Product Data Provision from Manufacturers to the Construction Industry: a Scoping Literature Review and Case Study Analysis

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Abstract
Increasing use of BIM requires solutions for sharing Product Data (PD), generated and governed by manufacturers, across applications and actors of the AECO industry. PD must be available in a machine-interpretable way to facilitate digital processing, but is usually provided in proprietary data formats. Aiming to analyse manufacturers' current approach to PD provision, a scoping literature review was conducted, supported by a case study investigating a database providing IFC BIM objects, and the possibility to represent PD using Linked Data (LD). Findings suggest that PD provision is limited for reasons spanning from lacking expertise to data management issues. While the representation of PD in IFC BIM objects as well as with LD was concluded to be possible with currently available means, it has yet to be adopted by the industry.

1. Introduction
The life cycle of a building begins with the construction process, encompassing the pre-design, design, production, and maintenance processes, before concluding with deconstruction when reaching the building's end-of-life phase (ISO 12006-2, 2015). Throughout this time, a vast amount of Product Data (PD) can be associated with the building's various elements, which consist of products supplied by manufacturers. Those manufacturers consequently also provide respective PD to stakeholders such as designers, owners, or operators. ISO 12006-2, 2015 defines *construction product* as any product intended to be used as construction resource.

This study investigates current approaches of PD provision, as well as explores and compares the realisation of PD provision using IFC and Linked Data (see section 1.3), respectively. It, thereby, aims to explore possible means of creating a digital connection between manufacturers the building industry, instead of relying on proprietary data formats (see section 1.2). The results are hoped to enhance the availability and currentness of data, as well as its implementation into building models. The term 'product' will be used aligned to the mentioned standard, with the limitation of being a direct resource to the construction process, meaning being supplied by a manufacturer without further decomposition.

1.1. Need for Information

Potential needs for PD can be derived from the BIM uses as defined by the University of Pennsylvania's College of Engineering, which have been proposed to be extended to encompass a building's end-of-life phase (Penn State University, 2024; van den Berg et al., 2021). Possible information needs throughout the whole life cycle are also documented in the European standard ISO 19650-1, 2019. Selecting products to satisfy defined requirements, simulating a design's impact on cost, carbon emissions, energy demand, waste, water consumption or other environmental effects, as well as the creation of preventative maintenance schedules necessitates access to PD throughout both planning and operation phase (Penn State University, 2024). At the end of a building's life or in case of replacement of individual components, the availability of PD may facilitate decisions on reuse, recycling, or disposal of used components, paving the way for circularity in the building industry (van den Berg et al., 2021).

Since PD does not only define the specifications and performance of a product, but also captures its value and possible advantage compared offerings of the competition, manufacturers have an inherent need to document and communicate PD (Bahrami et al., 2019). The described stakeholders in the construction industry rely on having access to PD, in a way that enables their desired actions. It can, thus, be inferred that the provision of PD is of major interest to the building industry.

1.2. Information Flow

To support an unrestricted information flow between manufacturers and stakeholders of the building industry, PD must be shareable between organisations, personas, and software applications. As pointed out by Kebede et al., 2022, not only digital availability but also machine-interpretability of data becomes increasingly important in light of progressing digitalisation.

Traditionally, manufacturers document their products' specifications in PDF documents, made available on the company's website (Nour, 2010). Catering to the use in specific design software, BIM objects in the software's proprietary file format can be offered. Alternatively, to enable the use of BIM objects with a broader range of software applications, those can also be stored in the standardised and non-proprietary IFC file format (Bahrami et al., 2019). When available in a machine-interpretable form online, pieces of information can also be shared using Linked Data (LD) technology (Pauwels et al., 2017), meaning that rather than transferring data, the source of the information is shared for retrieval when needed.

1.3. Product Data Provision

In present research, PD is being discussed in terms of its uses within construction processes, as well as its communication between different industries, stakeholders and software applications relevant to the building sector. The handling of PD throughout a building's life cycle is sometimes summarised by the term Product Information Management (PIM) (Annunen et al., 2022; Bahrami et al., 2019). The field of related topics encompasses traceability (Davari et al., 2023), BIM objects, Digital Product Passports (DPP) (Bellini & Bang, 2022), as well as data transfer using Semantic Web (SW) and LD technologies (see section 2.3).

Playing a key role for manufacturers in the diffusion of their products, different platforms for BIM objects have been investigated (Bahrami et al., 2019). Linked Data technologies have been demonstrated to enable incorporation of PD into BIM models (Kebede et al., 2022). Both IFC BIM objects and LD are therefore feasible approaches for a digital provision of PD to a wide range of BIM applications (Daniotti et al., 2020; Kebede et al., 2022). To the best of the author's knowledge, however, no case study on the current practices of PD provision in the building industry, combined with a comparison of the alternative methods of using IFC BIM objects or LD, has been conducted so far.

2. Theoretical Background

As a tool for the exchange of digital information, BIM offers new opportunities for processing information on products incorporated in buildings. While PIM has the potential to facilitate processes throughout all life phases, it demands an unrestricted information flow between applications and stakeholders (Palos et al., 2014). This, in turn, necessitates the use of open data formats such as IFC and the existence of standards in regard to product specifications.

2.1. Hindrances of Product Data Provision

The availability, interoperability, and quality of data are commonly described to be problematic in the usage of PD (Annunen et al., 2022; Bahrami et al., 2019; Daniotti et al., 2020). More specifically, Kebede et al., 2022 and Wagner et al., 2022 state that digital PD is often provided by the manufacturers in proprietary formats, such as BIM objects in file formats of specific design software. Consequently, the accessibility and interoperability of information is limited. Moreover, the information delivered in BIM objects on common platforms was observed to lack completeness or even correctness (Bahrami et al., 2019; Daniotti et al., 2020). The fact that manufacturers mostly rely on product documentations in PDF format poses a general problem for data availability: Although being digital, the information cannot be imported to any software tool, rendering it effectively inaccessible (Kebede et al., 2022).

2.2. Information Quality

The quality of any given information is difficult to assess, considering the multidimensionality and context-dependency of the concept (Silvola et al., 2016). Synthesising existing literature on data quality and adapting it to the context of BIM objects, however, Bahrami et al., 2019 have extracted the following indicators for the value of BIM objects: compatibility, functionality, accessibility, accuracy, adequacy, comprehensibility, currency, applicability, and reliability.

As pointed out by Halttula et al., 2020, good data quality over the whole life cycle also necessitates data management and maintenance. Consequently, a framework for data governance is presented, including the roles of data steward, data owner, data manager and data user. Practicing data governance is meant to ensure the quality, consistency, usability, security, and availability of data over its whole life cycle.

2.3. Exchange of Information

To tackle the problems of Product Data provision from manufacturers to the Building Industry, different and partly contradicting solutions are being proposed. Ramaji and Memari, 2020 suggest the enrichment of IFC files with the necessary information to guarantee interoperability in the context of cost calculation and structural analysis, respectively. An opposing approach is the use of a centralised database. Again, propositions differ whether this should provide pure PD (Annunen et al., 2022) or host a library of quality-ensured BIM objects in the non-proprietary IFC file format, acting as information carriers (Bahrami et al., 2019). Lastly, use of Semantic Web technologies, as suggested by

Kebede et al., 2022 and Pauwels et al., 2017, would make PD – non-centrally hosted on manufacturers' websites — not only available to software but also machine-interpretable and queryable by providing the necessary meta-data inherent to data modelled after the Resource Description Framework (RDF).
Independent of the means of data exchange, researchers widely agree on the necessity of standardised property sets, possibly defined by Product Data Templates (PDT) or Digital Product Passports (DPP), to ensure interoperability by consistently describing products (Bellini & Bang, 2022; Davari et al., 2023) .

3. Methods

The theoretical background to this study was established through a scoping literature review. It was then complemented by a case study, further investigating the provision of PD via IFC BIM objects on the example of objects obtained from a public database. As an alternative approach, the use of SW technologies was explored. Based on the gained insights, a Use Case was formulated.

3.1. Scoping Literature Review

To assess the state of the industry, a scoping literature review was conducted. Starting by using the PICOC framework (Booth et al., 2016), the field of research was established as indicated in Table 1. Subsequently, the search was carried out in the scientific database SCOPUS, yielding 114 results. A paper was included when addressing the concepts of the established research field, and excluded when failing to do so or not being available in English or German language. The obtained papers were condensed following the PRISMA strategy (Page et al., 2021), leading to the selection of papers synthesised in the literature review.

Table 1: Establishing the research field using the PICOC framework.

Population and their problem	Manufacturers and the Building Industry Integration of PD into BIM models
Intervention and issue	Digital connection Availability of data, implementation
Comparative intervention	Technical specification in proprietary data formats
Outcome or themes	Currentness, direct integration
Context	Building Industry

3.2. Case Study

The database dataholz.eu[1] is a project of the Austrian Forest Products Research Society, aiming to serve as a reference work fulfilling requirements of both users and building regulations by providing certified data on wooden construction products. It offers not only BIM objects in the non-proprietary IFC file format, but also supplies data sheets specifying the individual products listed on the website. Those data sheets are issued by independent testing and research institutes, guaranteeing correctness of the provided data. For its unique combination of offering BIM objects as well as supplementary certificates, as well as being industry-based, dataholz.eu was considered to be an interesting example to be studied in further detail.
The conducted case study was comprised of four parts: clarification of practical purpose through formulation of a Use Case, assessment of quality of the data provided on dataholz.eu, investigation of the used IFC BIM objects as carriers for PD in general, as well

[1] https://www.dataholz.eu/

as an investigation of PD provision using Linked Data as an alternative approach. The results of the case study are documented in chapter 4.

3.2.1. Use Case

To clarify the purpose and scope of the envisioned information exchange, the case study was begun with the definition of a formal Use Case. BuildingSMART International (bSI), with their Use Case Management (UCM) initiative[2], offers a framework for defining Use Cases along with a platform for publishing them. However, bSI demands a Use Case to capture not only purpose and scope of the information exchange, but also to define a set of attributes that is to be exchanged (Exchange Requirements). Since the objective of this study is not to delineate a procedure in one specific scenario, but rather to explore general means of information exchange applicable to various scenarios, the Use Case developed in this study does not strictly follow the framework of bSI, but adapts it to the study's objectives.

3.2.2. Data Quality

The quality of the provided data was assessed following concepts extracted from the literature review, meaning the value of the BIM objects was evaluated based on indicators defined by Bahrami et al., 2019. A systematic qualitative analysis, however, as conducted by the referred researchers, was prevented by a lack of objective data. For those indicators that could not be evaluated based on objective evidence, a set of questions was addressed to a representative of the database. Additionally, the formulated questions also addressed management and maintenance of the provided data, aiming to establish whether the operators of the database follow a data governance framework as or comparable to the one presented by Halttula et al., 2020 (see chapter 2).

3.2.3. Data Provision using IFC BIM Objects

Based on the quality assessment of data carried by the IFC BIM objects provided on dataholz.eu, a general investigation of Product Data provision using IFC BIM objects was conducted. Since data on the product level was found to be missing in the modelled wall assembly, the obtained IFC file was enriched with PD. This was done selecting only the core layer as an example, using data from a matching product listed on dataholz.eu. Following the documentation on IFC 4, the information from the product's specification sheet was added to the original IFC BIM object, while referencing entries of the data dictionary *industry-dictionary for products in wood*[3], created by the European Woodworking Industry Confederation (CEI-Bois), to define the added properties.

3.2.4. Data Provision using Linked Data

To investigate the possibility of sharing PD using LD technologies, the investigated wall assembly was modelled using the existing Building Product Ontology[4] (BPO). This ontology facilitates a semantic description of building products, offering methods to represent assembly structures as well as properties connected to incorporated products, having template-driven product descriptions in mind (Wagner et al., 2022).

Using the BPO, the specification sheet of the used product was translated according to the Resource Description Framework (RDF). In a separate file, the wall assembly was then described using the BPO, referring to the previously created RDF description of the incorporated product. Thus, demonstrating the use of Linked Data in a model of a building element.

[2] https://ucm.buildingsmart.org/

[3] https://search.bsdd.buildingsmart.org/uri/cei-bois.org/wood

[4] https://www.projekt-scope.de/ontologies/bpo/

4. Results

Since the results of the scoping literature review were already presented in chapter 2, the following section focuses on the results of the conducted case study. Links to investigated files are provided upon mention. Developed files, as well as the created Use Case are made available in a GitHub repository[5].

The investigated BIM object represents a compound wall element. In the IFC schema, such a wall is represented as a singular element (*IfcBuiltElement*) with multiple layers (*IfcMaterialLayer*), and its constituting products are described as materials (instances of *IfcMaterial*). The term 'material level' will be used to describe the assembly level in which *IfcMaterial*'s are allocated, '(material) layer' corresponds to the *IfcMaterialLayer*. Consequently, PD is being carried on the material level of the IFC wall element.

4.1. Use Case

The scope of the developed Use Case is the description of means of PD provision that could be applied to realise information exchanges envisioned by existing Use Cases such as *Materialpass mit Produktklassifizierung*[6] (material pass with product classification). It is the objective of this description to satisfy information needs defined in the related Use Case. The described means constitute two possible approaches how product information can be stored and shared between actors and applications, realising a traceable, digital, and machine-interpretable information flow throughout a building's life cycle.

The Use Case describes the representation of PD using the IFC and RDF format, respectively. For both approaches, a schema defining leveraged methods and concepts is proposed.

4.2. Data Quality

Against expectations, the obtained BIM objects were observed to only carry properties associated with the whole wall assembly. On the material level, where each layer represents one product constituting the assembly, no product specific attributes exist. The quality of the contained information, evaluated based on the indicators defined in section 3.2 and in the context of this study, are displayed in Table 2.

No answer from dataholz.eu was received to the questions addressing currency of information and data management, and no information on this subject seems to be publicly available. Hence, this part of data quality could not be assessed.

4.3. Data Provision using IFC BIM Objects

The IFC schema accounts for attributes to be defined on the material level of a wall assembly. Following this, the selected IFC BIM object[7], chosen for its minimal count of components, was enriched with product specific information.

The enrichment was conducted exemplarily on the core layer, with information from a suiting CLT product listed in the same database. The attributes from the product's Declaration of Performance[8] (DOP) were added to the IFC file as *IfcPropertySingleValue*, grouped into a property list using *IfcMaterialProperties*. Since most added properties are not natively defined by the IFC schema, a reference to a buildingSMART Data Dictionary (bSDD) definition was included, using the *Description* attribute (renamed to *Specification* with IFC 4.3). The enriched file was subsequently validated using the bSI Validation Service[9], reporting only one error that was inherited from the original file.

[5] https://github.com/jochembe/pdpExamples

[6] https://ucm.buildingsmart.org/use-case-details/3097/de

[7] https://www.dataholz.eu/bauteile/trennwand/variante/kz/twmxxo02a/nr/01.htm

[8] https://www.dataholz.eu/fileadmin/dataholz/media/baustoffe/DoPs/dop_hbs-berga-bsp_de_en.pdf

[9] https://technical.buildingsmart.org/services/validation-service/

Table 2: Quality of information in BIM object, evaluated based on indicators defined by Bahrami et al., 2019.

Indicator	Question	Evaluation
Compatibility	Is the object compatible with common design and calculation software?	Yes: IFC format standardised and widely adopted
Functionality	Is the object sufficient for performing accurate calculations and simulations?	No: only averaged properties for energy and environm. analysis
Accessibility	Can users easily access the information in the content of a selected object?	Yes: properties are displayed in Revit after import
Accuracy	Is the information accurate?	Yes: certified
Adequacy	Is sufficient information included in the BIM objects?	No: no information on individual products
Comprehen-sibility	Does the information give a clear understanding of the product?	No: no information on individual products
Currency	Is the information up to date?	(not assessed)
Applicability of content	Does the information enable the user to compare different brands and choose the products with better attributes?	No: no information on individual products
Reliability	Has the information been verified or certified?	Yes: certified

4.4. Data Provision using Linked Data

In a similar process as described in the previous section, the specification sheet of the same CLT product was translated into RDF data representing the properties obtained from the DOP. This was done using the BPO, with every property referring to the same bSDD definitions used in the enrichment of the IFC file.

After translating the product specification, the wall assembly was modelled in a separate file. Each material layer was represented as a *bpo:Product*, together constituting the wall assembly represented using *bpo:Assembly*. The core layer references the previously modelled product using the predicate *bpo:realisesObject*, thereby linking the defined properties to the respective component of the assembly (illustrated in Figure 1).

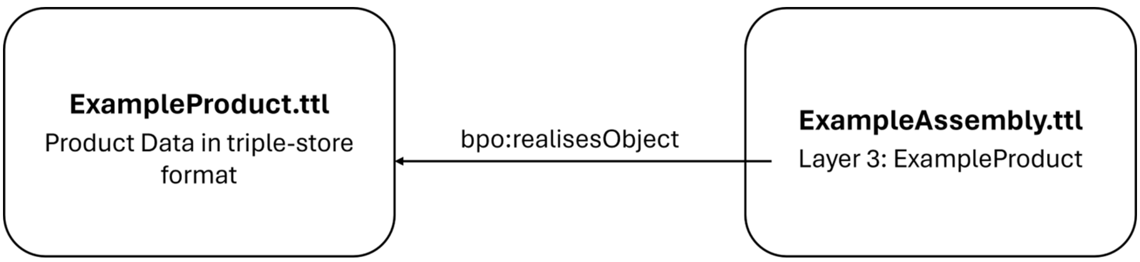

Figure 1: Representation of a wall assembly as RDF data, with a specific layer referencing product data from a different source (own illustration).

5. Discussion

While establishing the theoretical background to this work, the literature review revealed the lack of a direct comparison between the use of IFC BIM objects and LD for PD provision, setting the ground for the subsequent case study. Given its scoping nature, however, it does not aspire to comprehensively synthesise the existing body of knowledge.

The enrichment of the obtained IFC BIM object was complicated by the lack of corresponding attributes predefined in the used IFC 4 schema. To comply with the desired result of a machine-interpretable information flow, as envisioned by Palos et al., 2014, a standardised use of attributes is obligatory, demanding custom properties to reference a data dictionary. The IFC 4 schema allows this by mapping the bSDD *PropertyCode* and *uri* (of *ClassProperty*) to *IfcPropertySingleValue.Name* and *IfcPropertySingleValue.Description*, respectively. Notably, this means that the human-readable bSDD *Name* is not reflected in the IFC file. A BIM application will only show the *PropertyCode*, unless it is able to access and retrieve the *Name* from bSDD. This could significantly impair user-friendliness and diffusion of innovation (Bahrami et al., 2019). However, IFC 4.3 already expanded on the predefined properties to include most of the attributes that were missed during this enrichment.
The correct mapping of mechanical properties from the product specification to bSDD properties was found to be particularly troublesome. Mechanical resistances of CLT are distinct in their direction compared to the orientation of the grain, combined with the orientation of the whole panel, and used names and descriptions are not always unambiguous. This problem seems to prevail with IFC 4.3, where direction of resistance compared to the direction of the grain seems to remain unspecified in the newly introduced properties.
Although attributes were matched to the best of the author's knowledge in the enrichment of the IFC BIM object as well as the creation of the RDF representation, uncertainties in referencing bSDD properties accompanied both parts of the case study. This highlights the need for standardised PDT as was stressed by researchers such as Bellini and Bang, 2022 and Davari et al., 2023.
Since SW and LD technologies rely on extending modules rather than one inherent schema used for IFC, referencing varying sources in the same graph comes more naturally. A possible conclusion is that smaller, specialised modules ease their application, whereas one all-encompassing schema becomes difficult to navigate with increasing complexity.

As pointed out in chapter 4, PD of the building element represented by the investigated BIM object is carried on the material level of the corresponding IFC wall element. Taking Autodesk Revit as example for a popular BIM application, a direct import of information on the material level would require import of a material library. These use a file format proprietary to Autodesk software, rather than IFC. A possible work-around would be the import of an element featuring the material as IFC BIM object. The material would then be available for further use in the Revit project's material library.
In the case of dataholz.eu, the offered BIM objects are already an assembly of product types. While dataholz.eu currently stops at the definition of product types, this or a similar database could provide the function to select specific products listed in the database. The corresponding BIM object could then be created to include product specific information on the material level, facilitating the transfer of actual PD. The platform hereby acts as an intermediary between manufacturers and BIM application. This process is necessary whenever the products to be represented are modelled as components of an assembly in the design software, and would, similarly, affect roofs and slabs.

The question arises how such a platform would retrieve PD from manufacturers in this scenario. Unless it is stored in the platform's database, which in turn necessitates proper management of the provided data, there is still a need to digitally access PD from the manufacturer on demand.

Provision of PD in form of RDF graphs directly by the manufacturer can facilitate not only that, but also allows working with generic building elements in the design software and specifying the exact product by linking to said RDF graph. The subsequent integration of PD from an RDF database into the design software Revit was successfully demonstrated by Kebede et al., 2022. This way of sharing PD negates the need for an intermediary, as well as for the management of a centralised database. Moreover, retrieving information directly from the manufacturer whenever needed ensures currentness of the information, and avoids clustering complex BIM models with large amounts of data. The risk of inflated IFC files speaks against their enrichment with PD as supported by Ramaji and Memari, 2020.

However, this approach also relies on the individual manufacturer to adopt new technology, potentially hampering the implementation of the concept. If information is hosted outside of the BIM model itself, continuous accessibility of the information throughout the whole life cycle of a building, using the same URI, must also be ensured. Notably, the importance of availability of PD and traceability of materials across life cycles was pointed out by Bellini and Bang, 2022 as well as Davari et al., 2023.

6. Conclusions

The building industry's transformation towards an increasingly digital and sustainable future relies on innovative solutions for handling data connected to building products.

By exploring current approaches of providing Product Data (PD) from manufacturers to the building industry, and means of integrating them into BIM models, this study established that the industry still heavily relies on the use of barely digital PDF files as product specifications, and even the more innovative BIM objects do not display the same information content as in respective product specification sheets. While the validity of using both BIM objects in the standardised IFC file format as well as Linked Data technology to leverage the provision of PD in the desired traceable and machine-interpretable way was demonstrated, only the latter allows referencing information directly from the manufacturer, rather than storing the data within the BIM model. Furthermore, Linked Data negates the need for an intermediary platform to provide BIM objects including products of several manufacturers.

Future research into sharing data between industries relevant to the building sector should focus on the development of a framework on the location of storage and its format for sharing across applications. This will need to be accompanied by respective standards, and possibly regulations regarding the long-term availability of data.

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