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Evaluation of Product Data Template initiatives

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Evaluations of Product Data Template initiatives

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Abstract.

The AEC (Architecture, Engineering, and Construction) industry has been undergoing a significant digitalization process in the last years. This transformation implies new challenges and adaptation concerning the exchange of data between different software applications. Therefore, in response to this problem the benefits of IFC as a solution for the exchange of data have been investigated. However, the current versions of IFC cannot achieve semantic clarity in mapping entities and relationships. Therefore, there have been several attempts to develop solutions and optimizing methods to improve the exchange of information of product data. This paper aims to identify and investigate the challenges of using product data templates (PDT) for exchange of information and different PDT has been evaluated and compared. The necessary data was collected through literature review and document analysis. Five challenges and five initiatives were identified during the literature review. The five initiatives are Semantic web and linked data, CoClass, Buildingsmart, COBie and Cobuilder. The result showed how these initiatives could solve the identified challenges.

Keywords: Construction industry, Building Information Management, Information Exchange, Product data, Product data Templates

1 Introduction

The AEC (Architecture, Engineering, and Construction) industry is undergoing a significant digitization process, with the rapid adoption of BIM (Building Information Modelling) in the design, construction and Operation & Maintenance stages [1]. However, this transformation implies new challenges and adoptions in the exchange of data between heterogeneous software applications [2]. As a response to this problem, industry professionals and researchers have extensively used and researched IFC with the expectation of improving the exchange of data between heterogeneous BIM authoring and application tool systems [3].

Industry Foundation Classes (IFC) is an open, object-based data format for defining and exchanging information concerning building and construction activities throughout the AEC/FM sector[4]. BIM cases based on IFC can include geometric information about building elements, such as 3D shape and enclosed areas, as well as nongeometric semantic information about the elements' attributes and connections [5].

IFC shows the ability of improving interoperability in the AEC sector and performing information sharing & exchange. However, the current versions of IFC files cannot achieve semantic clarity in mapping entities and relationships, which can lead to ineffective data exchange between different applications or participants.[6] At the same time the semantic classification for domain-specific, innovative, or adoptive product data definition is not covered in the IFC data schema, leading to a difficult enrichment of product data [7].

A product data is defined as data that has been defined and organized in a way that it is searchable and immediately identifiable. Furthermore, it should be machine readable within an electronic file [8]. Product data contains different types of information such as general product information, design information, manufacturer's information, field information or computer-generated information. This type of information is frequently unstructured, available in a wide range of forms, and comes from a large number of sources such as catalogues or websites, which makes it difficult to map all the information[8].

There have been several attempts to develop solutions and optimizing methods to improve the exchange of information of product data [2]. Referring to the level of products, the development of BIM libraries and Product data templates (PDTs) are two of the approaches that have seen improvements in the management of information within the AEC sector [2,11].

A PDT is a standardized data format that defines the characteristics of any product type in such a way that can be linked back to a reliable source, such as product standards that define performance criteria and test

methodologies [8]. The PDT strategy relies on having standard formatted building product data that can be shared and exchanged across different tools at various phases of the project life cycle [12]. A PDT becomes a product data sheet (PDS) when a manufacturer's product information is filled in by the manufacturers [8]. A BIM library is a database composed of BIM objects (the geometry of a product and its characteristics), where the information may be downloaded, modified, and used for design purposes [13].

For several product categories, efforts have been made to standardize (Product) Data Templates (DT). The majority of these works are based on "PPBIM" (prEN ISO 23386/23387), which outlines a methodology and the framework for properties and Data Templates [14]. Dictionaries are one of the most important instruments in methodology. Dictionaries are used to store and retrieve terms, called proprieties, associated to construction products and methods. The purpose of a data dictionary is to standardize proprieties and the ways in which machines understand meaning regardless of semantics [15]. The dictionaries should have the descriptions of the attributes (such as measure, value, unit, etc.) that describe a product's property [8].

EN ISO 23386 and EN ISO 23387 have been created by intergovernmental organizations, approved by several nations, and are accessible for use and consideration globally [15].

The main purpose of the standard ISO 23386 is to establish the rules which define properties used in construction industry and it can be used as methodology for authoring and maintaining these properties [15]. The standard includes a list of attributes which defines properties and groups, definitions and roles, and provides different requirements to establish the management rules to data dictionaries through the mapping process. The standard ISO 23386 is mainly focused on the definition of rules to simplify the communication between different data dictionaries [16].

The aim of ISO 23387 is to support digital processes by creating different structures to group the properties according to ISO 23386 into data structure, namely data template [15]. Furthermore, this standard provides rules and principles for linking data between IFC and data templates within a data dictionary. It also defines a specific data model in order to create machine interpretable data templates for different construction products, such as a product, system, assembly, space, building, etc [16].

Several international and national actions for defining Product Data have been taken in the recent years [2]. In spite of standardization attempts, there is still no universally agreed upon product data standard by which manufacturers may digitally develop and deliver product data [14].

In this context, the issue refers to the absence of a common standardized structure and format when exchanging product data between product data providers (manufacturers or distributors) and product data requesters (architects, constructors or facility managers) within AEC sector [9,10].

The aim of this paper is to investigate the challenges of using product data templates for the exchange of information in the AEC sector. In this study different PDT initiatives will be evaluated and compared in order to get an overview of the exchange of information of product data. In order to respond to the research aims, the following research questions have been formulated:

RQ 1: What are the challenges concerning information exchange of product data today?

RQ 2: How can the use of the current initiatives overcome the challenges identified?

2 Materials/Methods

A qualitative approach was applied to this study and relevant data was collected through literature review and document analysis focused on answering challenges concerning information exchange of product data and to identify and compare different initiatives. The result of the qualitative analysis contributed to answering challenges with information exchange of product data and to analyze and compare current initiatives.

2.1 Data collection

In order to investigate the existing documents and initiatives, document analysis and literature review were conducted. While conducting a study different type of documents can be used as sources of data, for instance conference papers, review papers, book chapters etc. In order to identify relevant scientific papers, the database Scopus and Google Scholar has been used. Different combinations of the keywords as shown in Table 1 have been used to identify and select the papers. As for the literature review which aimed to understand the concept of product data and the integration challenges of it. Firstly, a comprehensive search with different combination of keywords, ("Information model*" OR "Information technolog*" OR "Information management" OR "data management" OR "data exchange"), AND ("Product data" OR "product manufacturer data" OR "product sheet" OR "product template" OR PDT"), AND ("Building information model*" OR "Building information management" OR "BIM technolog*"), in order to identify relevant papers. As for the document analysis, different combination of keywords

including the initiatives ("Construction Operations Building Information Exchange" OR "NBS BIM Library"), ("buildingSMART"), ("linked data" OR "linked datum" OR "resource description framework" OR "semantic description*" OR "semantic web" OR "web ontolog*"), ("Classification system*"), ("Cobuilder Define" OR go-BIM), used to identify relevant papers for the initiatives.

Table 1. Search concepts and synonyms.

Combinations	Concept	Synonyms
C1	Product data template	"Building catalog*" OR "Building compo- nent*" OR "Building prod- uct*" OR "Object type librar*" OR "Online product library" OR "Prod- uct catalog*" OR "Product data" OR "Product manufacturer data" OR "Product template" OR "PDT initiatives"
C2	Information Exchange	"Information model*" OR "Information tech- nolog*" OR "Information management" OR "Data management" OR "Data exchange"
C3	Construction industr*	AEC OR "Building industr*" OR "Construction industr*" OR "Con- struction sector"
C4	BIM	"Building information model*" OR "Building information management" OR "BIM service" OR "BIM technolog*"

2.2 Paper selection process

Table 2 shows the results of conducted document analysis and literature review with the different combinations of keywords and a total of 1710 hits were reported.

Table 2. Combinations and hits of keywords

Combinations	Hits
C1 & C2 & C3	173
C1 & C2 & C3 & C4	111
C1 & C3	476
C1 & C4	446
C1 & C3 & C4	129
C1 & C2 & C4	375

Given the large number of hits, search limitation by year and language were applied. As for the inclusion and exclusion of the papers, the following criteria were stated during the selection:

- Papers that discuss the implementation of product data using different initiatives are to be included.
- Papers that discuss challenges concerning the exchange of information are to be included.
- Papers that do not discuss the challenges concerning information exchange of product data template are to be excluded.

The process started by removing the duplicates and keeping only the papers written between 2012 and 2022 within European countries. Subsequently only the papers written in English were selected, leaving 408 for further investigation. As for the second step in the process, the papers were screened for inclusion by analyzing the titles of the articles. In total 102 papers were left for further analysis. Then the abstracts were read, resulting in 26 articles. 10 additional papers were found by using the platform google scholar. A total of 36 studies were included for the review and the process of the paper selection are presented with PRISMA flow diagram as shown in figure 1.

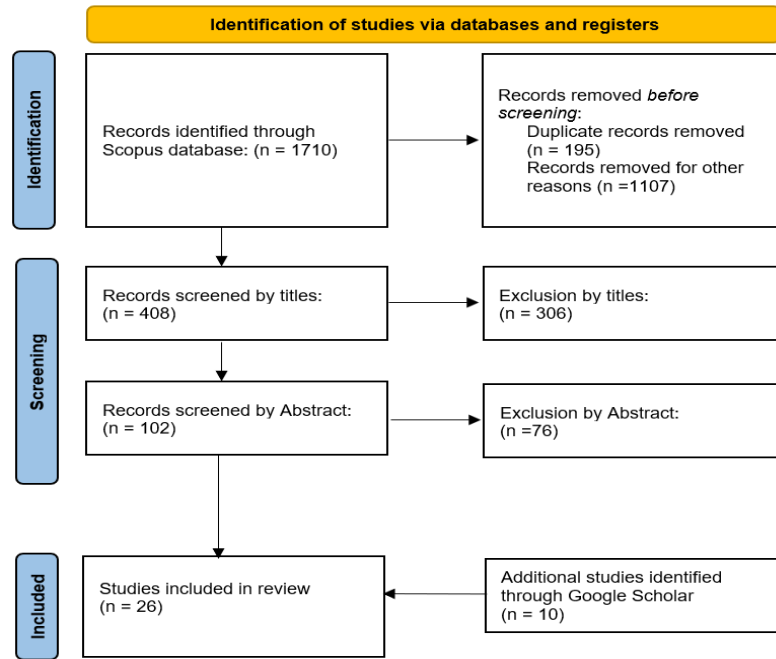


Figure 1. Paper selection process, PRISMA Flow chart from (MJ McKenzie et al, 2020)

3 Result

In this section the results of the literature study and the documents analyzed by the PRISMA flow chart are presented. The literature review identifies the challenges concerning information exchange of product data and identifies some of the current PDT initiatives, while the document analysis analyses the identified initiatives and answers the second research question.

3.1 Challenges concerning information exchange of Product Data

3.1.1 Different types of information establish a product dataset. A comprehensive product dataset includes both 3D geometrical data and non-geometrical data. The majority of the nongeometrical data is found in data sheets and product specification documentations [17]. Manufacturers tend to store and deliver such information in pdf format. Although it is possible to attach product data as pdf files to BIM platforms, machines cannot interpret and compute product data available in such format [18].

3.1.2 During the design, construction, operation, and maintenance stages of a building, several domain specialists are engaged. For the construction elements, each domain expert contributes specific information. De-signers, for example, specify design attributes, schedulers decide construction schedules, and cost estimators offer cost information for building components. Although BIM platforms such as Autodesk Revit offer the capacity to store specific building element attributes or product information, most BIM models do not include a large amount of building-related data such as residual hazards, sustainability performance, life expectancy, and dangers, which are mainly O&M data [18,19].

3.1.3 When it comes to the communication between designers in the construction sector and designers in the manufacturing sector it has been demonstrated that there is a significant difference in how products are defined by each industry [20]. This is mostly because of the enormous number of categories and the work required by manufacturers to construct extensive libraries [21].

3.1.4 Another issue when it comes to the exchange of information refers to the naming structure (ontology) [19]. The absence of standard ontologies has been a major difficulty for the construction sector [22]. The use of separate ontologies for a specific purpose makes combining and reusing them for other purposes extremely challenging [18].

3.1.5 During the design process, a large variety of products might be reviewed, and a final product selection made. However, in order for this to be useful, product information must be automatically obtained. The problem largely includes data storage, querying, and reasoning [22].

3.2 PDT initiatives

Initiatives to develop PDTs have been created across the industry, especially in the UK, including considerable work by companies such as CIBSE, CoBuilder and the National BIM Toolkit [23]. All the templates developed by coBuilder are according to ISO 23387 and ISO 23386 and are based on a coherent data template structure. Cobuilder is one of the first companies to adopt these standards [24]. In the UK, a PDT should be based on the national standard COBie (Construction Operation Building Information Exchange) [21]. COBie is the most widely used open standard for the delivery of building information in use today [25]. It has been mandated in all public UK projects the use of COBie format structure for non-geometric information exchange in open data format [23]. Thus, the product data templates created for the public projects in the UK must contain COBie parameters [24].

As an international approach, the Semantic Web (SW) and Linked Data (LD) technologies have been presented in several papers and current projects as an interoperable and adaptable solution for supplying product information from manufacturers during the design and building stages [18].

The international standard ISO 23386 suggests methodology for managing data properties within interrelated data dictionaries [25]. One such dictionary, and perhaps the most often used, is the buildingSMART Data Dictionary (bsDD) developed by Building Smart [26]. The BSDD is a data dictionary that, in addition to linking definitions to the concepts they are meant to define, links definitions to a particular language in order to increase interoperability in the construction industry [27].

On the other hand, classification systems utilized in information exchange and management plays a key role in handling the communication issues between BIM systems [28]. According to ISO 23387 data templates within a data dictionary enable interoperability between actors and software by using existing classification systems within established work processes [29]. CoClass, one of the 'new age' classification systems, tends to have properties defined for each class level. That means that CoClass has defined property groups at the lowest level class which aim to allow further specification of objects by using their properties [30].

3.3 Analyze the identified PDT initiatives

CoClass:

Coclass is an object-oriented classification system for all types of building environments. It is based on a Swedish adoption and extension of several international standards. Each property in CoClass has a different property code consisting of 4 letters and for each of these properties there is also an attribute name which describes the structured name for application in information models.

One of the standards CoClass is connected to is ISO 19650-1, which provides different principles and concepts to support information management among different phases of the industry. By adopting CoClass, there is a possibility to create different structures based on unique codes, activities and properties which can be shared among the other parties. The codes and structures of CoClass can be reached by different software such as Revit by the accessibility of the API [31].

There are two ways to evaluate information management in CoClass, namely horizontally and vertically evaluation. The vertical evaluation can be achieved by considering from an object-oriented view and datasets. As for the horizontal evaluation, which allows to get an overview and track of every component throughout their life cycle. By using CoClass as a common language and data structure, the advantages are that the information during all phases will be verified and validated throughout whole life cycle [28].

Coclass consists of several tables which can be used in order to classify different components of a product, namely construction entity, functional systems, constructive systems and components. Each of these tables contains several classes which follow one defined division basis and pair different objects with a common property. CoClass manages product data by linking properties to different objects in a product and by connecting them to predefined codes and classifying them according to the tables in CoClass [32]. CoClass contains different descriptions of objects, activities, and properties which makes it accessible to a common language with the same terminologies and concepts. Additionally, CoClass creates stricter IFC structure which is based on ISO 12006-2 [33]. Each class and table in CoClass have the possibility to be referred to as Uniform Resource Locators (URL) which works as linking to CoClass concept in both humanly and machine-readable formats [34].

Semantic web (SW) and Linked Data (LD):

The Semantic Web is a framework for sharing and reusing data across application, business, and community boundaries [35]. It can be used in order to improve the interoperability in the AEC industry thus results in an integrated and successful data exchange environment which provides different ways to describe and understand information in a good manner [18].

The usage of ontologies is the first step in integrating semantic web technologies to create a unified instance of heterogeneous data obtained from multiple manufacturers' systems in order to improve the information exchange processes with the building industry. Ontologies, often known as the semantic web's backbone, play a key role in allowing interoperability and common understanding across diverse applications [36].

Ontologies can be used as a way to describe and model information by using SW languages like Resource Description Framework Schema (RDFS) and Web Ontology Language (OWL) [18].

RDF schema (RDFS) is an RDF vocabulary that describes properties and classes of resources that are RDF-based [37]. Meanwhile, OWL (Web Ontology Language), which is a language that processes web information, further improves the RDFS concept in order to make it possible to create more complex RDF relations. Examples of this relations are cardinality and type restrictions as well as complex class expressions [38].

These two technologies make it possible to model and mix heterogeneous information from several different domains. This is important due to the fact that building product information is heterogeneous, not structured and created in incompatible semantics in AEC industry [19].

An RDF-based knowledge base may be queried using open standards like SPARQL, which also includes various extra constructs for processing results (e.g. limit, order, offset) [39]. By allowing data integration and complicated search queries across several data sources, semantic web technologies have been shown to provide value to BIM. Semantic web technologies have been viewed as a way to promote interoperability in the AEC industry, resulting in a more integrated and successful data interchange environment. Semantic web technologies, in particular, appear to give a mechanism to define information in a way that computers can comprehend. Machines will be able to understand semantic texts and data thanks to the Semantic Web [26].

BuildingSMART:

BuildingSMART is an open neutral and non-for-profit organization with the focus of creating and developing different ways of working for the build asset industry. BuildingSMART has developed several initiatives in order to improve and work more efficiently throughout the entire project and asset lifecycle [38].

The initiatives that have been developed and are still developing by BuildingSMART are, IFC, BuildingSMART Data Dictionary (bsDD), Information Delivery Manual (IDM), Information delivery specification (IDS), BIM Collaboration format (BCF) and Model View Definition (MVD) [40].

When it comes to tools, templates, and functionality of using PDT, BuildingSMART has developed Product Room which enables the use of PDT and other structured content for openBIM. The main key objectives of Product Room are to develop different tools and templates that support bsDD, which makes it easier to accelerate the translation and localization of IFC. However, bsDD is a library of data which allows the users to identify objects and properties which can be used in the Product data Template. BsDD are based on ISO 12006-3 and when it comes to storing properties in product data, bsDD fulfills the requirements of EN ISO 23386 and EN ISO 23387 when it comes to storing properties in PDT [42].

COBie:

Construction Operation Building (COBie) is a non-proprietary data format for delivering asset data from buildings. COBie specifies the format for exchanging mandatory asset information, but it does not specify when and by whom that information must be delivered [42]. It is a national standard, used primary in the UK and the USA, that enable a quick reference to information that is normally concealed deep inside the building project's designs and data, represented through a xml spreadsheet file [43,44] that contains several tabs that list information on the facility's documents [22]. This study focuses on the way COBie is used to exchange information in the UK. Technologically, the easiest way to fulfil the COBie requirements is through the use of Excel, which is familiar to most of the users.

It practically means that the COBie deliverable contains all the non-graphical information in construction projects, and it does not support geometry, but it enables the transmission of alphanumeric information for the operation and maintenance phases [44]. Required data concerning design, without including the geometry, can be mapped by using a plugin installed in Revit, that generates the information into the Excel file.

A database approach for meeting the COBie requirements has been considered as being potentially more manageable since data type can be controlled easier within a database than Excel. The main issue in working with Excel is that the workflow and laborious are error prone [45].

Cobuilder Define:

Cobuilder is a data governance software firm headquartered in Norway that was created in 1997. It specializes in developing PDTs (product data templates) based on industry standards in order to facilitate cooperation and translation of data across several locations and languages. It is tightly linked to the industry's several standards bodies

[46]. To author and manage dictionaries of properties, property set and data templates Cobuilder has developed Cobuilder Define. The users of Cobuilder Define will be able to create different properties uniquely based on name, definition and attaching different standard documents as sources to the credibility of naming and definitions. The users can further develop by managing attributes to all properties and assign further details to the specifics of the property as well as the domain it belongs to [47].

The data templates created within Cobuilder Define can be created based on different types of data structures which can be used in different systems in order to collect and store information and requirements about products. The users have the possibility to create unique and private dictionaries or have the possibility to build on existing dictionaries such as bsDD. The platform of Cobuilder Define can be connected to other dictionaries if this is required [48]. Cobuilders' purpose is to collect product data and use schemas and translation tools to create GUIDs (Global Unique Identifiers) for each product, allowing them to convert from PDF-based digital data to accurate machine-readable data [46].

3.4 How can the use of the current initiatives overcome the challenges identified?

To overcome these challenges, several efforts have been devoted. Several data exchange formats and schemas have been developed in the construction industry with the purpose of representing data and improving communication between different applications [49]. Thus, Product Data Templates have been defined through a number of international and national events as prone to transfer information in a structural and consisted way [44].

Table 3. Challenges and comparison of different initiatives

Challenges	Initiatives				
	Semantic web and linked data	CoClass	Buidling Smart	COBie (the UK national standard)	CoBuilder Define
3.3.1 Exchange of non-geometrical data	HTML and RDF	IFC	IDS	Spread-sheetXML	goBIM
3.3.2 Building data related to O&M	Manu Service ontology	PIM and AIM	MVD	Spreadsheets	Cobuilder Collaborate
3.3.3 Communication between AEC designers and manufacturing designers	Ontologies	ISO 19650- 1	ISO 23386/7	BS 1192-4	ISO 23386/7
3.3.4 Create BIM-related shared knowledge base	ifcOWL	-	ifcOWL	COBieOWL	Cobuilder Define
3.3.5 data storage, querying, and reasoning	PARQL	CoClass API	OpenCDE API	SPARQL(CONSTRUCT)	Cobuilder Define™

3.3.1 Format for exchanging information:

The RDF data model will allow manufacturers to gather real-time and up-to-date information on the technical features of their products and processes. They can distribute this data as a file or a database, both of which can be searched using the SPARQL query language and used by those in the construction business who have access to the data [50]. Humans and robots may both utilize the web as an information resource. Both agents can get resource representations in the format that is most convenient for them, such as HTML for people and RDF for machines [51].

Each project in the construction industry contains a large amount of data information, and these data are difficult to maintain and structure manually. By conducting CoClass, it reduces the unnecessary waste in the process, and it is beneficial when it comes to structure the data and increasing the productivity in the construction industry. When it comes to format for exchange information, the components and properties within CoClass are mapped and structured for IFC according to the international standard ISO 19650-1 [52].

When it comes to information delivery, BuildingSMART are developing a solution namely Information Delivery Specification (IDS) which is a computer interoperable document which defines the requirements of model data based on the exchanged information. IDS consists of different definitions of how different objects, properties, classification needs to be structured, delivered, and exchanged [52]. IDS can be used to define the level of information, which is needed, and it can further be used as a solution when it comes to reliable and predictable data exchange workflow [53].

Data from COBie is interoperable and provided in the form of spreadsheet template (excel spreadsheet) or ifcXML [39], [43]. COBie spreadsheet can be created manually in spreadsheet as well as directly from BIM software by using the STEP Physical File Format (ISO 10303 Part 21) files conforming to the Industry Foundation Class (ISO 16739) COBie Model View Definition [54]. At each level, the COBie standard specifies the transfer of COBie data in spreadsheet XML format [55].

Cobuilder is dedicated to helping producers in sharing their data throughout the supply chain in the forms and languages that their customers need. This implies that they can export their data to IFC, COBie, and digital formats like REVIT, using the provided program for producing PDTs, goBIMG [56]. GoBIM is a tool created by cobuilder, where if the manufacturer has a geometry and their data available separately the clients/users can select the data they require in the format they require it in, and then attach the data to the object in the model [57].

3.3.2 Addition of building-related data related to O&M:

Existing efforts show that in a cloud manufacturing environment, an ontological approach for customizable product definition can provide a reliable method for cross-company and cross-domain data integration. This is because semantics, reusability, and interoperability are all improved. Although these protocols may not be immediately applicable to cloud manufacturing situations, concepts from multiple ISO standards and ontologies can be employed. For instance, the ManuService ontology includes all of the concepts required for cloud-based service supply, such as product specifications, quality limitations, manufacturing processes, organizational information, cost expectations, logistical needs, and so on [58].

The Project Information Model (PIM) and Asset Information Model (AIM) are the two primary results of information management within Coclass. PIM contains details on asset geometry, building part locations, performance specifications for building design, construction techniques, project timeline, costing, installed equipment and component details, and maintenance needs. The AIM content involves information regarding the equipment registers, maintenance cost, records of installation, maintenance dates and so on. Information management with life cycle perspective is defined in two phases, delivery phase which forms PIM, and operational phase that deals with AIM [28].

BuildingSMART has created the MVD approach to make model interchange between apps utilizing the IFC format easier. The definition of the exchange requirements, which are put together using an IFC subset and MVD concepts to satisfy a particular exchange scenario, is the main emphasis of this technique. This data definition is referred to as a subset of the building product model schema that offers a complete illustration of the information concepts required for a specific use case in an AEC/FM process [41].

Spreadsheets are the most used format to deliver COBie data for building rooms, technical equipment and so on [59]. Properly compiled and organized COBie data automatically produces O&M manuals [58].

Cobuilder Collaborate is a Cobuilder platform solution that is unique in its collaborative data collecting and automated data verification approach. It promotes data quality by implementing standards for building product data management and data governance in general. Developers and construction teams can use Cobuilder's Project Data Management Solution 'Collaborate' to create data requirements, gather data directly from the supply chain, automatically validate it against the stated needs, and distribute checked data to Asset Information Models [60].

3.3.3 Communication between AEC designers and manufacturing designers:

By creating ontologies for various domains needed for performance simulations, such as construction product standards and regulations, product specification including product cost information, climate data, etc., SW and LD technologies can be used to close the gap between the real-world product description and their abstraction in BIM tools [17].

ISO 19650 is an international standard which is focused on supporting information management throughout built asset life cycle. This standard contains different series, and ISO 19650-1 is among these series. ISO 19650-1 provides guidelines for a framework when it comes to managing the exchange of information [28]. Each

component in CoClass has predefined code which makes it human- and machine readable. As for the communication between different designers in the construction industry, by taking advantages of CoClass as a common language would be beneficial when it comes to expressing the requirements and at the same time verify the information during all project phases which are some factors accordingly to ISO 19650-1 [28].

EN ISO 23386 and EN ISO 23387 describe a methodology and the framework for properties and Data Templates. One of the main tools in these standards is dictionaries. The dictionaries should contain the definitions of the attributes describing a property of a product and give each attribute a GUID [29]. Cobuilder and Buildingsmart are aligned with these standards [61,62].

BS 1192-4 is a British standard that has created significant improvement in terms of establishing uniform policies and procedures for COBie data collection. For designers putting up their BIM models, having a common code of conduct is crucial to guarantee that they properly populate Excel data sheets [63].

3.3.4 Create BIM-related shared knowledge base

Several ideas for converting an EXPRESS schema to an OWL ontology have been presented in recent years [53]. The ifcOWL is an open ontology for expressing building data in the RDF format. It also speeds up the processing of BIM data in a variety of engineering applications using semantic web and linked data technologies [64]. The computer automatically enables reasoning about data from numerous data sources using the ontology, which represents diverse ideas and their relationships, in order to change relevant data or locate new information [65], ifcOWL is developed and standardized by buildingSMART [66].

COBie data eliminates the expense of paper file reproduction, delivers electronic handover information using current software, facilitates collaboration and integration of all project participants, and enhances the role of construction submittals in construction handover [48].

There are various advantages of utilizing COBieOWL to represent building models in BIM. It enables the application of logical rules to respond to general questions, infer new information from existing data, and enhance the underlying model without compromising data interoperability [67].

Several attempts have been made to standardize product manufacturer's specification forms using product data template [26]. PDTs are responsible for supplying COBie-compliant data and complete manufacturer data for a given product [68].

Cobuilder created a software solution based on principles and features from bSDD and distributed it as a Software Service. End-users can establish a Context with Cobuilder DefineTM. A context, as specified by the bSDD Content Guidelines, allows businesses to form associations between idea types that make up ontologies that specify various functionalities of buildings, infrastructure, goods, systems, and rooms in the construction sector [69].

3.3.5 data storage, querying, and reasoning:

Construction material providers would be able to give material information as knowledge bases that could be searched and queried by distant computers if a common material ontology is developed [67]. Manufacturers will be able to use the RDF data model to record real-time and up-to-date information on the technical features of their processes or products. They can publish this data as a file or a database, both of which can be searched using the SPARQL query language and accessed by those in the construction sector [22].

The product data in CoClass is according to ETIM, which is a format to share and exchange data based on taxonomic identification. The concept of taxonomic identification is a hierarchical structure which consists of sets and subsets, these sets and subsets are based on properties of a product [50]. When it comes to CoClass API allows the users to create their own data structure based on various tables within CoClass [30].

Open Common Data Environment Application programming interface (opendCDE API) is a standard API used by buildingSMART to exchange information between online connected data environments. The users of opendCDE API interact with a web page directly, such as bsDD [68].

Storing COBie data as an OWL-based ontology allows formal query languages like SPARQL to be used to query building information. When just spreadsheet software (such as Excel) is used to manipulate building data, this is not feasible. Building views, such as the COBieOWL sub-graph, may also be extracted from the filled COBieOWL ontology using SPARQL features like CONSTRUCT [32].

Users of the API v1 of goBIM will be able to combine structured data with external 3D authoring tools and numerous plugins much more quickly and scalable. This translates to improved performance and a higher volume of queries. These structured data connectors provide the benefit of a consistent data flow to external client-facing software, which is becoming increasingly significant as a marketing channel for the manufacturer [69].

4 Discussion

In this study a literature review was conducted to identify the challenges that occur when product data are exchanged between AEC parts as well as to identify relevant initiatives that are currently used for the exchange of product data. The literature review identified five challenges that arise when exchanging product data. Furthermore, five different initiatives were identified as being among the most used and the most referred to in the AEC industry for exchanging product data [14,23,25,31].

The data collected from the literature review indicates that the product data templates are especially helpful for the manufacturers and their use brings multiple benefits in the communication between manufacturing and construction industry [41,2,9]. A document analysis was conducted to identify how each of the five initiatives can handle the identified challenges.

Format for exchanging information:

The format for non-geometrical data is one of the main challenges identified in this study. Most of the manufacturers deliver this type of information in pdf format, which is not machine readable. Therefore, building designers need to introduce this information into their tool BIM manually.[10]. Different approaches such the use of RDF, IDS or xml spreadsheets have been identified in this study as possible solutions in solving this issue.

Addition of building-related data related to O&M:

Another challenge found in this study highlights the differences between how the manufacturers and building designers defined product data. European standards such as ISO 23386 or 23387 have been created to create a common way to create product data.

Communication between AEC designers and manufacturing designers:

Although the Operation and Maintenance is the longest and most expensive phase during the lifecycle of a construction [70]. An important amount of building-related data is not included in the exchanged product data [17]. Different approaches such as Manu Service ontology, PIM and AIM or MVD were found in this study for adding Operation and Maintenance data in the exchange process.

Create BIM-related shared knowledge base:

BIM-related shared knowledge base has been identified as being an issue when creating product data. The use of ontologies has been seen as a solution since an ontology provides a shared vocabulary, which can be used to model a domain [35]. The five initiatives will give the opportunity to improve the exchange of information by creating common ontologies for product data that can be accessed by both manufacturers and AEC designers through online databases or libraries [16]. Different alternatives such as ifcOWL, COBieOWL and Cobuilder DefineTM were identified as attempts to overcome the issues related to creating BIM related-shared knowledge base [32,21,40].

Data storage, querying, and reasoning:

It's also important to mention that ontologies can be used as a foundation for integrating information sources and as a query model for information sources as they evolve. The capacity to link product manufacturers' data with building data is an important use of information source integration that has been proved in various research [19,16].

5 Conclusions

The result revealed that the use of the five initiatives can have a positive impact on the creation and exchange of product data. The identified challenges can be solved to a certain extent by the use of the five mentioned initiatives. When it comes to the first challenge connected to the exchange of non-geometrical data in a machine-readable way, it can be ensured by using the formats mentioned in the result part. Among those RDF format seems to be a promising approach since the data can be stored as files or databases and afterwards searched using the SPARQL query language, becoming in this way reusable for other projects. The Operation and Maintenance data can be included in the exchange of information of product data by using the methods specified in the result part.

Regarding the challenge of creation of BIM-related shared knowledge base, the use of ontologies was identified as one of the solutions for creating a common way to define product data. Ontologies are helpful for formalizing knowledge representation and building shared knowledge bases from which information can be automatically extracted, enabling manufacturers to generate ideas for new products. In order to overcome the issue regarding the communication between manufacturers and designers in the AEC sector standards such ISO 23386, ISO 23887, ISO 19650- 1 or BS 1192-4 (British standard) have been created.

Suggestions for further research could be to conduct these initiatives in some case study/project in the construction industry, with the focus of exchange of information for different components. Alternatively, undergoing a case study and comparing the outcomes.

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