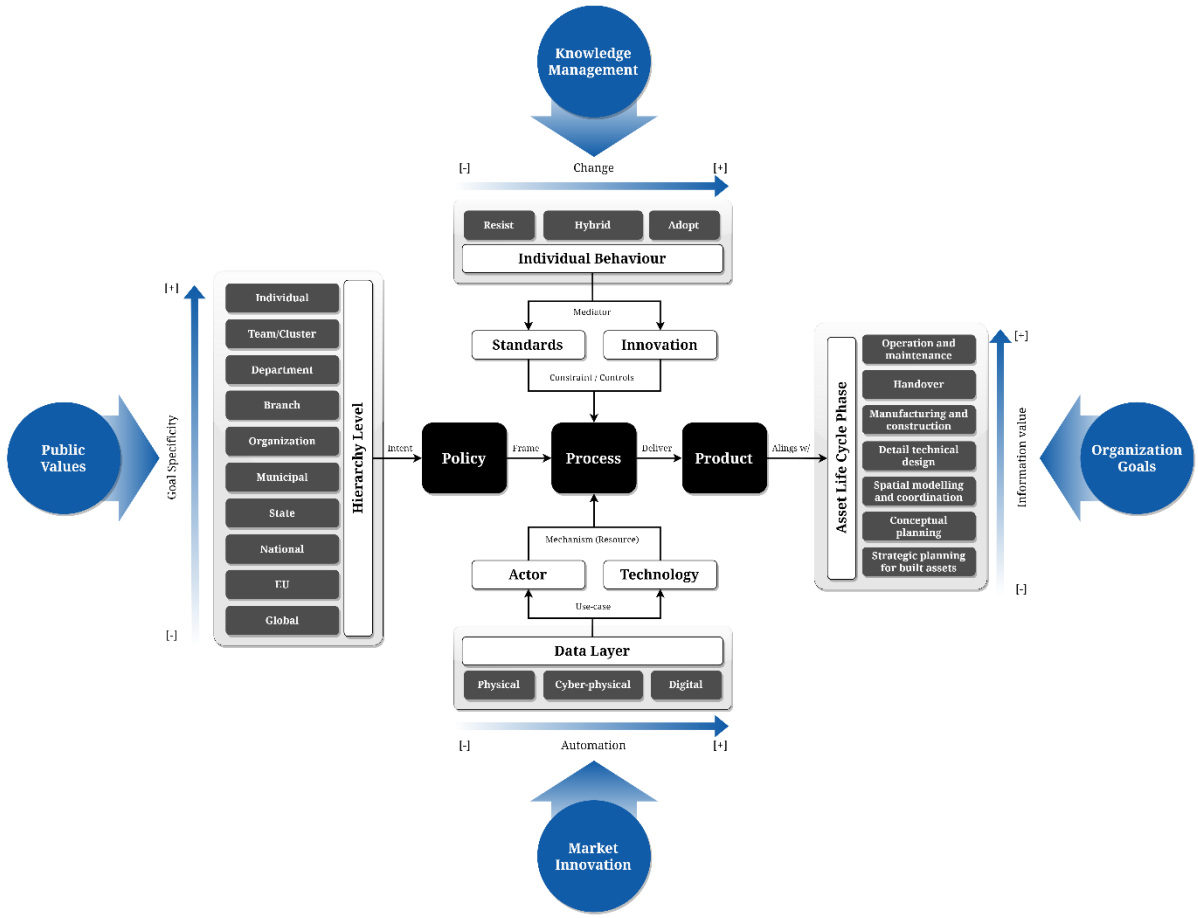



Figure 21 | PPP (people-process-product) complex system model (by author)

The PPP complex system model addresses the complexity domains as follows:

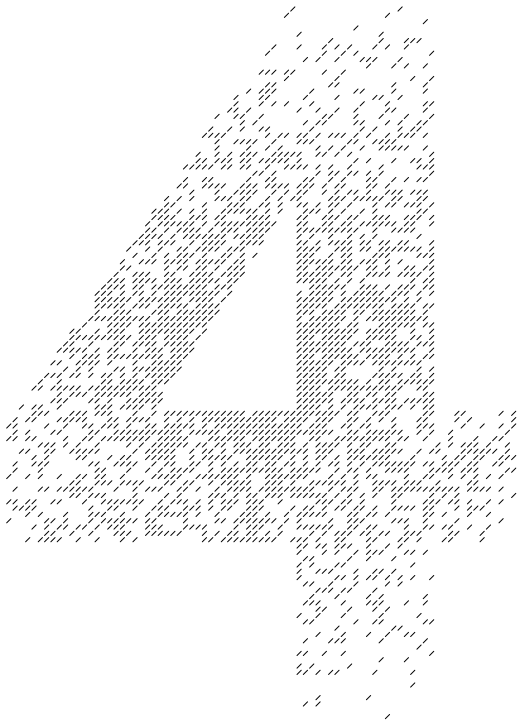
To address the domain of policy hierarchy levels, a relationship is established between the hierarchical position and the specificity of goals. As policy instrumentation corresponds to its position within the hierarchy, the specificity of intentions (goals) increases as the level becomes more granular (Kuiper, 2021; Sundstrom et al., 2023). The benchmark for policy specificity is shaped by the pursuit of creating public values, which are derived from regional policies (Mendez et al., 2024). This process identifies the intent of an organization's strategic formulation, which is ultimately translated into specific implementation policies (Nieboer, 2011).

To address the data layer domain, a relationship is established between the category of the data layer and its potential for automation. Automation is facilitated and made more efficient when digital data layer formats are available (Karmakar & Delhi, 2021). The automation benchmark is influenced by market innovations that enhance the potential for more effective and efficient IT solutions. However, interoperability issues and data omissions often compel FM and AM managers to manually input data into their management systems (S. T. Matarneh et al., 2019). Understanding the technical limitations of data interoperability across various management systems is crucial for determining the appropriate approach to adopt. As defined by Lindblad and Gerrero (2020), organizations can choose between a client-led approach, where data is insourced (self-generated), and a supplier-led approach, which involves procuring data creation services. Defining a specific use case provides the necessary context for assessing organizational maturity in this area and determining whether external services need to be procured (Siebelink et al., 2018). This evaluation, in turn, informs the planning of resource allocation, encompassing both actors and technology.

To address the individual behaviour domain, a relationship is established between an individual's attitude toward change and the specific change initiative being undertaken. Individual behavioural intentions toward IT use significantly influence the adoption of new IT systems, either facilitating or hindering organizational change (Shirish & Batuekueno, 2021). Furthermore, individual behavioural intentions toward IT use are shaped by the organization's knowledge management system, which positively influences its capacity to adapt and achieve desired outcomes (Abubakar, 2019). Although hybrid approaches to IT use are common among public clients (Chan, 2020), the framework explicitly defines the intended behavioural stance for each initiative to prevent "black-boxing" the managerial process, as advocated by Lindblad (2019). The intended behavioural stance acts as a mediator, shaping which standards and innovative practices serve as the foundation for controlling the process.

Lastly, to address the domain of asset life cycle phases, a relationship between information value and the asset life cycle phase is established. According to Eastman (2011), facility data information value increases during the D&C phases, with each subsequent life cycle phase adding more value. This research, however, emphasizes the emergent value of facility data during the O&M phases, demonstrating that information value continues to grow throughout these phases as well. The value of information is benchmarked against the effectiveness of data in meeting information requirements aligned with the formulated goals.

—End of Chapter—



# 4 Empirical research

## 4.1 Organization’s context

The BLB NRW, established in 2001, is a relatively new organization created to unify the State of NRW's real estate and construction management activities under a single entity (BLB NRW, 2023a). It consists of 8 main locations and 2,894 employees, managing 8,233 construction projects and 4,038 owned buildings, with a total balance sheet value of €9.3 billion (BLB NRW, 2023b). In 2018, the state government initiated a comprehensive reform of the BLB NRW to enhance customer orientation, operational efficiency, and adaptability, while advancing the goal of achieving a climate-neutral state administration (Ministerium der Finanzen, 2021). This reform was supported by an approved budget, which focused on modernizing assets through renovations and new construction projects (BLB NRW, 2022b). Key measures introduced included a centralized client service model, transparent rental calculations, and expanded consulting services (Ministerium der Finanzen, 2021). The strategy emphasizes eliminating redundancies and prioritizing critical areas such as budget control and risk management (BLB NRW, 2023a). These reforms aim to integrate practical solutions into daily operations, fostering sustainable improvements and a more client- focused approach.

In response, BLB NRW defined its mission statement and implemented a governance framework to enhance transparency in decision-making, streamline strategic and operational processes, clarify responsibilities, and standardize workflows. The mission statement articulates the organization's vision, values, and goals, which include *Employer Appeal, Customer Focus, Partnership, Sustainability, Innovation Strength, and Economic Efficiency* (BLB NRW, 2023a). Furthermore, knowledge and idea management frameworks were developed as part of a modern quality management strategy to promote continuous improvement. These efforts include a range of training and development programs, onboarding initiatives, and certification opportunities.

Digitization, digitalization, and digital transformation all play pivotal roles in modernization efforts, bridging the organization's need for robust risk and budget control with performance metrics for climate-neutral asset operations (BLB NRW, 2022a). Various initiatives are underway, including digitizing old-paper-form archived documents, establishing roadmaps for implementing new software platforms, and investing in modernizing ICT infrastructure by introducing Wi-Fi in all BLB NRW offices and integrating telephone services with new digital communication tools. The introduction of a change management team and a requirements management team under the digitalization department ensures that proposed solutions align with security specifications while coordinating the equitable distribution of IT resources across all branch offices (BLB NRW, 2022a).

BLB NRW is actively pursuing the establishment of a single source of truth for its operations. Each organizational function is paired with a conceptualized platform optimized for its specific technical needs: construction management utilizes a project-based Common Data Environment (CDE), facility management operates through a Computer-Aided Facility Management (CAFM) system, asset management relies on an Enterprise Resource Planning (ERP) platform, portfolio strategy and management is supported by a dedicated Inventory Management System, and compliance and accountability are addressed through an Enterprise Content Management (ECM) system (BLB NRW, 2022a). These platforms serve as single sources of truth for their respective functions and are being integrated to enable the linking of information across platforms in a read-only mode. This integration ensures that information related to a particular function of a built asset is managed and modified exclusively by those with the required

technical expertise, while still allowing critical data to be viewed or linked within other platforms (BLB NRW, 2022a).

## 4.2 Refining scope

Organizations such as BLB NRW are characterized by complex organizational structures that include departments, branch offices, specialized units, and project teams. While these entities operate under a unified framework, their activities are not always seamlessly coordinated. The internal mechanisms of public clients like BLB NRW are typically not accessible to external parties due to considerations such as data security, privacy protection, anti-terrorism measures, and stakeholder relations. Consequently, an internship within the organization was deemed necessary to access the detailed information required for this study.

At the onset of the internship, two preliminary steps were undertaken to identify key interview participants and relevant organizational documents. First, informal discussions were held with colleagues, guided by the theoretical framework of the research, to gain a comprehensive understanding of the organization's structure and its internal sources of information. These discussions identified three principal sources of data: the organization’s handbook, organizational charts (organigrams), and the intranet colleague search function. The intranet proved particularly valuable, offering profiles for each employee that included contact details, job titles, and, when provided by individuals, information on their expertise, experience, and other relevant attributes. This initial analysis facilitated the refinement of the research scope.

As outlined in the BLB NRW (2023) organizational handbook, the organization operates on behalf of both the State of North Rhine-Westphalia (NRW) and the Federal Government. However, BLB NRW’s involvement in federal projects is confined to construction management, whereas state-level projects include both construction management and real estate management. Given the study's focus on the entire asset life cycle, the analysis was restricted to the organizational structures relevant to state-level projects.

BLB NRW comprises eight offices: a central office and seven branch offices. Due to data protection requirements, all interviews were conducted in person. However, branch offices requiring over an hour of travel by public transportation were excluded from the study due to scheduling constraints and a shortened data collection period caused by unforeseen delays. Ultimately, the research was conducted in four offices: the central office, Duisburg, Düsseldorf, and Köln. Figure 22 presents the organizational structure of BLB NRW, with the areas included in this research highlighted.

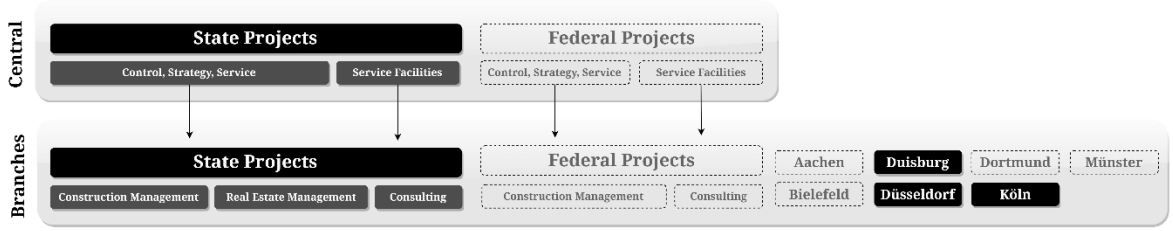



Figure 22 | BLB NRW organizational structure
adapted from (BLB NRW, 2023a)

A closer examination of the organizational structures of each office was conducted to identify individuals representing various strategic and operational aspects of managing an asset's lifecycle. The central office, primarily responsible for oversight, strategy development, and client and facility services, has a structure that differs significantly from the branch offices. In contrast, the branch offices focus on construction management and real estate management

operations. Figure 23 illustrates the organizational structure of the central office, while Figure 24 depicts the common framework of the branch offices. In these figures, relevant divisions or departments are highlighted in black, and the specific teams within those segments—whose members were ultimately invited to participate in the interviews—are highlighted in grey.

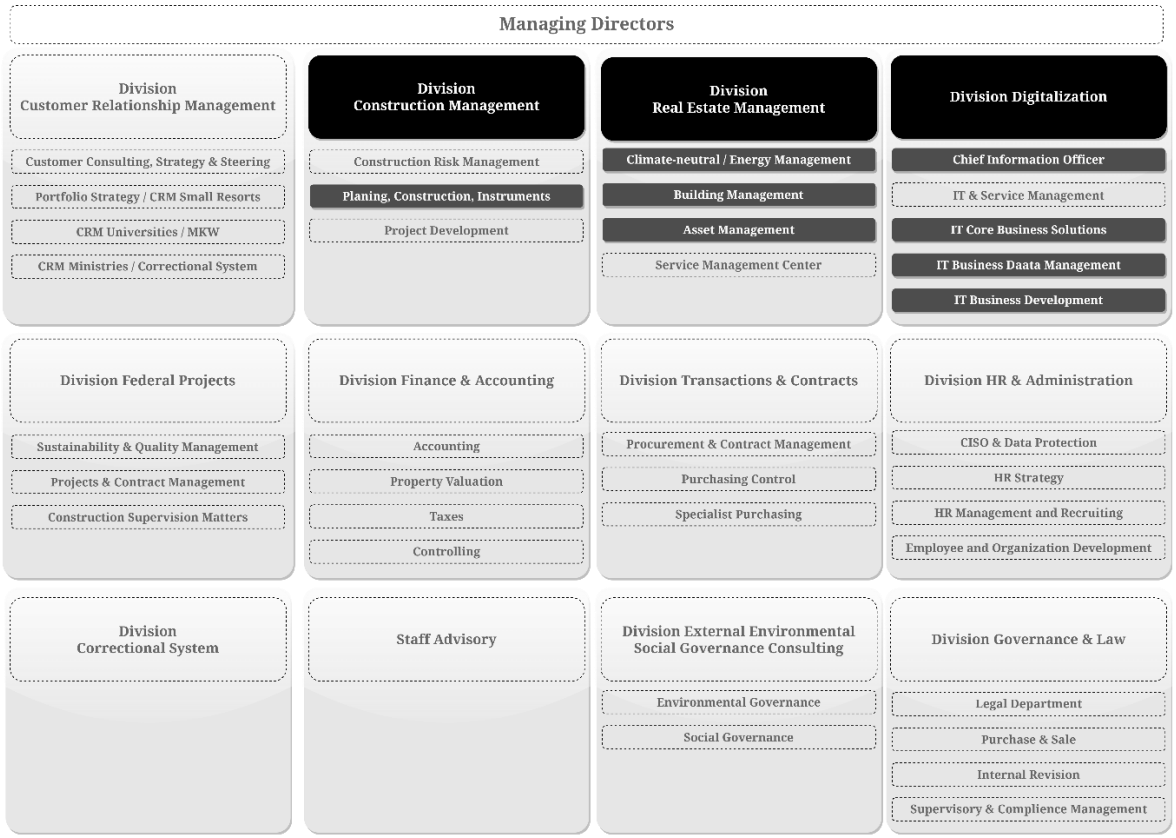



Figure 23 | BLB NRW Central organizational structure
adapted from (BLB NRW, 2023a)

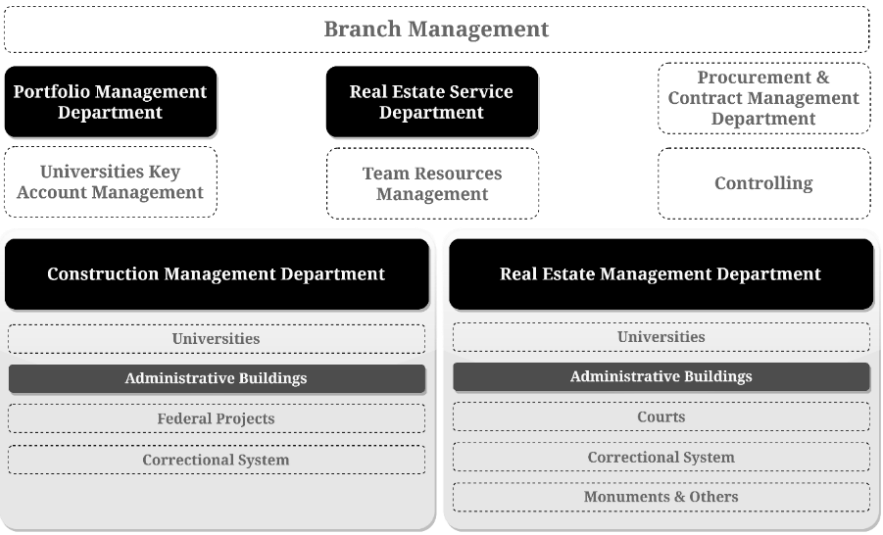



Figure 24 | BLB NRW Brach organizational structure
adapted from (BLB NRW, 2023a)

Although a common framework guides the organization of each branch (see Figure 24), subtle differences exist in how this framework is implemented across branches. For instance, some departments may be merged, renamed, or omitted in certain branches. Despite these variations, the departments selected for this research align with the areas highlighted in Figure 24, including the Portfolio Management Department, Real Estate Service Department, Construction Management Department, and Real Estate Management Department. For the latter two departments, however, only teams that work with clients in the Administrative Buildings category—such as ministry buildings for interior, finance, culture, labour, and police departments—were included in the study. This category was chosen as it best represents the area where BLB NRW participates in both the D&C and O&M phases of the building asset life cycle.

Following the identification of relevant organizational areas for inclusion in the research, the subsequent step involved selecting individuals to participate in the interview process. The identification of potential interview candidates was conducted through a multi-stage process. Initially, colleagues provided recommendations of individuals deemed suitable for the study. Concurrently, the organizational chart and intranet were analysed to compile a preliminary list of prospective participants. This list was subsequently reviewed by department and team leaders, who evaluated the appropriateness of the selected individuals and suggested alternative candidates where necessary. To ensure adherence to organizational protocols and ethical considerations, consultations were also held with the employee union representative. Ultimately, 68 interview invitations were disseminated, resulting in 20 participants. Table 02 provides a detailed summary of the interviewees and their key attributes.

| Interview Nr. | Branch | Division | Department | Team | Role | Role Experience | Total Experience |
|---|---|---|---|---|---|---|---|
| **01** | Z | Digitalization | IT Business Development | Requirements Management | Strategic | 1y | 5y |
| **02** | Z | Construction Management | Planning, Construction, Instruments | - | Strategic | 5y | 10y |
| **03** | Z | Construction Management | Planning, Construction, Instruments | - | Strategic | 7y | 10y |
| **04** | Z | Digitalization | IT Business Development | Requirements Management | Strategic | 5y | 30y |
| **05** | DU | - | Real Estate Service | Sustainability, Climate Protection & Energy Consultancy | Operative | 1y | 5y |
| **06** | DU | - | Real Estate Service | Sustainability, Climate Protection & Energy Consultancy | Advisory | 5y | 30y |
| **07** | Z | Digitalization | IT Core Business Solutions | - | Strategic | 3y | 33y |
| **08** | DU | - | Real Estate Management | Real Estate Management Interior Ministries | Operative | 1y | 12y |
| **09** | Z | Digitalization | IT Core Business Solutions | - | Strategic | 2y | 11y |
| **10** | D | - | Real Estate Service | Sustainability, Climate Protection & Energy Consultancy | Operative | 1y | 35y |
| **11** | Z | Construction Management | Planning, Construction, Instruments | - | Strategic | 2y | 6y |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **12** | Z | Asset Management | Real Estate Management | Strategic and Technical Asset Management | Advisory | 1y | 15y |
| **13** | K | - | Real Estate Service | Building Management Consultancy | Operative | 15y | 35y |
| **14** | K | - | Real Estate Service | Facility Management Service | Operative | 5y | 5y |
| **15** | K | - | Real Estate Service | Facility Management Service | Operative | 5y | 20y |
| **16** | DU | - | Real Estate Service | Infrastructural building management | Operative | 5y | 20y |
| **17** | Z | Asset Management | Facility Management | - | Strategic | 6y | 20y |
| **18** | Z | Digitalization | IT Core Business Solutions | - | Strategic | 1y | 15y |
| **19** | D | - | Construction Management | Administration Buildings | Operative | 23y | 31y |
| **20** | K | - | Real Estate Management | Asset Management Police & Special Assets | Operative | 9y | 40y |

Z = Central, DU = Duisburg, K = Köln, D = Düsseldorf

Table 02 | List of interviewees

After identifying the areas of interest within the organization and compiling a list of potential interviewees, internal documents pertaining to the relevant departments and teams were collected using BLB NRW's internal information search tools, including the Intranet and BLB-Kompass. Guided by the three dimensions of the study, documents related to policies, processes, and information requirements were systematically gathered for analysis. A summary of the documents included in the analysis is presented in Table 3.

| Nr. | Policy | Process | Product |
|---|---|---|---|
| **01** | Organization Handbook | | |
| **02** | Sustainable State Administration | | |
| **03** | Digitalization Strategy | | |
| **04** | | Feedback BIM Pilot Projects (Questionnaire) | |
| **05** | | Feedback BIM Pilot Projects (Protocol 1) | |
| **06** | | Feedback BIM Pilot Projects (Protocol 2) | |
| **07** | | Retrospective Construction Analysis | |
| **08** | | | BIM-Guidelines |
| **09** | | | Asset Information Requirements (AIR) |
| **10** | | | Project Information Requirements (PIR) |
| **11** | | | Employer Information Requirements (EIR) |
| **12** | | | BIM Use-cases Description |
| **13** | | | BIM Special Contractual Conditions |
| **14** | | | Template BIM Execution Plan |

Table 03 | List of internal documents analysed

## 4.3 Analysis instruments

### 4.3.1 Emergent topics & literature themes

Both social and technological aspects are recognized as significant influences on an organization's ability to achieve desired outcomes (Siebelink, 2021). However, to effectively relate these factors to a specific organizational structure, it is essential to consider the scale and pace at which they operate (C. K. May, 2022). Smaller, faster-moving factors tend to manifest as emergent topics, while larger, slower-moving factors form well-documented and enduring themes (Sundstrom et al., 2023). Together, these socio-technical elements—comprising both topics and themes—serve as the foundation for the empirical analysis.

The literature review informed the selection of ten social aspect themes (see Table 4) and ten technological aspect themes (see Table 5). Meanwhile, the interview analysis (Phase 2) identified 25 emergent topics (see Table 6). While the themes are explicitly linked to either social or technological aspects, the topics are more transient and do not exhibit a strong alignment with either category. To enhance context and clarity, each topic is correlated with a corresponding theme during the analysis. The document analysis (Phase 3) utilizes the emergent topics identified through interviews and the themes defined in the literature to identify evidence of their presence within the organizational documents.

| Nr. | Social Aspect Theme | Description | Source |
|---|---|---|---|
| **SA1** | Collaboration | A unified effort within the complex domain, requiring unity and solidarity to navigate uncertainty and achieve shared goals | (Ford, 2024) |
| **SA2** | Goal Interpretation | The process of translating formulated goals into specific tasks aligned with the sub-levels of an organization | (Kuiper, 2021) |
| **SA3** | Knowledge Acquiring | Leveraging membership and participation in external networks to acquire knowledge and insights unavailable within one's own network | (Clement et al., 2018) |
| **SA4** | Knowledge Archiving | The systematic process of storing and organizing knowledge in various formats and structures ensuring its accessibility and integration into organizational memory for future use | (Abubakar, 2019) |
| **SA5** | Knowledge Gaining | Informal and formal educational activities undertaken to acquire new skills, develop specializations, or gain additional knowledge | (Ullah et al., 2019) |
| **SA6** | Knowledge Sharing | The process of exchanging information, expertise, or assistance between individuals, groups, or organizations to foster learning and innovation | (Abubakar, 2019) |
| **SA7** | Maturity | The extent to which an organization has developed, optimized, and consistently applies its processes, systems, and capabilities to achieve strategic goals and sustain high levels of performance | (Siebelink et al., 2021) |
| **SA8** | Power Dynamics | The interplay of influence and authority among individuals or groups, shaped by their actor's network position, which impacts decision-making and resource allocation | (Soda et al., 2018) |
| **SA9** | Preference | An individual or group's expressed position regarding task completion in relation to policies, mandates, or initiatives. | (Lindblad, 2019) |
| **SA10** | Stakeholder Relations | The activities undertaken to ensure that the interests of internal and external groups are identified, managed, and incorporated into decision-making and outcomes | (Kuitert et al., 2019) |

Table 04 | Social Aspect Teams

| Nr. | Technological Aspect Theme | Description | Source |
|---|---|---|---|
| **TA1** | Data Access | The ability to retrieve information, governed by access rights, availability, scarcity, and ownership | (Alreshidi et al., 2017) |
| **TA2** | Data Interoperability | The ability of systems, processes, and actors to seamlessly exchange, interpret, and use data across different platforms or formats | (Dixit et al., 2019) |
| **TA3** | Data Processing | The systematic collection, transformation, and analysis of data to generate meaningful insights and support decision-making and operational activities | (Alreshidi et al., 2017) |
| **TA4** | Data Relevance | The extent to which data is applicable, useful, and aligned with specific organizational goals, decision-making processes, or operational needs | (Dixit et al., 2019) |
| **TA5** | Data Security | The practices and technologies employed to protect organizational data from unauthorized access, breaches, loss, or corruption, ensuring confidentiality, integrity, and availability | (Alreshidi et al., 2017) |
| **TA6** | Data Storage | The methods and systems used to securely retain digital data, ensuring its accessibility, integrity, and longevity for operational, analytical, or regulatory purposes | (Alreshidi et al., 2017) |
| **TA7** | System Capability | The capacity of ICT systems and infrastructure to effectively support operations, meet organizational objectives, and adapt to evolving demands | (Alreshidi et al., 2017) |
| **TA8** | System Efficiency | The ability ICT systems to perform tasks and processes with minimal resource consumption, time, and waste while maximizing output and effectiveness | (Alreshidi et al., 2017) |
| **TA9** | System Legacy | Inherited information systems, software, or technologies that continue to be used despite newer alternatives, often due to their critical role in operations, integration challenges, or high replacement costs. | (Dixit et al., 2019) |
| **TA10** | System Usability | The ease with which users can interact with a system to achieve their goals efficiently and effectively, influenced by the design of user interfaces, the intuitiveness of navigation, and the complexity of system integration with other technologies | (Siebelink et al., 2021) |

Table 05 | Technological Aspect Themes

| Nr. | Emergent Topic | Description |
|---|---|---|
| **T1** | Client / Tennant | The government entity, agency, or public body that commissions or occupies a property, relying on the organization for services such as construction, renovation, maintenance, or leasing, aligned with public sector objectives and regulations |
| **T2** | Continuous Improvement | The ongoing effort to enhance processes, services, and outcomes by identifying inefficiencies, implementing incremental changes, and aligning improvements with public sector goals, regulations, and stakeholder expectations |
| **T3** | Contracts | Legally binding agreements between the organization and external parties, such as contractors, service providers, or tenants, that outline the terms, responsibilities, deliverables, and conditions governing the provision of construction, maintenance, or property management services in alignment with public sector regulations and objectives |
| **T4** | Coordination | The organized effort to align activities, resources, and stakeholders across departments, agencies, and external partners to ensure seamless execution of projects, compliance with public sector regulations, and achievement of organizational objectives |
| **T5** | Documentation | The systematic creation, collection, and maintenance of records, reports, and other written or digital materials that capture project details, processes, decisions, and compliance requirements to support accountability, transparency, and operational efficiency |
| **T6** | External Governance | The oversight, regulations, and policies imposed by external entities, such as government bodies, regulatory agencies, or stakeholders, to ensure accountability, transparency, compliance with legal frameworks, and alignment with public interest objectives |

| | | |
|---|---|---|
| **T7** | Information Access Rights | The permissions and restrictions that govern who can access, view, or modify specific data or information within the organization, ensuring security, compliance with regulations, and appropriate use of sensitive or proprietary information |
| **T8** | Information Distribution | The process of disseminating relevant data, reports, or communications to appropriate stakeholders, departments, or external entities, ensuring timely and accurate sharing of information to support decision-making, transparency, and project execution |
| **T9** | Information on New Developments | Updates, reports, or communications regarding recent changes, innovations, or projects in areas such as policies, technologies, construction techniques, or property management practices that impact the organization's operations or strategic objectives |
| **T10** | Information Quality | The accuracy, completeness, reliability, relevance, and timeliness of data and information used to support decision-making, project management, compliance, and stakeholder communication |
| **T11** | Information Search | The process of locating, retrieving, and accessing relevant data or documents within internal or external systems to support decision-making, project planning, compliance, and operational activities |
| **T12** | Information Structuring | The organization and categorization of data and information into logical, accessible formats or systems to enhance clarity, efficiency, and usability for decision-making, project management, and compliance |
| **T13** | Integration & Mentoring | The process of onboarding new employees or stakeholders by providing structured support, guidance, and knowledge transfer to ensure their effective adaptation to the organization’s culture, processes, and objectives |
| **T14** | Internal Governance | The frameworks, policies, and procedures established within the organization to guide decision-making, ensure accountability, manage resources, and align operations with strategic objectives and regulatory requirements |
| **T15** | Leadership & Proactivity | The ability of leaders to anticipate challenges, take initiative, and guide teams toward achieving strategic goals, while fostering innovation, accountability, and responsiveness in alignment with public sector objectives |
| **T16** | Legal Norms | The established legal standards, regulations, and guidelines that govern the organization’s operations, ensuring compliance with laws, ethical practices, and public sector accountability |
| **T17** | Roles & Responsibilities | The specific duties, tasks, and obligations assigned to individuals or teams, clearly defining their contributions to achieving organizational objectives and ensuring accountability and efficiency in operations |
| **T18** | Service Provider | An external entity or contractor engaged to deliver specific services, such as construction, maintenance, or facility management, in alignment with the organization’s objectives and regulatory requirements |
| **T19** | Software & Hardware Resources | The technological tools and infrastructure, including computer programs, applications, devices, and equipment, used to support operations, data management, communication, and decision-making processes |
| **T20** | Software Support & Updates | The maintenance, troubleshooting, and enhancement of software systems through regular updates, patches, and technical assistance to ensure optimal performance, security, and alignment with evolving operational needs |
| **T21** | Sustainability | The adoption of practices, policies, and strategies that balance economic, environmental, and social considerations to ensure long-term resource efficiency, reduced environmental impact, and alignment with public sector goals for sustainable development |
| **T22** | Task Completion | The successful execution of assigned duties or responsibilities within a specified timeframe, meeting quality standards and aligning with organizational objectives and regulatory requirements |
| **T23** | Teamwork | The collective effort of individuals within a group to achieve shared goals, leveraging diverse skills, roles, and perspectives to enhance efficiency, innovation, and project outcomes |
| **T24** | Templates & Guidelines | Standardized documents and procedural frameworks designed to ensure consistency, compliance, and efficiency in project planning, execution, and decision-making processes |
| **T25** | Training & Development | Structured programs and initiatives aimed at enhancing employees' skills, knowledge, and competencies to improve performance, support career growth, and align with organizational objectives and public sector requirements |

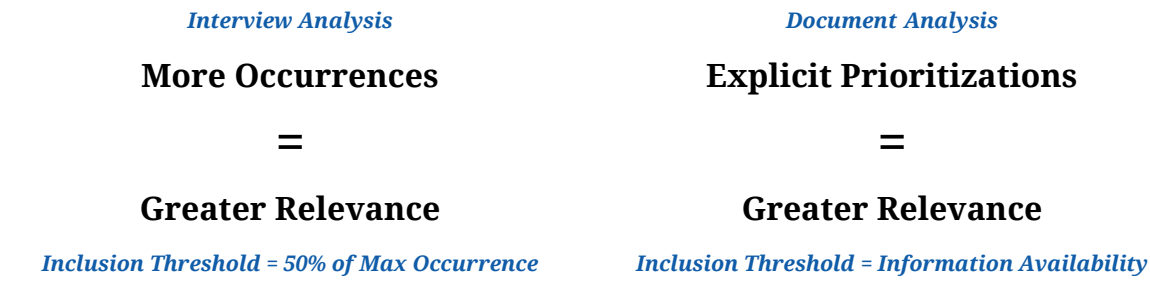
Table 06 | Interview Emergent Topics

### 4.3.2 Element inclusion and distilling mechanisms

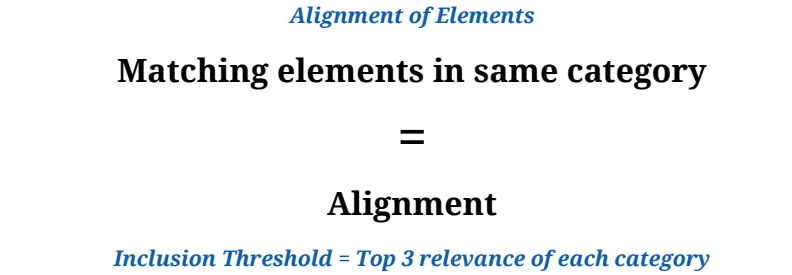
The logic applied during the data analysis to distil the essential elements was as follows:

Selected passages from the interview transcripts were categorized into corresponding dimensions—data need, data demand, or data barrier—and subsequently analysed to identify associated themes and topics. Each passage was evaluated only once for topics, themes, or dimensions to ensure clarity and consistency. In total, 1,319 quotes were analysed from 20 transcripts. Summary tables of the elements included in each dimension for the interview analysis were created using occurrence counts as the threshold. An element was included if its occurrence count reached at least 50% of the maximum value for the highest-occurring topic or theme (see Table 7, 8, 9).

The elements included in the summary tables for each dimension in the document analysis were determined through a process of subtraction. Starting with a comprehensive list of elements, an element was included in the table if a matching statement was found in the documents. If the statement explicitly mentioned that the element was a high priority for the organization, its relevance was further emphasized. Elements not referenced in the selected documents were excluded from the tables (see Tables 10, 11, and 12). The following diagram summarizes the steps undertaken in the process.




The top three elements in terms of relevance from each table were compared in the (mis)alignment analysis. If the current state (as determined by the interview analysis) and the desired state (as determined by the document analysis) contained matching elements, irrespective of their order of relevance, these were considered aligned elements (see Figure 48, 49, and 50). The following diagram summarizes the steps undertaken in the process.




Lastly, to distil the essential elements for each dimension, a ranking process was applied to the top three relevant elements from each category. The ranking process followed this logic: elements with alignment between the current state (interview analysis) and the desired state (document analysis) were given the highest rank. The weight of each element was determined through an internal validation session, where elements were assigned a score from 1 to 5 (with 5 being the highest). Finally, the order of relevance was considered (see Figures 51, 52, and 53).

Using this process, a summary table of essential elements was created (see Tables 15, 16, and 17). The following diagram illustrates the steps undertaken in this process.

***Distilling Elements***

**Alignment > Weight > Relevance**

**=**

**Essential Elements**

***Inclusion Threshold = Top 3 ranking of each category***

These essential elements are applied in conjunction with the theoretical framework to derive a set of managerial actions, as demonstrated in the example provided in segment 5.4, *Process design*.

### 4.3.3 Current state mapping instrument

To visualize the relationship between the dimensions—data needs, data barriers, and data demands—of an organization's current state, the 1,319 element occurrences are depicted using a sunburst diagram (see Figure 25). The diagram maps the themes associated with each dimension, categorizing them into social and technological aspects, and further highlights the specific topics that correlate within these themes.


Figure 25 | Mapping of the current state of the BLB NRW's data needs, data barriers, and data demands influencing elements
(by author)

The sunburst diagram provides guidance on the weighting of managerial actions derived from the essential elements. It reveals that elements influencing data needs (46%) occur more frequently than those related to data barriers (32%) and data demands (22%). Within the data needs dimension, 70% of occurrences are linked to social aspects, while 30% pertain to technological aspects. For the data barriers dimension, 56% of occurrences are linked to social aspects, while 44% are related to technological aspects. In the data demands dimension, 59% of occurrences are linked to social aspects, while 41% pertain to technological aspects.

Overall, across all dimensions, 63% of occurrences relate to social aspects, compared to 37% for technological aspects. This demonstrates that social aspects have a greater influence within the BLB NRW than technological aspects, supporting observations from the literature, which highlight the importance of a socio-technical approach (Chan, 2020; Lee & Borrmann, 2020; Siebelink, 2021).

## 4.4 Interview analysis

### 4.4.1 Tacit data needs

**Social Aspects -** The most influential social aspects topics related to data needs include *coordination* [T4], *roles and responsibilities* [T17], *information search* [T11], and *teamwork* [T23] (see Figure 26). Additionally, the most prevalent social aspect themes encompass *maturity* [SA7], *knowledge sharing* [SA6], *knowledge gaining* [SA5], *stakeholder relations* [SA10], and *goal interpretation* [SA2] (see Figure 27). Together, these elements shape how data needs are managed within the organization, affecting collaboration efficiency, role clarity, and information retrieval processes.

When analysing the correlation between topics and themes (see Figure 28), it becomes evident that coordination is fundamental to enabling both knowledge sharing and knowledge gaining. Nine out of twenty interviewees emphasized that regular exchange and communication are central to their workflows, facilitated through team meetings, Jour-fixe sessions, and cross-departmental gatherings. This exchange extends beyond intra-team collaboration, often involving interactions across departments and locations. For instance, Transcripts 03 and 05 highlighted the importance of sharing information with other branches, aiding in concept refinement and practical applicability. The critical role of coordination is further underscored by the consistent emphasis on knowledge sharing, essential for fostering collective learning and aligning on shared goals.

The theme of maturity is particularly linked to roles and responsibilities and information quality. Four out of twenty interviewees identified challenges in ensuring consistently accurate and usable information, reflecting broader issues in data governance and process maturity. Transcripts 12 and 16 revealed that inconsistencies in data definitions and validation processes often result in misunderstandings across teams, creating confusion about appropriate actions. This underscores the need for more mature, standardized practices to manage roles and responsibilities effectively and ensure data quality meets stakeholder requirements.

Information search is another crucial topic, closely tied to knowledge gaining and stakeholder relations. Three out of twenty interviewees noted that they frequently rely on external resources, such as specialized literature, internet searches, and platforms like YouTube, to supplement internal data. For example, Transcripts 02 and 04 described instances where internal data gaps were bridged through online research. Additionally, stakeholder relationships influence information search behaviours; several interviewees highlighted the importance of consulting knowledgeable colleagues or leveraging established networks to

obtain required information. This reliance on personal expertise and connections underscores a need for a centralized repository to ensure efficient and equitable access to information.

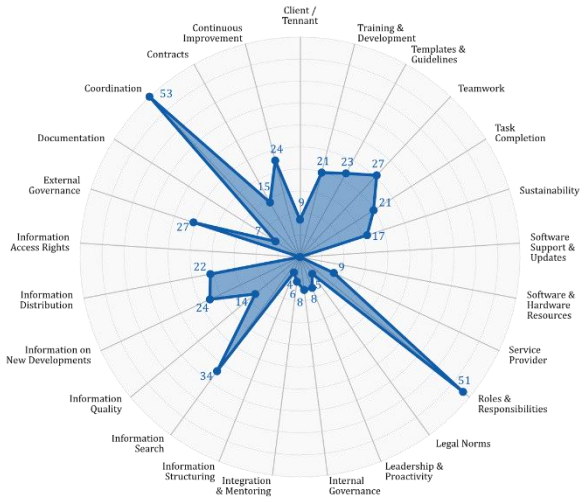



Figure 26 | Distribution of Data Needs Topics related to Social Aspects

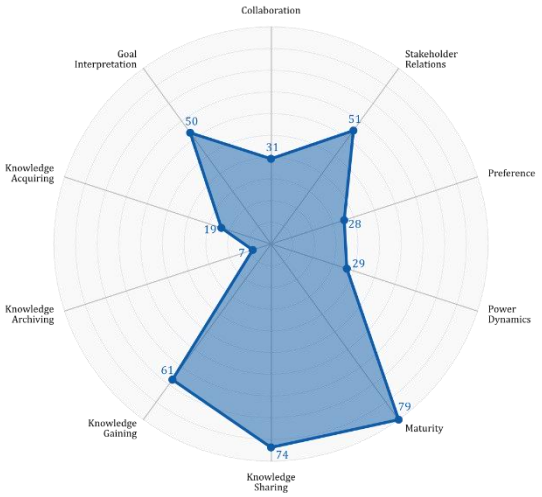



Figure 27 | Distribution of Social Aspect Themes related to Data Needs

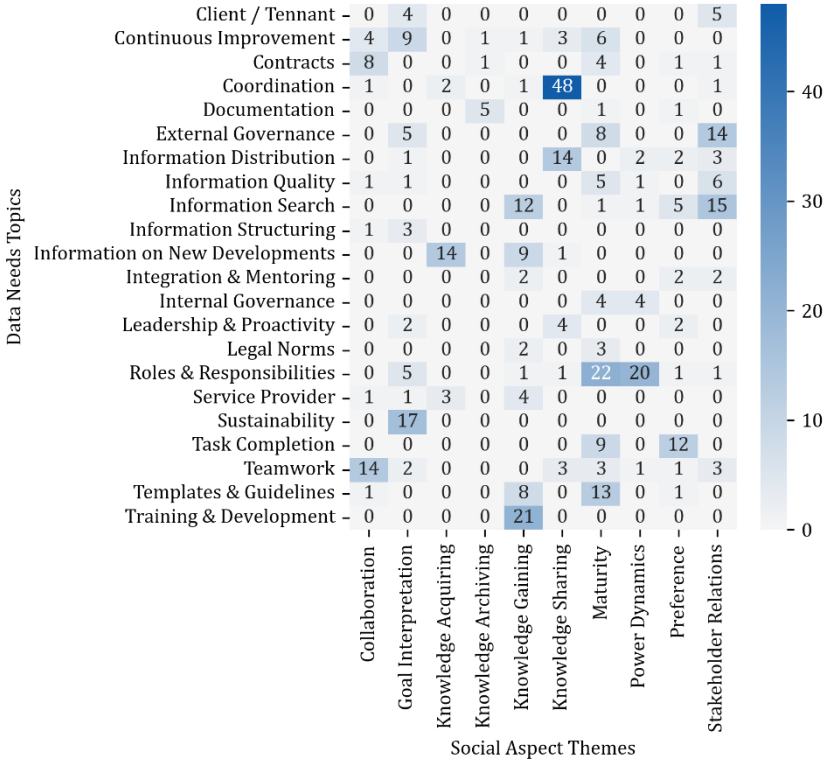



Figure 28 | Heatmap of Data Needs Topic Occurrences by Social Aspect Themes

Teamwork also plays a pivotal role in addressing data needs, particularly regarding goal interpretation and stakeholder relations. Four out of twenty interviewees highlighted teamwork's importance in achieving shared objectives, often through cross-functional collaboration. For example, Transcript 03 detailed how workshops and meetings serve as platforms to align goals and collectively address ongoing tasks. This collaborative environment

helps mitigate misunderstandings about project objectives and roles, facilitating better management of complex projects requiring input from multiple teams.

The organization's structure, particularly its power dynamics and clearly defined roles, also affects the efficiency of knowledge exchange. Incomplete or unclear information searches are often delegated to other individuals who are perceived to have the appropriate responsibility or authority to handle the task. This delegation underscores how organizational structure influences both the efficiency of information sharing and the outcomes of information search activities. While this delegation process is often effective, it also highlights potential inefficiencies where the knowledge flow relies on individual capacities rather than standardized systems or processes. Eleven out of twenty interviewees mentioned experiencing these delegations, which demonstrates how power dynamics and clearly defined roles play a crucial role in the dissemination of knowledge within the organization.

The analysis highlights that *coordination*, *roles and responsibilities*, *information search*, and *teamwork* are deeply interconnected with themes such as *maturity*, *knowledge sharing*, *knowledge gaining*, *stakeholder relationships*, and *goal interpretation*. Effective coordination and consistent knowledge sharing are crucial for addressing the organization's data needs, though challenges related to data maturity and reliance on individual expertise persist. Addressing these challenges requires adopting a more mature approach to data governance, clarifying roles and responsibilities, and promoting standardized practices to minimize inefficiencies and dependence on informal networks. Despite strong collaborative mechanisms, the organization's reliance on individual preferences, ad-hoc interactions, and variable stakeholder engagement highlights the need for greater standardization. Addressing process, template, and guideline gaps can enhance efficiency, reduce reliance on informal knowledge networks, and encourage more consistent knowledge sharing. Furthermore, the impact of organizational structure and power dynamics underscores the necessity of clearly defined roles and responsibilities to ensure effective information flow.

**Technological Aspects -** The The most influential technological aspect topics related to data needs are *information structuring* [T12], *information distribution* [T8], *information access rights* [T7], *information quality* [T10], and *information search* [T11] (see Figure 29). Additionally, the most prevalent technological aspect themes include *system efficiency* [TA8], *data storage* [TA6], *system capability* [TA7], and *data relevance* [TA4] (see Figure 30). These elements collectively shape how data is stored, accessed, shared, and utilized across the organization, influencing both daily operations and strategic decisions.

When analysing the correlation between topics and themes (see Figure 31), it is evident that information access rights and data storage are intricately connected, with significant emphasis on providing consistent access to shared information repositories. Fourteen out of twenty interviewees highlighted that their teams used shared drives (e.g., ECM, Windows Fileserver) for centralized data access and storage. This approach ensures that employees work with the most current data, as stated in Transcript 01. This focus on shared data repositories directly correlates with the system efficiency and data storage themes, which reflect efforts to reduce redundancy and improve data consistency across different departments.

Information distribution is also a crucial aspect, as observed in the use of system capabilities like project management systems and internal portals (e.g., BLB Portal, ECM, Kompass). Thirteen interviewees mentioned the importance of these platforms for information structuring and in facilitating the flow of information among teams. These systems enable employees to access important updates, guidelines, and collaborative tools effectively, as highlighted in Transcript 09. The correlation between system efficiency and information distribution suggests

that these platforms play a critical role in enabling smooth knowledge exchange, making collaboration more efficient and structured.

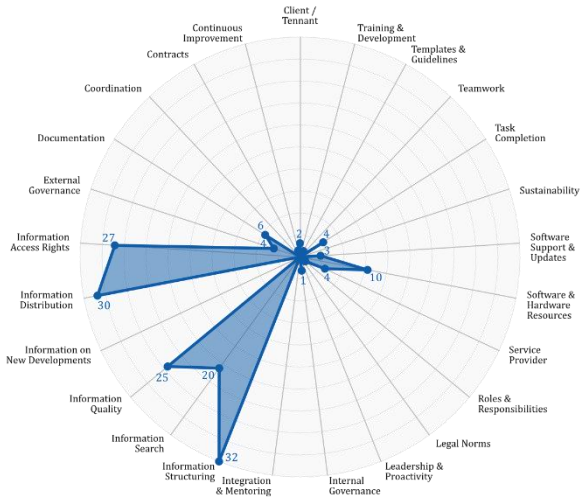



Figure 29 | Distribution of Data Needs Topics related to Technological Aspects

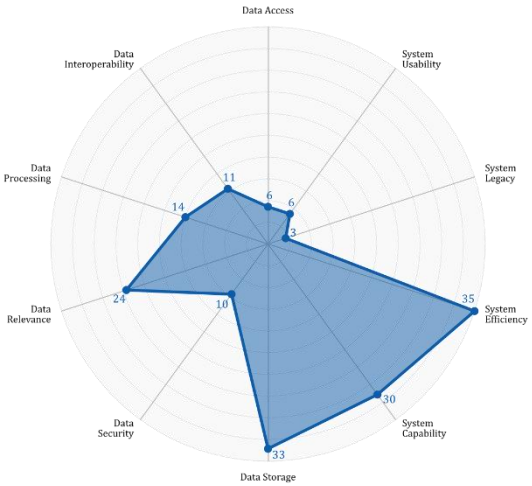



Figure 30 | Distribution of Technological Aspect Themes related to Data Needs

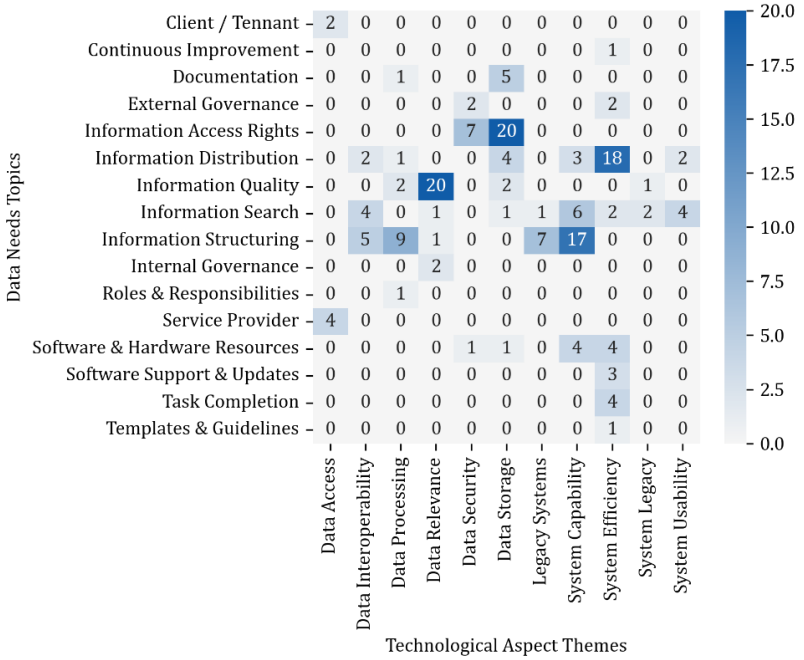



Figure 31 | Heatmap of Data Needs Topic Occurrences by Technological Aspect Themes

Information quality emerged as a key topic, especially in relation to data relevance. Ten out of twenty interviewees emphasized their reliance on the quality and accuracy of data within core systems such as SAP and CAFM (Transcript 20). They stressed the importance of ensuring that data is not only up-to-date but also verified for accuracy before being utilized in decision-making. This focus on data accuracy is reinforced by established verification processes and checks, which ensure that the information is suitable for both operational use and external sharing. The emphasis on data relevance is a direct reflection of the organization's priority to maintain high-quality data standards to support business processes and minimize errors.

The theme of information structuring is closely related to system capability and the ability to provide structured, task-specific data access. Nine out of twenty interviewees pointed out that their use of tools such as SAP, CAFM, and other internal systems is integral for effectively managing and organizing information. These systems are used for storing various forms of data, such as contractual documents, technical plans, and project-specific records (Transcript 08). This structured approach to data management ensures that all relevant information is easily accessible, supporting a streamlined workflow.

Information search also plays a prominent role in the technological aspects of data needs. Eight out of twenty interviewees noted that information retrieval often involves utilizing multiple tools, such as SAP or digital archives, for data discovery. As mentioned in Transcript 06, SAP serves as an important primary source for specific information, and other systems are used to supplement this with additional context or details. The relationship between information search and system capability indicates that the organization is actively working to improve access pathways, although there remain areas for optimization, particularly in reducing the complexity of navigating different tools.

The analysis reveals that the technological aspects of data management within the organization are closely interwoven. *Data storage* and *information access rights* are foundational to ensuring that employees have consistent and centralized access to the latest data. The efficiency of *information distribution* and the maintenance of *information quality* are critical for ensuring effective collaboration and decision-making. The correlation between *system capability*, *information structuring*, and *information search* further highlights the organization's ongoing efforts to streamline data access and improve the overall quality of data interactions. However, the need for better integration across different tools and platforms also points to opportunities for improvement in system efficiency and data management practices.

**Summary -** Based on the inclusion rules described in segment 4.3.2, Table 07 summarizes the elements influencing tacit data needs, ordered by the magnitude of relevance.

| Relevance | Elements Influencing Tacit Data Needs | | | |
|---|---|---|---|---|
| | **Social Aspects** | | **Technological Aspects** | |
| | **Topics** | **Themes** | **Topics** | **Themes** |
| 1 | T4 *Coordination* | SA7 *Maturity* | T12 *Information structuring* | TA8 *System Efficiency* |
| 2 | T17 *Roles & Responsibilities* | SA6 *Knowledge Sharing* | T8 *Information Distribution* | TA6 *Data Storage* |
| 3 | T11 *Information Search* | SA5 *Knowledge Gaining* | T7 *Information Access Rights* | TA7 *System Capability* |
| 4 | T23 *Teamwork* | SA10 *Stakeholder Relations* | T10 *Information Quality* | TA4 *Data Relevance* |
| 5 | - | SA2 *Goal Interpretation* | T11 *Information Search* | - |

Table 07 | Summary of elements influencing tacit data needs

### 4.4.2 Tacit data barriers

**Social Aspects -** The most influential social aspect topics related to data barriers are *task completion* [T22], *information quality* [T10], and *external governance* [T6] (see Figure 32). Additionally, the most prevalent social aspect themes include *preference* [SA9], *maturity* [SA7], and *power dynamics* [SA8] (see Figure 33). These elements collectively influence how data

barriers are experienced within the organization, affecting the efficiency of task completion, data reliability, and adherence to external governance.

When analyzing the correlation between topics and themes (see Figure 34), it becomes clear that *task completion* is significantly influenced by *preference*. For instance, eighteen out of sixty interviewees indicated that individual preferences regarding how work is approached or completed often result in inefficiencies or inconsistencies between different locations. This variability is particularly notable across various offices and teams, leading to a lack of unified approaches, as highlighted by respondents in Transcript 06 and Transcript 01. This autonomy, while providing flexibility, often results in open tensions or inconsistencies that become barriers to smooth task completion.

The theme of maturity is particularly critical in understanding the challenges surrounding information quality. Fourteen out of sixty interviewees emphasized the difficulty of ensuring that the data they use is both accurate and consistent, reflecting a broader issue of organizational maturity regarding data governance. The lack of standardized definitions or validation processes for data, such as different interpretations of construction dates or inconsistent data labelling, often leads to confusion and miscommunication (e.g., Transcript 12 and Transcript 09). This suggests that while there are efforts to improve data quality, there is still considerable work needed to establish more mature, consistent practices that can support accurate and reliable information across the organization.

External governance also presents a significant barrier, particularly in relation to power dynamics and task completion. Eleven out of sixty interviewees expressed frustration with the complexity of external regulations, including procurement laws and bureaucratic oversight, which can hinder their ability to complete projects efficiently. For example, in Transcript 09, respondents highlighted that public procurement requirements add significant delays and complications, making it challenging to respond quickly to emerging needs. Moreover, Transcript 17 pointed out the overwhelming regulatory landscape that organizations must navigate, leading to inefficiencies and delays in project execution.

The theme of preference also plays a substantial role in influencing both task completion and information quality. Respondents frequently mentioned that the processes in place are often real-life adaptations based on individual or departmental preferences rather than standardized protocols. This reliance on individual decision-making introduces a level of inconsistency that affects how effectively tasks are completed and data is managed. Thirteen out of sixty interviewees noted that differing preferences for how data is collected, labelled, or stored often result in fragmented information systems, as seen in Transcript 03 and Transcript 04. In some cases, there was a lack of motivation to verify data from multiple sources, with some interviewees admitting that once they found an acceptable version, they did not seek further validation (Transcript 15).

Power dynamics also play a crucial role in shaping the efficiency of task completion. Twelve out of sixty interviewees reported that hierarchical structures within the organization can act as barriers, making it difficult for staff to access necessary data or make decisions without approval from senior levels. For example, Transcript 18 mentioned that even when it is clear what actions need to be taken, the formal approval process can be time-consuming and hinder timely task completion. These power dynamics are particularly challenging in a public-sector environment, where adherence to formal procedures and oversight is both expected and required, adding layers of bureaucracy that complicate otherwise straightforward tasks.

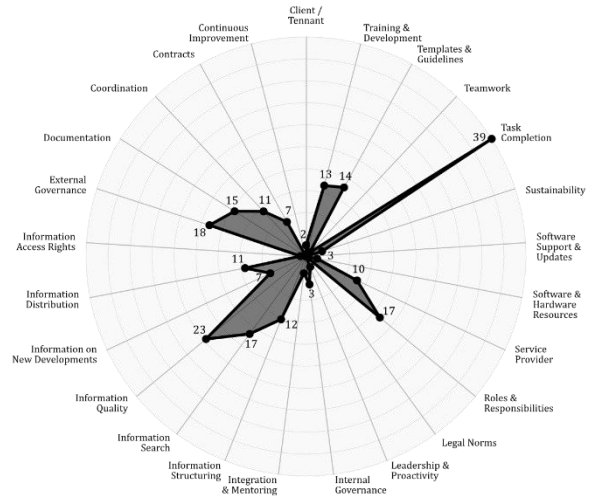



Figure 32 | Distribution of Data Barriers Topics related to Social Aspects

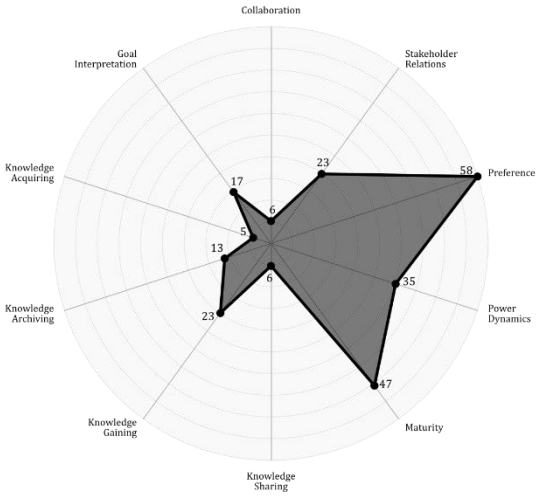



Figure 33 | Distribution of Social Aspect Themes related to Data Barriers

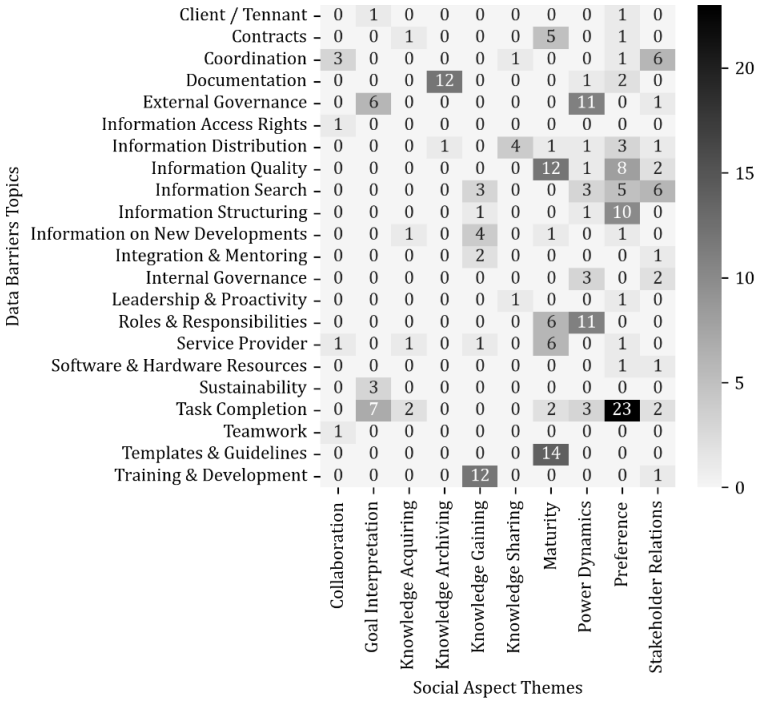



Figure 34 | Heatmap of Data Barriers Topic Occurrences by Social Aspect Themes

The analysis shows that *task completion*, *information quality*, and *external governance* are deeply interconnected, primarily influenced by *preference*, *maturity*, and *power dynamics*. While autonomy and personal preferences allow for tailored approaches, they also create inconsistencies that hinder standardization and efficiency. The barriers related to data quality and external governance underscore the need for greater maturity in data practices and a more unified approach to navigating external regulations. Addressing these barriers requires targeted efforts to enhance data governance, standardize work practices, and streamline processes to mitigate the negative impacts of hierarchical power structures on productivity.

**Technological Aspects -** The most influential technological aspect topics related to data barriers are *information structuring* [T12], *information quality* [T10], and *information search*

[T11] (see Figure 35). Additionally, the most prevalent technological aspect themes include *system legacy* [TA9], *data relevance* [TA4], *system efficiency* [TA8], *system capability* [TA7], *data processing* [TA3], *data storage* [TA6], *system usability* [TA10], and *data access* [TA1] (see Figure 36). These elements collectively highlight the significant challenges associated with accessing, managing, and utilizing data within the organization.

When analysing the correlation between topics and themes (see Figure 37), legacy systems significantly hinder both information quality and effective data structuring. Fourteen out of twenty interviewees indicated that older or poorly documented data, such as undigitized building information or incomplete historical records, significantly impacts the quality of data available for decision-making. For example, Transcript 20 and Transcript 19 highlighted how missing or incomplete documentation due to the legacy of past practices leads to inefficiencies in current operations. This directly influences the quality and reliability of the data, creating barriers to effective data use.


Figure 35 | Distribution of Data Barriers Topics related to Technological Aspects

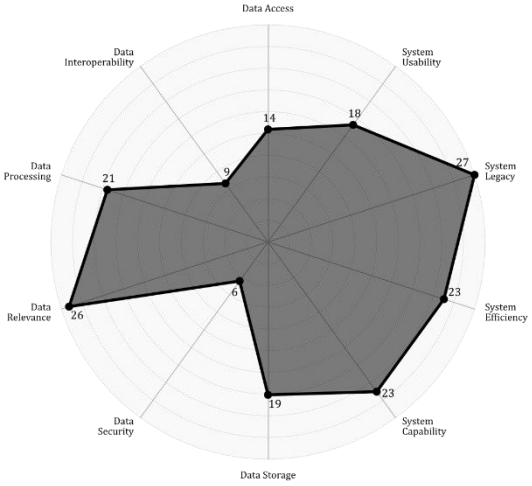



Figure 36 | Distribution of Technological Aspect Themes related to Data Barriers

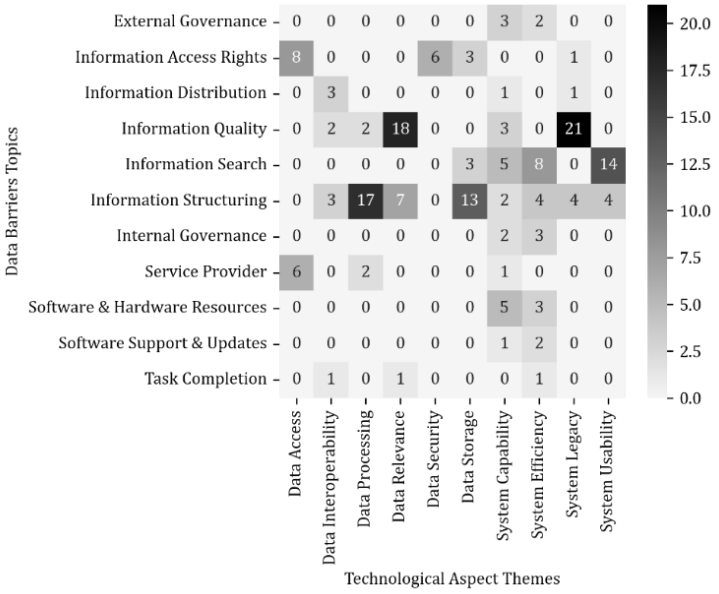



Figure 37 | Heatmap of Data Barriers Topic Occurrences by Technological Aspect Themes

Data structuring also emerges as a significant barrier, with sixteen out of twenty interviewees pointing out the inconsistent structuring of data across different storage systems. Multiple transcripts (e.g., Transcript 05, Transcript 10) mentioned that data is spread across various platforms, many of which are unstructured or redundant, leading to confusion and inefficiencies in retrieving relevant information. This inconsistency is further complicated by system usability challenges, where interviewees reported difficulties in navigating through different systems to locate needed data, thereby hampering information search efforts.

Information search itself is closely tied to both system efficiency and system usability. Thirteen interviewees described how searching for data is often an inefficient process due to the dispersed nature of information storage and the lack of integrated search functionalities across systems. As noted in Transcript 14 and Transcript 05, users often need to consult multiple sources or manually contact colleagues to find specific information, resulting in delays and reduced productivity. The lack of centralized access to data was emphasized as a major hindrance, underscoring the need for better system integration and usability improvements to streamline information retrieval. The theme of data relevance also plays a crucial role in shaping the challenges associated with information quality. Eleven out of twenty interviewees highlighted issues related to the relevance and accuracy of the data stored in their systems. For instance, Transcript 18 and Transcript 02 indicated that outdated or irrelevant data continues to be a problem, which not only impacts decision-making but also requires additional time and resources to validate the information. This is further complicated by system legacy issues, where older systems and data that have not been updated or digitized still play a significant role in daily operations, affecting the overall data quality.

The analysis reveals that technological barriers such as system legacy, data structuring, and system inefficiencies are deeply interconnected with themes like data relevance, information quality, and system usability. Addressing these barriers will require a concerted effort to modernize legacy systems, improve data structuring practices, and enhance system capabilities and usability to reduce the reliance on manual processes and facilitate more efficient data access and use.

**Summary -** Based on the inclusion rules described in segment 4.3.2, Table 08 summarizes the elements influencing tacit data barriers, ordered by the magnitude of relevance.

| Relevance | Elements Influencing Tacit Data Barriers | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T22** *Task Completion* | **SA9** *Preference* | **T12** *Information Structuring* | **TA9** *System Legacy* |
| 2 | **T10** *Information Quality* | **SA7** *Maturity* | **T10** *Information Quality* | **TA4** *Data Relevance* |
| 3 | **T6** *External Governance* | **SA8** *Power Dynamics* | **T11** *Information Search* | **TA8** *System Efficiency* |
| 4 | - | - | - | **TA7** *System Capability* |
| 5 | - | - | - | **TA3** *Data Processing* |
| 6 | - | - | - | **TA6** *Data Storage* |
| 7 | - | - | - | **TA10** *System Usability* |
| 8 | - | - | - | **TA1** *Data Access* |

Table 08 | Summary of elements influencing tacit data barriers

### 4.4.3 Tacit data demands

**Social Aspects -** The most influential social aspect topics related to data demands are *information quality* [T10], *external governance* [T6], *coordination* [T4], and *information distribution* [T8] (see Figure 38). As well, the most prevalent social aspect themes include *maturity* [SA7], *goal interpretation* [SA2], *collaboration* [SA1], and *stakeholder relations* [SA10] (see Figure 19). These elements collectively demonstrate that data demands are heavily influenced by the capability of organizations to align expectations, coordinate efforts, and manage stakeholder relationships effectively.

When analysing the correlation between topics and themes (see Figure 40), it becomes evident that coordination and collaboration play crucial roles in meeting data demands, as emphasized by 15 out of 20 interviewees. Several respondents highlighted the importance of effective coordination, particularly in ensuring that data quality meets organizational standards. For example, Transcript 13 and Transcript 19 pointed out that the lack of structured coordination between teams can lead to inconsistent information quality, which directly impacts decision-making capabilities. Furthermore, stakeholders must often coordinate across multiple levels within and outside the organization to ensure seamless information distribution and fulfil data needs.

The theme of stakeholder relations was also frequently mentioned, with 13 interviewees emphasizing its critical role in managing data demands. It was noted that stakeholder involvement and communication are vital for ensuring that data-related requirements are well-understood and effectively communicated across different teams. As highlighted in Transcript 12 and Transcript 01, the importance of tailoring communication to the specific needs of each stakeholder group was repeatedly noted. This helps in creating a shared understanding, thereby preventing miscommunication and ensuring that data is appropriately distributed and utilized.

Maturity emerged as a recurring theme in the discussions around information quality, with 11 out of 20 interviewees indicating that the maturity level of both processes and systems greatly influences how data demands are met. For instance, Transcript 18 and Transcript 16 illustrated that a mature approach to data management often results in better data quality, while a lack of maturity leads to inconsistencies and challenges in information validation. Mature processes are particularly necessary when dealing with external governance requirements, where adherence to regulations and guidelines impacts the quality of data and its availability.

Goal interpretation, as discussed by 10 interviewees, was a key factor affecting data demands, especially in contexts involving external governance. Many respondents mentioned that aligning data needs with broader organizational or governmental goals often requires careful interpretation of these goals. Transcript 16 and Transcript 20 specifically highlighted how external initiatives or regulations can create additional data demands that require adaptation and alignment by internal teams. Misinterpretation of such goals can lead to data gaps or misaligned data collection efforts, thereby complicating the process of achieving data quality and usability.

Finally, collaboration was identified as a fundamental element in meeting data demands, with 14 out of 20 interviewees mentioning its importance. Effective collaboration across different teams and departments was seen as crucial for ensuring that data is not only collected effectively but also shared and utilized in a way that adds value to the organization. Transcript 03 and Transcript 19 illustrated how collaboration between operational and strategic teams can help balance competing interests, such as cost efficiency versus data comprehensiveness, thereby supporting better overall decision-making.


Figure 38 | Distribution of Data Demands Topics related to Social Aspects


Figure 39 | Distribution of Social Aspect Themes related to Data Demands

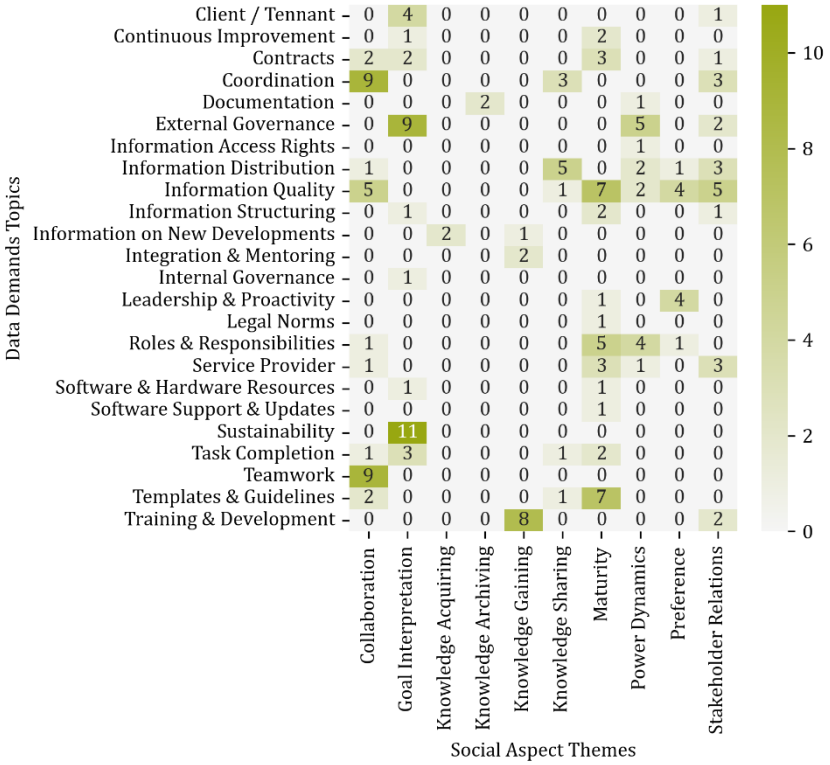



Figure 40 | Heatmap of Data Demands Topic Occurrences by Social Aspect Themes

The analysis reveals that social aspects such as stakeholder relations, coordination, maturity, and goal interpretation are deeply interconnected with data demands. Addressing these aspects requires enhancing collaboration efforts, establishing mature data practices, and improving communication strategies to align data needs with organizational goals and external governance requirements.

**Technological Aspects -** The most influential technological aspect topics related to data demands are *information structuring* [T12], *information quality* [T10], and *information search* [T11] (see Figure 41). As well, the most prevalent technological aspect themes include *data*

*relevance* [TA4], *data processing* [TA3], and *system capability* [TA7] (see Figure 42). These elements collectively emphasize the intricate interplay between efficient data handling and the technological limitations faced by the organization, highlighting how these factors influence data management outcomes.

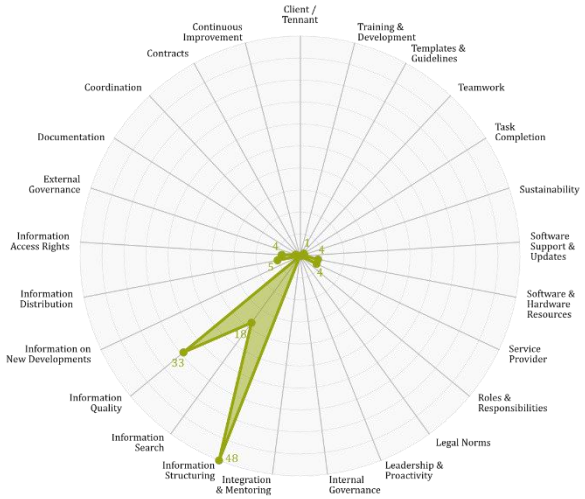



Figure 41 | Distribution of Data Demands Topics related to Technological Aspects

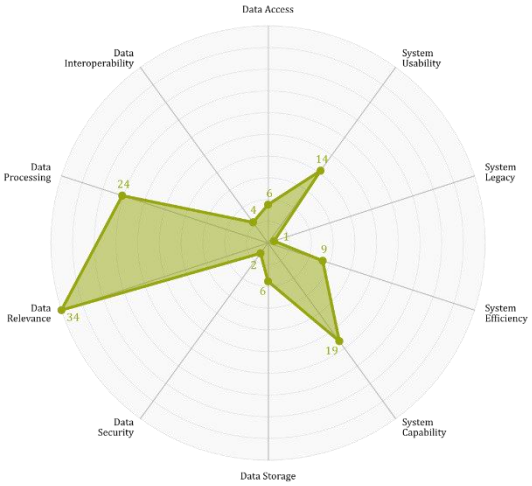



Figure 42 | Distribution of Technological Aspect Themes related to Data Demands

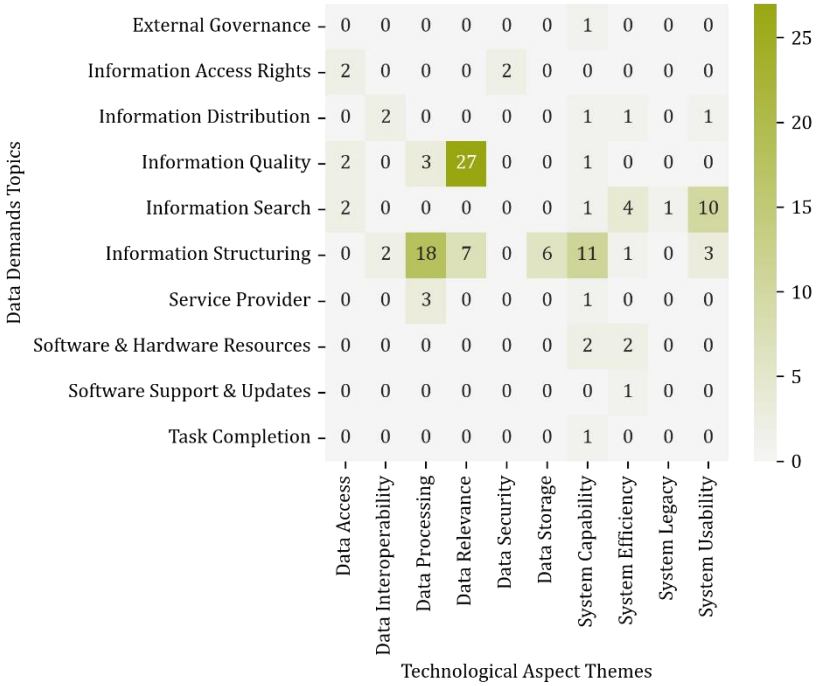



Figure 43 | Heatmap of Data Demands Topic Occurrences by Technological Aspect Themes

When analysing the correlation between topics and themes (see Figure 43), it becomes evident that data relevance and information quality are critically connected across many aspects of technological constraints. Twelve out of twenty interviewees mentioned issues related to data relevance, stressing that the accuracy and up-to-date nature of data are fundamental to

meaningful information quality. For example, Transcript 18 and Transcript 05 underscored the need to avoid generating "data clutter" that provides no real value, suggesting that it is crucial to maintain only pertinent and well-structured information in the systems.

Another recurring theme was the importance of information structuring in ensuring reliable data quality and usability. Fourteen out of twenty interviewees indicated that challenges in data structuring were a major technological barrier impacting data utilization. For instance, Transcript 17 and Transcript 11 highlighted that having unstructured or inconsistently organized data leads to inefficiencies, making it difficult to retrieve and validate important information. This reflects the strong relationship between information structuring and data relevance, where structured data directly contributes to the overall value and reliability of information.

Data processing was also emphasized by eleven interviewees as a crucial step for achieving effective data management. Several transcripts, such as Transcript 09 and Transcript 07, mentioned the need for sustainable and automated data processing methods to handle the increasing volume of data efficiently. The reliance on manual processes not only hampers efficiency but also contributes to inconsistencies in data quality, which were noted as barriers to using data effectively in decision-making. The frequent mention of automation points to the pressing need for improving system capability to enhance data processing.

System capability emerged as another key factor, with ten interviewees referencing the limitations of current systems in terms of handling complex data requirements. Transcript 19 and Transcript 12 emphasized the need for systems that support advanced data modelling, such as BIM, especially in the context of managing older or more complex assets. Improving system capability would directly address the challenges related to both data processing and information structuring, helping to streamline workflows and enhance the accuracy of data outputs.

The analysis reveals that the technological barriers involving system capability, data processing, and structuring are deeply interconnected with the themes of data relevance and quality. Addressing these barriers would involve enhancing system capabilities, automating data processing wherever possible, and standardizing data structuring practices to create a more streamlined and reliable data management environment. Such improvements would facilitate a more effective use of data, ultimately supporting better decision-making and operational efficiency within the organization.

**Summary -** Based on the inclusion rules described in segment 4.3.2, Table 09 summarizes the elements influencing tacit data demands, ordered by the magnitude of relevance.

| Relevance | Elements Influencing Tacit Data Demands | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T10** *Information Quality* | **SA7** *Maturity* | **T12** *Information Structuring* | **TA4** *Data Relevance* |
| 2 | **T6** *External Governance* | **SA2** *Goal Interpretation* | **T10** *Information Quality* | **TA3** *Data Processing* |
| 3 | **T4** *Coordination* | **SA1** *Collaboration* | **T11** *Information Search* | **TA7** *System Capability* |
| 4 | **T8** *Information Distribution* | **SA10** *Stakeholder Relations* | - | - |

Table 09 | Summary of elements influencing tacit data demands

## 4.5 Document Analysis

### 4.5.1 Explicit data needs

**Social Aspects -** The analysis of organizational policy documents to identify factors influencing data needs reveals that the most relevant social aspect topics are *external governance* [T6], *internal governance* [T14], and *roles & responsibilities* [T17]. Additionally, the most relevant social aspect themes include *maturity* [SA7], *stakeholder relations* [SA10], and *power dynamics* [SA8].

Within the social dimension, governance frameworks—both external and internal—emerge as pivotal in shaping roles, responsibilities, and organizational maturity. External governance ensures alignment with regulatory standards, while internal governance enforces policy adherence and operational discipline (ISO, 2018; Lindblad & Guerrero, 2020). The concept of roles and responsibilities is closely tied to organizational maturity, as well-defined roles enhance accountability and strategic alignment (Abbasnejad et al., 2021; Siebelink, 2021).

Stakeholder relations serve as a bridge, harmonizing the interests of internal and external actors and mitigating conflicts (Kuitert et al., 2019; Mendez et al., 2024). Meanwhile, power dynamics play a significant role in influencing decision-making and resource allocation, highlighting the importance of equitable and transparent processes to foster collaboration and organizational cohesion (Shirish & Batuekueno, 2021; Kuiper, 2021).

**Technological Aspects -** For technological aspects, the most relevant topics related to data needs are *sustainability* [T21], *task completion* [T22], and *information quality* [T10]. The most relevant technological aspect themes are *system legacy* [TA9], *system capability* [TA7], and *system efficiency* [TA8].

In the technological aspects domain, sustainability, task completion, and information quality are critical themes that intersect with the technical capabilities of systems. Sustainability emphasizes the need for efficient resource use and long-term viability, often challenged by legacy systems that, while critical for continuity, may hinder innovation (Lu et al., 2021; ISO, 2018). Task completion relies on robust system capabilities and usability, enabling users to access and process data effectively (Karmakar & Delhi, 2021; Abbasnejad et al., 2021). Furthermore, the quality of information underpins operational success, requiring efficient processing and storage mechanisms (Chan, 2020; Benn & Stoy, 2022).

Technological themes such as system legacy, capability, and efficiency collectively address these concerns, ensuring that systems not only meet immediate operational needs but also support strategic sustainability (S. T. Matarneh et al., 2019; Godager et al., 2021).

**Summary -** The analysis highlights the symbiotic relationship between social and technological aspects, where governance, maturity, and stakeholder management in the social domain align with system efficiency, capability, and sustainability in the technological domain. This alignment is crucial for addressing complex data needs and achieving cohesive organizational performance.

Cross-aspect relationships further illustrate the interconnectedness of social and technological factors. Governance frameworks depend on technological systems to enforce sustainable practices and operational efficiency (ISO, 2018; Lu et al., 2021). For instance, stakeholder relations bridge the gap between governance demands and technological sustainability, ensuring that organizational objectives align with public sector expectations (Lindblad &

Guerrero, 2020; Mendez et al., 2024). The clarity of roles and responsibilities in the social sphere is complemented by technological support, as usable systems and high-quality information enable task execution with precision (Abbasnejad et al., 2021; Chan, 2020).

Additionally, power dynamics influence decisions around legacy systems and modernization efforts, often dictating whether efficiency and sustainability goals are prioritized (Shirish & Batuekueno, 2021; Kuiper, 2021). Mature organizations are particularly well-positioned to integrate these aspects, leveraging technological capabilities to ensure high information quality and informed decision-making (Siebelink, 2021; Benn & Stoy, 2022).

Based on the inclusion rules outlined in segment 4.3.2, Table 10 summarizes all influential elements of explicit data needs, ranked by their magnitude of relevance.

| Relevance | Elements Influencing Explicit Data Needs | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T6** *External Governance* | **SA7** *Maturity* | **T21** *Sustainability* | **TA9** *System Legacy* |
| 2 | **T14** *Internal Governance* | **SA10** *Stakeholder Relations* | **T22** *Task Completion* | **TA7** *System Capability* |
| 3 | **T17** *Roles & Responsibilities* | **SA8** *Power Dynamics* | **T10** *Information Quality* | **TA8** *System Efficiency* |
| 4 | **T5** *Documentation* | **SA2** *Goal Interpretation* | **T12** *Information Structuring* | **TA10** *System Usability* |
| 5 | **T1** *Client / Tennant* | **SA1** *Collaboration* | **T8** *Information Distribution* | **TA1** *Data Access* |
| 6 | **T2** *Continuous Improvement* | **SA5** *Knowledge Gaining* | **T11** *Information Search* | **TA6** *Data Storage* |
| 7 | **T15** *Leadership & Proactivity* | **SA4** *Knowledge Archiving* | **T19** *Software & Hardware Resources* | **TA4** *Data Relevance* |
| 8 | **T13** *Integration & Mentoring* | **SA6** *Knowledge Sharing* | **T20** *Software Support & Updates* | - |
| 9 | **T25** *Training & Development* | **SA9** *Preference* | - | - |
| 10 | **T23** *Teamwork* | - | - | - |
| 11 | **T24** *Templates & Guidelines* | - | - | - |

Table 10 | Summary of elements influencing explicit data needs

### 4.5.2 Explicit data barriers

**Social Aspects -** The analysis of process evaluation documents to identify factors influencing data barriers reveals that the most relevant social aspect topics are *roles & responsibilities* [T17], *templates & guidelines* [T24], and *contracts* [T3]. Additionally, the most relevant social aspect themes include *maturity* [SA7], *knowledge gaining* [SA5], and *goal interpretation* [SA2].

Within the social dimension, roles and responsibilities, templates and guidelines, and contracts emerge as pivotal topics in overcoming data barriers. Clearly defined roles and responsibilities are critical in mitigating confusion and ensuring accountability, particularly in data-related processes (ISO, 2018; Abbasnejad et al., 2021). Templates and guidelines provide standardization, streamlining workflows and ensuring consistency in data handling and interpretation (Godager et al., 2021; Karmakar & Delhi, 2021). Contracts, meanwhile, establish the foundational agreements that govern the exchange and use of data, necessitating clear terms to prevent ambiguities and conflicts (ISO, 2018; Lindblad & Guerrero, 2020).

These topics are intrinsically linked to organizational maturity, which reflects the development and consistent application of processes to minimize barriers (Siebelink, 2021; Wildenauer & Basl, 2021). Knowledge gaining further supports this effort by equipping personnel with the skills and expertise necessary to navigate complex data landscapes (Nonaka, 1994; Ford, 2024). Additionally, goal interpretation ensures that data-related tasks align with organizational objectives, bridging the gap between strategic intent and operational execution (Mendez et al., 2024; Chan, 2020).

**Technological Aspects -** For technological aspects, the most relevant topics related to data barriers are *information quality* [T10], *information structuring* [T12], and *software & hardware resources* [T19]. The most relevant technological aspect themes are *system efficiency* [TA8], *data interoperability* [TA2], and *data access* [TA1].

Within the technological aspect's domain, barriers to information quality, structuring, and software and hardware resources are particularly influential. Information quality is foundational to decision-making and operational success, and poor-quality data can significantly hinder organizational efficiency (Chan, 2020; Benn & Stoy, 2022). Structuring information in logical, accessible formats is equally critical, as disorganized or fragmented data contributes to inefficiencies and limits usability (Godager et al., 2021; Karmakar & Delhi, 2021). Software and hardware resources further compound these challenges, as outdated or incompatible systems restrict data accessibility and limit operational effectiveness (S. T. Matarneh et al., 2019; ISO, 2018).

To address these barriers, system efficiency, data interoperability, and data access are essential themes. System efficiency ensures that technological processes minimize resource consumption while maximizing output, critical for overcoming data-related inefficiencies (Ford, 2024; Karmakar & Delhi, 2021). Data interoperability facilitates seamless exchange and integration of information across platforms, addressing the challenges posed by fragmented systems (ISO, 2018; Lindblad & Guerrero, 2020). Data access, governed by permissions and availability, ensures that relevant data is readily available to authorized users, supporting decision-making and operational needs (Shirish & Batuekueno, 2021; Siebelink, 2021).

**Summary -** The analysis illustrates that data barriers requires a holistic understanding of the relationships between social and technological aspects. Social themes such as maturity, knowledge gaining, and goal interpretation must align with technological capabilities like system efficiency, data interoperability, and data access. By fostering clarity in roles, standardizing processes through templates and guidelines, and leveraging robust technological systems, organizations can effectively mitigate data barriers and enhance overall efficiency.

Cross-aspect relationships highlight the interplay between social and technological barriers to data efficiency. For instance, the clarity of roles and responsibilities in the social dimension directly impacts the usability of technological systems, as clearly defined roles enable more effective use of software and hardware resources (ISO, 2018; Abbasnejad et al., 2021). Similarly, templates and guidelines in the social domain align with information structuring in the technological domain, promoting consistency and accessibility in data formats (Godager et al., 2021; Karmakar & Delhi, 2021). Contracts, as a social topic, depend heavily on data interoperability and access, as well-defined agreements require seamless data exchange and secure access to relevant information (ISO, 2018; Lindblad & Guerrero, 2020).

Organizational maturity further underpins these relationships, as mature organizations are better equipped to harmonize social and technological processes (Siebelink, 2021; Wildenauer & Basl, 2021). Knowledge gaining within the social aspect complements technological efforts by

ensuring that personnel are equipped to leverage system capabilities (Nonaka, 1994; Ford, 2024), while goal interpretation bridges strategic objectives with operational tools and resources (Mendez et al., 2024; Chan, 2020).

**B**ased on the inclusion rules outlined in segment 4.3.2, Table 11 summarizes all influential elements of explicit data barriers, ranked by their magnitude of relevance.

| Relevance | Elements Influencing Explicit Data Barriers | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T17** *Roles & Responsibilities* | **SA7** *Maturity* | **T10** *Information Quality* | **TA8** *System Efficiency* |
| 2 | **T24** *Templates & Guidelines* | **SA5** *Knowledge Gaining* | **T12** *Information Structuring* | **TA2** *Data Interoperability* |
| 3 | **T3** *Contracts* | **SA2** *Goal Interpretation* | **T19** *Software & Hardware Resources* | **TA1** *Data Access* |
| 4 | **T4** *Coordination* | **SA10** *Stakeholder Relations* | **T22** *Task Completion* | **TA4** *Data Relevance* |
| 5 | **T25** *Training & Development* | **SA1** *Collaboration* | **T18** *Service Provider* | **TA7** *System Capability* |
| 6 | **T1** *Client / Tennant* | **SA6** *Knowledge Sharing* | **T23** *Teamwork* | **TA9** *System Legacy* |
| 7 | **T18** *Service Provider* | - | **T20** *Software Support & Updates* | **TA6** *Data Storage* |
| 8 | **T5** *Documentation* | - | - | - |

Table 11 | Summary of elements influencing explicit data barriers

### 4.5.3 Explicit data demands

**Social Aspects -** The analysis of information requirements documents to identify factors influencing data demands reveals that the most influential social aspect topics are *coordination* [T4], *teamwork* [T23], and *roles & responsibilities* [T17]. Additionally, the most prevalent social aspect themes include *maturity* [SA7], *collaboration* [SA1], and *goal interpretation* [SA2].

Within the social domain, coordination, teamwork, and roles and responsibilities emerge as critical topics influencing the effective management of data demands. Coordination ensures the alignment of activities, resources, and stakeholders, facilitating seamless data-related workflows across departments and partners (Kuitert et al., 2019; Lindblad & Guerrero, 2020). Teamwork complements coordination by fostering collective efforts to achieve shared goals, leveraging diverse perspectives and skills (Ford, 2024; Shirish & Batuekueno, 2021). Roles and responsibilities provide clarity in task assignments, ensuring accountability and efficiency in meeting data demands (ISO, 2018; Abbasnejad et al., 2021).

These topics are deeply interwoven with organizational maturity, which reflects the consistent optimization of processes and systems to handle data effectively (Siebelink, 2021; Wildenauer & Basl, 2021). Collaboration further enhances these efforts by emphasizing unity and solidarity in navigating complex data landscapes (Lindblad & Karrbom Gustavsson, 2021; Nonaka, 1994). Goal interpretation serves as a crucial link between organizational objectives and operational tasks, ensuring that data initiatives align with broader strategic aims (Mendez et al., 2024; Chan, 2020).

**Technological Aspects -** For technological aspects, the most influential topics related to data demands are *sustainability* [T21], *documentation* [T5], and *information quality* [T10]. The most prevalent technological aspect themes are *data relevance* [TA4], *data access* [TA1], and *data processing* [TA3].

In the technological domain, sustainability, documentation, and information quality are the most influential topics shaping data demands. Sustainability ensures that data systems and practices support long-term operational and strategic goals, balancing resource efficiency with robust performance (Lu et al., 2021; UN, 2015). Documentation plays a vital role in maintaining comprehensive and accessible records, which are critical for accountability, transparency, and operational continuity (ISO, 2018; Godager et al., 2021). Information quality is a cornerstone for meeting data demands, as accurate, reliable, and relevant data supports informed decision-making and operational efficiency (Chan, 2020; Benn & Stoy, 2022).

These topics are supported by prevalent technological themes such as data relevance, data access, and data processing. Data relevance ensures that the information aligns with organizational needs and decision-making processes (Karmakar & Delhi, 2021; S. T. Matarneh et al., 2019). Data access facilitates the retrieval and use of necessary information by authorized personnel, ensuring operational efficiency and security (ISO, 2018; Lindblad & Guerrero, 2020). Data processing ensures that collected information is transformed into actionable insights, directly supporting the organization's ability to meet data demands (Ford, 2024; Benn & Stoy, 2022).

**Summary -** The analysis highlights that data demands requires a coordinated approach that integrates social aspects such as teamwork, roles, and collaboration with technological themes like sustainability, data relevance, and processing. The synergy between these dimensions ensures that data-related activities are not only efficient but also strategically aligned, enabling organizations to meet their data demands effectively and sustainably.

Cross-aspect relationships further highlight the interconnectedness of social and technological factors in addressing data demands. For instance, coordination and teamwork in the social domain rely heavily on technological capabilities such as data relevance and access to ensure that stakeholders can collaborate effectively using timely and pertinent information (Karmakar & Delhi, 2021; Lindblad & Guerrero, 2020). Roles and responsibilities are closely tied to data processing, as clear task assignments ensure that data is analyzed and utilized efficiently (ISO, 2018; Abbasnejad et al., 2021).

Organizational maturity serves as a foundation for bridging these aspects, as mature organizations are better equipped to harmonize social collaboration and technological capabilities (Siebelink, 2021; Wildenauer & Basl, 2021). Collaboration within the social dimension complements technological sustainability, as unified efforts are essential for maintaining long-term data systems (Lu et al., 2021; Benn & Stoy, 2022). Similarly, goal interpretation in the social aspect ensures that data documentation and processing are strategically aligned with organizational objectives, reinforcing coherence between data demands and broader goals (Mendez et al., 2024; Chan, 2020).

Based on the inclusion rules outlined in segment 4.3.2, Table 12 summarizes all influential elements of explicit data demands, ranked by their magnitude of relevance.

| Relevance | Elements Influencing Explicit Data Demands | | | |
|---|---|---|---|---|
| | **Social Aspects** | | **Technological Aspects** | |
| | **Topics** | **Themes** | **Topics** | **Themes** |
| 1 | **T4** *Coordination* | **SA7** *Maturity* | **T21** *Sustainability* | **TA4** *Data Relevance* |
| 2 | **T23** *Teamwork* | **SA1** *Collaboration* | **T5** *Documentation* | **TA1** *Data Access* |
| 3 | **T17** *Roles & Responsibilities* | **SA2** *Goal Interpretation* | **T10** *Information Quality* | **TA3** *Data Processing* |
| 4 | **T24** *Templates & Guidelines* | **SA9** *Preference* | **T12** *Information Structuring* | **TA5** *Data Security* |
| 5 | **T22** *Task Completion* | **SA10** *Stakeholder Relations* | **T18** *Service Provider* | **TA6** *Data Storage* |

Table 12 | Summary of elements influencing explicit data demands

—End of Chapter—

# 5 Validation

## 5.1 (Mis)alignment

### 5.1.1 Current state cross dimensional analysis

Cross-dimensional analysis by topics reveals influential connections across different dimensions, which can be further broken down by social and technological aspects (see Figure 44 and 45).

*Coordination* [T4], for example, is a critical topic that appears across data needs (blue), data barriers (black), and data demands (green), reflecting its foundational role in facilitating collaboration and communication. Effective coordination ensures that data is shared and utilized optimally, reducing misunderstandings and aligning goals across teams. This topic is central to creating a cohesive work environment where roles are clearly defined, and responsibilities are understood, thus minimizing inefficiencies. *Information quality* [T10] is also significant across dimensions and is closely tied to the social aspect of collaboration, as maintaining high-quality data often requires the collective effort of multiple stakeholders. Ensuring information quality requires not only proper governance but also active participation and validation from individuals across different teams.

From a technological perspective, *information structuring* [T12] emerges as a key topic that influences both data barriers and data demands, as well-structured data is crucial for retrieval, interpretation, and application. This highlights the importance of focusing on data organization to reduce inefficiencies and enhance usability. Proper structuring ensures that information is accessible and usable, which directly impacts the efficiency of data processes. Additionally, i*nformation search* [T11] is relevant to the technological dimension as it affects how quickly and effectively data can be retrieved. The reliance on multiple tools and platforms for information search points to existing gaps in system integration, thereby underscoring the need for more cohesive technological solutions that simplify data discovery and access.

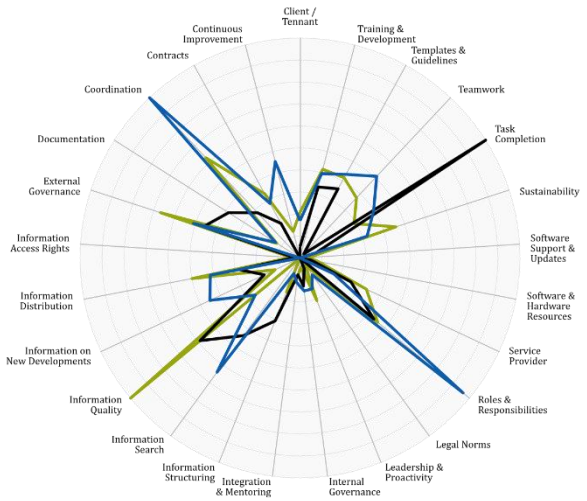



Figure 44 | Cross Dimension comparison of Social Aspects Topics

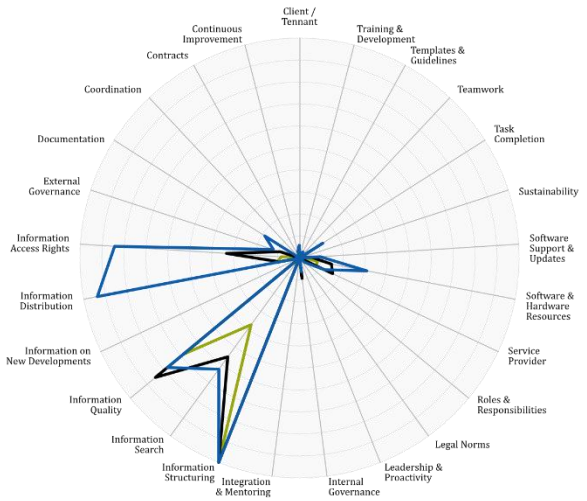



Figure 45 | Cross Dimension comparison of Technological Aspect Topics

Cross-dimensional analysis by themes also highlights several recurring issues that cut across multiple dimensions, both social and technological (see Figure 46 and 47).

For social themes, *maturity* [SA7] consistently appears across data needs (blue), data barriers (black), and data demands (green), underscoring its pivotal role in shaping both organizational efficiency and data quality. Maturity influences not only how data needs are met but also how barriers are mitigated, and demands are addressed. A mature approach leads to more standardized practices and processes, thereby reducing inconsistencies and improving data reliability. Similarly, *stakeholder relations* [SA10] is prevalent across the data needs and data demands dimensions, indicating that effective stakeholder communication is essential for both fulfilling data needs and aligning data expectations. Stakeholder engagement plays a crucial role in bridging gaps between different teams and ensuring that data processes are aligned with organizational goals. *knowledge sharing* [SA6] also emerges as a theme that is vital across multiple dimensions, emphasizing the importance of creating an environment where information flows freely and is accessible to all relevant stakeholders.

On the technological side, *data relevance* [TA4] and *system capability* [TA7] are prevalent across multiple dimensions, highlighting the importance of having relevant data and capable systems that can support data processes efficiently. The presence of *data relevance* [TA4] across data needs, barriers, and demands indicates that ensuring data is both accurate and meaningful is a core requirement for effective data management. Similarly, *system capability* [TA7] being present across dimensions points to the critical role that system infrastructure plays in enabling or hindering data processes. Without capable systems, even the best data practices cannot be effectively implemented, which highlights the need for ongoing system enhancements and updates.


Figure 46 | Cross Dimension comparison of Social Aspects Themes

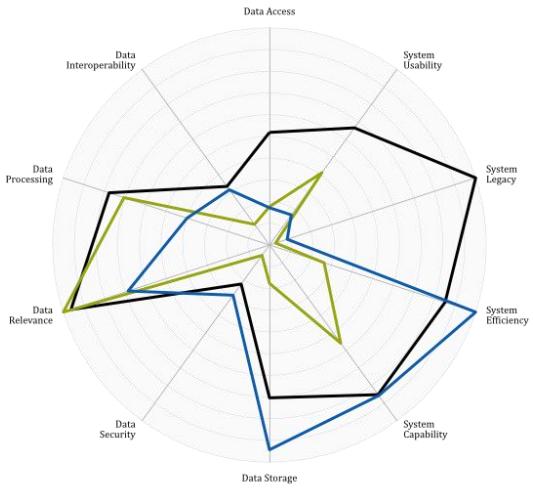



Figure 47 | Cross Dimension comparison of Technological Aspect Themes

### 5.1.2 (Mis)alignment data needs

The influencing elements of the current and desired states align in the social aspects of data needs, specifically with the topic of *roles and responsibilities* [T17] and the theme of *maturity*

[SA7]. However, for technological aspects, no topics align, while the themes of *system efficiency* [TA8] and *system capability* [TA7] do show alignment.

The alignment indicates that the policy's intent is well understood by individuals within the organization, particularly regarding the need to enhance data maturity and to acknowledge the evolving roles and responsibilities that accompany this growth. Similarly, the introduction of new platforms to build system capacity is well understood as a necessary step towards more efficient operations.

The misalignment in technological aspects topics is linked to the ongoing transition within BLB NRW. As the organization adopts new ICT systems, the current state reflects emergent challenges associated with these new systems, such as adapting to new information structures and learning to navigate new information access constraints. Specifically, access rights are designed to integrate with other IT data security systems (e.g., Active Directory, employee user accounts, email system) (BLB NRW, 2022a). These meta-controls and rights matrices impose new limitations on information access that users had not previously encountered.

Figure 48, based on the alignment rules outlined in segment 4.3.2, highlights the aligned and misaligned elements that influence both tacit and explicit data needs.

| Relevance | Elements Influencing Tacit Data Needs | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T4** *Coordination* | **SA7** *Maturity* | **T12** *Information Structuring* | **TA8** *System Efficiency* |
| 2 | **T17** *Roles & Responsibilities* | **SA6** *Knowledge Sharing* | **T8** *Information Distribution* | **TA6** *Data Storage* |
| 3 | **T11** *Information Search* **[3]** | **SA5** *Knowledge Gaining* | **T7** *Information Access Rights* | **TA7** *System Capability* |

*vs.*

| Relevance | Elements Influencing Explicit Data Needs | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T6** *External Governance* | **SA7** *Maturity* | **T21** *Sustainability* | **TA9** *System Legacy* |
| 2 | **T14** *Internal Governance* | **SA10** *Stakeholder Relations* | **T22** *Task Completion* | **TA7** *System Capability* |
| 3 | **T17** *Roles & Responsibilities* | **SA8** *Power Dynamics* | **T10** *Information Quality* | **TA8** *System Efficiency* |

*Aligned*
*Misaligned*

Figure 48 | (Mis)alignments of elements influencing data needs

### 5.1.3 (Mis)alignment data barriers

In the social aspects of data barriers, the influencing elements of the current and desired states show alignment only in the theme of *maturity* [SA7], with no topics aligning. For technological aspects, the topics of *information structuring* [T12] and *information quality* [T10] align, while *system efficiency* [TA8] is the only theme showing alignment.

The alignment suggests that building maturity capacity is a recognized challenge, both in internal documentation and in the organization's perception. Similarly, the topics of information structuring and information quality are closely related, as they highlight the challenges of working with data under conditions of sub-optimal maturity. Conversely, while the theme of system efficiency aligns, the reasons for its prioritization differ between the current and desired states. In the current state, system efficiency is primarily associated with the challenge of locating the right information across multiple unlinked platforms. In contrast,

the desired state focuses on optimizing the functionality of each platform independently. Both challenges must be addressed concurrently.

The misalignment in social aspects topics highlights a disconnect in how day-to-day challenges are documented. The emergent topics of the current state are linked to the 2018 restructuring of BLB NRW, which introduced more stringent political oversight over the organization's operational mechanisms (Ministerium der Finanzen, 2021). Challenges persist in accommodating tasks arising from oversight activities by ministries, often issued with little notice and tight deadlines. These spontaneous information requests are burdensome due to their unstructured nature and high priority, creating additional strain on the existing prioritized tasks and responsibilities of staff members. While these challenges are understood to be part of the job, failing to address them explicitly and strategically may lead to employee frustration and dissatisfaction, which contradicts the organization's stated goal of providing an attractive work environment (BLB NRW, 2023a).

Figure 49, based on the alignment rules outlined in segment 4.3.2, highlights the aligned and misaligned elements that influence both tacit and explicit data barriers.

**Elements Influencing Tacit Data Barriers**

| Relevance | Social Aspects | | Technological Aspects | |
|---|---|---|---|---|
| | Topics | Themes | Topics | Themes |
| 1 | **T22** *Task Completion* | **SA9** *Preference* | **T12** *Information Structuring* | **TA9** *System Legacy* |
| 2 | **T10** *Information Quality* | **SA7** *Maturity* | **T10** *Information Quality* | **TA4** *Data Relevance* |
| 3 | **T6** *External Governance* | **SA8** *Power Dynamics* | **T11** *Information Search* | **TA8** *System Efficiency* |

*vs.*

**Elements Influencing Explicit Data Barriers**

| Relevance | Social Aspects | | Technological Aspects | |
|---|---|---|---|---|
| | Topics | Themes | Topics | Themes |
| 1 | **T17** *Roles & Responsibilities* | **SA7** *Maturity* | **T10** *Information Quality* | **TA8** *System Efficiency* |
| 2 | **T24** *Templates & Guidelines* | **SA5** *Knowledge Gaining* | **T12** *Information Structuring* | **TA2** *Data Interoperability* |
| 3 | **T3** *Contracts* | **SA2** *Goal Interpretation* | **T19** *Soft-Hardware Resources* **[2]** | **TA1** *Data Access* |

*Aligned*
*Misaligned*

Figure 49 | (Mis)alignments of elements influencing data barriers

### 5.1.4 (Mis)alignment data demands

The influencing elements of the current and desired states align in the social aspects of data demands on the topic of *coordination* [T4]. Furthermore, all three themes of *maturity* [SA7], *goal interpretation* [SA2], and *collaboration* [SA1] show alignment. In the technological aspects, the topic of *information quality* [T10] aligns, along with the themes of *data relevance* [TA4] and *data processing* [TA3].

The absence of misaligned topics and themes between the current and desired states suggests a strong consensus between policy intents and emerging topics on the considerations required for demand formulation. This observation aligns with Kuitert et al. (2019), who noted that procedural obligations are formally well-defined among public clients. Notably, the complete alignment of social aspects themes highlights a mature capacity for demand formulation. This is further supported by internal documentation, which prescribes interdisciplinary collaboration for both program and demand formulation procedures (BLB NRW, 2023a). The process encompasses the full spectrum of complexity, from coordination to collaboration, as described by Ford (2024). For particularly complex projects, commissioning management

(*Inbetriebnahmemanagement*) is introduced to ensure that technical requirements are met across all trades (BLB NRW, 2023a).

Figure 50, based on the alignment rules outlined in segment 4.3.2, highlights the aligned and misaligned elements that influence both tacit and explicit data barriers.

| Elements Influencing Tacit Data Demands | | | | |
|---|---|---|---|---|
| Relevance | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T10** *Information Quality* | **SA7** *Maturity* | **T12** *Information Structuring* | **TA4** *Data Relevance* |
| 2 | **T6** *External Governance* | **SA2** *Goal Interpretation* | **T10** *Information Quality* | **TA3** *Data Processing* |
| 3 | **T4** *Coordination* | **SA1** *Collaboration* | **T11** *Information Search* | **TA7** *System Capability* |

*vs.*

| Elements Influencing Explicit Data Demands | | | | |
|---|---|---|---|---|
| Relevance | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T4** *Coordination* | **SA7** *Maturity* | **T21** *Sustainability* | **TA4** *Data Relevance* |
| 2 | **T23** *Teamwork* | **SA1** *Collaboration* | **T5** *Documentation* | **TA1** *Data Access* |
| 3 | **T17** *Roles & Responsibilities* | **SA2** *Goal Interpretation* | **T10** *Information Quality* | **TA3** *Data Processing* |

*Aligned*
*Misaligned*

Figure 50 | (Mis)alignments of elements influencing data demands

## 5.2 Internal validation

The internal validation session included members of the Department of Planning, Construction, and Instruments, whose role is to develop improvement strategies across these three areas. The session began with a presentation introducing the research project, followed by a group discussion in which interview quotes were contextualized within topics and themes, and their interpretations were explained. The group of seven attendees then assigned weighted values to each quote and explanation, considering their significance to the organization's prioritization efforts. It was noted during the group session that if a different set of individuals from the organization were to evaluate the same quotes, the results might differ. However, since one of the research objectives is to position BIM throughout the asset life cycle and given that the department is responsible for BIM implementation and its integration with other platforms, such as CAFM, their evaluation of the topics and themes is considered appropriate. The complete protocol for the internal validation session is provided in Appendix 8.

The evaluation results indicate that the topics of *sustainability* [T21] and *information quality* [T10] received the highest prioritization weight of 5. Following these were the topics of *coordination* [T4], *information distribution* [T8], *information structuring* [T12], and *teamwork* [T23], each with a prioritization weight of 4. This evaluation aligns with the desired state construct, where both information quality and sustainability are prominently represented. In contrast, the prioritization of topics T4, T8, T12, and T23 reflects the roles and responsibilities of the department, which aims to optimize strategies related to these areas.

Table 13 presents the weighted values assigned to interview emergent topics during the internal validation group's discussion.

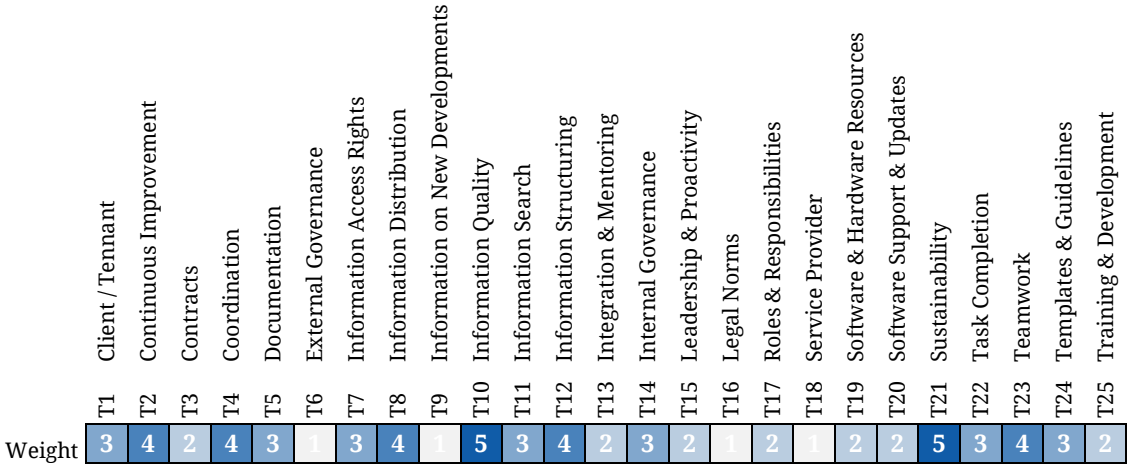



Table 13 | Internal validation of topics

The literature themes of *data interoperability* [TA2], *data processing* [TA3], and system legacy [TA9] received the highest prioritization weight of 5. Following these were the themes of *goal interpretation* [SA2], *stakeholder relations* [SA10], and *system capability* [TA7] each with a prioritization weight of 4. This evaluation also aligns with the desired state construct, as outlined in several BLB NRW policy documents, which emphasize the modernization of assets—including digitizing analogue file formats, updating ICT systems, and resolving system integration bottlenecks (BLB NRW, 2022a, 2023a). These themes all fall within the technological domain, indicating that higher-level policy intents place greater emphasis on these aspects. Additionally, the prioritization of themes SA10, SA2, and TA7 is consistent with recent efforts by BLB NRW to enhance client relations and operational efficiency (Ministerium der Finanzen, 2021).

Table 14 presents the weighted values assigned to literature themes during the internal validation group's discussion.

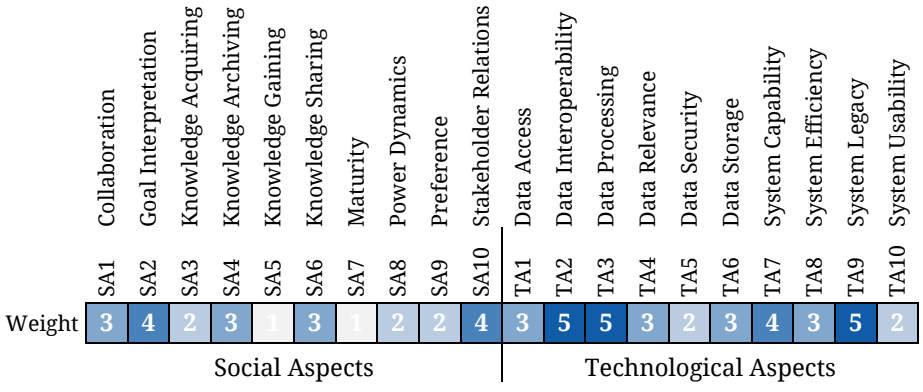



Table 14 | Internal validation of themes

The internal validation session confirms that the interpretation of the emergent topics and associated literature themes is not only evident within the organization but also aligns with the policy objectives that guided the BLB NRW's 2018 restructuring.

## 5.3 Essential elements

To distil the essential elements, the current and desired states are consolidated using the ranking rules outlined in segment 4.3.2. This rule-based process ensures a consistent methodology, minimizing the influence of personal preferences in prioritization. Figures 51, 52, and 53 illustrate the ranking process applied to the current and desired states of the influential elements related to data needs, barriers, and demands, respectively.

**Elements Influencing Tacit Data Needs**

| Relevance | Social Aspects | | Technological Aspects | |
|---|---|---|---|---|
| | Topics | Themes | Topics | Themes |
| 1 | T4 *Coordination* [4] 2 | SA7 *Maturity* [1] 1 | T12 *Information Structuring* [4] 3 | TA8 *System Efficiency* [3] 2 |
| 2 | T17 *Roles & Responsibilities* [2] | SA6 *Knowledge Sharing* [3] 3 | T8 *Information Distribution* [4] | TA6 *Data Storage* [2] |
| 3 | T11 *Information Search* [3] 3 | SA5 *Knowledge Gaining* [1] | T7 *Information Access Rights* [3] | TA7 *System Capability* [4] 1 |

*vs.*

**Elements Influencing Explicit Data Needs**

| Relevance | Social Aspects | | Technological Aspects | |
|---|---|---|---|---|
| | Topics | Themes | Topics | Themes |
| 1 | T6 *External Governance* [1] | SA7 *Maturity* [1] | T21 *Sustainability* [5] 1 | TA9 *System Legacy* [5] 3 |
| 2 | T14 *Internal Governance* [2] | SA10 *Stakeholder Relations* [4] 2 | T22 *Task Completion* [3] | TA7 *System Capability* [4] |
| 3 | T17 *Roles & Responsibilities* [2] 1 | SA8 *Power Dynamics* [2] | T10 *Information Quality* [5] 2 | TA8 *System Efficiency* [3] |

# *Selection*
Alignment > Weight > Relevance

Figure 51 | Distilling elements influencing data needs

**Elements Influencing Tacit Data Barriers**

| Relevance | Social Aspects | | Technological Aspects | |
|---|---|---|---|---|
| | Topics | Themes | Topics | Themes |
| 1 | T22 *Task Completion* [3] 2 | SA9 *Preference* [2] 3 | T12 *Information Structuring* [4] | TA9 *System Legacy* [5] 2 |
| 2 | T10 *Information Quality* [5] 1 | SA7 *Maturity* [1] | T10 *Information Quality* [5] | TA4 *Data Relevance* [3] |
| 3 | T6 *External Governance* [1] | SA8 *Power Dynamics* [2] | T11 *Information Search* [3] 3 | TA8 *System Efficiency* [3] |

*vs.*

**Elements Influencing Explicit Data Barriers**

| Relevance | Social Aspects | | Technological Aspects | |
|---|---|---|---|---|
| | Topics | Themes | Topics | Themes |
| 1 | T17 *Roles & Responsibilities* [2] | SA7 *Maturity* [1] 1 | T10 *Information Quality* [5] 1 | TA8 *System Efficiency* [3] 1 |
| 2 | T24 *Templates & Guidelines* [3] 3 | SA5 *Knowledge Gaining* [1] | T12 *Information Structuring* [4] 2 | TA2 *Data Interoperability* [5] 3 |
| 3 | T3 *Contracts* [2] | SA2 *Goal Interpretation* [4] 2 | T19 *Soft-Hardware Resources* [2] | TA1 *Data Access* [3] |

# *Selection*
Alignment > Weight > Relevance

Figure 52 | Distilling elements influencing data barriers

| Relevance | Elements Influencing Tacit Data Demands | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | T10 *Information Quality* [5] 2 | SA7 *Maturity* [1] 3 | T12 *Information Structuring* [4] 3 | TA4 *Data Relevance* [3] |
| 2 | T6 *External Governance* [1] | SA2 *Goal Interpretation* [4] | T10 *Information Quality* [5] 1 | TA3 *Data Processing* [5] 1 |
| 3 | T4 *Coordination* [4] | SA1 *Collaboration* [3] | T11 *Information Search* [3] | TA7 *System Capability* [4] 3 |

*vs.*

| Relevance | Elements Influencing Explicit Data Demands | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | T4 *Coordination* [4] 1 | SA7 *Maturity* [1] | T21 *Sustainability* [5] 2 | TA4 *Data Relevance* [3] 2 |
| 2 | T23 *Teamwork* [3] 3 | SA1 *Collaboration* [3] 2 | T5 *Documentation* [3] | TA1 *Data Access* [3] |
| 3 | T17 *Roles & Responsibilities* [2] | SA2 *Goal Interpretation* [4] 1 | T10 *Information Quality* [5] | TA3 *Data Processing* [5] |

# *Selection*
Alignment > Weight > Relevance

Figure 53 | Distilling elements influencing data demands

The essential elements comprise 36 components representing an organization's emergent topics and established themes across three dimensions of concern: data needs, data barriers, and data demands. These elements are associated with both social and technological aspects. They are applied alongside the theoretical framework to contextualize areas of concern and translate these concerns into actionable managerial strategies. Their purpose is to bridge short- and long-term concerns when addressing data demand formulations, ensuring alignment between data need expectations and explicit information requirements.

Tables 15, 16, and 17 summarize the BLB NRW's selected essential elements influencing data needs, data barriers, and data demands, respectively, ranked by their relative magnitude of relevance.

| Relevance | Essential Elements Influencing Data Needs | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | T17 *Roles & Responsibilities* | SA7 *Maturity* | T21 *Sustainability* | TA7 *System Capability* |
| 2 | T4 *Coordination* | SA10 *Stakeholder Relations* | T10 *Information Quality* | TA8 *System Efficiency* |
| 3 | T11 *Information Search* | SA5 *Knowledge Sharing* | T12 *Information Structuring* | TA9 *System Legacy* |

Table 15 | Summary of essential elements influencing data needs

| Relevance | Essential Elements Influencing Data Barriers | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | T10 *Information Quality* | SA7 *Maturity* | T10 *Information Quality* | TA8 *System Efficiency* |
| 2 | T22 *Task Completion* | SA2 *Goal Interpretation* | T12 *Information Structuring* | TA9 *System Legacy* |
| 3 | T24 *Templates & Guidelines* | SA9 *Preference* | T11 *Information Search* | TA2 *Data Interoperability* |

Table 16 | Summary of essential elements influencing data barriers

| Relevance | Essential Elements Influencing Data Demands | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T10** *Information Quality* | **SA7** *Maturity* | **T10** *Information Quality* | **TA8** *System Efficiency* |
| 2 | **T22** *Task Completion* | **SA2** *Goal Interpretation* | **T12** *Information Structuring* | **TA9** *System Legacy* |
| 3 | **T24** *Templates & Guidelines* | **SA9** *Preference* | **T11** *Information Search* | **TA2** *Data Interoperability* |

Table 17 | Summary of essential elements influencing data demands

## 5.4 Process design

To demonstrate the application of the theoretical framework alongside the essential elements, the following figures provide a detailed breakdown of its application across various levels of the complexity domains (see Figure 54). Next, identify the control mechanisms and allocate the necessary resources to address the demands of these complexity domains (see Figure 55). Finally, determine the specific objectives and outputs associated with the process (see Figure 56).

This fictitious example demonstrates a potential application within the BLB NRW, focusing on modernizing an office building with a historically listed façade. Figure 54 illustrates the intent of the state-level climate-neutral administration policy. The use case involves conducting a BIM-based Life Cycle Assessment (LCA) to evaluate the project's feasibility, risks, and the extent to which the listed façade can be modified in consultation with the monument protection authority. The organization is dedicated to achieving a higher standard of sustainability by surpassing the minimum requirements for sustainable construction and aiming for a Gold Rating (BNB-BK) certification under the national Sustainable Construction Assessment System. This commitment necessitates a shift in current practices and the adoption of innovative measures by the team. The project is currently in the early stages of strategic planning, necessitating that the program formulation fully aligns with the organization's sustainability goals.

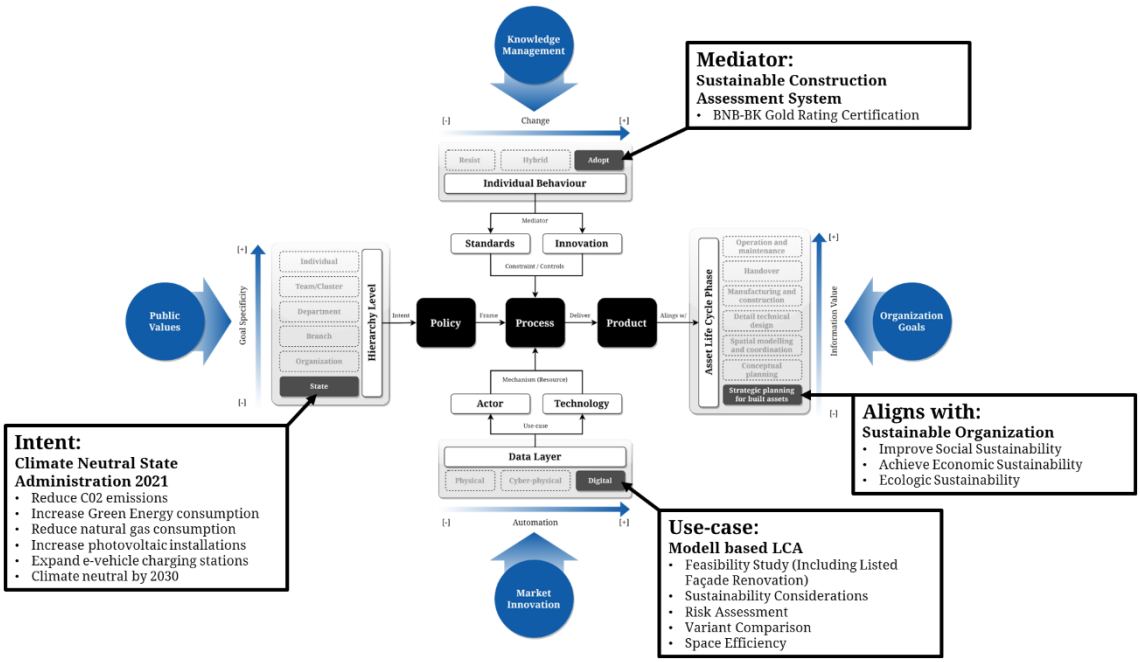



Figure 54 | PPP complex system model application - complexity drilldown

A balancing act between controls and resource allocation is required (see Figure 55). Two sets of standards with seemingly divergent outputs need to be consolidated. To streamline the integration of these outputs, innovative workflows leveraging BIM models are implemented to produce the documentation necessary for the certification process. Additionally, a point-cloud laser scan of the listed façade must be conducted, enabling design consultants to propose solutions for discussion with the monument protection authority.

While the organization prefers to use its proprietary digital tools ecosystem, public procurement regulations mandate a product-neutral approach to delivery. Consultants interested in the project must demonstrate their ability to work with open file formats, such as IFC. Given the project's complexity, internal organizational guidelines prescribe the involvement of an interdisciplinary team, which includes the early procurement of both an LCA consultant and a surveyor to conduct the 3D laser scanning.

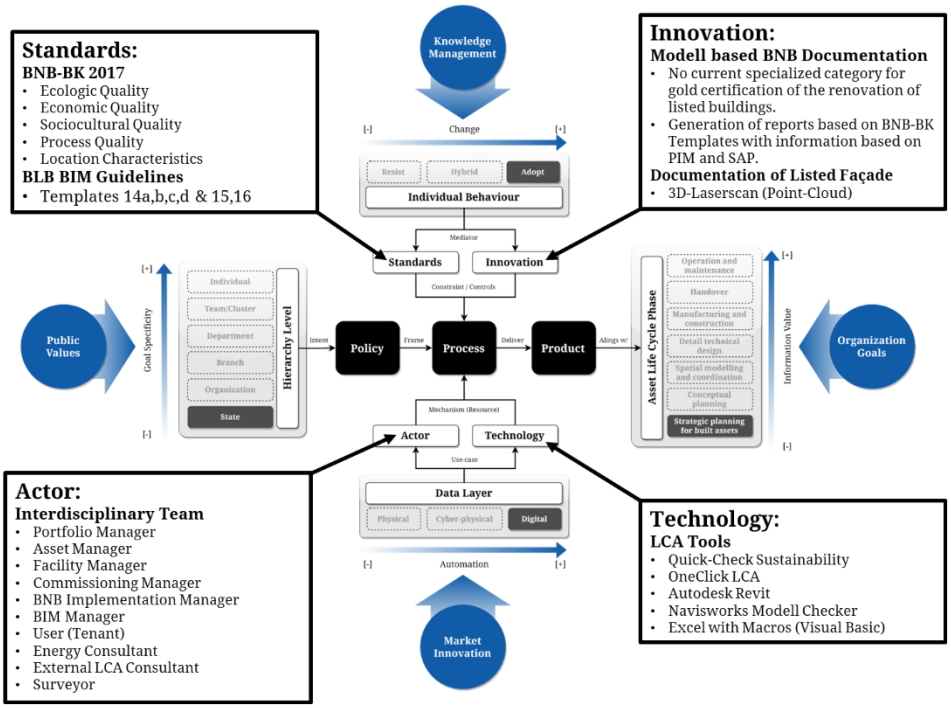



Figure 55 | PPP complex system model application – balancing act between controls and resources

Following, the level of information needed (LOIN) for the use case is defined (see Figure 56). Technical information requirements necessary for measuring KPIs during the O&M phase of the project are identified in alignment with the project's target goals. It is essential to integrate the information requirements as a constant baseline value, while allocating a separate parameter to capture the actual realized value. This approach facilitates comparative analysis for KPI evaluation.

A process is undertaken to consolidate the information requirements needed to perform the LCA and achieve the BNB-BK Gold certification. Parameters serving dual functions are identified and assigned a unified nomenclature and position within the IFC schema to streamline data management. Ultimately, it is determined that two separate EIRs (Employer's Information Requirements) will be created, each designed to deliver an information model of distinct format and quality.

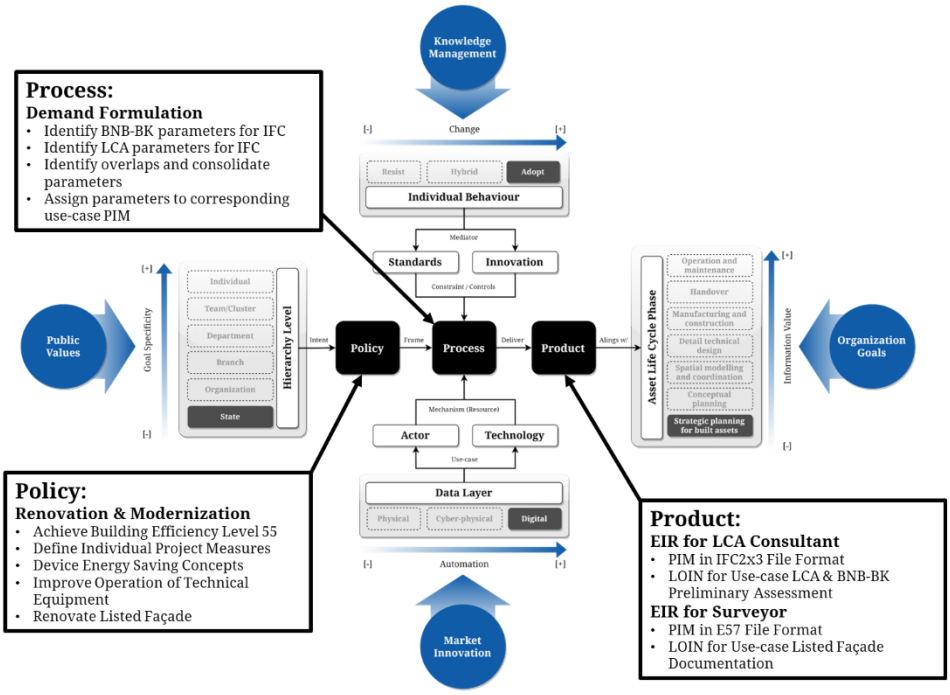



Figure 56 | PPP complex system model application – determining LOIN

With the LOIN consolidated, the essential elements are applied to develop contextualized considerations. Guided by empirical data, each topic and theme are transformed into a question for consideration. These questions are addressed through dedicated managerial tasks. Given the nature of these considerations, both short-term and long-term managerial processes must be integrated. Figures 57, 58, and 59 illustrate the considerations and corresponding actions for addressing the dimensions of data needs, data barriers, and data demands, respectively. By utilizing the framework alongside the essential elements, we can effectively identify and establish effective data demands

| LCA Data Needs | Format | Property Set | Parameter | Data Type | Unit | Description |
|---|---|---|---|---|---|---|
| Target Embodied Carbon Emmisions | IFC2x3 | Pset_LCA | EmbodiedCarbonTarget | Real | tC02e/t | Target value of tons of C02 emissions per tons of material |
| Estimated Embodied Carbon Emmisions | IFC2x3 | Pset_LCA | EmbodiedCarbonEstimate | Real | tC02e/t | Estimated value of tons of C02 emissions per tons of material |
| Target Green Energy Consumption | IFC2x3 | Pset_LCA | GEConsumptionTarget | Real | kWh | Target green energy consumption in kilowatt-hour |
| Estimated Green Energy Consumption | IFC2x3 | Pset_LCA | GEConsumptionEstimate | Real | kWh | Estimated green energy consumption in kilowatt-hour |
| Etc… | … | … | … | … | … | … |

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| | Essential Elements Influencing Data Needs | | | |
|---|---|---|---|---|
| | Social Aspects | | Technological Aspects | |
| Relevance | Topics | Themes | Topics | Themes |
| 1 | **T17** *Roles & Responsibilities* | **SA7** *Maturity* | **T21** *Sustainability* | **TA7** *System Capability* |
| 2 | **T4** *Coordination* | **SA10** *Stakeholder Relations* | **T10** *Information Quality* | **TA8** *System Efficiency* |
| 3 | **T11** *Information Search* | **SA5** *Knowledge Sharing* | **T12** *Information Structuring* | **TA9** *System Legacy* |

## *Considerations*

**T17:** Who is responsible for ensuring all data needs have been compiled?
**T4:** How many rounds of coordination do we need to establish the data needs?
**T11:** Where is the information regarding model based LCA?
**SA7:** Do we have the in-house expertise to evaluate a model based LCA?
**SA10:** Which stakeholders need to be consulted/invited to the LCA data needs definition?
**SA5:** How do we communicate the lessons learned/outcomes of the LCA data needs definition?

**T21:** Which values of the existing asset related to energy & gas consumption need to be linked to the PIM?
**T10:** How important is the completeness, consistency and accuracy of the information to be delivered?
**T12:** How and where does the PIM fit into the organization information structure?
**TA7:** Does the current Soft-Hardware landscape support the use of the PIM format?
**TA8:** Which tools are best suited to document the data needs?
**TA9:** Which BLB Platforms are incompatible with the PIM and what is the impact?

## *Actions*

**T17:** Assign or elect individual during kick-off meeting, document this decision
**T4:** Establish a roadmap for the group meetings
**T11:** Gather all relevant information and centrally link to all information sources
**SA7:** Identify in-house experts available & willing to of assistance to the project
**SA10:** Establish a few open meetings between external & internal stakeholders
**SA5:** Device a concept for what, how and when knowledge is to be shared

**T21:** Consult AM & FM about current information quality and structure
**T10:** Prioritize the data needs into "must have", "nice to have", and "given"
**T12:** Draw a diagram of where PIM could be used and in which platforms
**TA7:** Identify which platforms support the PIM
**TA8:** Identify new tools for managing data needs with machine readable formats
**TA9:** Describe and document workarounds for incompatible platforms

Figure 57 | Considerations and actions for identifying data needs

| LCA Data Needs | Format | Property Set | Parameter | Data Type | Unit | Description |
|---|---|---|---|---|---|---|
| Target Embodied Carbon Emmisions | IFC2x3 | Pset_LCA | EmbodiedCarbonTarget | Real | tC02e/t | Target value of tons of C02 emissions per tons of material |
| Estimated Embodied Carbon Emmisions | IFC2x3 | Pset_LCA | EmbodiedCarbonEstimate | Real | tC02e/t | Estimated value of tons of C02 emissions per tons of material |
| Target Green Energy Consumption | IFC2x3 | Pset_LCA | GEConsumptionTarget | Real | kWh | Target green energy consumption in kilowatt-hour |
| Estimated Green Energy Consumption | IFC2x3 | Pset_LCA | GEConsumptionEstimate | Real | kWh | Estimated green energy consumption in kilowatt-hour |
| Etc… | … | … | … | … | … | … |

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| Essential Elements Influencing Data Barriers | | | | |
|---|---|---|---|---|
| Relevance | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T10** *Information Quality* | **SA7** *Maturity* | **T10** *Information Quality* | **TA8** *System Efficiency* |
| 2 | **T22** *Task Completion* | **SA2** *Goal Interpretation* | **T12** *Information Structuring* | **TA9** *System Legacy* |
| 3 | **T24** *Templates & Guidelines* | **SA9** *Preference* | **T11** *Information Search* | **TA2** *Data Interoperability* |

## *Considerations*

**T10:** Who is responsible for ensuring the information quality?
**T22:** Can the market supply the information requirements?
**T24:** Are there existing templates or guidelines for the parameter nomenclatures?
**SA7:** Do we have in-house expertise in defining data needs?
**SA2:** What related data needs derived from organizational goals can be included?
**SA9:** What project specific parameters could be introduced to test innovative developments?

**T10:** What tools can be used to check the information quality?
**T12:** How to verify that the information structure is suited for the use-case?
**T11:** How to search if a data needs have been already defined?
**TA8:** What issues exist in the information exchange between platforms?
**TA9:** How to exchange information with legacy platforms?
**TA2:** How to integrate analog legacy data into the project?

## *Actions*

**T10:** Assign or elect an information quality manager for the project
**T22:** Consult with external parties to gauge the market maturity level
**T24:** Research current developments in LCA open standards
**SA7:** Identify in-house experts available & willing to of assistance to the project
**SA2:** Discuss weather organizational goals are align project data needs
**SA9:** Clearly demark which parameters are deviating from standards and why

**T10:** Establish workflows for information quality control routines
**T12:** Research publications illustrating workflows for the use-case
**T11:** Investigate if similar approach has been attempted for other projects
**TA8:** Benchmark the workflows of import/linking PIM to the various platforms
**TA9:** Identify data formats compatible with legacy platforms
**TA2:** Establish workflow for digitizing and processing the relevant analog data

Figure 58 | Considerations and actions for overcoming data barriers

| LCA Data Needs | Format | Property Set | Parameter | Data Type | Unit | Description |
|---|---|---|---|---|---|---|
| Target Embodied Carbon Emmisions | IFC2x3 | Pset_LCA | EmbodiedCarbonTarget | Real | tC02e/t | Target value of tons of C02 emissions per tons of material |
| Estimated Embodied Carbon Emmisions | IFC2x3 | Pset_LCA | EmbodiedCarbonEstimate | Real | tC02e/t | Estimated value of tons of C02 emissions per tons of material |
| Target Green Energy Consumption | IFC2x3 | Pset_LCA | GEConsumptionTarget | Real | kWh | Target green energy consumption in kilowatt-hour |
| Estimated Green Energy Consumption | IFC2x3 | Pset_LCA | GEConsumptionEstimate | Real | kWh | Estimated green energy consumption in kilowatt-hour |
| Etc… | … | … | … | … | … | … |

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| Essential Elements Influencing Data Demands | | | | |
|---|---|---|---|---|
| Relevance | Social Aspects | | Technological Aspects | |
| | Topics | Themes | Topics | Themes |
| 1 | **T4** *Coordination* | **SA2** *Goal Interpretation* | **T10** *Information Quality* | **TA3** *Data Processing* |
| 2 | **T10** *Information Quality* | **SA1** *Collaboration* | **T21** *Sustainability* | **TA4** *Data Relevance* |
| 3 | **T23** *Teamwork* | **SA7** *Maturity* | **T12** *Information Structuring* | **TA7** *System Capability* |

## *Considerations*

**T4:** How do we ensure the data demands do not overlap within the requests?
**T10:** Which data needs can be incorporated into the demands earlier than usual at this phase?
**T23:** How to ensure the interdisciplinary data needs are capture in the demands?
**SA2:** How to ensure that the project goals align with organizational goals?
**SA1:** Are the data demands providing a basis for better operations & maintenance?
**SA7:** Is the organization ready to work integrate the PIM into existing workflows?

**T10:** Are we requesting too much information for the use-case?
**T21:** Can all the sustainability data needs be delivered with the PIM?
**T12:** What other data formats can be demanded to supplement the PIM?
**TA3:** How to update information on the platforms that link to the PIM?
**TA4:** How to check if the PIM adheres to the information quality?
**TA7:** Are the available tools and platforms the best solutions for the use-case?

## *Actions*

**T4:** Consolidate the data demands in a data base or central storage location
**T10:** Assess if the use-case can be expanded from classical frameworks
**T23:** All interdisciplinary team members should review the data demands
**SA2:** Host rounds with external stakeholders to discuss the data demands
**SA1:** Discuss with AM and FM the data demands
**SA7:** Arrange workshops and training sessions with O&M team

**T10:** Perform a final assessment of data demand inclusion in a group-session
**T21:** Demark which data demands are best delivered in other digital formats
**T12:** Describe other data formats needed along side the PIM
**TA3:** Determine automatic or manual workflows for updating PIM
**TA4:** Describe in the EIR the need for the BEP to incorporate IQ routines
**TA7:** Evaluate alternative tools and platforms for the use-case

Figure 59 | Considerations and actions for demand formulations

## 5.5 External validation

The external validation session included feedback from three reviewers: Dr. Ilsa Kuiper, Dr. Sanders Siebelink, and Prof. Dr. Adrian Wildenauer. The full protocol for the external validation session is provided in Appendix 9. Their insights focused on the specificity of the research context, the broader applicability of the findings, and factors necessary for the effective translation of digital transformation strategies. The key themes and observations raised during the session are summarized to enhance the clarity and relevance of the research.

The feedback highlighted the importance of appropriately contextualizing the findings and communicating them clearly. Emphasizing the specificity of the study while providing practical tools and steps for adaptation will help bridge the gap between research and practice. The

reviewers stressed the need for transparency about the study's scope and limitations, as well as a clear roadmap to guide organizations through digital transformation.

**Specificity and Contextual Emphasis**

Dr. Kuiper provides an in-depth critique of the presentation, acknowledging the considerable effort in detailing the research's scope and highlighted elements. She emphasizes the importance of establishing upfront the specificity of the study, clarifying that the findings are confined to a discrete domain while still allowing for broader applicability. One key point is the need for clarity on the intended audience, particularly regarding the implementation of digital policies, which may be specific to particular organizational units. Dr. Kuiper suggests a more application-focused introduction to establish context earlier, ensuring that different organizational contexts are considered in the research. She acknowledges the nuance of mapping an organization's current status, highlighting the uniqueness of each entity. The presented methodology should reflect this uniqueness, positioning findings as an initial step that requires further adaptation. Transparency about both the potential and limitations of the research is crucial.

Dr. Kuiper further discusses translating research findings into actionable tools for organizations, noting the variability in implementation across sectors or regions. She highlights that successful digital transformation requires executive-level support, adequate tools, and investment, all of which are essential for progress. Acknowledging institutional gaps, Dr. Kuiper draws parallels between her research experiences and the challenges identified in the presentation, particularly regarding the disconnect between stakeholder needs and data infrastructure. She advises positioning the research within a broader context, which adds rigor and transparency to the study by explicitly delineating its boundaries and implications without undermining its value. Overall, the feedback encourages clearer contextual framing, transparency in the applicability of findings, and an emphasis on broader institutional challenges to enhance the study's impact

**Broader Applicability and Competence Considerations**

Dr. Siebelink provides insightful observations regarding the research model's applicability and its practical challenges. He raises a critical question about the feasibility of adopting the proposed approach across diverse client types, emphasizing the importance of understanding how various clients might process the model and handle the required information analysis. He seeks further elaboration on how these practical considerations have been addressed, which would enhance the model's adaptability to different contexts.

Furthermore, Dr. Siebelink notes that although the research focuses on a technologically advanced front-runner, even such an organization likely faced challenges in reaching a higher level of maturity. He suggests identifying common barriers that other clients are likely to face on a similar journey. Highlighting these obstacles would make the research more broadly applicable by providing practical insights for those striving to achieve similar competencies.

Additionally, Dr. Siebelink recommends including a detailed outline of the competence levels and the types of roles or personnel required for successful implementation of the frameworks. This addition would serve to bridge contextual differences across organizations, offering clearer guidance on the skills and resources necessary for successful adoption. His suggestions aim to ensure the research is accessible and actionable for a wider audience, thereby enhancing its practical utility.

**Terminology and Practical Guidance**

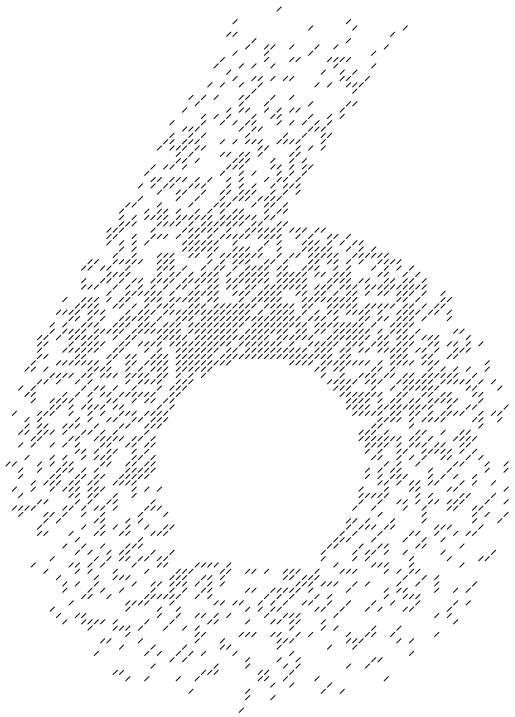
Dr. Wildenauer offers constructive feedback on both the terminology and the broader applicability of the research. He suggests reconsidering the use of the term 'digitalization' in favour of 'digital transformation,' which he believes is more suitable for the context. He notes that this distinction has caused confusion, particularly in regions like Germany and Switzerland, about what 'digital transformation' entails.

In relation to ISO standards, He advises strict adherence to the accepted terminology, specifically regarding Exchange Information Requirements (EIR). He points out that the presentation used the outdated term 'Employer Information Requirements,' which preceded the current ISO standards. Correcting this terminology would ensure consistency with the established standards and improve the presentation's accuracy.

Dr. Wildenauer also concurs with Dr. Kuiper on the challenge of working with a unique client—a proactive public entity from North Rhine-Westphalia—that is not representative of typical public clients in Germany. He appreciates the boldness of attempting to generalize findings from this distinct case study for broader applicability but acknowledges the difficulty of such an approach. He stresses the importance of bridging the gap between the unique context of the BLB NRW and other, less adaptive public entities, suggesting that clearer practical applications could help achieve this.

To enhance the practical impact of the research, Dr. Wildenauer recommends developing a clear list of key steps that public clients could follow: outlining where to start, the actions to take, and how to proceed. Such a roadmap could be highly beneficial for other public clients attempting similar transformations. He also emphasizes the fundamental role of trust—both in data and within organizations—as a critical factor for the success of digital transformation projects. Without trust in data, even the most well-designed projects will struggle to gain traction. He appreciates the emphasis placed on this aspect during the presentation.

—End of Chapter—



# 6 Conclusion

## 6.1 Summary of research findings

This report provides a comprehensive exploration of both theoretical frameworks and empirical findings, focusing on digitization, digitalization, digital transformation, and the implementation of Building Information Modelling (BIM) within complex organizational structures. It establishes clear distinctions between these concepts, noting digitization as the conversion of physical information to digital formats, digitalization as leveraging IT to streamline operations, and digital transformation as the strategic deployment of IT to enhance organizational value (Vrana & Singh, 2021; Koutamanis, 2022). The study emphasizes the knowledge ladder's progression from data to information to knowledge, distinguishing between tacit and explicit knowledge, and highlights the significance of data formats such as structured, semi-structured, and unstructured data in BIM applications (Ford, 2024; Parsanezhad, 2015; Koutamanis, 2022).

The PPP (Policy-Process-Product) complex system model offers a multidimensional framework designed to address the complexities inherent in managing digital transformation and data needs across organizational and asset life cycles. It integrates key domains of complexity, including policy hierarchy levels, data layers, individual behaviours toward change, and phases of the asset life cycle, presenting them in a structured, two-dimensional representation. The model connects the hierarchical specificity of policy goals—ranging from abstract objectives at higher levels to granular, actionable plans at lower levels—with the layers of data automation, spanning structured, semi-structured, and unstructured formats (Kuiper, 2021; Karmakar & Delhi, 2021). By mapping data needs and their alignment with organizational goals, the PPP model supports strategic alignment in program formulation while fostering organizational memory through documentation of interconnected data, processes, actors, and outcomes. This memory enables continuous improvement and maximizes the value of digital transformation initiatives. Moreover, it considers the emergent value of facility data, particularly during the operational and maintenance phases, illustrating how information accrues value throughout an asset's life cycle. Ultimately, the model provides a holistic tool to align organizational goals with public values and technical capabilities, ensuring informed decision-making and efficient resource management within complex socio-technical systems.

The empirical findings, rooted in the case study of BLB NRW, reveal critical dimensions influencing organizational efficiency in adopting BIM and digital strategies. Key social aspects include coordination, roles and responsibilities, teamwork, and stakeholder relations, while maturity, knowledge sharing, and goal interpretation emerge as central themes. Technological aspects, such as data access, interoperability, and system usability, were equally significant. The study identifies barriers such as inconsistent data governance and knowledge-sharing inefficiencies, underscoring the socio-technical nature of these challenges (Lee & Borrmann, 2020; Siebelink, 2021).

Empirical data collected from 20 interviews within BLB NRW emphasizes the organization's reliance on structured processes like regular team meetings and cross-departmental coordination to facilitate knowledge exchange and refine operational concepts. However, the analysis highlights misalignments between current practices and desired states, particularly in roles clarity and data governance, stemming from fragmented knowledge archiving and sharing practices. The findings underline the importance of integrating socio-technical approaches to address these barriers and align operations with public sector objectives (Kuiper, 2021; Abubakar, 2019).

The study further delves into the adoption of BIM standards and frameworks, such as ISO 19650, and their role in addressing information exchange challenges. Despite these standards' potential, the report finds varying degrees of adoption and maturity across the organizations. It notes the pivotal role of clients in driving industry-wide change, advocating for clear policy frameworks and internal capabilities to act as system integrators (Lindblad & Guerrero, 2020).

The findings reveal a nuanced interplay of social and technological factors impacting digital transformation within public sector organizations. By emphasizing continuous improvement, standardization, and alignment of socio-technical elements, the report provides a framework for understanding and addressing the complexities of digital transformation and BIM implementation. This dual focus on theoretical and empirical insights offers valuable guidance for advancing strategic initiatives in similar organizational contexts.

To summarize the key findings from the empirical analysis of the BLB NRW case study, the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis highlights the following takeaways:

**Strengths**

- **Strong Coordination and Teamwork -** Coordination plays a critical role in facilitating knowledge sharing, gaining, and collaboration within and across departments. This is bolstered by regular communication mechanisms like team meetings, workshops, and cross-departmental gatherings, which enhance shared understanding and collective learning.

- **Knowledge Sharing and Stakeholder Relations -** There is an established culture of knowledge sharing through direct interactions, workshops, and meetings. This fosters collective learning, facilitates goal interpretation, and helps in refining concepts, enhancing overall productivity.

- **Effective Use of Technological Tools for Collaboration -** Technological platforms such as BLB Portal, ECM, and BLB-Kompass play a vital role in facilitating information distribution and structuring, which supports knowledge exchange, project management, and operational efficiency.

- **Efforts to Improve Data Quality -** There are ongoing efforts to address information quality issues, with some interviewees recognizing the importance of improving data governance practices

**Weaknesses**

- **Reliance on Informal Networks and Individual Expertise -** Information search and knowledge sharing often depend on personal expertise, ad-hoc interactions, and informal networks. This reliance on individuals rather than standardized processes creates inefficiencies and inconsistencies in knowledge dissemination.

- **Complexity of Information Retrieval -** Information search often involves multiple tools, which can be cumbersome and complex. Employees must navigate different systems like SAP, ECM, and external platforms, pointing to opportunities for simplifying access pathways.

- **Inefficiencies in Role Clarity and Delegation -** Unclear roles and responsibilities related to data often result in ineffective delegation of information searches, which can hinder efficiency and delay the completion of tasks. Power dynamics further complicate this issue, leading to inconsistent dissemination of knowledge.

- **Manual Data Processing -** Dependence on manual processes for data handling contributes to inefficiencies and increases the likelihood of errors. The lack of automation in data processing methods creates bottlenecks, impacting overall data quality and usability.

**Opportunities**

- **Enhanced Training for Data Maturity -** Investment in training programs and organizational development can enhance data governance maturity. This includes teaching best practices for data collection, labelling, and validation to improve information quality and reduce inconsistencies.

- **Development of a Centralized Knowledge Repository -** Implementing a centralized repository for information search could mitigate the reliance on personal expertise and informal networks. This would facilitate equitable access to information and improve the efficiency of data retrieval processes.

- **Standardization of Data Structuring -** Standardizing data structuring practices can create a more streamlined and reliable data management environment. Such standardization will improve data accessibility and contribute to overall operational efficiency.

- **Integrated Data Access and Usability Improvements -** Enhancing system usability and integrating data repositories would improve data search and access. This could help break down silos and foster better collaboration, thus allowing teams to make faster and more informed decisions.

**Threats**

- **Dependency on Key Individuals -** The reliance on key individuals for knowledge sharing and decision-making poses a risk of knowledge silos and potential disruptions if these individuals become unavailable, leading to information gaps.

- **Data Fragmentation and Relevance Issues -** Inconsistent structuring of data across various storage systems results in fragmented information. This fragmentation, combined with outdated or irrelevant data, poses risks to informed decision-making and could lead to poor operational outcomes.

- **Resistance to Change and Standardization -** Efforts to standardize processes and implement mature data governance practices face resistance from teams accustomed to informal knowledge-sharing and personal preferences in data collection and storage. This reliance on informal methods can hinder the adoption of more efficient practices.

- **System Legacy Issues -** Legacy systems and outdated software significantly hinder data processing, storage, and retrieval. These issues contribute to inefficiencies, low data quality, and reliance on manual workarounds like Excel.

## 6.2 Discussion

The development of the PPP complex system model introduces a novel approach to addressing the interconnected challenges in the implementation of digital transformation within the AECOO sector. Unlike earlier frameworks, such as the People-Process-Technology (PPT) framework (Leavitt, 1964) or its adaptation into the People-Process-Policy (PPP) framework (Lee & Borrmann, 2020), this model goes beyond surface-level interactions by incorporating multiple dimensions of complexity. Specifically, the PPP complex system model uniquely integrates four critical domains: hierarchical policy levels (Kuiper, 2021; Sundstrom et al., 2023), data layer distinctions (Karmakar & Delhi, 2021), individual behavior toward change (Shirish & Batuekueno, 2021), and phases of the asset life cycle (Eastman, 2011). This integration enables the model to map out not only the alignment of organizational goals with public values but also the interplay between these goals and technological and human factors across all phases of asset management. By doing so, the model provides a more granular and actionable understanding of how digital transformation initiatives can be tailored to specific organizational contexts.

What can be learned from the development of the PPP complex system model is the importance of addressing complexity in a structured yet adaptable manner. The model's use of hierarchical policy levels demonstrates how higher-level, abstract goals influence granular, operational policies, ensuring alignment across organizational scales (C. K. May, 2022; Sundstrom et al., 2023). Its focus on data layers reveals the necessity of managing technical interoperability challenges while optimizing automation potential (Karmakar & Delhi, 2021; S. T. Matarneh et al., 2019). Moreover, the emphasis on individual behaviour toward change highlights the critical role of human factors in determining the success of new technologies, encouraging strategies that foster motivation, competence, and capacity for adaptation (Siebelink, 2021; Abubakar, 2019). Finally, by emphasizing the emergent value of information across all phases of the asset life cycle, the model underscores the ongoing need to refine processes and leverage data effectively in operational and maintenance phases, not just during design and construction (Eastman, 2011; Godager et al., 2021).

Collectively, these insights emphasize the need for a multidimensional, dynamic approach to digital transformation, one that continuously aligns policy, people, processes, and products within a complex organizational landscape. The PPP complex system model, therefore, advances the discourse by bridging theoretical constructs and practical applications, offering a framework capable of addressing the nuanced challenges of digital transformation within the AEC industry.

Additionally, the empirical research based on the case study of the BLB NRW, offers critical insights into the interplay between socio-technical dimensions, data needs, and strategic objectives. One of the primary lessons is the importance of aligning data practices with both short-term operational requirements and long-term strategic goals. This alignment necessitates a nuanced understanding of organizational data demands, including tacit needs such as coordination, collaboration, and stakeholder relations, as well as explicit demands like data structuring, documentation, and system interoperability. Studies such as those by Abbasnejad et al. (2021) and Karmakar & Delhi (2021) emphasize that effective alignment enables organizations to bridge operational gaps while ensuring that data demands support strategic priorities.

Empirical findings also highlight the critical role of social factors, including knowledge sharing and stakeholder engagement, in fostering collaboration and ensuring that organizational goals are met. Nonaka's (1994) work on knowledge management underscores that systematic knowledge sharing and archiving are key to building a resilient organization capable of

leveraging past experiences to inform future decisions. Furthermore, technological capabilities, such as system efficiency and data security, are equally crucial. Research by Benn & Stoy (2022) suggests that modernized systems capable of real-time data processing significantly enhance operational coordination and decision-making.

Barriers identified in empirical research, such as outdated systems, data interoperability issues, and misaligned stakeholder communication, provide a roadmap for improvement. Studies like those by Lindblad & Guerrero (2020) and S. T. Matarneh et al. (2019) point out that overcoming these barriers requires investment in system upgrades, clearer governance structures, and capacity-building initiatives. Moreover, empirical data reveals that addressing these challenges not only supports immediate project delivery but also contributes to long-term sustainability and innovation, as highlighted by Lu et al. (2021) and the EUBIM Task Group (2017).

Empirical evidence also underscores the value of continuous improvement, with themes like system maturity and knowledge management being critical for addressing internal barriers. Research by Ford (2024) and Shirish & Batuekueno (2021) demonstrates that fostering a culture of learning and adaptability allows organizations to evolve in response to emerging challenges and technologies. Additionally, empirical insights suggest that the integration of social coordination with technological advancements, such as enhanced data interoperability, fosters robust data practices that align with both regulatory and operational needs.

Ultimately, the empirical research informs best practices for aligning organizational needs, barriers, and data demands. By incorporating insights from interviews and document analysis, organizations can refine their strategies to support economic efficiency, stakeholder satisfaction, and sustainability. This alignment is critical for navigating the complex socio-technical landscape of public real estate and construction management, as argued by researchers like Lindblad & Karrbom Gustavsson (2021) and Mendez et al. (2024).

Regarding best practices, Kämpf-Dern and Pfnür's (2014) research offers valuable insights for addressing the methodological, contextual, and theoretical challenges mentioned during the external validation session. The study argues that there is no “one-size-fits-all” solution and examines the relationship between three benchmarks used to evaluate Corporate Real Estate Management (CREM) systems: best practice, best model, and best fit benchmarks. A best practice benchmark serves as a universal guideline or principle for achieving effectiveness. A best model benchmark provides a comprehensive, theoretically grounded framework. In contrast, a best fit benchmark emphasizes a tailored, context-specific approach that ensures CREM systems function effectively within particular organizational and environmental conditions (Kämpf-Dern & Pfnür, 2014).

However, Kämpf-Dern and Pfnür's (2014) highlight the need for empirical studies to develop generalized best fit benchmarks across the sector. This requires mapping the diverse taxonomies of best fit constructs. The approach presented in this research could be enhanced through a cross-sectoral study aimed at developing a taxonomy to systematically organize and classify the diverse and complex parameters influencing data demand formulation systems. Such a taxonomy would help identify recurring archetypes in successful designs, thereby increasing the likelihood of its application across various contexts.

A second observation from the case study highlights how information systems have been structured to mirror the “siloed” operational functions of the organizations. This structure exposes a common misconception about the term "single source of truth" (SSoT). While the term is technically accurate in describing the infrastructure of the platform ecosystem at BLB NRW, SSoT does not imply the existence of a single program or file containing all information. Instead,

as demonstrated in the BLB NRW solution, each platform serves as the single source of truth for its specific function—such as the CAFM system for FM or ERP for AM—while emphasizing the critical importance of interconnecting these systems to allow them to display each other's SSoTs.

The fragmented approach to IT systems, driven by purpose-built software solutions tailored to the unique needs of operational silos, is a well-recognized challenge in the literature. For example, Krämer et al. (2023) underscore the necessity of a unified integration and query layer to overcome interconnectivity issues in FM information systems. Similarly, BLB NRW is investigating solutions to these challenges through the development of a Business Intelligence (BI) interface (Transcript 9). Whereas Watson et al. (2019) and Li et al. (2020) propose using a digital ledger powered by Blockchain technology to record transactions between disparate information systems, effectively transforming the transaction layer into a unifying integration and query layer. However, such approaches often introduce additional complexity to IT systems and face significant hurdles regarding the ability of individual software platforms to interconnect and exchange information effectively. A new paradigm is needed to create a truly centralized and unified SSoT, simplifying and aligning IT systems while addressing the limitations of current approaches.

Although information silos created by IT systems designed to reflect operational functions can be mitigated through technological solutions that facilitate information exchange as described by Krämer et al. (2023), the research findings indicate that social factors within the BLB NRW are more prominent (70%) compared to technological factors (30%) (see Figure 25). This highlights the importance of addressing social dimensions in achieving Eastman's (2011) theoretical model of no information loss across project life cycle phases through a collaborative BIM-based delivery process (see Figure 3). To achieve this ideal, dedicated managerial actions targeting contextualized social aspects must be implemented. While the PPP complex system model provides a framework for capturing project information, it must be complemented by managerial actions explicitly designed to address the organization's prevailing socio-technical challenges (*essential elements*); otherwise, information loss between project life cycle phases is likely to persist.

The PPP complex system model, on its own, does not offer sufficient guidance to overcome information silos. However, it provides clarity and transparency during the Design and Construction (D&C) phase, as well as organizational remembrance for the Operations and Maintenance (O&M) phase, thus its application is recommended for all levels of project complexity. In contrast, the empirical research is necessary to establish the context (*current state*) for the project design phases. While conducting such research for every project may be labour-intensive, it is recommended for projects internally identified as complex.

Thirdly, Lindblad and Guerrero (2020) propose that the role of public clients in fostering innovation and change is mediated by their managerial approach, which can be positioned either as client-led or supplier-led. This perspective is integrated into the application of the PPP complex system model, specifically in relation to the constraint/control mechanisms within a use-case process. While findings from the STA case study suggest that these two client roles are inherently contradictory and should not be applied simultaneously, such conclusions are context-specific, as they arise from STA's "black-boxing" of BIM as a procurement requirement (Lindblad 2019).

In contrast, the broader implications of this research indicate that it is possible to simultaneously adopt both roles within a project by ensuring transparency in the managerial approach for each use-case. To resolve the internal conflict between these roles, the PPP complex system model explicitly delineates the client's position by identifying individual

behaviours toward change. This approach is particularly relevant due to the nuanced nature of BIM implementation, which involves various BIM goals from which multiple BIM use-cases are derived for a given project.

As suggested by Lindblad and Karrbom Gustavsson (2021), since BIM is understood as a systemic innovation, policies must remain flexible to accommodate the unique circumstances of each project. Consequently, each use-case should be individually evaluated to determine whether a client-led or supplier-led approach aligns with the client's maturity and capacity for that specific use-case. In line with Lindblad and Karrbom Gustavsson's (2021) recommendations, the PPP complex system model embraces project complexities and fosters creative solutions by ensuring transparency in the positioning of the managerial approach.

Another issue relates to the definition of the Asset Information Model (AIM). While ISO 19650 outlines what an AIM is, it does not address the diversity of AIMs required for different operational contexts. For instance, in the BLB NRW case, the Level of Information Need (LOIN) for BIM in FM differs significantly from that of BIM for AM or BIM for CREM. This distinction is also evident in the software solutions designed for these operations. While CAFM systems enable FM to incorporate highly detailed PIMs as a foundation, platforms designed for AM or higher-level portfolio strategies often lack the capacity to process complex models (Benn & Stoy, 2022; Deng et al., 2021; S. T. Matarneh et al., 2019). Rather they require more often simple and abstract LOGs with simplified LOIs that address high level evaluations, that require basic facts, such as overall footprint, total usable areas, efficiency of use, etc. If the organization does not have the capacity to abstract a highly detailed as-built PIM into LOINs that suit other O&M operations, these use-cases must be defined and services procured to deliver these variants. Alternatively, new methods of automating the abstraction of Information Models needs to be developed, levering AI or similar advanced object recognition methodologies.

Lastly, throughout the interview sessions, a notable observation emerged regarding the topics of roles and responsibilities, as well as data stewardship. While all interviewees agreed on the importance of their personal responsibility in ensuring the quality of data directly related to their own functions, the same level of responsibility for the accuracy and quality of data originating from other departments or operational functions was not uniformly acknowledged. Some interviewees mentioned that they would notify relevant individuals about data inconsistencies and ensure that corrections were made appropriately. However, this ingrained sense of responsibility for one's own domain was also noted to sometimes result in unintended consequences. For example, a project manager (PM) might meticulously curate all information during the D&C phase through to the handover phase. Yet, when the PM transitions to a new project, certain details about the previous project may be lost in the process. Similarly, efforts undertaken within a single department or project may face a comparable risk of knowledge loss.

As digital information transactions and IT systems become increasingly complex, the need for a dedicated data steward becomes evident. Jernite et al. (2022) describe the data stewardship function as a key organizational role within a data governance framework, specifically for managing Large Language Models (LLMs). In this framework, new data-related roles are defined to clarify functions and responsibilities. Similarly, to effectively manage data throughout the whole asset life cycle, the introduction of a data steward is essential. Data stewards can play a critical role in ensuring that the unifying and integration layer functions not merely from a perspective of functional data quality but also in terms of data relevance.

## 6.3 Research questions answered

***SQ1:*** *How do digitization, digitalization, and digital transformation relate to BIM implementation, and what strategies do public clients employ to manage these interconnected initiatives effectively?*

Digitization, digitalization, and digital transformation are deeply interrelated with the implementation of Building Information Modelling (BIM), representing a continuum of digital progress that underpins modern construction and asset management practices. Digitization, as the process of converting analogue information into digital formats, serves as the foundational step for creating structured, semi-structured, or unstructured data necessary for BIM workflows (Koutamanis, 2022; Vrana & Singh, 2021). Digitalization builds on this by using digital data to streamline operations, enabling better information management and coordination within construction projects (May et al., 2023; Vrana & Singh, 2021). Digital transformation encompasses the organizational strategies and value-driven methodologies required to integrate these digital processes into a cohesive system that supports decision-making and innovation (Vrana & Singh, 2021; May et al., 2023).

BIM represents a key enabler of digital transformation, providing a framework for managing structured data in the form of Building Information Models and facilitating collaboration across the project life cycle (ISO, 2018). It aligns with digital transformation goals by integrating data into decision-making processes, enhancing operational efficiency, and enabling the adoption of Industry 4.0 technologies such as IoT, Digital Twins, and AI (Kagermann & Wahlster, 2022). However, the successful implementation of BIM requires addressing challenges such as interoperability, inconsistent standards, and the need for customized digital workflows (Deng et al., 2021; Kuiper, 2021).

Public clients play a pivotal role in managing these interconnected initiatives by acting as both adopters and promoters of digital innovation. Strategies employed by public organizations often include developing robust Exchange Information Requirements (EIR) to align BIM goals with organizational and project-specific needs, as outlined in the ISO 19650 series (ISO, 2018). These strategies also involve fostering absorptive capacity, enabling public clients to recognize, assimilate, and apply digital and BIM-related knowledge within their organizations (Lindblad & Karrbom Gustavsson, 2021). To address the complexity of digital transformation, public clients may adopt two primary roles: a client-led approach, where they act as system integrators fostering collaboration among stakeholders, or a supplier-led approach, which relies on market-driven solutions to promote innovation (Lindblad & Guerrero, 2020).

Effective management of these initiatives requires public clients to address both technical and non-technical factors. Non-technical considerations, such as organizational culture, training, and the development of internal expertise, are crucial for ensuring that digitization, digitalization, and digital transformation are seamlessly integrated with BIM workflows (Lee & Borrmann, 2020). Moreover, aligning these processes with broader public value objectives—such as social, economic, and environmental outcomes—further reinforces the role of public clients as agents of innovation and change in the construction sector (Mendez et al., 2024; Kuitert et al., 2019).

By integrating digitization, digitalization, and digital transformation into their BIM strategies, public clients can address current challenges, enhance decision-making, and drive innovation in the construction industry, while creating public value through more efficient and effective project delivery. This approach not only ensures that BIM implementation aligns with organizational goals but also advances the broader digital transformation of the AECOO sector.

***SQ2:*** *What theoretical framework can be used to evaluate an organization's current state in relation to its desired state in digital transformation adoption efforts?*

To evaluate an organization's current state in relation to its desired state in digital transformation adoption efforts, a comprehensive theoretical framework that integrates both socio-technical and organizational change perspectives is essential. One such framework is the People, Process, Technology (PPT) model, which emphasizes the interconnections between these three key dimensions to facilitate effective digital transformation (Karmakar & Delhi, 2021). The PPT model provides a structured lens through which organizations can assess their readiness for adopting new digital methodologies, such as Building Information Modelling (BIM), by analysing how people (individuals and teams), processes (operational workflows and practices), and technologies (digital tools and systems) interact within the organization (Lee & Borrmann, 2020).

However, given that digital transformation is not solely driven by technological change but also requires social and cultural shifts, frameworks like Enterprise BIM (EBIM), which integrates BIM with the broader organizational strategy, may offer valuable insights into aligning digital tools with organizational goals across the asset life cycle (Godager et al., 2021). Additionally, the PPP (People-Process-Policy) framework can be adapted to assess the role of policies in guiding the transition and ensuring that both internal processes and external regulations are harmonized to support the digital transformation journey organization (Lee & Borrmann, 2020). This framework focuses on aligning people, processes, and policies with the broader goals of the organization and the industry, making it particularly suitable for evaluating the gaps between the current and desired states in digital transformation. For more complex systems, the integration of models such as the Panarchy Framework, which addresses hierarchical policy structures and emergent changes, can provide deeper insights into the dynamic and evolving nature of digital adoption, enabling organizations to navigate and adapt to the challenges they encounter at different organizational levels (C. K. May, 2022).

Together, these frameworks from the PPP (Policy-Process-Product) complex system model that offers a mean to assess the current state of digital transformation efforts, identify gaps, and formulate strategic actions toward achieving the desired future state by addressing complexity.

The PPP complex system model (see Figure 21) addresses the complexity domains as follows:

**Policy Hierarchy Levels -** It establishes a relationship between the hierarchical position of policies and the specificity of goals, ensuring alignment with public values and strategic organizational objectives.

**Data Layers -** It links data layer categories to their automation potential, emphasizing the importance of digital formats to enhance efficiency while addressing challenges related to interoperability and data omissions.

**Individual Behaviour -** It connects individual attitudes toward change with the success of change initiatives, highlighting the role of knowledge management systems in shaping behavioural intentions and fostering organizational adaptability.

**Asset Life Cycle Phases -** It defines a relationship between the value of information and asset life cycle phases, recognizing the continued growth of information value, particularly during the Operation and Maintenance (O&M) phases.

By addressing these domains, the model provides a structured approach to managing complexity and aligning organizational processes, technology, and behaviour with overarching goals. This model is intended to be a strategic tool for aligning project goals, implementing BIM, and improving continuous learning and adaptation in organizations through digital transformation initiatives.

***SQ3**: What are the organization's data needs, and how do they relate to its short- and long-term goals?*

The data needs of an organization are fundamentally shaped by its strategic objectives, both short- and long-term. These needs span social and technological dimensions, which influence how data is collected, processed, shared, and used within the organization to support its goals. Figures 60 and 61 show the relationship between topic and themes to the organizational goals.

In terms of social aspects, the organization's data needs are closely linked to the need for *collaboration* [SA1], *knowledge sharing* [SA6], and *stakeholder relations* [SA10]. Themes such as knowledge acquiring, sharing, and archiving underscore the importance of data in fostering learning, collaboration, and ensuring that knowledge is systematically stored for future use (Ford, 2024; Nonaka, 1994). This is particularly relevant for short-term goals, where immediate access to relevant and up-to-date data is necessary for efficient decision-making and project execution (Parsanezhad, 2015; S. T. Matarneh et al., 2019). Additionally, data supporting stakeholder relations ensures that the interests and concerns of both internal and external stakeholders are effectively addressed, aligning organizational activities with public sector objectives (Kuitert et al., 2019; Lindblad & Guerrero, 2020).

Organizational Goals

Implementation Timeline: Short → Long

Topics

| | Economic Efficiency | Customer Focus | Partnership | Employer Appeal | Innovation Strength | Sustainability |
|---|---|---|---|---|---|---|
| **T1** *Client / Tennant* | x | x | x | | | |
| **T2** *Continuous Improvement* | x | | | x | x | x |
| **T4** *Coordination* | x | x | x | | | |
| **T5** *Documentation* | x | | | | | x |
| **T6** *External Governance* | | x | x | | | |
| **T7** *information Access Rights* | x | | x | | | |
| **T8** *Information Distribution* | | x | x | | | |
| **T10** *Information Quality* | | | | x | x | x |
| **T11** *Information Search* | x | | | x | x | |
| **T12** *Information Structuring* | x | x | | | x | x |
| **T13** *Integration & Mentoring* | | | x | x | | |
| **T14** *Internal Governance* | x | x | x | x | | |
| **T15** *Leadership & Proactivity* | | | | x | x | x |
| **T17** *Roles & Responsibilities* | x | x | x | x | | |
| **T19** *Software & Hardware Resources* | x | | | x | x | |
| **T20** *Software Support & Updates* | x | | | x | x | |
| **T21** *Sustainability* | x | | | x | x | x |
| **T22** *Task Completion* | x | | | | | |
| **T23** *Teamwork* | | x | x | x | | |
| **T24** *Templates & Guidelines* | x | | | | x | |
| **T25** *Training & Development* | x | | | x | | |

Figure 60 | Topics related to Organizational Goals

Organizational Goals

Implementation Timeline: Short → Long

Themes

| | Economic Efficiency | Customer Focus | Partnership | Employer Appeal | Innovation Strength | Sustainability |
|---|---|---|---|---|---|---|
| **SA1** *Collaboration* | x | x | x | x | | |
| **TA1** *Data Access* | x | | | x | x | |
| **TA4** *Data Relevance* | x | x | | | | x |
| **TA6** *Data Storage* | | | | | x | |
| **SA2** *Goal Interpretation* | | | | x | x | |
| **SA4** *Knowledge Archiving* | x | | | x | x | |
| **SA5** *Knowledge Gaining* | | | | x | x | |
| **SA6** *Knowledge Sharing* | | | | x | x | |
| **SA7** *Maturity* | x | x | | | | |
| **SA8** *Power Dynamics* | x | x | x | | | |
| **SA9** *Preference* | | | | x | x | x |
| **SA10** *Stakeholder Relations* | | x | x | x | | |
| **TA7** *System Capability* | x | | | | x | x |
| **TA8** *System Efficiency* | x | | | | x | x |
| **TA9** *System Legacy* | | | x | x | | |
| **TA10** *System Usability* | x | | x | x | x | |

Figure 61 | Themes related to Organizational Goals

On the technological front, *data access* [TA1], *data interoperability* [TA2], and *data security* [ TA5] are paramount for ensuring that data is available to the right individuals while maintaining confidentiality and regulatory compliance (ISO, 2018). Efficient and user-friendly system capability, efficiency, and usability are also crucial, particularly in the short-term, to ensure that the organization's ICT infrastructure can support its operational needs (S. T. Matarneh et al., 2019; Benn & Stoy, 2022). These technological themes enable real-time access to data, facilitating rapid decision-making and operational coordination, which are essential for short-term success (Karmakar & Delhi, 2021; Godager et al., 2021).

In relation to the organization's short-term goals, data needs typically focus on operational efficiency, project delivery, and stakeholder communication. For instance, data relevance and data quality are essential for ensuring that the information utilized in daily operations is both timely and pertinent (Eastman, 2011; Lindblad, 2019). This is critical for maintaining efficiency and ensuring that projects are completed on schedule and within regulatory requirements (Siebelink et al., 2021). Similarly, data access rights and effective coordination between departments and external partners are central to the organization's ability to manage resources and execute tasks seamlessly, meeting the demands of ongoing projects (Abbasnejad et al., 2021; Chan, 2020).

Looking toward long-term goals, the organization's data needs become more strategic, focusing on sustainability, knowledge management, and process optimization. The ability to archive knowledge and manage system legacy is key for ensuring continuity and leveraging past experiences to inform future decisions (Kuiper, 2021; Wildenauer, 2023). In this context, sustainability (as an emergent topic) plays a significant role, as organizations increasingly rely on data to guide sustainable practices, reduce environmental impacts, and comply with long-term regulatory frameworks (Lu et al., 2021; UN, 2015). Additionally, long-term success demands that the organization's data systems are interoperable and adaptable, ensuring the ability to integrate emerging technologies and scale operations as required by evolving market conditions (Kagermann & Wahlster, 2022; EUBIM Task Group, 2017).

Emergent topics identified in interviews, such as *continuous improvement* [T2], *contracts* [T3], and *coordination* [T4], further highlight the organization's need for data that supports both tactical and strategic decision-making. Data on contracts, for instance, ensures that project deliverables are met in compliance with legal frameworks (Bruggeman, 2020; Wildenauer & Basl, 2021), while continuous improvement relies on data analytics to identify inefficiencies and optimize processes over time (Shirish & Batuekueno, 2021; Abbasnejad et al., 2021). Additionally, the systematic creation, maintenance, and structuring of documentation ensure that both short-term project needs and long-term organizational goals are supported through transparent, organized data management practices (Charef et al., 2019; Lindblad & Guerrero, 2020).

An organization's data needs are intricately tied to its short- and long-term goals. Short-term objectives necessitate the availability of accurate, timely data to support immediate operational needs and decision-making, while long-term goals depend on the strategic management of data to foster sustainability, knowledge retention, and ongoing process improvements. The alignment of data needs with both immediate and future objectives is critical for optimizing organizational performance, supporting innovation, and ensuring compliance with evolving regulatory and stakeholder expectations (Nieboer, 2011; Lee & Borrmann, 2020).

***SQ4**: What internal barriers, shortcomings, or peculiarities should be considered when formulating demands in accordance with the needs?*

To effectively formulate demands in accordance with organizational needs, it is crucial to understand and address the internal barriers, shortcomings, and peculiarities that influence the process. Social and technological aspects, both significant influences on an organization's ability to achieve desired outcomes, must be thoroughly considered in this context (Siebelink, 2021). Internal barriers often arise from both smaller, emergent topics that evolve rapidly and larger, enduring themes that shape long-term organizational dynamics (C. K. May, 2022; Sundstrom et al., 2023). The interplay of these socio-technical elements is essential in formulating effective organizational demands. The following themes are the areas of consideration:

- **Social Barriers -** Social barriers such as *collaboration* [SA1], *goal interpretation* [SA2], and *stakeholder relations* (SA10) can hinder the clarity and execution of formulated demands. A unified effort through collaboration is often difficult due to fragmented approaches and differences in goal interpretation at various sub-levels of the organization (Chan, 2020; Lindblad & Guerrero, 2020). This misalignment leads to inefficiencies in achieving shared objectives, particularly when roles and responsibilities are unclear (Kuitert et al., 2019; Lindblad, 2019). Stakeholder engagement, a critical factor in aligning organizational goals with public sector values, is often impacted by inconsistent communication and unclear accountability structures (Mendez et al., 2024; Shirish & Batuekueno, 2021).

- **Technological Shortcomings -** Technological shortcomings, including *system legacy* [TA9], *data interoperability* [TA2], and *system capability* [TA7], also present critical barriers. Outdated systems create challenges for managing and processing data efficiently, while poor data interoperability limits the seamless integration of information across systems (ISO, 2018; Karmakar & Delhi, 2021). These issues are further exacerbated by limitations in system capabilities, which hinder the organization's ability to adapt to evolving demands and technological advancements (Benn & Stoy, 2022; Godager et al., 2021). As digital transformation initiatives emphasize adaptability and efficiency, addressing these technological barriers becomes increasingly important for ensuring that public clients can meet both immediate and long-term goals (Kagermann & Wahlster, 2022; Kuiper, 2021).

- **Themes of Maturity and Knowledge Management -** Moreover, the themes of *maturity* [SA7] and *knowledge gaining* [SA5] are indicative of an organization's preparedness to address internal challenges. A lack of maturity in processes and systems results in inconsistent practices, which obstruct the formulation and fulfilment of strategic demands (Siebelink, 2021; Abbasnejad et al., 2021). Additionally, *knowledge gaining* [SA5], and *knowledge sharing* [SA6] are essential for ensuring that personnel are equipped with the skills and expertise needed to navigate complex socio-technical environments (Ford, 2024; Nonaka, 1994). Without continuous learning opportunities, gaps in understanding and skills can further exacerbate internal barriers (Shirish & Batuekueno, 2021; Wildenauer & Basl, 2021).

- **Enhancing Formulation of Demands -** The formulation of demands within public cleints must consider a range of internal barriers, both social and technological. Addressing these barriers involves enhancing collaborative efforts, ensuring clear roles and responsibilities, modernizing legacy systems, and improving data interoperability (S. T. Matarneh et al., 2019; Charef et al., 2019). By aligning socio-technical processes with organizational goals, the effectiveness of demand formulation can be significantly enhanced, leading to better-aligned outcomes and improved organizational efficiency (Nieboer, 2011; Lindblad & Karrbom Gustavsson, 2021). Ultimately, this alignment

enables public clients to overcome internal barriers and leverage digital transformation to achieve strategic objectives (Lee & Borrmann, 2020; Vrana & Singh, 2021).

***SQ5**: What are the organization's data demands, and how are they communicated to market parties?*

The organization's data demands encompass both tacit and explicit needs that are intricately linked to social and technological aspects. Tacit data demands are influenced by social elements such as stakeholder relations, coordination, collaboration, and the maturity of organizational processes, as well as technological factors like system capability, data structuring, and automation (Kuitert et al., 2019; Siebelink, 2021). These tacit demands are often communicated through effective coordination mechanisms, where the alignment of internal and external stakeholders ensures the proper understanding and dissemination of data requirements (Shirish & Batuekueno, 2021; Lindblad & Guerrero, 2020). Tailored communication strategies are employed to adapt data-sharing practices to the specific needs of each stakeholder group, fostering shared understanding and minimizing the risk of miscommunication (Abbasnejad et al., 2021; Ford, 2024).

Explicit data demands, on the other hand, are shaped by well-defined topics such as coordination, teamwork, roles and responsibilities, sustainability, documentation, and information quality (ISO, 2018; Kuiper, 2021). These demands are formalized through documentation, clear definitions of roles and responsibilities, and established data-sharing guidelines, which help ensure that data requirements are effectively communicated to market parties (Benn & Stoy, 2022; Godager et al., 2021). Explicit demands often involve the integration of technological capabilities such as data access, processing, and sustainability practices to meet both operational and strategic objectives (Lu et al., 2021; M. May et al., 2023). The organization uses systematic communication channels to relay explicit data requirements to market parties, emphasizing transparency, accountability, and alignment with public sector regulations (Mendez et al., 2024; Lee & Borrmann, 2020).

By integrating social aspects—such as collaboration, teamwork, and stakeholder engagement—with technological themes like data relevance, processing efficiency, and system capabilities, the organization ensures that its data demands are not only understood internally but also communicated effectively to external market participants (C. K. May, 2022; Sundstrom et al., 2023). This dual approach of addressing both tacit and explicit data needs allows the organization to fulfill its data demands comprehensively while supporting robust decision-making processes and fostering long-term relationships with market stakeholders (Shirish & Batuekueno, 2021; Wildenauer, 2023).

**Key Relationships -** The analysis suggests that a synergy between social and technological aspects is crucial for addressing both tacit and explicit data demands effectively. Key relationships include:

- **Social Coordination and Technological Capabilities -** These factors must align to facilitate collaboration using accurate, timely information (Karmakar & Delhi, 2021; Lindblad, 2019).

- **Roles and Responsibilities with Data Processing -** Clear assignments enhance efficiency in data analysis and utilization (ISO, 2018; Abbasnejad et al., 2021).

- **Collaboration and Technological Sustainability -** Joint efforts across teams are essential for maintaining robust data systems over the long term (Lu et al., 2021; Benn & Stoy, 2022).

Addressing data demands in public real estate and construction management organizations requires enhancing organizational maturity, promoting effective stakeholder communication, and improving technological infrastructure for efficient data handling and sustainability (Chan, 2020; Kuiper, 2021). By doing so, organizations can build a foundation for more effective project delivery, strategic alignment, and long-term innovation (Nieboer, 2011; Mendez et al., 2024).

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***SQ6**: What are the (mis)alignments between the needs, barriers, and demands in relation to the organization's short- and long-term goals?*

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The alignment and misalignment between the needs, barriers, and demands of the organization, in relation to its short- and long-term goals, can be examined through the interplay of social and technological aspects across emergent topics and literature themes. These socio-technical dimensions reveal critical insights into the organization's capacity to achieve its strategic objectives.

- **Alignments -** The analysis demonstrates significant alignments in both social and technological aspects, particularly where organizational themes and topics intersect with established short- and long-term goals. Social aspects such as *stakeholder relations* [SA10] and *collaboration* [SA1] emerge as crucial enablers of the organization's objectives, reflecting a strong emphasis on fostering partnerships and customer-focused strategies (Kuitert et al., 2019; Lindblad & Guerrero, 2020). Similarly, technological themes like *data relevance* [TA4] and *system capability* [TA7] align closely with the organization's goals for economic efficiency and innovation strength (ISO, 2018; Benn & Stoy, 2022). These alignments underscore the organization's strategic prioritization of robust systems and effective stakeholder engagement to drive progress.

  Short-term goals, such as improving economic efficiency and customer focus, are well-supported by topics including *coordination* [T4] and *information distribution* [T8], which facilitate streamlined operations and better communication among stakeholders (Charef et al., 2019; Ford, 2024). For long-term objectives like sustainability and innovation strength, topics such as *sustainability* [T21] and *information quality* [T10] are pivotal (Lu et al., 2021; UN, 2015). These topics highlight the organization's commitment to sustainable practices and the production of high-quality, actionable data to support innovation.

  Additionally, the themes of *maturity* [SA7] and *goal interpretation* [SA2] reflect a progressive understanding of organizational growth and adaptability (Siebelink, 2021; Abbasnejad et al., 2021). Their presence across short- and long-term goals indicates an alignment in fostering a structured yet flexible approach to achieving strategic objectives. The alignment between social aspects like *knowledge sharing* [SA6] and technological themes such as *system efficiency* [TA8] suggests a well-integrated approach to enhancing operational capabilities while promoting a culture of collaboration and continuous learning (Nonaka, 1994; Lindblad & Karrbom Gustavsson, 2021).

- **Misalignments -** Despite these alignments, several misalignments are apparent, particularly in areas where emergent topics highlight operational challenges that do not fully support strategic goals. For example, technological aspects like *system legacy* [TA9] and *data interoperability* [TA2] present barriers to achieving long-term innovation and

sustainability (S. T. Matarneh et al., 2019; Kagermann & Wahlster, 2022). These misalignments are indicative of outdated systems and integration challenges, which constrain the organization's ability to modernize and leverage interconnected data platforms effectively.

In social aspects, misalignments arise in themes like *power dynamics* [SA8] and *roles and responsibilities* [T17] where unclear authority structures and ambiguous task definitions hinder efficiency and stakeholder engagement (Kuiper, 2021; Wildenauer, 2023). Similarly, the theme of *preference* [SA9] reveals potential conflicts between individual or departmental priorities and the broader organizational goals, particularly in achieving economic efficiency and customer focus (Miles, 2017; Shirish & Batuekueno, 2021).

Technological misalignments are further exacerbated by emergent topics such as *information search* [T11] and *software support & updates* [T20], which point to inefficiencies in accessing and maintaining critical data systems (Karmakar & Delhi, 2021; Godager et al., 2021). These gaps suggest a need for improved technological infrastructure and better alignment of ICT capabilities with the organization's evolving demands (ISO, 2018; Stange, 2020).

- **Implications for Short- and Long-term Goals -** The identified alignments and misalignments have significant implications for the organization's strategic trajectory. In the short term, addressing issues related to *task completion* [T22] and *internal governance* [T14] can enhance operational efficiency and foster a more responsive organizational environment (Lindblad, 2019; Mendez et al., 2024). This would support immediate objectives like economic efficiency and customer satisfaction.

  In the long term, overcoming barriers such as *system legacy* [TA9] and *data security* [TA5] is critical to achieving sustainability and innovation goals (Benn & Stoy, 2022; S. T. Matarneh et al., 2019). These challenges require targeted investments in system modernization and a stronger emphasis on securing and optimizing data management processes (Lee & Borrmann, 2020; Wildenauer & Basl, 2021).

  The themes of *knowledge archiving* [SA4] and *training & development* [T25] also warrant attention to ensure that the organization's human and technological resources are adequately prepared to meet future demands (Ford, 2024; Nonaka, 1994). The alignment of these themes with long-term goals suggests a need for sustained focus on capacity building and resource optimization (Kuiper, 2021; Abbasnejad et al., 2021).

The alignment of social and technological dimensions with the organization's short- and long-term goals reflects that the BLB NRW has a well-founded strategy that leverages collaboration, stakeholder engagement, and system capability to achieve desired outcomes. However, addressing misalignments in areas like system interoperability, power dynamics, and legacy systems is essential for overcoming operational barriers and ensuring that the organization remains on track to fulfill its strategic vision (Nieboer, 2011; Lindblad & Guerrero, 2020). By balancing immediate improvements with long-term investments in technology and human capital, the organization can navigate its socio-technical landscape more effectively, fostering resilience and adaptability in a dynamic operational environment (Shirish & Batuekueno, 2021; Mendez et al., 2024).

***SQ****7: What are the essential elements needed to align organizational needs and barriers into effective data demands for public clients?*

A comprehensive understanding of socio-technical dynamics, as outlined in the empirical and theoretical frameworks, is essential. These dynamics incorporate both emergent topics and enduring literature themes, which interact to influence data needs, barriers, and demands. This interaction is central to achieving alignment and fostering effective data-driven decision-making within public sector organizations. The essential elements can be described using the following categories:

**Social and Technological Foundations -** Social aspects are pivotal in establishing collaborative environments, defining roles, and managing relationships that directly affect data processes. Themes such as *maturity* [SA7], which denotes an organization's capability to standardize and optimize its practices, and *stakeholder relations* [SA10], which emphasize effective communication and alignment of expectations, are foundational for addressing organizational needs (Siebelink, 2021; Mendez et al., 2024). Technologically, themes like *system capability* [TA7] and *data interoperability* [TA2] underscore the importance of robust, adaptable systems that facilitate seamless data exchange across platforms, ensuring that technological infrastructure supports social initiatives (ISO, 2018; Karmakar & Delhi, 2021).

**Emergent Topics for Bridging Operational Gaps -** Emergent topics provide insight into transient but critical operational issues that must be addressed to align needs and barriers with effective data demands. For instance, *information quality* [T10] and *coordination* [T4] are consistently identified as central topics, highlighting the necessity of accurate, reliable data and cross-departmental collaboration (Chan, 2020; Lindblad & Guerrero, 2020). These topics are directly linked to the enduring themes of *system efficiency* [TA8] and *collaboration* [SA1], emphasizing their importance in bridging short-term operational needs with long-term organizational goals (Godager et al., 2021; Benn & Stoy, 2022).

**Alignment of Needs, Barriers, and Demands -** The alignment of organizational needs and barriers into actionable data demands requires a dual focus on both social and technological elements:

- **Addressing Data Needs -** Themes such as *roles and responsibilities* [T17] and *maturity* [SA7] are critical to ensuring clarity in data requirements. Technologically, *system capability* [TA7] and *sustainability* [TA8] play a role in supporting evolving organizational goals (Abbasnejad et al., 2021; Lu et al., 2021).

- **Overcoming Data Barriers -** Barriers often stem from issues in *information structuring* [T12] and data *interoperability* [TA2]. Addressing these requires a focus on enhancing internal governance and adopting technologies that integrate legacy systems with modern platforms (ISO, 2018; S. T. Matarneh et al., 2019).

- **Formulating Data Demands -** Effective data demands emerge from aligning goals with operational realities. This alignment is evident in the themes of *goal interpretation* [SA2] and *data relevance* [TA4], which ensure that demands are both actionable and aligned with strategic priorities (Mendez et al., 2024; Karmakar & Delhi, 2021).

**Essential Elements for Alignment -** The integration of these elements is facilitated by a prioritization of both short- and long-term goals:

- **Short-term goals -** Focus on immediate operational efficiency through themes like *data storage* [TA6] and topics such as *training and development* [T25] to build organizational capacity (Chan, 2020; Siebelink, 2021).

- **Long-term goals -** Address sustainability and innovation by emphasizing *system legacy* [TA9] and *knowledge sharing* [SA6] to foster resilience and adaptability (Nonaka, 1994; Ford, 2024).

Aligning organizational needs and barriers into effective data demands for public clients requires a structured approach that integrates emergent operational topics with enduring socio-technical themes. By addressing both the immediate and strategic requirements of data processes, public organizations can ensure their data practices align with overarching policy objectives and operational goals, fostering efficiency, transparency, and stakeholder trust (Kuiper, 2021; Lindblad & Karrbom Gustavsson, 2021).

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***RQ**: How can public clients develop a comprehensive and holistic framework for data demand formulation that aligns with their asset life cycle needs, organisational goals, and desired public values?*

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Public clients can develop a comprehensive and holistic framework for data demand formulation by integrating a range of socio-technical and organizational strategies that align with asset life cycle needs, organizational goals, and public values. Central to this approach is the need to address both immediate operational requirements and long-term strategic objectives, ensuring that data demands are actionable, sustainable, and aligned with broader policy frameworks (ISO, 2018; Siebelink, 2021). Frameworks like People, Process, Technology (PPT) and other established models offer foundational insights for evaluating an organization's readiness and gaps in data management practices (Karmakar & Delhi, 2021; Abbasnejad et al., 2021). However, the PPP (Policy-Process-Product) complex system model, as elaborated in this research, extends these foundational approaches by providing an advanced mechanism to address the multifaceted challenges faced by public clients.

The PPP framework introduces a structured way to examine the interdependencies between social dimensions (e.g., collaboration, stakeholder relations), technical capabilities (e.g., data interoperability, system efficiency), and policy imperatives (e.g., compliance, public accountability). By addressing domains such as policy hierarchy, data automation potential, and the alignment of individual behaviour with organizational goals, the model offers valuable insights into how data demands can be formulated to support asset life cycle phases, particularly in enhancing decision-making during the Operation and Maintenance (O&M) stages.

While the PPP framework provides a sophisticated framework for managing complexity, public clients must also focus on addressing more immediate challenges such as outdated systems, unclear roles, and barriers to stakeholder engagement (Chan, 2020; Lindblad & Guerrero, 2020). Integrating principles of knowledge management, sustainability, and continuous improvement into data practices ensures that short-term operational efficiency is balanced with long-term innovation and resilience (Nonaka, 1994; Benn & Stoy, 2022). This includes leveraging digital methods like Building Information Modelling (BIM) to enhance data relevance and interoperability while promoting organizational adaptability to emerging market demands (EUBIM Task Group, 2017; Lee & Borrmann, 2020).

The development of a holistic data demand framework also requires a focus on transparency and alignment with public sector values. Policies must not only guide internal processes but also ensure that external stakeholder expectations are met, fostering trust and accountability (Mendez et al., 2024; Kuiper, 2021). By combining the insights provided by the PPP complex system model with practical measures to modernize technological infrastructure and foster collaboration, public clients can create a dynamic and adaptable framework. This approach

ensures that data demands are not only reflective of current needs but also positioned to support strategic alignment and sustainable growth across the asset life cycle (Lu et al., 2021; ISO, 2018).

## 6.4 Practical implications

The research offers several practical implications, particularly for organizations engaged in digital transformation and the implementation of Building Information Modelling (BIM) within complex socio-technical systems. These implications are particularly relevant for public sector organizations, such as BLB NRW, but also provide insights applicable to broader contexts in asset management, construction, and real estate. The practical implications are as follows:

- **Improved Alignment of Policy, Processes, and Data Needs -** The PPP complex system model emphasizes the necessity of aligning organizational goals with hierarchical policy levels and actionable processes (Godager et al., 2021; Kuiper, 2021). Public clients can leverage this model to clarify their strategic objectives, translate them into operational guidelines, and ensure that these align with their data infrastructure and technological capabilities. By adopting this structured approach, organizations can minimize inefficiencies and inconsistencies in their digital transformation efforts, particularly in handling complex, multi-stakeholder projects (ISO, 2018; Sundstrom et al., 2023).

- **Enhanced Focus on Socio-Technical Barriers -** The study highlights the importance of addressing socio-technical barriers, such as coordination challenges, unclear roles and responsibilities, and inadequate knowledge-sharing mechanisms (Siebelink, 2021; Shirish & Batuekueno, 2021). Practical measures such as structured onboarding programs, regular interdepartmental meetings, and the development of unified communication platforms can mitigate these issues. By prioritizing the social dimensions of digital transformation, organizations can foster a culture of collaboration and adaptability, critical for successful technology adoption (Nonaka, 1994; Dossick & Neff, 2011).

- **Customized Approaches to BIM Implementation -** The findings stress the need for tailored strategies in BIM implementation, particularly regarding Exchange Information Requirements (EIRs) (ISO, 2018; EUBIM Task Group, 2017). Organizations should avoid adopting generic templates and instead focus on customizing BIM use cases and requirements to fit their specific needs, capacities, and goals. This approach ensures that BIM delivers value throughout the asset life cycle, from design and construction (D&C) to operations and maintenance (O&M) (Benn & Stoy, 2022; S. T. Matarneh et al., 2019).

- **Development of Organizational Maturity -** The research underscores the necessity of developing organizational maturity in both technological and procedural dimensions (Abbasnejad et al., 2021; Lindblad & Guerrero, 2020). Practical steps include investing in training programs to enhance staff competencies, formalizing data governance policies, and adopting pilot projects to incrementally build expertise and confidence in BIM and other digital tools (Ford, 2024; Siebelink, 2021). These measures can help organizations establish robust frameworks for continuous improvement and innovation.

- **Role of Leadership and Change Management -** The findings emphasize that effective leadership and proactive change management are pivotal for digital transformation. Public clients must empower leaders to act as system integrators, capable of aligning diverse internal and external stakeholders (Lindblad, 2019; Shirish & Batuekueno, 2021). Additionally, establishing clear communication channels and decision-making

processes can help mitigate resistance to change and ensure smoother transitions to new technologies and practices (Chan, 2020; Lindblad & Karrbom Gustavsson, 2021).

- **Prioritization of Data Interoperability and Quality -** Given the identified challenges in data interoperability and governance, organizations must prioritize investments in technologies and protocols that enable seamless data exchange across platforms and stakeholders (ISO, 2018; S. T. Matarneh et al., 2019). Ensuring data quality—accuracy, relevance, and timeliness—is critical to maximizing the utility of digital transformation efforts, particularly in the context of BIM's reliance on structured and semi-structured data formats (Karmakar & Delhi, 2021; Benn & Stoy, 2022).

- **Public Sector Innovation through Digitalization -** The research identifies public clients as key drivers of innovation in the construction and asset management industries (Lindblad & Guerrero, 2020; Mendez et al., 2024). By adopting a client-led approach to digitalization and setting clear, actionable standards, public organizations can influence market trends and encourage widespread technological adoption. These efforts not only enhance internal efficiencies but also generate broader societal value by fostering sustainable and innovative practices (Lu et al., 2021; Kuiper, 2021).

- **Continuous Feedback Loops for Policy and Process Adaptation -** The study demonstrates the importance of integrating feedback mechanisms into digital transformation initiatives. Organizations should actively collect and analyse feedback from pilot projects, stakeholders, and operational outcomes to refine policies, processes, and technologies (Al Ahbabi & Alshawi, 2015). This iterative approach supports continuous improvement and ensures that digital strategies remain aligned with evolving organizational goals and external demands (Godager et al., 2021; Sundstrom et al., 2023).

The practical implications of this research emphasize a holistic, socio-technical approach to managing digital transformation and BIM implementation. By addressing both human and technological dimensions, public sector organizations can optimize their processes, enhance stakeholder engagement, and drive sustained innovation and value creation (Chan, 2020; Mendez et al., 2024).

## 6.5 Limitations

The research has several limitations that are both methodological and contextual in nature, impacting the breadth and depth of its findings, these are as follows:

- **Methodological Limitations -** The study's reliance on qualitative data gathered from in-person interviews presents constraints. While the interviews provided rich, context-specific insights, the geographical and logistical limitations meant that only participants from a subset of branch offices were included. This selective sampling risks omitting diverse perspectives from other branches with distinct operational challenges or innovative practices (Miles, 2017; Siebelink, 2021). Furthermore, the reliance on participant recommendations and internal hierarchies to identify interviewees may have introduced selection bias, privileging perspectives aligned with organizational leadership while potentially neglecting dissenting or less mainstream views (Shirish & Batuekueno, 2021; Abbasnejad et al., 2021).

- **Contextual Limitations -** Contextual limitations stem from the study's focus on a single organization, BLB NRW, and its emphasis on state-level operations. By excluding

federal-level projects, the research misses the opportunity to explore differences in governance, operational strategies, and policy implementation between state and federal domains (Kuiper, 2021; Mendez et al., 2024). This narrower focus on state-level projects also limits the transferability of the findings to organizations managing broader or multi-level governmental operations (Lindblad & Guerrero, 2020).

- **Data Limitations -** Data limitations also emerge from the reliance on internal documents such as organizational handbooks, BIM guidelines, and feedback from pilot projects. While these sources are valuable, they often reflect idealized or normative representations of processes rather than actual on-the-ground practices (Godager et al., 2021; Wildenauer & Basl, 2021). This disconnect between documented policies and lived realities can lead to discrepancies between the theoretical framework and empirical observations. Moreover, the study does not address the extent to which these documents are regularly updated or adhered to, potentially resulting in outdated or irrelevant findings (Chan, 2020; Abbasnejad et al., 2021).

- **Theoretical Scope -** The study's theoretical scope is another limitation. While it employs robust frameworks like the PPP complex system model, these frameworks inherently simplify the dynamic and multi-layered nature of socio-technical systems (Ford, 2024; Sundstrom et al., 2023). For instance, the interaction between policy, process, and product is subject to constant evolution influenced by external factors such as regulatory changes, technological advancements, and market dynamics (Kagermann & Wahlster, 2022; Lee & Borrmann, 2020). These external variables are acknowledged but not fully explored, which may lead to oversimplifications in the analysis.

- **Sector-Specific Limitations -** Additionally, the focus on the public sector context means that findings may not be directly applicable to private sector organizations, which often operate under different economic pressures, strategic priorities, and innovation incentives (Lindblad & Karrbom Gustavsson, 2021; Stange, 2020). Public sector organizations typically face unique challenges such as bureaucratic inertia, compliance-driven operations, and the need to align with public values, all of which shape their approach to digital transformation and BIM implementation (Mendez et al., 2024; Kuiper, 2021). Consequently, private organizations with profit-driven motives and more flexible structures might require adapted strategies not covered by this research.

- **Temporal Limitations -** Finally, the study does not fully account for the temporal dimension of digital transformation, which involves long-term cultural and operational shifts (Shirish & Batuekueno, 2021; Kuiper, 2021). The research primarily examines current states and immediate challenges but may not capture the iterative learning processes and gradual adaptations that shape long-term success (C. K. May, 2022). As such, its findings offer a snapshot rather than a longitudinal understanding of digital transformation dynamics.

## 6.6 Further research

The research identifies numerous areas for further exploration to enhance understanding and practices related to digital transformation and Building Information Modelling (BIM). One significant opportunity lies in conducting longitudinal studies to capture the long-term effects of digital initiatives, providing insights into how organizations adapt to new technologies, processes, and cultural shifts over time (Lindblad & Karrbom Gustavsson, 2021). Comparative studies across sectors, particularly between public and private organizations, could illuminate differences in motivations, barriers, and outcomes, offering transferable lessons and strategies

(Chan, 2020; Kuiper, 2021). Expanding the geographical and contextual scope of research to include diverse regions and governance structures would further enrich understanding, particularly through cross-country analyses that explore the role of cultural and policy differences in shaping digital transformation outcomes (Mendez et al., 2024; Sundstrom et al., 2023).

Emerging technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and Digital Twins (DT) offer exciting avenues for exploration. Future research could investigate how these tools integrate with BIM and other digital frameworks, particularly in enhancing data interoperability, decision-making, and stakeholder coordination (Lu et al., 2021; Godager et al., 2021). Addressing the persistent challenge of interoperability, research could focus on developing and testing new data standards, protocols, and frameworks that facilitate seamless exchange across platforms (ISO, 2018; S. T. Matarneh et al., 2019). Behavioural and psychological perspectives also merit deeper investigation, particularly in understanding resistance to change, motivation, and the development of digital competencies, which are critical to successful technology adoption (Shirish & Batuekueno, 2021; Nonaka, 1994). Studies could examine how leadership styles and organizational culture influence these factors, providing actionable insights for managers (Ford, 2024; Lindblad, 2019).

The role of public clients in driving innovation presents another rich research area, particularly in examining the effectiveness of procurement strategies such as client-led versus supplier-led innovation (Lindblad & Guerrero, 2020; Kuitert et al., 2019). Relatedly, further studies could validate and adapt frameworks like the PPP complex system model for broader applications, testing its utility across different organizational contexts, project types, and technological systems (Godager et al., 2021; Kämpf-Dern & Pfnür, 2014). With sustainability becoming a central focus, future research could assess how digital transformation supports environmental, social, and economic sustainability goals, exploring topics like lifecycle impacts, green building certification, and sustainable design practices (Benn & Stoy, 2022; Lu et al., 2021).

Policy development and alignment also warrant deeper exploration, especially in addressing misalignments between hierarchical policy levels—micro, meso, and macro—and organizational practices (Kuiper, 2021; Mendez et al., 2024). Research could examine how regulatory frameworks influence digital transformation adoption rates and outcomes (ISO, 2018; EUBIM Task Group, 2017). Similarly, studies on knowledge management and archiving could focus on strategies to better capture and leverage tacit and explicit knowledge, ensuring that organizations can effectively document and use lessons learned (Nonaka, 1994; Siebelink, 2021). Stakeholder dynamics represent another critical area, particularly in understanding the roles, power dynamics, and collaboration mechanisms among internal and external actors involved in digital transformation (Shirish & Batuekueno, 2021; Lindblad & Karrbom Gustavsson, 2021).

Resistance to change remains a persistent barrier, and further research could investigate strategies to overcome this challenge, such as tailored training programs, incentive structures, and communication initiatives that emphasize the long-term benefits of digital transformation (Chan, 2020; Abbasnejad et al., 2021). Economic assessments of these initiatives could provide additional insights, analysing cost-benefit dynamics, return on investment, and broader economic impacts at organizational and societal levels (Ford, 2024; Stange, 2020). Finally, ethical considerations, particularly around data privacy, security, and surveillance, are becoming increasingly critical in the digital age. Research could explore how organizations balance innovation with ethical responsibilities, ensuring that technological advancements are aligned with societal values (Lu et al., 2021; Kuiper, 2021).

Together, these avenues for future research promise to build on current findings, fostering a deeper and more comprehensive understanding of digital transformation and BIM adoption across sectors and contexts.

## 6.7 Recommendations

The study provides a comprehensive set of recommendations to facilitate the adoption of digital transformation and Building Information Modelling (BIM) in complex public sector organizations, particularly those contending with socio-technical challenges. These recommendations encompass strategies at organizational, technological, and policy levels to achieve enhanced outcomes.

A central recommendation is the adoption of a holistic socio-technical framework. Organizations are advised to implement models such as the PPP complex system framework, which integrates policy, process, and product dimensions across hierarchical levels and asset life cycles (Siebelink, 2021; Godager et al., 2021). This approach enables a comprehensive alignment of data needs, barriers, and demands with organizational objectives, ensuring strategic coherence and technological efficacy. Tailoring such frameworks to the specific characteristics of the organization and its regional policy environment is crucial for optimizing their impact (Kuiper, 2021; Sundstrom et al., 2023).

Enhancing coordination and knowledge sharing is identified as a pivotal strategy. Standardized knowledge-sharing platforms, including centralized repositories or intranet systems, should be established to facilitate efficient access to shared resources such as project data, guidelines, and lessons learned (Nonaka, 1994; Ford, 2024). Interdepartmental collaboration should be fostered through regular cross-departmental meetings and workshops, while informal knowledge exchange can be supported through interactive sessions such as brainstorming workshops to strengthen tacit knowledge transfer (Dossick & Neff, 2011; Shirish & Batuekueno, 2021).

The implementation of customized BIM strategies is emphasized as critical to addressing project-specific goals and stakeholder requirements. Key actions include developing Exchange Information Requirements (EIRs) tailored to the unique objectives of projects, in alignment with ISO 19650 guidelines (ISO, 2018; Charef et al., 2019). Pilot projects should be employed as testing grounds for refining BIM practices before broader application, while interoperability challenges should be addressed through the adoption of open data standards and protocols to ensure seamless information exchange (EUBIM Task Group, 2017; Benn & Stoy, 2022).

Investments in organizational maturity and training are highlighted as essential for the effective execution of digital transformation initiatives. Structured training programs should be designed to enhance technical competencies and understanding of BIM processes among employees (Abbasnejad et al., 2021; Siebelink, 2021). Leadership development initiatives should equip leaders to manage interdisciplinary teams and align efforts with strategic objectives. Furthermore, maturity assessment frameworks should be employed to evaluate and progressively improve organizational processes, policies, and technological infrastructures (Lindblad & Karrbom Gustavsson, 2021; Wildenauer & Basl, 2021).

The importance of data governance and quality is underscored as foundational to successful digital transformation. Organizations are encouraged to establish robust data governance policies that clearly define data ownership, access rights, and security protocols (ISO, 2018; Godager et al., 2021). Interoperability standards, such as the Industry Foundation Classes (IFC) for BIM, should be rigorously adopted, and data quality should be routinely monitored to ensure accuracy, relevance, and completeness (S. T. Matarneh et al., 2019; Stange, 2020).

The role of leadership is deemed critical, with recommendations to strengthen leadership and change management. Clear definitions of leadership roles, such as BIM champions or digital transformation leaders, are necessary to oversee technological and procedural integration (Lindblad, 2019; Kuiper, 2021). Proactive change management strategies should address resistance to transformation by emphasizing the benefits of new systems, while accountability mechanisms should ensure the achievement of project milestones (Shirish & Batuekueno, 2021; Lee & Borrmann, 2020).

The integration of feedback loops for continuous improvement is advocated to enhance adaptability and effectiveness. Pilot project outcomes should be systematically reviewed to inform broader implementation strategies (Ford, 2024; Godager et al., 2021). Stakeholder feedback, including input from clients, tenants, and external partners, should be actively incorporated into evaluations of BIM and digital initiatives. A structured approach to documenting and disseminating lessons learned across projects is recommended to build institutional memory (Nonaka, 1994; Lindblad & Guerrero, 2020).

To promote innovation through public procurement, public clients should articulate clear expectations for suppliers by embedding innovation requirements and digital solutions into procurement policies (EUBIM Task Group, 2017; Mendez et al., 2024). Collaboration with private sector stakeholders is encouraged to co-develop technologies, while organizations should strategically balance client-led and supplier-led innovation approaches based on internal capabilities and project demands (Lindblad & Guerrero, 2020; Kuitert et al., 2019).

Policy integration across hierarchical levels is highlighted as a critical enabler. Policies should be tailored to the specific needs and operational contexts of organizations, avoiding one-size-fits-all solutions (Kuiper, 2021; Sundstrom et al., 2023). Flexibility in policy implementation should be maintained to accommodate project complexities while ensuring alignment with overarching strategic goals. Engagement with regional and national policymakers is recommended to harmonize organizational objectives with broader public policy priorities (Mendez et al., 2024; Stange, 2020).

Finally, the study emphasizes the integration of long-term sustainability goals into digital transformation strategies. Digital initiatives should align with environmental and social sustainability objectives, such as reducing resource consumption and improving building efficiency (Lu et al., 2021; UN, 2015). BIM tools should be leveraged to model and analyse the environmental impacts of construction and operational decisions, while long-term value creation should be measured in terms of economic, social, and environmental benefits (Benn & Stoy, 2022; Chan, 2020).

By adhering to these recommendations, public sector organizations can address the socio-technical challenges inherent in digital transformation and BIM adoption, ensuring alignment with organizational priorities and public sector values. These strategies have the potential to foster innovation, enhance operational efficiency, and deliver sustainable, long-term value across diverse projects and stakeholders.

—End of Chapter—

# 7 References


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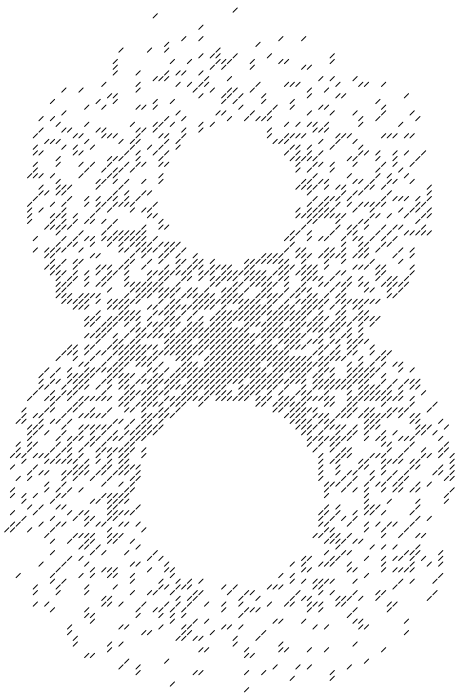

# 8 Appendix

Appendix 1: Reflection

Appendix 2: Participant Information

Appendix 3: Explicit Consent Points

Appendix 4: Interview Questions

Appendix 5: Interview Protocol

Appendix 6: Data Management Plan

Appendix 7: Interview Transcripts (Confidential)

Appendix 8: Internal Validation Protocol

Appendix 9: External Validation Protocol

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January 14, 2025

# Appendix 1 - Reflection

## 1.1 Lessons learned

### 1.1.1 How and why the approach work or did not work and to what extent?

The approach was carefully tailored to a specific client context—namely a public client from North Rhine-Westphalia, who was both proactive and open to change. This allowed for an in-depth exploration of issues and solutions that were highly relevant to the client's needs, rather than adopting a generic approach that might not fit as well. By being context-specific, the research could directly address the operational realities of this particular client, ensuring relevance and practical value.

The emphasis on translating findings into actionable tools and instruments was a significant factor of the approach. The research didn't stop at theoretical insights; it also aimed to provide actionable recommendations and instruments that could help the organization move forward in its digital transformation journey. Such practical, ready-to-use guidance is often key to successfully implementing change, particularly when it comes to complex processes like digital transformation.

While the methodology recognizes the uniqueness of each organization and the need to adapt the framework accordingly, it positions the findings as a preliminary tool—an initial consideration. This approach underscores that, although it offers a foundational basis, customization is necessary to suit the specific conditions of each organization.

### 1.1.2 How have I incorporated the mentor's feedback?

Prof. Bruggeman provided invaluable feedback during the early phases of the research design. Her insights, gained through numerous in-depth discussions, were instrumental in establishing the perspective that issues related to BIM implementation in public clients should be analysed as issues concerning its fundamental element: data. By reframing the research scope to encompass the characteristics of data and its relationship to various organizational operations, a more comprehensive understanding of interdependencies emerged. Additionally, Prof. Bruggeman directed attention to highly influential literature, which forms the foundation for the majority of this research.

Dr. Straub played a pivotal role in shaping the research methods and aligning the research questions with appropriate methodologies. Beyond providing extensive constructive feedback on the structure of the report, the sequence of arguments, and the clarity of communication, his experience in conducting research in collaboration with public clients was crucial for navigating the procedural challenges encountered during the empirical research. His feedback was reflected in each draft of this report, and with every iteration, a more refined version of the research objectives emerged.

Prof. Fleischmann-Bergstein played an instrumental role in inspiring the initiation of this research project. Having known him in a personal capacity for several years, it was during one of our many informal exchanges that the idea of pursuing a research collaboration with BLB NRW emerged. Prof. Fleischmann-Bergstein was key in establishing trust with the organization, facilitating access, and ensuring cooperation. Throughout the process, he provided guidance on data representation techniques for the report, as well as strategies for effectively communicating the results. His feedback offered essential technical support, which helped to overcome several challenges encountered during the research.

## 1.2 General reflection questions from graduation manual

### 1.2.1 What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

The graduation project aligns with the studio theme of *User Perspective*, focusing on the concept of "internal commissioning," as defined by Hermans et al. (2018). This concept emphasizes the organizational integration of responsibilities related to the built environment, encompassing strategic needs assessment, need specification, demand formulation, and supplier selection. Within this framework, the project specifically addresses two key processes: need specification and demand formulation. It explores the translation of (data) needs into (data) demands within the context of procuring digital information for construction projects and asset management activities.

The Master's programme in *Management in the Built Environment (MBE)* at TU Delft is distinguished by its focus on this emerging field of study and its strong theoretical foundation, which supports advanced research in areas of academic and professional relevance. Although TU Delft is based in the Netherlands and the graduation company is located in Germany, the MBE programme at TU Delft offers a comprehensive theoretical approach with opportunities to develop advanced research skills, making it a uniquely suitable choice.

The curriculum at TU Delft, particularly its dedicated courses in research methods and the option to participate in the Honours Master Programme (HMP), has provided valuable academic exposure. Although the HMP research could not be fully completed, the practical experience gained during the project greatly influenced the approach and scope of the graduation project. The programme's emphasis on a rigorous academic foundation, combined with the enthusiasm, energy, and unwavering support of mentors, has significantly enriched the process, creating a rewarding and enjoyable learning experience.

### 1.2.2 How did your research influence your design/recommendations and how did the design/recommendations influence your research?

At the outset of studies at TU Delft, the primary focus was on the exchange of information requirements for projects, particularly in the context of Building Information Modelling (BIM). This perspective shaped the development of the research proposal for the Honours Master Programme (HPM). However, deeper engagement with the literature revealed that the research scope could be more effectively framed by examining data needs across the organization, rather than focusing solely on BIM and the delivery phase.

The importance of addressing social dimensions in the implementation and adoption of new technologies has been emphasized by numerous scholars. This perspective was frequently corroborated through interviews conducted during HPM research at the Rijksvastgoedbedrijf

(RVB). Similarly, interviews with professionals at the Bau- und Liegenschaftsbetrieb NRW (BLB NRW), who are responsible for developing and implementing new technologies, also highlighted the critical role of social factors. It was repeatedly noted that social barriers represent some of the most influential challenges impacting the success of digitalization efforts within organizations.

Recommendations from the literature have played a significant role in shaping the structure and direction of the research. By integrating these insights, the study aims to provide a more comprehensive understanding of how data needs are defined and how social considerations influence the adoption of digital technologies within organizational contexts.

### 1.2.3 How do you assess the value of your way of working (your approach, your used methods, used methodology)?

The value of the approach has been assessed primarily through feedback provided by mentors and validation sessions. Additionally, responses and reactions from individuals at the two organizations where the research was presented have served as important measures of its relevance and effectiveness. Positive feedback received during these interactions has highlighted the significance and necessity of the research, providing encouragement throughout the process. Although not without its limitations, the analytical approach adopted in the research offers a strong justification for its potential utility, a point reiterated during the external validation session with experts.

Attention to feedback from interviewees has also been a key aspect of the process, with deliberate efforts made to address areas for improvement. For example, during initial outreach, some participants suggested that consent forms should be made compatible with digital completion and signatures. This recommendation was promptly implemented, resulting in only one reported issue with the digital form. Such adaptability has enhanced the overall efficiency and professionalism of the research process.

### 1.2.4 How do you assess the academic and societal value, scope and implication of your graduation project, including ethical aspects?

Ethical considerations have been a central focus of the research process, with strict adherence to the data privacy and security policies of the host organization. Although these requirements have occasionally posed challenges, they have been consistently upheld throughout both research projects. At this stage, it is not yet possible to fully assess the value of the research, as it is still ongoing. However, the host organization has expressed interest in the findings and their potential application to improve operational practices.

A critical milestone for the research will be the internal validation group session, which will provide an opportunity to evaluate how the findings are received by *BLB NRW*. As a public client, the organization has the potential to use the outcomes of this graduation project to enhance its ability to deliver services—such as the construction and management of state buildings in North Rhine-Westphalia (NRW)—that align more effectively with societal values.

From an academic standpoint, the lessons learned from these two research projects offer a foundation for further exploration and development of innovative solutions within this emerging field.

### 1.2.5 How do you assess the value of the transferability of your project results?

Several individuals at the *BLB NRW* have expressed the view that the organization positions itself as one of the most well-prepared and advanced public clients in the state of North Rhine-Westphalia (NRW) regarding digitalization and the use of Building Information Modelling (BIM) in planning processes. This perception underscores the potential influence of the research on other public clients in the region, such as municipalities or housing associations, which may face challenges related to digitalization and digital transformation.

The research aims to design a process for identifying valuable data within an organization. This objective is considered to have broad applicability and transferability, making it particularly valuable for organizations seeking to address similar challenges. The potential for such a framework to support digitalization efforts across various public entities further emphasizes its significance and utility.

### 1.2.6 What aspects of your research have been unexpected?

A key motivation for enrolling in the Master's programme was the opportunity to gain practical experience in conducting research. As is often the case, unforeseen circumstances can create a divergence between the theoretical description of a process and its execution in practice. Despite maintaining frequent communication with BLB NRW for nearly two years regarding the intention to undertake an internship in connection with the master's thesis, procedural complexities still arose that were difficult to manage. Detailed discussions about potential procedural delays and associated concerns did not appear to have been fully considered by the relevant individuals. These challenges became apparent only when the task of arranging the internship was actively undertaken. Due to these unforeseen circumstances, the graduation project could not be completed within the given timeframe.

Similarly, significant delays were encountered in obtaining access to information from the Rijksvastgoedbedrijf (RVB), which formed the primary reason for not being able to complete the project within the given timeframe. One of the primary difficulties involved reconciling the need to arrange access to information with a research design that was still under development. In both cases, the research design did not take its final form until the conclusion of the P2 phase, which added complexity to planning and the legal clarifications of data collection efforts.

To mitigate such issues in future research projects, particularly those not constrained by an educational program's timeframe, it may be beneficial to finalize the research design before engaging with public organizations. This approach would enable more effective planning of the time required for data collection and reduce procedural delays.

### 1.2.7 Has the research fulfilled your own personal goals?

The Master's programme has been instrumental not only in providing new knowledge but also in fostering the development of valuable research skills. The adoption of tools such as Zotero for reference management and Obsidian for knowledge management has significantly enhanced the ability to recall and retrieve relevant information from diverse sources. Additionally, familiarity with advanced literature search platforms, including ResearchRabbit, Scite, and Connected Papers, has improved the efficiency of identifying pertinent research materials.

The guidance and support provided by mentors have been invaluable throughout the research process. Their dedication and efforts have been instrumental in addressing challenges and alleviating insecurities encountered during the project. While expertise in research is still a work in progress, confidence in conducting research has substantially increased, reflecting the effectiveness of the program and mentorship in cultivating these skills.

Delft University of Technology | Department of Management in the Built Environment

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January 19, 2024

# Appendix 2 - Participant Information

You are being invited to participate in a research study titled:

> *"Designing the process for aligning the data needs of public clients into useful data demands – An exploration of a continuous improvement approach, juxtaposing the current state of data demand formulation in the Bau- und Liegenschaftsbetrieb NRW (BLB NRW) of Germany and the Central Government Real Estate Agency (Rijksvastgoedbedrijf) of the Netherlands."*

This study is being conducted by Leonardo F. Micolta Diaz, a student from Delft University of Technology, as part of his graduation project research associated with the Faculty of Architecture and the Built Environment, Department of Management in the Built Environment. The goal of the graduation project is to provide master's students with an opportunity to develop and improve research skills through a topic chosen based on the students' own interests. The research seeks to map the current state of digital data utilization in the management/operations of built assets and the commissioning of construction works at the BLB NRW. By capturing multiple perspectives from key actors at the BLB NRW, the study aims to identify sources of misalignment among intra-organizational data needs, goals, and current capabilities. You have been identified by Ms. Klingsporn as an important individual whose perspective on the subject matter is of great relevance to this research.

Your participation in this research will be conducted in a semi-structured interview session, lasting approximately 1 hour. You will be asked questions related to your professional background, your role at the BLB NRW, and your experience with digital tools, related concepts, your specific data needs, and the methods and processes you employ whilst performing your tasks. To facilitate notetaking, the interview will be audio recorded. The audio recordings will be deleted after they are transcribed. A copy of the transcript will be shared with you. You may be approached for a shorter second interview to be scheduled via phone or video-conference call in the case that there is a need for clarification to interpretations in the transcript or follow-up questions not captured during the first interview. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by pseudonymizing any personal identifiable information you may provide. Please refer to Appendix 3 – Explicit Consent Points for more detailed information.

Your participation in this study is entirely voluntary and you can withdraw at any time. At the conclusion of the research, a report will be submitted to TU Delft and BLB NRW and will include a summary of findings and the pseudonymized transcripts of all interviews. Data will not be able to be removed from the report once it has been submitted, if you wish to withdraw data from the research, please contact the primary researcher prior to **April 30, 2024**. Any questions or concerns regarding this study can be directed to the primary researcher:

Thank you for your interest and participation in this research.

Leonardo Fred Micolta Diaz, primary researcher - l.f.micoltadiaz@student.tudelft.nl

Delft University of Technology | Department of Management in the Built Environment

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Prof. M. (Moritz) Fleischmann-Bergstein, third mentor - moritz.fleischmann@hs-duesseldorf.de

**January 19, 2024**

# Appendix 3 - Explicit Consent Points

In this document, LEONARDO FRED MICOLTA DIAZ is hereinafter referred to as the **primary researcher**,

and _____ is hereinafter referred to as the **participant**.

Dear participant, please mark the appropriate box under the columns YES or No for each question. Your signature is required on Page 4. If you have any questions, contact the primary researcher for further information.

| PLEASE TICK THE APPROPRIATE BOXES | YES | NO |
|---|---|---|
| **A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION** | | |
| 1. I have read and understood the **Participant Information (Appendix 2)** form dated **January 19, 2024**, or it has been read to me. I have been given time to ask questions about the study and my questions have been answered to my satisfaction. | ☐ | ☐ |
| 2. I voluntarily consent to participate in this study, understanding that I have the right to refuse to answer questions and can withdraw from the study within the specified time frame (see Point 3) without providing a reason. | ☐ | ☐ |
| 3. I acknowledge that the right to withdraw from the study is subject to a time limit.<br>• The right to withdrawn from the study can be exercised until **April 30, 2024**, through any means of contact. After this date, it will not be possible to retrieve or withdraw data previously collected and incorporated into the research report. | | |
| 4. I understand that taking part in the study involves:<br>• Audio recording to facilitate notetaking.<br>• Transcribing audio to text.<br>• The audio recordings will be deleted after transcription.<br>• Any Personally Identifiable Information (PII) of the participant captured during the audio recording will be de-identified (pseudonymized) in the transcription process.<br>• The participant will receive a copy of the transcript. | ☐ | ☐ |

| PLEASE TICK THE APPROPRIATE BOXES | YES | NO |
|---|---|---|
| • During the specified timeframe, the participant is encouraged to submit comments or inquiries regarding the content and interpretation of the transcript.<br>• During the specified timeframe, the primary researcher may reach out to the participant for a follow-up interview to address any needed clarifications or additional questions arising from the contents and interpretation of the transcript. | | |
| **B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)** | | |
| 5. I understand that taking part in the study involves collecting specific Personally Identifiable Information (PII) and associated Personally Identifiable Research Data (PIRD) with the potential risk of my identity being revealed, such as:<br>• Full Name<br>• Work E-mail<br>• Work phone number<br>• Job title<br>• Professional experience<br>• Educational background | ☐ | ☐ |
| 6. I understand that taking part in the study involves the following risks:<br>• Potential for re-identification of de-identified research data (PIRD), which can lead to impacts on public/professional reputation.<br>• Minor emotional risks, including mental fatigue, embarrassment, frustration or discomfort.<br>• Loss of time, including potential conflicts with important communications or work activities during the scheduled interview timeslot. | ☐ | ☐ |
| 7. I understand that these risks will be mitigated by:<br>• By providing the participant with the transcript before distributing the final research report, allowing for the review of the transcript's content, provision of feedback, and/or request for data removal.<br>• The ability to refuse to answer any question with or without giving a reason.<br>• The ability to stop or pause at any point during the interview to rest, attend to other matters, or without a giving reason.<br>• The ability to reschedule or cancel the interview appointment with any means of communication with or without giving a reason. | ☐ | ☐ |
| 8. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach:<br>• Access to the raw audio recordings will be limited only to the primary researcher.<br>• The raw audio recordings will be securely stored on the personal computer of the primary researcher, which has hardware encryption and two factor login identification.<br>• The folder containing the audio recordings will have password protected access.<br>• The document used as the participant de-identified key will have password protected access. | ☐ | ☐ |

| PLEASE TICK THE APPROPRIATE BOXES | YES | NO |
|---|---|---|
| 9. I understand that personal information collected about me that can identify me, such as, my name and job title, will not be shared beyond the study team. The participant answers will be de-identified, and only de-identified data will be included as part of the research report. | ☐ | ☐ |
| 10. I understand that the identifiable personal data I provide will be destroyed by the principal researcher at the latest by the end of the research study on March 15, 2024. | ☐ | ☐ |
| **C: RESEARCH DISSEMINATION AND APPLICATION** | | |
| 11. I understand that after the research study the de-identified information I provide will be used for:<br>• The completion of a research report as part of the master graduation project of the Faculty of Architecture and the Built Environment of Delft University of Technology (TU Delft).<br>• As supplementary research data to support similar studies or academic discourse, conducted by the primary researcher or other researchers.<br>• As basis for future research focused on identifying solutions, informing policy, or decision-making procedures by the primary researcher or other researchers.<br>• As an academic example of the output produced in relationship with TU Delft and the associated academic mentors. | ☐ | ☐ |
| 12. I agree that my responses, views or other input can be quoted anonymously in research outputs. | ☐ | ☐ |
| **D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE** | | |
| 13. I give permission for the transcript, which includes de-identified information I provide, to be archived in the TU Delft education repository for future research and learning purposes. | ☐ | ☐ |
| 14. I understand that access to this repository is open and unrestricted to the public. | ☐ | ☐ |

**Signatures**

_____ _____ _____

Name of participant [printed] Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____ _____ _____

Name of primary researcher [printed] Signature Date

Study contact details for further information:
Leonardo F. Micolta Diaz
l.f.micoltadiaz@student.tudelft.nl

Delft University of Technology | Department of Management in the Built Environment

**Interviewer**: Leonardo Fred Micolta Diaz - l.f.micoltadiaz@student.tudelft.nl

**Interviewee**: Name, Job title – e-mail

**Location:** Place, City
**Time**: Month DD, 2024: HH:00 – HH:00

# Appendix 4 - Interview Questions

To help you prepare for the interview, the following is the interview protocol and main interview questions.

- Opening Statement – 5 minutes
- Research Introduction – 3 minutes
- Seeking Consent – 5 minutes
- Interview questions: - 45 minutes

1. What is your current job title?
2. How long have you been in your current role?
3. How many years of professional experience do you have in your current field?
4. Could you describe your day-to-day tasks and responsibilities?
5. Could you guide me through one of your most important tasks from start to finish?
6. How often and in what ways do you collaborate with other teams and departments?
7. Are you a member of any professional networks or organizations, and if so, why did you join them?
8. Are you part of any internal BLB NRW task groups or special units dedicated to developing internal policies, standards, or procedures? If so, could you share more about it?
9. How do you stay updated on new technological developments relevant to your job?
10. How do you share your knowledge within others in your team and the BLB NRW as a whole?
11. Can you describe if any of the current BLB NRW initiatives are necessitating changes or adaptations in how you complete your tasks?
12. What standards or protocols are crucial for achieving the desired task completion quality?

13. What are some typical barriers or roadblocks you face during task execution?
14. How do the BLB NRW goals impact your role and task performance?
15. Could you mention some of the most common digital tools you use in your day-to-day tasks?
16. What are the key factors influencing your digital information needs?
17. What specific short-term BLB NRW goals can be achieved with the digital information currently at your disposal?
18. What type of digital information helps you plan tasks to achieve long-term BLB NRW goals?
19. Where do you typically look for the digital information needed to complete tasks?
20. How do you cross-reference digital information related to your task?
21. How and where is digital information stored or archived?
22. How do you request digital information that you need but don't currently have?
23. If the basis for your digital information request changes, how do you update it?
24. If the supplied digital information does not meet your request's expectations, what do you do?
25. What type of digital information is most commonly missing or difficult to acquire?

- Outro – 2 minutes

Delft University of Technology | Department of Management in the Built Environment

**Interviewer**: Leonardo Fred Micolta Diaz - l.f.micoltadiaz@student.tudelft.nl

**Interviewee**: Name, Job title – e-mail

**Location:** Place, City
**Time**: Month DD, 2024: HH:00 – HH:00

# Appendix 5 - Interview Protocol

## Opening Statement

Good day, first of all, thank you for allocating some time to meet with me and to agreeing to participate in this study. First, let me introduce myself. My name is Leonardo Micolta Diaz, I am a Colombian born, US citizen, German registered architect with over 12 years of international work experience and a specialization in all aspects of Building Information Modelling (planning, implementation, and management). As of last year, I am also a student at Delft University of Technology, completing a master program on Management in the Built Environment of the Faculty of Architecture and the Built Environment to which this study is part of. I will share more on the research topic in a few moments, **however prior to doing so, could you tell me a little bit about yourself?**

Notes:

_____

_____

_____

_____

_____

## Research Introduction

Thank you, moving on with the research introduction. First a bit about the graduation project. The primary goal is to provide master's students, like me, with an opportunity to develop and improve research skills through a topic chosen from my own interests. My area of interest is digitalization in the built environment. I have chosen research topic that explores how public clients can improve their internal process of identifying data needs for new construction and renovation projects and life cycle asset management, in this case, will be focusing on you guys, the BLB NRW. The research seeks to map the current state of digital data utilization in the management/operations of built assets and in the commissioning of construction. Aside from theoretical research, I am conducting empirical research as well, in the form of interviews with key actors, such as yourself. By capturing multiple perspectives at the BLB NRW, the study aims to identify sources of misalignment among intra-organizational data needs, goals, and current capabilities. The research findings will be used in future research to design a process for managing the intra-organizational information needs, to ensure their proper representation in the demand formulation process and procurement of services. With that said, the study does not aim to evaluate your specific techniques nor professional qualifications, instead, your perspective on the matter will be useful in shinning a light at how the organization as a whole, and the individual actors involved, influence the process of translating data needs into data requirements.

## Seeking Consent

Moving on to administrative matters, in the email I had sent to you prior to this meeting, I had attached two important forms: an introduction letter, document named Appendix 2 Participant Information, and an Appendix 3 with Explicit Consent Points. In the case you don't have it with you, I have brought two printed copies with me.

To summarize the contents of the consent form, I would like to highlight that to facilitate notetaking, I would like to audio record our conversation today. I have setup these two laptops to record the interview. For your information, only I will have access to the audio recordings which will eventually be destroyed after they are transcribed. In addition, you must sign a form devised to meet our human subject requirements. Essentially, this document states that: (1) all information will be held confidential, (2) your participation is voluntary, and you may stop at any time if you feel uncomfortable, and (3) we do not intend to inflict any harm. Please take your time to read through the form, answer every question by marking the box corresponding to your answer, under the YES or NO columns. Don't forget to sign and print your name on the last page.

**Have you had a chance to look over both documents?**
**If not, you can take some time now to look over the documents.**
**If you have any questions, feel free to ask me prior to signing it?**

Would you like to keep a physical copy of this agreement? Otherwise, I will scan it and send it to you via email. I need to bring back with me at least one signed copy.

**Consent Form Signed [ ]**

Thank you, OK now we can proceed with the interview. In a few moments, I will start the audio recording, and I will be asking you to confirm verbally that you have given consent to proceed with the recording and the interview.

I have planned this interview to last no longer than one hour. During this time, I have several questions that I would like to cover. If time begins to run short, it may be necessary to interrupt you to push ahead and complete this line of questioning.

**Start audio recording [ ]**

## Interviewee Background

This is Leonardo Micolta Diaz, student of Delft University of Technology, today is **[ Month day, 2024]**, and I am with **[Interviewee name]** of the Bau- und Liegenschaftsbetrieb, NRW (BLB NRW), who has voluntarily, and kindly agreed to participate in this study, has given me consent to audio record this conversation and has provided me with a signed informed consent form.

Mr. **[Interviewee name]**, could you please reaffirm in the recording that the previous statement is correct? **[ ]** -> Thank you.

We will start simple, by establishing a bit of your background information:

What is your current job title? _____

How long have you been in your current position? _____ years

(Probe) Is that the same as the total amount of years you have been at the BLB NRW? _____ years

(Probe) In total how many years of professional experience do you have in your current field: _____ years

Notes:
_____
_____
_____
_____
_____

## Actor Positioning & Knowledge

4. You mentioned that your job title is [...], could you describe your day-to-day tasks and responsibilities?
    - (Probe) -> Can you tell me more about specific strategies and workflows you use?
5. Could you guide me through one of your most important tasks from start to finish?
    - (Probe) -> What prompts you to start this task?
    - (Probe) -> Must you report your progress to someone or another department?
6. How often and in what ways do you collaborate with other teams and departments?
    - (Probe) -> What triggers the collaboration?
7. Are you a member of any professional networks or organizations, and if so, why did you join them?
    - (Probe) -> Does being a member of such network/organization assist you with gaining new knowledge needed to perform your tasks at the BLB NRW?
8. Are you part of any internal BLB NRW task groups or special units dedicated to developing internal policies, standards, or procedures? If so, could you share more about it?
    - (Probe)-> What is the function of the task group?
    - (Probe)-> Can you describe your role in this task group?
    - (Probe)-> How do you communicate to your colleagues the decisions or findings from the task group?
9. How do you stay updated on new technological developments relevant to your job?
    - (Probe) -> Does the BLB NRW provide you with resources for continuous professional development, such as learning how to use new technological tools?

- (Probe) -> Is there a support network or an internal educational database where you can access training and resources for new information?

## Actor Data Context & Barriers

10. Can you describe if any of the current BLB NRW initiatives are necessitating changes or adaptations in how you complete your tasks?
    - (Probe) -> Are any of these initiatives specifically promoting the use of digital tools or digitized methods?
11. What standards or protocols are crucial for achieving the desired task completion quality?
    - (Probe) -> How is the quality of the completed task audited?
12. What are some typical barriers or roadblocks you face during task execution?
    - (Probe) -> Do any of these barriers or roadblocks prevent you from retrieving or acquiring the information you need to perform that task?
13. How do the BLB NRW goals impact your role and task performance?
14. Could you mention some of the most common digital tools you use in your day-to-day tasks?
    - (Probe) -> For communication?
    - (Probe) -> For task management?
    - (Probe) -> For information storage and retrieval?
    - (Probe) -> What kinds of file formats or databases are you most commonly using?
    - (Probe)-> What can you tell me about the current use of Relatics as data management software?

## Actor Data Needs

15. What are the key factors influencing your digital information needs?
    - (Probe) -> How is digital information represented?
16. What specific short-term BLB NRW goals can be achieved with the digital information currently at your disposal?
17. What type of digital information helps you plan tasks to achieve long-term BLB NRW goals?
18. Where do you typically look for the digital information needed to complete tasks?
    - (Probe) -> What happens when you do not find the information where you expected to be found?

- (Probe) -> Are you in-charge of making sure the correct information is found where it is at the place it is supposed to be?
- (Probe) -> How do you go about solving this issue?

19. How do you cross-reference digital information related to your task?
20. How and where is digital information stored or archived?

## Actor Data Demands

21. How do you request digital information that you need but don't currently have?
    - (Probe)-> how does the process differ if the information request is address to internal or external parties?
22. If the basis for your digital information request changes, how do you update it?
    - (Probe)-> Do you keep a log of information requests?
    - (Probe)-> How are these logs shared or communicated?
    - (Probe)-> Who has access to these logs?
23. If the supplied digital information does not meet your request's expectations, what do you do?
    - (Probe)-> Do you need to validate information delivered by third parties? If so, how do you go about it?
24. What type of digital information is most commonly missing or difficult to acquire?

## Outro

This concludes our conversation. In a few moments I will stop the audio recordings. In the coming days I will be transcribing this audio recording, at which point the audio recordings will be deleted. I will send you a copy of the transcript as soon as it is completed. In the case that I have questions regarding the interpretation of some of the transcripts, is it possible that I reach out to you again and schedule a video conference, no more than 30 minutes long, to clarify or follow up unclear points with you? If need to be, I will first reach out via email to arrange the follow up meeting.

Again, thank you very much for your participation and sharing with me your insights.

**Stop audio recording [ ]**

Open Notes:

_____
_____
_____
_____
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_____
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_____
_____
_____

Delft University of Technology | Department of Management in the Built Environment

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Prof. M. (Moritz) Fleischmann-Bergstein, third mentor - moritz.fleischmann@hs-duesseldorf.de

January 19, 2024

## Appendix 6 – Data Management Plan

# DESIGNING THE PROCESS FOR ALIGNING THE DATA NEEDS OF PUBLIC CLIENTS INTO USEFUL DATA DEMANDS.

### 0. ADMINISTRATIVE QUESTIONS

**1. Name of data management support staff consulted during the preparation of this plan.**

My faculty tutor, Prof.mr.dr. EM Bruggeman.

**2. Date of consultation with support staff.**

2024-01-19

### I. DATA DESCRIPTION AND COLLECTION OR RE-USE OF EXISTING DATA

**3. Provide a general description of the type of data you will be working with, including any re-used data:**

| Type of data | File format(s) | How will data be collected (for re-used data: source and terms of use)? | Purpose of processing | Storage location | Who will have access to the data |
|---|---|---|---|---|---|
| Pseudonymization of data on project schematic design output including project name, company name and file author | .docx or .pdf files | Re-use of existing data from BLB NRW company | To analyze the status of BIM implementation process of the BLB NRW | BLB NRW provided project storage in German server | The organization and the primary researcher |
| Pseudonymization of data on Project Employer Information Requirements inlcuding company name, project name and project team members | .docx or .pdf files | Re-use of existing data from BLB NRW company (data available under a data processing agreement) | To form a baseline from which the analysis of the status of BIM implementation process of the BLB NRW can be based on | BLB NRW provided project storage in German serve | The organization and the primary researcher |

| | | | | | |
|---|---|---|---|---|---|
| Pseudonymization of data on Project BIM Execution Plan, including company name, project name and project team members | .docx or .pdf files | Re-use of existing data from BLB NRW company | To analyze how the project was executed and its impact on the status of the project schematic design output | BLB NRW provided project storage in German server | The organization and the primary researcher |
| Pseudonymization of data on Focus group meeting sign in sheet including name and company name | .pdf files | Meeting notes protocol | To correlate attendants' responses with notes taken during the focus group discussion | Project Microsoft Sharepoint cloud storage in EU server | The primary researcher |
| Pseudonymization of data on in-depth interviews including name and company name | .mp4 files | Audio Recording of in-depth interviews | To correlate interviewee recordings during transcribing | Project Microsoft Sharepoint cloud storage in EU server | The primary researcher |
| Pseudonymization of data on transcribed interviews including name and company name | .docx files | Re-use of existing data from audio recordings of in-depth interviews | To form the basis for the analysis of the interviews | Project Microsoft Sharepoint cloud storage in EU server | The primary researcher |

**4. How much data storage will you require during the project lifetime?**

- > 5 TB

**Data Volume**
The EIR, BAP and other confidential documents will be hosted on a server of the organization BLB NRW. Access to the primary researcher is given by the creation of a secured local user-account as part of an internship agreement. At the conclusion of the research, the server access and user account will be revoked to the primary user. Only the pseudonymized data will be shared as part of the dissemination of the graduation report. A Data Auditor will ensure compliance with privacy and data protection regulations prior to the dissemination of pseudonymized data.
Only the data with pseudonymization will be made publicly available long term in the TU Delft Education Repository, the relevant analysis of the data and pertaining methods will be incorporated into the final report and be made publicly available. Not included are the audio recordings of the in-depth interviews. Long term storate of data will be <250GB.

**Data Collection**
Policy documents, EIR and BAP documents will be accessed from their original archival origins by the organization BLB NRW. The project folder will be created by the organization for the temporary use by the primary researcher. A copy of the relevant documents and files will be placed in the temporary folder by the primary researcher and individuals of the BLB NRW. The files content will be analyzed, and sensitive data will be pseudonymized, according to a key-list of projects, and replace all references of authors in parsed information and metadata with the assigned pseudonames.

**II. DOCUMENTATION AND DATA QUALITY**

**5. What documentation will accompany data?**

- Graduation report.

- Appendixes of research instruments and protocols used.

**III. STORAGE AND BACKUP DURING RESEARCH PROCESS**

**6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?**

- OneDrive – Primary researcher personal space
- SharePoint Site – Provided by the Organization BLB NRW

BLB NRW provided project storage in its own Germany located server. Access to this server can be granted to the primary researcher through an internship agreement.
A project Microsoft Sharepoint drive will be set, and access administered by the project's Data Manager. The Sharepoint drive can be linked to a personal OneDrive or directly synced to a local machine by each project team member.

**IV. LEGAL AND ETHICAL REQUIREMENTS, CODES OF CONDUCT**

**7. Does your research involve human subjects or 3rd party datasets collected from human participants?**

- Yes

**8A. Will you work with personal data? (information about an identified or identifiable natural person)**

***If you are not sure which option to select, ask your*** Faculty Data Steward ***for advice. You can also check with the*** privacy website ***or contact the privacy team: privacy-tud@tudelft.nl***

- Yes

Consent forms and pseudonymization of personal data will be used, these include names, company names, job titles and project names.

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

***If you are not sure which option to select, ask your*** Faculty Data Steward ***for advice.***

- Yes, data which could lead to reputation/brand damage (e.g. animal research, climate change, personal data)
- Yes, data related to competitive advantage (e.g. patent, IP)
- Yes, confidential data received from commercial, or other external partners

BIM Execution Plans contain confidential data including, names of project team members, email addresses, company names, and their project roles. The information will be visible to the primary researcher, but it will not be used as basis for the research. In the case of need to refer to a specific BEP, pseudonymization of company name, or team members will be used.

Ifc files are competitive advantage data formats, no imagery from its 3D information or reference to the authors will be used in the research. The information will be visible to the primary researcher, but it will not be used as basis for the research.

9. How will ownership of the data and intellectual property rights to the data be managed?

***For projects involving commercially-sensitive research or research involving third parties, seek advice of your*** Faculty Contract Manager ***when answering this question. If this is not the case, you can use the example below.***

Confidential data, such as Ifc files, EIR or BAP will be hosted on a server managed by the owner organization BLB NRW. Access to the server will be managed by the organization. Project team members who wish to access the server need to request access and agree to the conditions of use. The data cannot be copied or transfered outisde of the provided server. Only the parsed informtaion and analysis of the data, after review of content, will be submitted to the public repository at the end of the project.

**10. Which personal data will you process? Tick all that apply**

- Other types of personal data - please explain below
- Data collected in Informed Consent form (names and email addresses)
- Signed consent forms
- Email addresses and/or other addresses for digital communication
- Names and addresses
- Company name and job titlle.

**11. Please list the categories of data subjects**

Industry professionals in Architecture, Engineering, Construction and Operations (AECO) industry. Organization's project management representatives, and facility managers.

**12. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?**

- No

**15. What is the legal ground for personal data processing?**

- Informed consent

**16. Please describe the informed consent procedure you will follow:**

All study participants will be asked for their written consent for taking part in the study and for data processing before the start of the interview and focus group interviews.

**17. Where will you store the signed consent forms?**

- Same storage solutions as explained in question 6

18. Does the processing of the personal data result in a high risk to the data subjects?

**If the processing of the personal data results in a high risk to the data subjects, it is required to perform a** Data Protection Impact Assessment (DPIA). **In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply).**
**If two or more of the options listed below apply, you will have to** complete the DPIA**. Please get in touch with the privacy team: privacy-tud@tudelft.nl to receive support with DPIA.**
**If you have any additional comments, please add them in the box below.**

- Evaluation or scoring

**19. Did the privacy team advise you to perform a DPIA?**

- No

**22. What will happen with personal research data after the end of the research project?**

- Anonymised or aggregated data will be shared with others

**25. Will your study participants be asked for their consent for data sharing?**

- Yes, in consent form - please explain below what you will do with data from participants who did not consent to data sharing

  Personal research data will be destroyed after the end of the research project

**V. DATA SHARING AND LONG-TERM PRESERVATION**

**27. Apart from personal data mentioned in question 22, will any other data be publicly shared?**

- No, all personal data cannot be publicly shared - please explain below which data and why cannot be publicly shared

The sources for the initial phase of the reserach are deemed confidential by the organization BLB NRW. These include Policy documents, Employer Information Requirements, and BIM Execution Plans, and internal guidelines. These will not be made publicly accessible, unless they are already done so by the BLB NRW.

**29. How will you share research data (and code), including the one mentioned in question 22?**

- All anonymised or aggregated data, and/or all other non-personal data will be uploaded to TU Delft Education Repository with public access

**30. How much of your data will be shared in a research data repository?**

- < 100 GB

**31. When will the data (or code) be shared?**

- At the end of the research project (July 2024)

**32. Under what licence will be the data/code released?**

- CC BY-NC
- MIT License

**VI. DATA MANAGEMENT RESPONSIBILITIES AND RESOURCES**

**33. Is TU Delft the lead institution for this project?**

- Yes, leading the collaboration - please provide details of the type of collaboration and the involved parties below

University of Applied Sciences Düsseldorf (HSD)- providing a third mentor to the primary researcher during the execution of the internship.
Bau- und Liegenschaftsbetrieb NRW (BLB NRW) - sponsor organisation/ gradation company

**34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?**

Prof.mr.dr. EM (Evelien) Bruggeman, main mentor (TU Delft)
Prof. M. (Moritz) Fleischmann-Bergstein, third mentor (HSD)

**35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?**

TU Delft Education Repository can archive 1TB of data per researcher per year free of charge for all TU Delft students. I do not expect to exceed this and therefore there are no additional costs of long-term preservation.

# Appendix 07 – Interview Transcripts

The interview transcripts include information about the graduation company, Bau- und Liegenschaftsbetrieb NRW, which is considered confidential. For access to this information or any related inquiries, please contact the primary researcher (author).

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# Appendix 8 – Internal Validation Protocol

Date: June 19, 2024, 14:30 - 15:30
Location: Bau- und Liegenschaftsbetrieb NRW Zentrale, Mecerdezstraße 12, 40470 Düsseldorf
Department: Department of Planning, Construction, and Instruments
Participants [Pseudonymize]: 7 Participants

The following statements were weighted during the internal evaluation group session.

| Theme | Theme association | Topic | Topic association | Transcript Quote | Weight |
|---|---|---|---|---|---|
| SA4 | Lack of Proper Documentation | T5 | Loss of institutional knowledge and difficulty in transferring expertise. | "When experienced colleagues retire without proper documentation, the historical values and decisions are often lost." | 3 |
| SA6 | Knowledge is exchanged primarily in “Silos” through Team meetings. | T4 | It is difficult to exchange company-wide knowledge that is retained only within a particular team. | "Ich habe den Eindruck, dass der Wissensaustausch außerhalb der Niederlassung sehr schwierig ist. Es ist bereits eine Herausforderung, Erkenntnisse an andere Abteilungen weiterzugeben." | 5 |
| TA6 | Inconsistent Data Management Practices | T12 | Different departments using their own methods for data storage, resulting in fragmented and unreliable data. | "The problem of data redundancies exists because data is stored multiple times in different places. This makes dealing with the data significantly more difficult." | 3 |
| SA1 | Inconsistent communication between departments | T8 | Hampers effective collaboration and can lead to misunderstandings and delays | "Die Kommunikation ist nicht immer einheitlich, zeitnah oder umfassend, was zu Schwierigkeiten führt. Auch agieren die Niederlassungen teilweise unterschiedlich, sodass ein Sachverhalt in den verschiedenen Niederlassungen unterschiedlich bearbeitet wird." | 4 |
| TA2 | Difficulty in accessing accurate and up-to-date digital records | T10 | Leads to frustration and inefficiencies among team members, impacting morale and productivity | "Pläne fehlen häufig, insbesondere bei älteren Gebäuden. Das habe ich bisher nicht erwähnt. Wir haben zwar eine Datenbank, in der Pläne abgelegt sind, aber gerade bei Gebäudeplänen gibt es viele Lücken." | 5 |
| TA4 | Late data delivery impacting early quality checks | T22 | Hinders collaborative problem-solving and timely feedback | "Data often arrives late in the project, limiting the ability to perform early quality checks and provide feedback for adjustments." | 3 |

| Theme | Theme association | Topic | Topic association | Transcript Quote | Weight |
|---|---|---|---|---|---|
| SA8 | Lack of clear responsibilities | T17 | Improving accountability and clarity in task management and information flow | "Übergeordnet ist es jedoch oft unklar, wer für bestimmte Themen zuständig ist oder ob das Wissen bereits vorhanden ist." | 2 |
| TA10 | Difficulty in accessing information | T25 | Ensuring all employees can easily find and use the necessary information | "Mir ist kein standardisierter Prozess bekannt. In der Praxis ist es oft so, dass jemand zufällig auf ein neues Programm oder eine neue Information stößt, feststellt, dass er keine Zugriffsrechte hat, und dann beginnt die Suche nach den richtigen Ansprechpersonen." | 2 |
| TA3 | Analog data collection methods | T1 | Dependence on outdated methods for data collection, which are labor-intensive and prone to error | "The greatest challenge is collecting data regularly and reliably. This is a very difficult topic because we urgently need this data, but accessing it is complicated. The collection of measurement data from analog measuring devices remains a significant hurdle." | 3 |
| SA5 | Lack of comprehensive training for new technologies | T9 | Employee adaptation and support | "Adequate training and support for new technologies are essential, but nowadays, you often have to learn on your own, which can be difficult for older employees." | 1 |
| TA9 | Limited access to historical project data | T21 | Challenges in evaluating past socio-cultural impacts and learning from previous projects | "Diese Informationen sind für uns notwendig. Häufig sind digitale Informationen in dieser Hinsicht fehlerhaft, insbesondere was Kennzahlen aus Projekten betrifft." | 5 |
| SA6 | Challenges in Effective Communication | T7 | Difficulty in sharing knowledge and updates across the organization efficiently | "Overall, communication is difficult in a company of our size. We use the intranet and occasionally a weekly Monday email, but the communication remains challenging." | 2 |
| TA4 | Inaccurate or outdated information from other teams | T10 | Collaboration and dependency | "Frequently, it is unclear whether the data in our online tool is up-to-date because it is difficult to determine when a data set was last updated." | 4 |
| TA8 | Dependency on manual follow-ups | T11 | Efficiency and workflow disruptions | "Sometimes I have to ask a colleague personally because not everyone can centrally store the information." | 3 |
| SA10 | Over-reliance on specific departments for data | T23 | Team dependency and workload distribution | "I depend heavily on the contract team, which is understaffed, leading to delays and inaccuracies in the data I receive." | 4 |

| Theme | Theme association | Topic | Topic association | Transcript Quote | Weight |
|---|---|---|---|---|---|
| SA1 | Lack of interdepartmental understanding | T4 | Improving collaboration and mutual support | "The understanding for the tasks of other departments is not always sufficient... If there was a better understanding, they could provide us with better support." | 2 |
| SA7 | Difficulty in standardizing protocols | T24 | Ensuring consistent processes and standards | "There were difficulties in implementing standardized work cards, and whether the service providers fully adopted them is uncertain." | 3 |
| SA7 | Challenges in ensuring data accuracy by external parties | T18 | Trust and reliability | "Das Problem besteht jedoch darin, dass die TGM-Dienstleister diese Aufgabe nicht immer gut erfüllen." | 1 |
| TA9 | Incomplete Historical Documentation | T12 | Challenges in evaluating past socio-cultural impacts and learning from previous projects | "Für alle Gebäude, die vor 2001 und somit vor der Gründung des BLB existierten und uns zur Verantwortung übergeben wurden, fehlen teilweise erheblich wichtige Unterlagen. Diese Unterlagen wären jedoch für die Arbeit vor Ort unerlässlich." | 4 |
| TA8 | Lack of Unified Data Pool | T17 | Difficulty in sharing knowledge and best practices | "Es gibt keinen übergeordneten Datenpool, auf den alle Datenbanken zugreifen können, um bereits vorhandene Daten abzurufen. Dies führt oft zu doppelter Arbeit." | 3 |
| TA3 | Lack of Advanced Analytical Tools | T19 | Insufficient use of modern analytical tools | "I would wish for more courage to use current tools, especially active use of Python, to develop our own statistical or machine learning models." | 2 |
| SA5 | Dependence on multiple platforms | T13 | Use of various platforms, making it challenging to locate and manage data efficiently. | "Dieses System ist nicht einfach zu erklären oder zu bedienen. Man kann nicht einfach in das System einsteigen und sofort wissen, wo und wie man suchen muss. Neue Mitarbeiter müssen speziell geschult werden, um zu verstehen, wie sie die richtigen Informationen finden können." | 2 |
| TA7 | Variability in software tools and standards across projects | T14 | Inconsistent use of software and adherence to standards | "With the BIM method, we cover quality checks in almost every performance phase, but there are also other projects that do not work according to BIM standards and still have to deliver high-quality data." | 3 |
| TA4 | Ensuring data accuracy and compliance | T17 | Ensuring that digital information matches real-world conditions and meets required standards | "I do not check whether the data on site is correct. For that, other people have to be responsible, who check whether what is shown in the model corresponds to reality." | 1 |

| Theme | Theme association | Topic | Topic association | Transcript Quote | Weight |
|---|---|---|---|---|---|
| **TA4** | Data redundancy | **T11** | Inefficiency due to lack of integrated data management | "The problem of data redundancies exists because data is stored multiple times in different places. This makes dealing with the data significantly more difficult." | **3** |
| **TA9** | Partially digitalized procurement process | **T3** | Efficiency and integration | "The digital procurement process is only partially digitalized, however, it still requires a combination of online and paper-based methods, which is time-consuming and inefficient." | **2** |
| **TA7** | Transition to New Data Systems | **T2** | Difficulties in migrating and standardizing data | "Dieser Prozess ist noch nicht vollständig abgeschlossen, auch bei mir persönlich fehlen noch einige Daten, die in diesem Jahr übertragen werden müssen." | **4** |
| **SA9** | Insufficient data quality management | **T15** | Data validation and consistency | "Ein wesentlicher Punkt, der im BLB definitiv fehlt, ist das Datenqualitätsmanagement." | **2** |
| **TA8** | Automation to reduce manual work | **T20** | Implementing automated systems to reduce manual data entry and increase efficiency. | "Bei TGM hingegen müssen alle Daten manuell eingegeben werden, was einen erheblichen Aufwand für die Objekt- und Gebäudemanager bedeutet. Daher gibt es Pläne, ein neues System einzuführen, das die Datenverwaltung deutlich erleichtern soll." | **2** |

Delft University of Technology | Department of Management in the Built Environment

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Dr.ir. A. (Ad) Straub, second mentor - A.Straub@tudelft.nl
Prof. M. (Moritz) Fleischmann-Bergstein, third mentor - moritz.fleischmann@hs-duesseldorf.de

# Appendix 9 – External Validation Protocol

Date: November 29, 202: 8:00 - 9:00
Location: Online meeting
Participants:
Dr. Ilsa Kuiper - Consultant MBB Group, Melbourne, Australia
Dr. Sanders Siebelink – Docent, University of Applied Sciences Saxion, Netherlands
Dr. Adrian Wildenauer – Professor of Digital Construction, University of Applied Sciences Berner, Switzerland

## Agenda:

5 mins: Greetings & Introductions
15 mins: Presentation of Research
5 mins: Introduction of Validation Session Format
35 mins: Feedback & Discussion

## Meeting Notes:

**Feedback Dr. Kuiper:**

I would like to make an observation. I fully acknowledge the substantial effort that has gone into this presentation, particularly with regard to sizing and the elements you have highlighted.

For me, part of the question concerns recognizing that the context in which the research has been applied is quite specific. It is important to emphasize this specificity upfront, clearly acknowledging that the study is meant to be confined to a discrete domain. This does not imply that the research lacks the potential for broader evolution or applicability to other contexts; rather, it helps clarify the scope of the study from the outset.

One element that I would like to emphasize is the need for clarity regarding the intended audience. Ensuring that readers or stakeholders fully understand that the policies and the enactment of digitalization addressed in the research are quite specific to certain organizational units will be crucial. Within an organization, different departments, groups, or branches may vary significantly, which could impact the relevance and focus of the elements you have identified, particularly in the SWOT analysis. Translating the findings into actionable tools or instruments that serve as foundational points for changing practices and identifying opportunities with data is critical. However, it felt as though this clarity emerged towards the end of the presentation rather than being established upfront. A more application-focused introduction might help set the stage more effectively. The elements are all present; the challenge is ensuring that they are clearly contextualized from the beginning.

I also want to acknowledge the nuance inherent in mapping an organization's current position or status. The challenge lies in recognizing that every organization is unique, and each must undertake a similar process to get an accurate snapshot of where they are and what they need. The methodology you present should account for this uniqueness. Consequently, the findings or outcomes of your research could be positioned as an initial consideration, a first-pass tool. However, organizations must also appreciate that these findings are only a starting point, and there may be a need for adaptation depending on their strengths, deficiencies, or particular

contexts. It is important to emphasize not only what your research can achieve but also its limitations—being transparent about what the research cannot do is equally powerful.

In terms of next steps, I was also considering how to effectively translate the questions or actions arising from your research into tools that organizations can implement systematically and effectively. This approach will, of course, differ by organization, sector, or even country. For instance, in Australia, organizational change often starts with a strategy that sets high-level goals and ambitions. However, this strategy is frequently informed by precisely the kind of research you have undertaken. Such strategies must then be contextualized to specific teams and tied into other organizational factors like budget, commercial imperatives, and executive buy-in.

For successful digital transformation, it is essential to have executive-level commitment, in-house capabilities, or external resources that foster change. Investments in the right tools are equally crucial, as failing to make these investments can disrupt progress. It is well known that many organizations fail to achieve their desired outcomes in terms of maturity regarding data or Building Information Modelling (BIM). Your research could help expose challenges at an executive or corporate level, helping organizations to understand the type of information they require and how to leverage it effectively.

As you noted, having a BIM model is conceptually powerful. However, there are often disconnects between what different stakeholders need. For example, while a project manager might need a straightforward cost and timeline dashboard, the BIM manager must align complex models with that request. The same challenges will likely recur whenever there is a disconnect between stakeholders about the types of information required and the language used to communicate about those models.

Throughout my own research, I encountered similar institutional gaps, particularly concerning data infrastructure. We are advancing with initiatives such as AI, but I fear that we are moving forward without sufficiently developed institutional frameworks. This can lead to repeated disappointments when investments fail to deliver, partly because organizations lack a means of accounting for the value of data in economic terms. Some organizations, such as National Highways in the UK, are working on articulating this value, but these efforts are not yet standardized. This is a different context than your focus on specific operational departments, but I believe your work still offers significant value in providing clarity and formulation for specific actions.

Even when discussing private or public sector frameworks, it is helpful to contextualize your work within the broader picture. Acknowledging that there is a bigger picture allows readers to better understand the boundaries or limitations of the research. Emphasizing this perspective does not diminish the value of your findings; instead, it demonstrates the rigor and awareness of the broader implications of your work.

**Feedback Dr. Siebelink:**

I noted down a few observations that align with what Ilsa mentioned. I am curious: is it feasible for all types of clients to adopt the approach you have created, or have you investigated how they might process your model and the necessary information analysis to provide all the required inputs? What has been your approach to addressing these questions? I would be very interested to hear more about this aspect.

Additionally, while I understand that you selected a technological front-runner for your research, I imagine that even they faced significant challenges in their journey towards

achieving higher maturity. It may be beneficial to identify the typical barriers that other clients are likely to face along this pathway. Understanding these challenges could help others who are attempting to achieve similar levels of competency and readiness.

Furthermore, I think it would be valuable to outline the competence levels required and the types of roles or personnel that organizations need to successfully implement these frameworks. This could provide clearer guidance on how to achieve the desired outcomes. Including these insights would help bridge the gap between different contexts and organizations, making your research applicable to a wider range of scenarios.

**Feedback Dr. Wildenauer:**

In your problem statement, you mentioned 'digitalization,' but shouldn't it be 'digital transformation'? I might be mistaken, but it seems to me that 'digital transformation' would be more appropriate in this context. Overall, this issue has caused confusion, particularly in Germany and Switzerland, about what 'digital transformation' really means. Nonetheless, I thought your presentation was excellent, and I appreciate the effort you put into it.

Regarding the work on ISO standards, please make sure to adhere to the adopted terminology of the meaning of EIR (Exchange Information Requirements). In your presentations you used the term Employer Information Requirements, which is the term that preceded the ISO standard.

I agree with Ms. Ilsa that one of the major challenges with your project is that you are dealing with a very specific client: a public client from North Rhine-Westphalia, who happens to be distinct within Germany as well. This client is not a typical public client since they are quite proactive and open to change, which is not always the case with most public entities. Thus, you are trying to generalize a method for a broader audience using a very unique case study, which is a bold approach.

I genuinely appreciate your methodology and presentation style; they are excellent. I find your insights to be highly educational. However, I think it is crucial to connect the dots and illustrate how your findings can be put into practice in other contexts. While the BLB NRW has their approach and is capable of adapting to change, I believe your intent is to show how others can also benefit from this model. It might be beneficial to create a clear list of key steps: where to start, what actions to take, and how to proceed further. This 'takeaway list' could serve as a roadmap for other public clients.

Ultimately, this endeavour depends on trust—trust in data and trust within the organization. If stakeholders do not feel confident in the data, then the project will struggle to gain traction. This is a crucial point, and I appreciate you for emphasizing it.