Digital building documentation as a basis for the sustainable and resource-saving construction, operation and dismantling of buildings

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Abstract
Digital building documentation plays a decisive role in sustainable and resource-saving construction and the preparation and dismantling of buildings. For the sustainable and efficient use of buildings, the construction and real estate industry needs the relevant data for the operation of the installed building products and technical systems. In the course of digitalization in the construction industry, Building Information Modeling (BIM) is a promising solution for this, which can be used to link product information with a 3D data model, among other things. In Germany, the building trade plays a central role in the creation of building documentation. Efficient and sustainable building documentation contributes to achieving the UN's Sustainable Development Goals, making documentation even more important. As a result, the topic of sustainability in the construction industry is becoming increasingly important, as specific templates also need to be created for the documentation and evaluation of construction products from a sustainability perspective. As part of the research projects "BIM Use Cases in the construction industry" and "Building contractors as the central instance of digital building documentation - DigiBauDok", templates for the creation of building documentation were developed on the one hand. On the other hand, technical solutions for automatically linking the documents and digital product data (digital product twins) with the BIM models were developed and validated in practice.

Keywords: As-Built-Model, BIM, Building products, Product Information, Sustainability, Digital Twin

1 Introduction

The construction industry plays a pivotal role in economic development and societal progress. However, it is also a significant consumer of resources and producer of CO2 emissions. (United Nations Environment Programme, 2022) To meet increasing ecological and economic demands, a sustainable transformation of this sector is imperative. Digital transformation, particularly through the enhanced use of Building Information Modeling (BIM), offers promising

opportunities to increase the efficiency of construction processes and contribute to achieving sustainability goals, such as those outlined in the Paris Agreement. (United Nations, 2016)
A major advancement in digital and sustainable transformation is the digitization of building documentation. Precise and comprehensive documentation of the materials used and technical installations is essential for sustainable construction and building use. However, challenges persist due to the lack of standardization in data models and the heterogeneous provision of information by manufacturers, which complicates the efficient processing of construction product information. (Piétron, et al., 2023, p. 15)

In Germany, the construction trades play a significant role in creating building documentation, as they are responsible for selecting the materials actually used in the building. (Stellmacher, et al., 2023) To support the construction trades in documentation creation, specific templates and technical solutions are needed to facilitate the documentation and evaluation of construction products. BIM has emerged as a promising solution in the course of digital transformation, significantly aiding in the efficient creation of digital building documentation by linking product information with a 3D building data model and enhancing transparency and traceability of construction processes.

In the research projects "BIM Application Cases in the Construction Trades" (University of Wuppertal - BIM-Institut, 2022) and "Construction Practitioners as the Central Instance of Digital Automated Building Documentation - DigiBauDok," (University of Wuppertal - BIM-Institut, 2022) templates for building documentation and technical solutions for automatically linking documents and digital product data with BIM models were developed and validated. For instance, in the "DigiBauDok" project, the use of QR codes to link construction product information with BIM models was successfully demonstrated. By scanning these QR codes, information can be directly integrated into the BIM model and retrieved in real time. This technology was tested on construction sites and showed a significant improvement in data accuracy and timeliness.

This work highlights the importance of digital building documentation for sustainable construction and examines how BIM and standardized data models can enhance efficiency and sustainability in the construction industry. The results of the mentioned research projects are presented, and the advantages of automated digital documentation are discussed. Finally, an outlook on future research efforts is provided, investigating the use of artificial intelligence to further promote sustainability in the construction sector.

2 The Role of Digital Building Documentation

Digital building documentation is a central component of modern construction processes, significantly contributing to efficiency and sustainability within the construction industry. It involves the systematic recording, management, and provision of all relevant data and information about construction products, materials, and technical systems of a building in digital form. This comprehensive documentation spans the entire lifecycle of a structure, from planning and construction to operation, demolition, and material reuse. By integrating Building Information Modeling (BIM), a precise and transparent data foundation is established, offering numerous advantages for sustainable building practices. (Moritz, 2023)

This information is provided in a structured and accessible digital format, covering all phases of the building lifecycle. The integration of BIM allows these data to be linked in a three-dimensional model, resulting in a detailed and transparent representation of the building. This not only facilitates planning and construction but also aids in the operation and eventual dismantling of the structure.

2.1 Advantages for Sustainable Building Practices

The benefits of digital building documentation for sustainable building practices are manifold:

1. **Increased Efficiency and Error Reduction**: The availability of precise and up-to-date data minimizes planning and construction errors. This leads to a reduction in material waste and rework, thereby enhancing the efficiency of construction processes. (Aziz, et al., 2024)

2. **Traceability of Construction Products**: Digital documentation allows for accurate tracking of the origin, composition, and properties of the materials used. This is particularly important for the reuse and recycling of materials. (Honic, et al., 2024)
3. **Reduction of Environmental Impacts**: By integrating sustainability criteria into planning and documentation, more environmentally friendly materials and construction methods can be chosen. Digital documentation facilitates environmental assessments and sustainability certifications. (Univ.-Prof. Meins-Becker, et al., 2023)
4. **Promotion of Collaboration**: Digital building documentation creates a common data foundation accessible to all participants in the construction process. This improves communication and coordination among architects, engineers, construction companies, and other stakeholders. (Kozlovska, et al., 2023)

2.2 Contribution to the UN Sustainable Development Goals

Digital building documentation significantly contributes to achieving the United Nations Sustainable Development Goals (SDGs): (United Nations, 2015)

- **Goal 9: Industry, Innovation, and Infrastructure**: By promoting innovation and digitization in construction, digital building documentation aids in modernizing and enhancing the efficiency of the construction industry.
- **Goal 11: Sustainable Cities and Communities**: Digital building documentation supports the creation of sustainable cities and communities through precise planning and monitoring of urban infrastructure.
- **Goal 12: Responsible Consumption and Production**: It promotes sustainable production and consumption by facilitating the reuse and recycling of construction products.

3 Development of Templates and Standardized Data Models and Their Practical Application

The role of building documentation in the construction industry is crucial for promoting sustainable and resource-efficient building practices. By integrating BIM and developing standardized data models, the efficiency and sustainability in the construction industry can be significantly enhanced.

The digital transformation of the construction industry offers substantial opportunities to increase efficiency and sustainability. The research projects "BIM Application Cases in the Construction Trades" and "DigiBauDok" have made significant contributions to the development of templates and technical solutions for digital building documentation. These projects address key challenges such as the standardization of data models and the automation of documentation through technologies like QR codes.

3.1 Research Project "BIM Application Cases in the Construction Trades"

In the project "BIM Application Cases in the Construction Trades," templates for creating digital building documentation were developed by consolidating and harmonizing the information requirements of various stakeholders involved in construction. This resulted in a comprehensive list of documents and characteristics of building materials that the construction trades must provide within the framework of digital building documentation. This clear definition of information requirements enables the construction trades to collect all necessary documents and information at the beginning of the construction services and to hand them over in a structured manner at the end. This promotes precise and consistent documentation, which is essential for sustainable construction processes.

3.2 Research Project "DigiBauDok"

The research project "DigiBauDok" goes a step further by developing technical solutions to automate building documentation, using QR codes on building materials that are linked to the Global Trade Item Number (GTIN) (Global Standard 1, 2024) of GS1 (Global Standard 1) for the respective building materials. This GTIN allows for unique identification and retrieval of comprehensive product information from an existing database, thereby improving the integration and timeliness of data in BIM models. A key prerequisite for this is the development of a standardized data model based on ISO 23386 and the industry standard of the UniversalTypes by buildingSMART, integrating information on master data, transaction data, event data, and sustainability information. A central component of this project is the expansion of the existing master data model of the building materials trade. This model serves as a starting point and is extended to include additional factors such as event and movement data as well as sustainability information (see Table 1). Event and movement data enable the traceability of processes and include orders, inventories, delivery notes, and invoices. Sustainability information covers economic, ecological, and social aspects and contributes to promoting sustainable building practices.

Due to the fragmentation of data processing in the construction industry, unified standardization of data models is required to avoid incompatibilities and ensure efficient workflows. Standardized data models create a common foundation for all stakeholders in the construction industry, significantly improving interoperability and efficiency. The integration of these models allows for precise assignment of product attributes and effective linking of construction product information with BIM models.

Standardized numbering structures such as the GTIN or batch number play a crucial role in seamlessly linking information along the entire value chain in construction. These structures are provided by GS1 and enable the unique identification of products, companies, and locations. Adhering to these standards is necessary to ensure seamless integration and efficient electronic data exchange. Analyses and discussions with professionals have shown that 70 to 80 percent of construction products in hardware stores like Obi, Hornbach, or Hagebau already have unique identification according to the GS1 standard, providing a solid foundation on which to build.

3.2.1 Structure of the Data Model

The development of a data model that allows seamless integration of property, movement, event, and sustainability information is an extremely complex process. This model is constructed from a Single Point of Truth (SPoT), which acts as a central hub containing all the attributes that manufacturers must provide for their construction products. These attributes are derived from the requirements in construction documents and the criteria for sustainability certifications.

3.2.2 Planning and Tendering

In the planning phase, the architect or specialist planner creates the As-Planned model based on the client's requirements and preferences. This model remains product-neutral but is based on a product-independent specification. However, the requirements of engineers and architects, such as U-values for windows or the specific selection of drywall panels in wet areas, can be linked to the corresponding virtual components using the UniversalType class UT05.

3.2.3 Quotation, Ordering, and Execution

In the tendering phase, the construction company makes targeted decisions regarding construction products and materials to enable precise calculation of individual service costs. The company's estimator can specify the exact product of a particular manufacturer. However, it should be noted that due to potential material or supply shortages, alternative products may be selected on-site, which may affect the reliability of the information provided by the estimator.

Table 1: Data structure based on the example of a drywall panel (own illustration)

Master data Product Description		Drywall panel	UT01	**What am I?**
Master data Product ID		e.g. GTIN, manufacturer article number, TGA-No....		
Other specific identification features		e.g. Brand Name		
Master data company		e.g. Knauf	UT02	**Who do I belong to?**
Company ID master data		e.g. GLN from Knauf or individual manufacturer number		
More details about manufacturer, dealer, data supplier		e.g. manufacturer sales tax identification number		
	Product specific properties	e.g. thermal conductivity - λ	UT05	
		more inidvidual product features 1-n	UT05	
		……	UT05	
	Logistics information	e.g. dangerous goods information	UT04	
		……	UT04	
	digital assets	e.g. product image, data sheet, sketches, …	UTNew	
		….	UTNew	
	Sustainability information	e.g. recyclable	UT09	
		……..	….	
Transaction data				
		e.g. quantity	UTNew	
		e.g. delivery note number	UTNew	
		……	….	
Event data				
		e.g. delivered on 01.01.xx	UTNew	
		e.g. installed on 01.01.xx	UTNew	
		…..	…..	
Sustainable Data				
		e.g. CO2 emissions	UTNew	
		e.g. waste production	UTNew	
		…		

3.2.4 Expansion of the Data Model

Linking attributes during the construction execution phase not only enriches the As-Built model with valuable information such as event data (e.g., installation dates) and movement data (e.g., delivery notes or invoices) but is also crucial for expanding the data model. These additional pieces of information form a solid foundation for creating digital product twins. Digital product twins are virtual representations of real construction products linked to their corresponding digital data. They enable a holistic and dynamic representation of the construction process, as well as comprehensive traceability of components and their properties, by establishing the connection between virtual components and real events and movements.

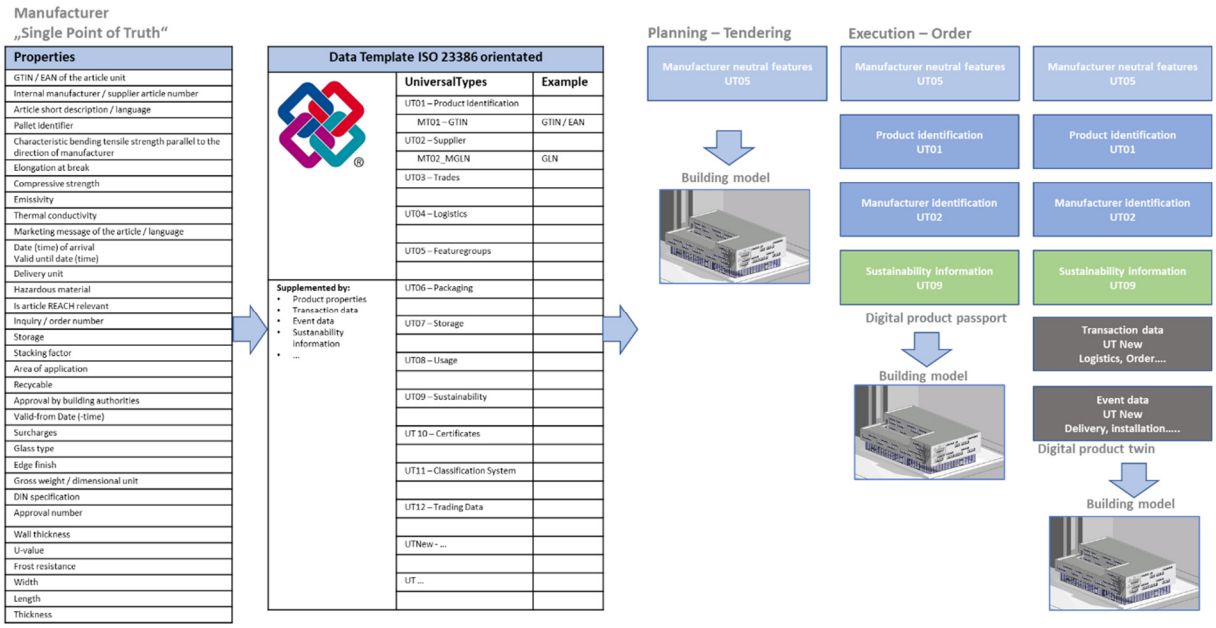

Figure 1: Developed data model for enriching the As-Planned model with features with assignment of UniversalTypes

4 Practical Applications and Case Studies

The implementation of standardized data models and BIM has the potential to significantly transform the construction industry. Concrete applications and case studies are essential to translate theoretical concepts into practice.

4.1 Automated Documentation of Drywall Components

The process of building a drywall, representing all products that can be directly marked with a barcode or QR code, was tested as the first scenario on the construction site of the List Group. This test analyzed not only the technical implementation but also the responsibilities for execution. The drywall panel was labeled with a QR code, through which product information could be retrieved from the producing company/ProMaterial using the developed data structure. An employee of the executing company could scan the QR code using the Kontrool app and read the product information. To establish spatial allocation in the BIM model, the QR code on the execution plans was also scanned. This QR code on the execution plan could be generated directly in the authoring software Revit and contains information such as the GUID (Globally Unique Identifier), through which the material information can be linked with the room or building component in the BIM model.

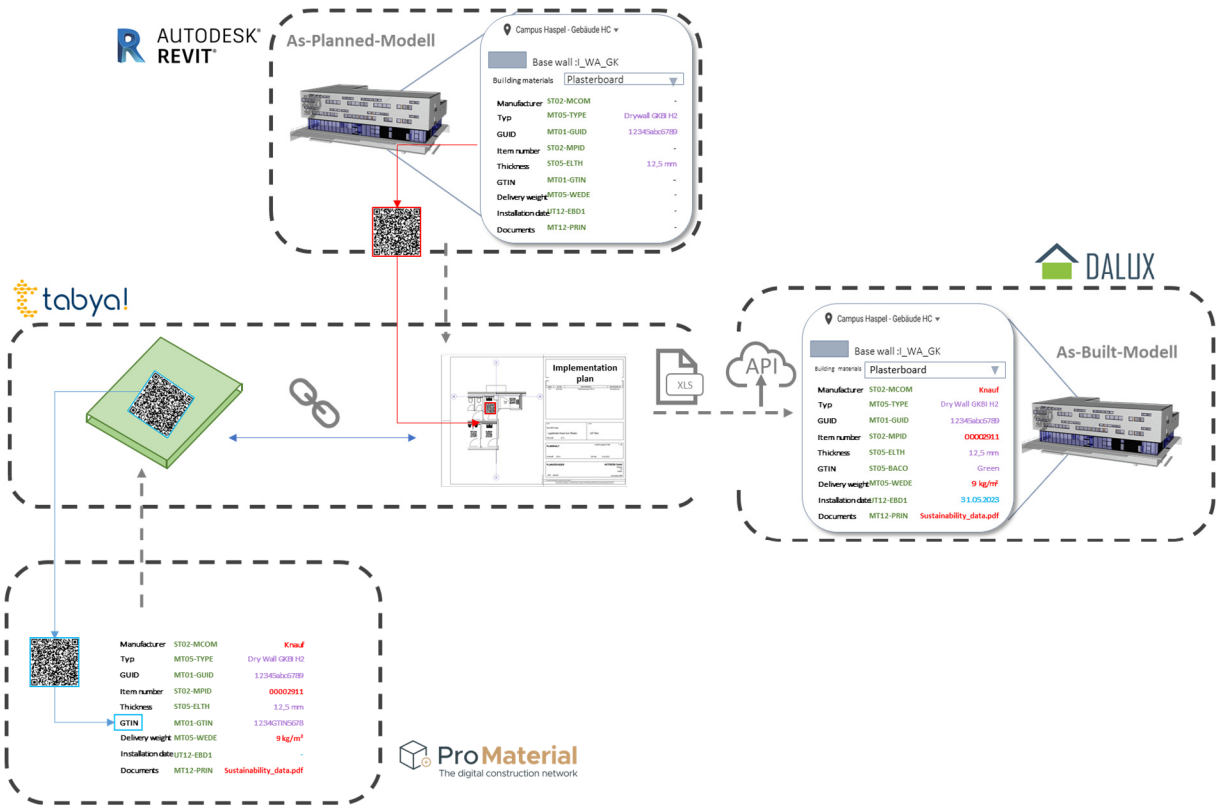

Figure 2: Process of automated digital building documentation using the example of a drywall panel

The data set linked in the Controll app by Tabya, consisting of the GUID and the GTIN of the building material, could then be imported into the BIM viewer by Dalux or automatically transmitted via a programmed API. There, the product information was automatically linked with the respective room in the BIM model using the existing GUID. The process illustrated in Figure 2 thus represents the first successfully conducted test run of automated, digital building documentation.

4.2 Automated Documentation of Concrete Components

Another scenario dealt with the documentation of concrete components. Since barcodes cannot be directly applied to the material, a QR code was printed on the delivery note, which contains both the properties of the concrete and the GUID of the corresponding components. By scanning the QR code on the delivery note, the information could be retrieved, and the spatial location in the BIM model could be directly assigned via the GUID. This process was successfully validated, demonstrating that effective digital documentation is also possible for materials such as concrete.

The Experimentation Lab "DigiBauDok" at the University of Wuppertal has shown how innovative technologies can contribute to the automation of digital building documentation. QR codes and other technologies have made construction processes more efficient and transparent, as practical examples from drywall and concrete documentation demonstrate. These technologies improve the efficiency and accuracy of building documentation and enable precise traceability of the materials used, which is particularly important for sustainability and resource efficiency.

However, limits and challenges have also become apparent, as not all information can be represented by the current data model and provided in a structured manner by manufacturers. Many data are still contained in not fully digitized documents, making integration and standardization difficult. These insights highlight the need for further research to close existing gaps and develop the technologies further.

Intensive research in this area continues at the University of Wuppertal.

5 Future Perspectives

The continuous development and implementation of BIM and digital building documentation will be crucial for further optimizing construction processes and achieving sustainability goals.

5.1 Artificial Intelligence

The use of artificial intelligence (AI) offers additional possibilities to further automate and optimize building documentation. Within the framework of the "NaConBau" project at the University of Wuppertal, a dynamic knowledge graph is being developed. Large Language Models (LLM) such as ChatGPT by OpenAI are utilized to automatically extract construction product information from existing data sources and transfer it in a structured manner into the graph database. In conjunction with the LLM, this system will support the construction trades in selecting sustainable building materials and documenting them.

5.2 Internet of Things (IoT)

The integration of the Internet of Things (IoT) into building documentation offers further possibilities for increasing efficiency. In the research project "BIM and IoT-based Traceability of Construction Products," (University of Wuppertal - BIM-Institut, 2024) event data in the supply chain of building materials is captured based on the data model and the EPCIS standard to ensure traceability. Through the networking of sensors and devices, real-time data on the condition and use of buildings can be collected and analyzed. This enables proactive maintenance and optimization of operational processes.

The implementation of these technologies will not only improve the efficiency and accuracy of building documentation but also promote sustainability and resource efficiency in the construction industry. Continuous research and development in these areas will be crucial for leading the construction industry towards a more sustainable and digitized future.

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