CHALLENGES IMPAIRING THE DATA QUALITY OF INFORMATION DELIVERABLES IN BIM DURING THE PLANNING PHASE OF OFFICE BUILDINGS IN GERMANY

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The German construction industry suffers from a low degree of digitalisation compared to other European countries. The reasons for this include limited investment in research and development, strong fragmentation, and the insufficient implementation of existing innovations. Building information modelling (BIM) is a prominent example of this deficit, despite evident benefits like integrated project delivery and lifecycle information management. The data quality of information deliverables constitutes one of the biggest obstacles to investment in this context. Therefore, the present study investigated challenges impairing the data quality of information deliverables and existing solutions from the client's perspective. The focus lay on the planning phase of office buildings in Germany. Data collection was conducted through a focus group interview with ten corporate real estate professionals. Based on the results, eight challenges and solutions were identified. The most affected data quality dimensions are information deliverables' completeness, reliability, and usability. The implementation of solutions should be initiated during project preparation or the early planning phase. Further research might develop approaches to implement these solutions during case studies to derive best-practice advice for future guidance.

Keywords: Building Information Modelling; client; data quality; information deliverable; planning phase

INTRODUCTION

The comparison of BIM implementation across Europe reveals that Germany trails behind many other countries regarding BIM maturity level and mandatory BIM use (BIMplus 2021). The low degree of digitalisation in the German construction industry poses a challenge already, yet the highly fragmented German office structure further exacerbates the problem. This severely impedes integrated project delivery and information management along the building lifecycle (Office of Technology Assessment at the German Bundestag [TAB] 2022). A study by the German Property Federation ("Zentraler Immobilien Ausschuss" [ZIA]) identified intransparent data structures and insufficient data quality of information deliverables as the biggest

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obstacles to investment in digitalisation in this context (Zentraler Immobilien Ausschuss e.V. [ZIA] 2023). This decelerates BIM implementation in Germany, as data quality is vital for BIM-based project delivery. Relevant research identified numerous factors compromising data quality, underscoring the scientific relevance of the underlying deficits (Fang *et al.,* 2022; Song *et al.,* 2017; Zadeh *et al.,* 2017). In the context of the planning phase in Germany, however, little research exists about the mechanisms and challenges impairing data quality.

LITERATURE REVIEW

Information Deliverables in BIM

The BIM method is characterised by centralised information management based on a digital representation in a federated information model. ISO 19650-1 specifies the information management perspectives during the delivery phase, which is divided into the specification of information requirements, planning for information delivery, and information delivery (International Organisation for Standardisation [ISO] 2018). The information management perspectives translate into new roles during BIM projects, comprising the BIM manager, coordinator, and modeller. In office buildings, multiple stakeholders like operators and users participate in the planning process, especially during the early planning phases (Euroboden *et al.,* 2022). Information management in BIM aligns with the asset life cycle. It is governed by decision-making during the asset life cycle, progressive information delivery, targeted information requests, and CDE-based collaboration. As a result, the information delivery processes involve numerous new functions, technical and stakeholder interfaces, data formats, and workflows. As the above-described ZIA study shows, these processes and roles still cause problems, compromising the production of information deliverables. However, assuring their data quality is vital as they serve as input for subsequent steps and the project information model (PIM) or asset information model (AIM) (Messner *et al.,* 2021). ISO 19650-1 does not explicitly specify the term “information deliverable”. Instead, relevant research offers several definitions. Mayo and Issa (2016) defined it in a wider sense, including many formats, for instance, industry foundation classes (IFC)-based BIM or PDF files. The National Building Specification [NBS] (2016) defines it as outputs of BIM processes, including the IFC-based PIM or AIM among other deliverables. Tsay *et al.,* (2023) used a strictly BIM-related definition, including only the IFC-based PIM and AIM. The present study defined information deliverables based on Tsay *et al.,* (2023), due to their focus on model-based information delivery.

Data Quality Dimensions in BIM

Integration, communication and collaboration between stakeholders rely heavily on data meeting the defined quality requirements. However, the dimensions of data quality and their delimitation remain subject to scientific research and debate. Song *et al.,* (2017) defined information quality based on six dimensions: Content, format, accuracy, currency, completeness, and consistency. Zadeh *et al.,* (2017) identified five categories of issues in the context of information deliverables: Incompleteness, inaccuracy, redundancy, well-formedness, and understandability. Fang *et al.,* (2022) identified four first-order data quality dimensions: Availability, usability, reliability, and relevance. Additionally, they identified six second-order data quality dimensions: Timeliness, credibility, accuracy, consistency, completeness, and fitness. Chang *et al.,* (2022) identified nine data quality dimensions: Accuracy, accessibility, availability, completeness, consistency, relevance, reliability, timelessness, and

usability based on comprehensive literature research. Tsay *et al.,* (2023) identified ten information quality criteria: Representativity, identity, classification, hierarchy, association, information identity, coordinated federation, clarity, phasing, and spatial orientation. Based on the relevant research, it becomes apparent that several intersecting concepts of data quality dimensions in BIM currently coexist. The present study built on the results of Chang *et al.,* (2022) in its further course, as their research stands out due to its extensive literature review on the subject. Their data quality dimensions were used to assess the impact of the identified challenges on information deliverables.

Planning Phase in Germany

The German construction industry's low level of digitalisation also manifests in poor BIM implementation. "Particular challenges regarding the introduction of BIM in the German construction industry [...] arise from the strong fragmentation and the high number of [small to medium-sized enterprises] (SMEs) as well as the strict separation of planning and execution services, which is also stipulated by procurement law" (TAB 2022: 3). The fact that 90 % of architecture and engineering offices in Germany had 9 or fewer employees in 2018 illustrates this fragmentation (Statistisches Bundesamt [Destatis] 2020). Despite small office sizes, architects play a pivotal role during project delivery, often coordinating all involved planners (Bund Deutscher Architektinnen und Architekten [BDA] 2011). Figure 1 illustrates the involvement of German architects based on the nine project phases defined in the German regulations on architects' and engineers' fees ("Honorarordnung für Architekten und Ingenieure" [HOAI]) in comparison to the usual involvement of UK or US architects.

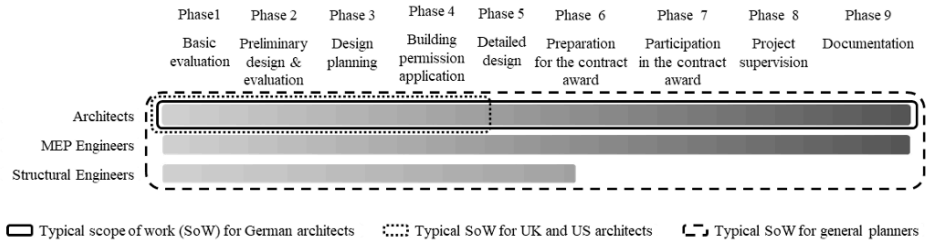

Figure 1: Involvement of German architects in construction projects based on the HOAI (BDA 2011)

The SMEs dominating the German construction industry rarely dispose of the necessary resources to quickly implement the BIM method. Therefore, the present study aims to help clients improve data quality by implementing existing solutions.

Office Building Projects in Germany

In 2022, office and administration buildings worth nearly 6 billion euros were built in Germany, corresponding to about 7% of total new construction activity (Statistisches Bundesamt, 2024). However, working and office culture in Germany undergoes fundamental transformations, many of which were triggered by the COVID-19 pandemic. Companies seek more central locations allowing flexible occupation scenarios and adjustments. This includes expanding meeting spaces promoting communication and knowledge exchange, which has become a major priority when developing office buildings today. Also, employees strongly support new symbioses between nature and the built environment involving concepts like urban farming (Euroboden *et al.,* 2022). Among changing company requirements and user

expectations, the planning and construction of office buildings have become more challenging for clients and planners alike.

Based on the identified research gaps, three research questions (RQ) were formulated:

RQ 1: What challenges impair the data quality of information deliverables during the planning phase of office buildings?

RQ 2: What existing solutions improve the data quality of information deliverables?

RQ 3: What moment in project delivery is best suited for implementing the solutions?

METHOD

The present study adopted an exploratory, mixed methods approach as a basis for the methodology shown in Figure 2.

Figure 2: Methodology of the present study (Li and Zhang 2022).

Literature reviews lay the groundwork for "making scholarly knowledge accessible, identifying gaps in this knowledge, [and] determining research questions for empirical research […]" (Dekkers *et al.,* 2022: xiii). Step 1 of the methodology included a literature review on data quality dimensions in BIM. It was conducted on the Web of Science (WoS) and Google Scholar databases. Publications were included if relevant, peer-reviewed, and published between 2014 and 2023. They were excluded if they were in a language other than English or German. The search string was ["BIM" OR "building information model*" OR “data qualit*" OR "information qualit*" OR "model qualit*" "dimension*"]. Five publications were identified and used as a starting point for the focus group interview

Data collection was conducted through a semi-structured focus group interview among corporate real estate professionals. This method was selected based on the qualitative nature of the research questions and the application of this method in similar research contexts (Li and Zhang, 2022; Ullah *et al.,* 2022). The focus group comprised ten professionals responsible for planning, constructing, operating, and maintaining corporate real estate. The focus group organisations were Germany-based companies from the chemical and pharmaceutical industries with more than 250 employees. This research focus was selected due to the financial impact of real estate-related costs for companies in this industry sector, making digitalisation of the building lifecycle a top priority (Deloitte Development 2020). The external validity of the interview results was enhanced by considering the population validity and the ecological validity during the interview preparation. The population validity was enhanced by letting the focus group organisations independently select the participants. The eligibility criteria included working in construction project management and having at least one year of BIM experience. The ecological validity was ensured by sharing the interview guide beforehand. A preliminary test interview was conducted to verify the clarity of the interview guide and to assess the interview

duration. An online meeting was chosen for logistical convenience. The focus group interview was conducted in September 2022. Table 1 shows the background information of each participant.

Table 1: Participants in the focus group interview (C = "Company", YoE = "Years of experience")

#	C.	Job title	YoE construction	YoE BIM
1	A	Real estate and construction project manager	4	2
2	B	Construction project manager	6	2
3	B	Head of laboratory and facility engineering	17	5
4	B	Facility management and maintenance	4	3,5
5	B	Construction project manager	9	4,5
6	C	Real estate and facilities manager	7	5
7	C	BIM coordinator and process owner	2	2,5
8	C	BIM coordinator	8	4
9	D	BIM manager	25	5,0
10	D	Facility manager	3	1

The first part of the focus group interview was designed to ensure the eligibility of each participant by collecting the background information shown in Table 1 and to identify challenges. The second part was designed to assign the affected data quality dimensions based on (Chang *et al.,* 2022), name existing solutions, and identify the best-suited project phase for implementation. Data analysis of the interview results was conducted through open, axial, and selective coding (Li and Zhang 2022).

FINDINGS AND DISCUSSION

Focus Group Interview

The focus group selected combined laboratory and office buildings constructed between 2016 and 2021 with gross floor areas between 14,000 and 36,000 m² as reference projects for the interview. Table 2 shows the identified challenges impairing the data quality of information deliverables during the planning phase of these projects. Challenges 1 and 2 include incomplete deliverables due to inadequately defined exchange information requirements (EIR) as well as enterprise resource system (ERP) and computer-assisted facility management (CAFM) requirements by the client. The focus group chose to treat these inadequacies individually due to the different stakeholders involved. The definition of EIR encompasses all lifecycle phases and involves many stakeholders, including external ones like planners or contractors. In contrast, the definition of ERP and CAFM requirements typically involves operators often belonging to the client organisation. Participant 2 commented on the interrelation between those challenges that they "often observe a lack of knowledge on the part of the planners. This leads to an incorrect interpretation of the requirements. On the other hand, we have to be honest too and admit that the definition of our ERP specifications is not always complete." The focus group suggested the initial definition and application of internal information requirement templates to address both challenges. Based on the experience of some participants with such templates, they agreed that the explicit reference to these templates in the contract documents would be the most direct approach to do so. Challenge 3 can be considered a direct consequence of the first two, as it describes the information loss due to incompatible file formats and unresolved interfaces between

BIM and ERP or CAFM. It highlights the importance of initial information flow analyses to correctly identify all information that should be included in the ERP and CAFM requirements. This also adds an important prerequisite to the information requirement definition process. Accordingly, the focus group suggested a similar solution as for the first two challenges but added an interface analysis.

Table 2: Challenges impairing the data quality of information deliverables and existing solutions, as well as the best-suited project phase (PP) to address each challenge

#	Challenge	Existing solution	Data quality dimensions									PP	
			Accuracy	Accessibility	Availability	Completeness	Consistency	Relevance	Reliability	Timeliness	Usability	Project preparation	Planning phase
1	Incomplete deliverables due to inadequately defined ERP and CAFM requirements by the client	Development of modelling templates	-	-	-	X	-	-	X	-	X	X	-
2	Incomplete deliverables due to inadequately defined EIR by the client	Development of modelling templates	-	-	-	X	-	-	X	-	X	X	-
3	Information loss due to incompatible file formats and unresolved interfaces between BIM and ERP or CAFM	Interface analysis during template development	X	-	X	X	-	-	X	-	X	X	-
4	Information loss due to planners who are unable to participate in Closed BIM, requiring manual or information exchange	Integration of IFC files for collision checking Specification of automated data exchange processes	-	X	X	X	-	-	-	X	-	X	-
5	Information loss due to insufficient BIM and data validation qualification by the operators	Specification of automated data exchange processes Training for operators	X	-	X	X	-	-	X	-	X	-	X
6	Inconsistencies and contradictions between the deliverables from different planners	Provision and updating of modelling templates	X	-	-	-	X	-	X	-	X	-	X
7	Incomplete deliverables due to incomplete implementation of the EIR by the planners	Provision and updating of modelling templates	-	-	-	X	-	-	X	-	X	-	X
8	Non-compliance with information delivery schedules as well as incorrect delivery folder structures	Pre-defined interactions and exchange of requirements through templates	-	-	-	X	-	-	X	-	X	-	X
Sum			3	1	3	7	1	0	7	1	7	4	4

Challenge 4 describes the inability of some planners to participate in Closed BIM. The focus group discussed this challenge extensively, as they all encountered similar problems. This challenge becomes particularly noticeable in the context of highly specialised planners that cannot be substituted easily. The following statement by Participant 1 illustrates this challenge: “We had the problem that contractors could not participate in Closed BIM. Now the question is whether this is common with contractors, I have the impression that it might be.”

The focus group suggested integrating IFC files for collision checking and the contractual specification of automated data exchange processes. The definition of data exchange processes allows clients to select reliable data exchange tools and make them mandatory for all planners, reducing the risk of compromised data exchange.

Regarding the best-suited project phase to address challenges 1 to 4, the focus group agreed on project preparation. Challenge 5 describes the information loss due to insufficient BIM and data validation qualification by the operators. Participant 7 elaborated that "in some cases, [they] see a lack of qualification on the part of the operators about independent data evaluation, starting with the review during planning and extending to the approval of the as-built model." The focus group discussed this challenge in the context of ERP and CAFM requirements, emphasising the inability of many operators to validate information deliverables during the planning phase. They suggested the specification of simplified and automated data validation by analogy with challenge 4 and specific training for operators. Challenges 6 and 7 describe inconsistencies and contradictions between the deliverables from different planners as well as incomplete deliverables due to incomplete implementation of the EIR by the planners. For both challenges, the focus group suggested modelling and information requirement templates that the planners should use during model creation. They also agreed that an internal BIM library containing pre-defined elements could be made accessible to planners to provide modelling templates during project delivery. Challenge 8 describes deviations regarding the scheduled information request and delivery, and incorrect delivery folder structures. The focus group suggested that the internal BIM manager participate comprehensively in the task information delivery plan and master information delivery plan specifications to monitor their correct execution during project delivery. Regarding the best-suited project phase to address challenges 5 to 8, the focus group agreed on the planning phase. The data quality dimensions completeness, reliability, and usability are the most affected by the identified challenges with six out of eight challenges affecting all three dimensions and each dimension being affected by seven challenges. The accuracy and availability are the second most affected with three challenges affecting each dimension. Accessibility, consistency, and timeliness are the third most affected with one challenge affecting each dimension. None of the identified challenges affected the relevance of information deliverables.

Starting Points for Improving the Data Quality of Information Deliverables

The identified solutions were assigned to the best-suited moments for implementation according to the focus group. Figure 3 illustrates these moments in the context of project delivery and the overall building lifecycle. In principle, the BIM method concentrates a much larger proportion of the decisions and specifications in early phases than the conventional planning method (Messner *et al.,* 2021). The starting points aligned with the early project phases commonly used in the BIM information delivery cycle. Starting point 1 was placed during the use phase to accommodate solutions 1 to 4 and the need to implement them during project preparation. When considering the necessary reverse engineering processes for defining comprehensive information requirements for the planning and the construction and use phases, the focus group agreed that these solutions should be implemented based on existing assets and their use phase. The amalgamation of these prerequisites results in the placement of starting point 1 during the use phase of comparable assets. Starting point 2 was placed at the beginning of the planning phase to accommodate solutions 5 to 8 and the need to implement them during the information delivery. The respective challenges affect the collaboration and information delivery during the planning phase and the data quality dimensions reliability and usability. Therefore, the focus group agreed that the solutions should be implemented at the beginning of project delivery, preferably before the contract award to the planners.

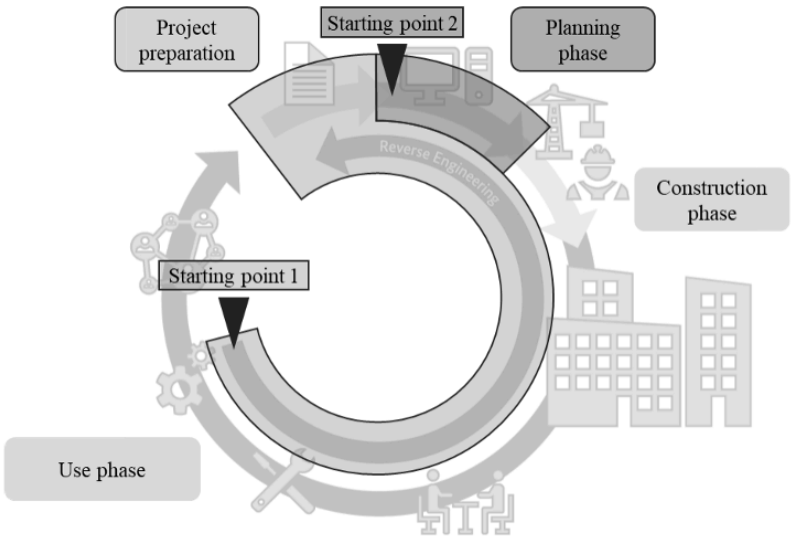

Figure 3: Starting points for the implementation of the identified solutions in alignment with the building lifecycle phases based on (Bundesministerium der Verteidigung 2022).

As BIM-based project delivery gains traction globally, the complexity of information management increases due to new functions, technical and stakeholder interfaces, data formats, and workflows. At the same time, it becomes evident that the data quality of information deliverables plays a pivotal role in enabling the underlying information management processes. Similarly, approaches like building lifecycle management rely on high-quality information allowing improved collaboration, coordination, and decision-making. The identified challenges coincide with relevant research and add valuable insights into the underlying mechanisms. Fang *et al.,* (2022) highlighted the negative impact of missing data attributes on data quality in asset management and the general lack of guidance in the context of a UK-based company. The present study confirms these findings in the context of German companies, especially regarding the repercussions of missing templates and ill-defined information requirements by the client. Still, the focus group displayed considerable awareness of existing solutions involving template documents and files. These suggestions integrate into existing BIM guidance like the UK BIM Framework (2021), equally suggesting the provision of document templates, 3D object libraries or custom line styles. This supports the assumption that many challenges stem from imperfect preparation and execution rather than insufficient understanding by the client. Implementing the solutions into the commonly used delivery cycles might best be approached on the people, process, and technology levels. This might include extending and refining current practice through case studies implementing the solutions and deriving best-practice advice for future guidance. The information deliverables' completeness, reliability, and usability were the most affected data quality dimensions in the observed cases. Tsay *et al.,* (2023) identified similar data quality dimensions as being the most affected in the context of hospitals and residential buildings. This indicates that the challenges encountered during BIM-based planning might be generalisable to a certain extent across building use classes and countries.

The extent to which the identified challenges and solutions can be generalised may be affected by the fact that all participants came from German companies. This is because the underlying construction projects were all located in Germany. However, relevant research indicates that many countries share the identified challenges. Furthermore, the present study identified challenges during the planning phase even

though other project phases undoubtedly entail further, equally significant challenges. This is because BIM implementation is most advanced in this phase. In the context of Germany, further research might investigate the construction phase.

CONCLUSIONS

The BIM method is not new anymore and its implementation progresses globally. Still, many companies struggle to leverage its benefits successfully. Many of the underlying challenges stem from the initial building lifecycle phases and beyond. The present study addresses this research gap in the context of office buildings in Germany to reveal current challenges and existing solutions. It aimed to enable companies to autonomously improve the data quality of information deliverables during the planning phase. A total of eight challenges impairing the data quality in the context of office buildings in Germany were revealed, particularly in the fields of information requirement definition and their correct execution. Seven challenges impair at least one of the data quality dimensions completeness, reliability, and usability of information deliverables. These challenges compromise integrated project delivery, collaborative workflows, and overall project performance. The focus group agreed that challenges 1 to 4 should be addressed during project preparation and challenges 5 to 8 during the planning phase. The results provide insights into the underlying mechanisms compromising information deliverables and highlight existing solutions that can be employed to enhance BIM-based planning efficiently. Further research might develop approaches to implement these solutions during case studies to derive best-practice advice for future guidance.

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