PAPER

Product Data Management for Sustainability: An Interoperable Approach for Sharing Product Data in a BIM Environment

View the article online for updates and enhancements.

IOP ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

Product Data Management for Sustainability: An Interoperable Approach for Sharing Product Data in a BIM Environment

M N Lucky[1, *], D Pasini[1] and S Lupica Spagnolo[1]

[1] Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano, Via Ponzio 31, Milano, 20133, Italy

*meherunnesa.lucky@polimi.it

Abstract. Several research and development projects in the construction industry show the need of coherent product libraries to ease information sharing among involved stakeholders. In these projects, designers are often the main actors addressed in the creation and fruition of such product libraries. Besides designers, the presented research addresses the needs of manufacturers, clients and users. To achieve this coherence of product libraries, there are issues such as standardisation of product data templates, numerosity and heterogeneity of products categories, interoperability in sharing data and scarce thrust of manufacturers in developing extensive libraries. Considering the European directives and regulations, manufacturers are required to provide detailed and structured information about their products, e.g. in the form of CE marks and/or Declaration of Performance (DOP). Hence, developing data structures that are already compliant with CE marks and DOPs information requirements improves manufacturers' capability of promoting their products. Moreover, this makes clients and users aware of provided information, giving them the possibility of comparing performances of different products and consequently choosing only those products that fit better their needs. The aim of the here described research activity is twofold: defining a common data structure for product data and using existing technologies to share these data. The presented research proposes a conceptual model for providing such structure for product data to facilitate Product Data Management (PDM). This structure relies on standardised Product Data Templates (PDT) and Product Data Sheets (PDS) for enhancing the sharing process within to a Building Information Modelling (BIM) environment. Moreover, an eXtensible Markup Language (XML) structure has been developed for transferring product data allowing a machine-readable exchange of information. The result of the described research is the definition of information requirements for developing an online product library that permits a user-friendly consultation by stakeholders and an automated extraction of data by software.

1. Introduction

While designing, constructing or operating a building, several construction products are adopted and different activities on them are required (e.g. for their installation, for their maintenance, for their disposal). For performing these activities, it is essential to deeply know each aspect (e.g. performance, dimension, composition, environmental impact) of the specific considered product. Hence, for tracking a product without information losses, it is required a complete description of its characteristics and an uninterrupted flow of product data along the building life cycle. However, several obstacles are still affecting information exchange processes, making them unreliable, redundant or uncomplete, and therefore not efficient. These obstacles are often related to difficulties in accessing and comparing data

because of the lack of a standardised and well defined structure for collecting information, but also due to difficulties in sharing data because of interoperability issues. Moreover, manufacturers are often discouraged in providing information about their products considering the vast number of categories and the efforts for developing extensive libraries.

For overcoming existing barriers, the presented research aims at identifying requirements for the development of a BIM library, relying on:

- the definition of a common data structure for product data, i.e. compliant with national and European directives, regulations and standards;
- the use of existing technologies to share these data, i.e. adopting XML.

2. Literature Review

This section provides the background information and research works related to BIM, product library, product data management and interoperability.

2.1. BIM

BIM is the process of designing, constructing or operating a building or infrastructure asset using electronic object orientated information [1]. This object orientated information refers not only to the geometric content, but also to the information needs for specific purposes [2]. These information needs can be different according to the stakeholders who use these data and according to the stage of the building process when the information is used or required [3].

Within the presented research, the requirements of manufacturers are addressed. Hence, while defining the informative content for describing products, the needs outlined since the design stage are taken into account.

For implementing BIM-based processes, digital solutions are often adopted for managing information in an ordered structure. Several efforts have been devoted for developing solutions and optimising methods for sharing information about buildings. Referring to the level of products, two improvements in the management of information are represented by the development of BIM libraries [4][5][6] and the definition of Product Data Templates (PDTs) [7][8][9][10]. BIM libraries are tools published on the web for hosting objects describing products; PDTs are structures for defining standardised data content, listing attributes required for describing objects from a geometrical and alpha-numerical point of view.

Generally, these two aspects are considered separately: on the market, several BIM libraries have been published without a clear and consistent structure for hosting information and, vice versa, PDTs have been developed without considering attributes describing objects in existing BIM libraries.

2.2. Product Library

Standardized information needs to be provided in a structured and consistent form. Within this context, several international and national activities have been developed for defining Product Data Templates (PDTs) and Product Data Sheets (PDSs) [11].

PDTs describe the data fields required to define products used during design, construction, operation and management. These data fields are sets of attributes and parameters for describing products. PDTs are presented in a structured tabular format using standardized fields to accurately describe objects, allowing like-for-like comparisons and informing model creation.

When populated with specific data of a product, PDTs become PDSs to be made available to different stakeholders (such as designers, installers or facility managers) to properly understand, check and take into consideration all the useful properties of a product. Nowadays, a series of standards is under development for covering the methodology for creating PDTs, especially with the efforts of CEN and ISO standardization bodies.

A PDS will be generally completed by a manufacturer/supplier. Considering the European directives and regulations, manufacturers are required to provide detailed and structured information about their products, e.g. in the form of CE marks and/or Declaration of Performance (DOP) [12]. Hence,

structuring information in consistent, detailed and coherent databases allow manufacturers to cope with their duty in accomplishing regulation and directives.

However, off the shelf BIM libraries offer different solutions, but their structure is often not compliant with existing regulations. Analysing the description offered for windows on three off the shelf BIM libraries, it is evident the lack of a complete description of the published products. Indeed, in two cases, no performances are listed, while in one case only the main properties are described (but there is not a complete set of information, as required by the standard EN 14351 [13]).

On the other side, among the main functionalities offered by the analysed BIM libraries, it is worth to outline the comparison among products, the indication of area of trademark or the direct link to the website of the manufacturer.

2.3. Product Data Management

PDM represents a solution for exchanging structured, consistent, detailed and coherent product data [14] and establishing links and relations between object attributes and properties [15]. Hence, PDM allows describing product life cycle properties.

However, while successful implementations of PDM is recognised in other industries, e.g. the mechanical engineering industry [16], several difficulties arise in the construction sector due to the differences and variables that have to be considered in each building process. Indeed, the advanced design process in other industries heeds the use and reuse of components during the design process, designed and made for mass-production [17]. Within this context, BIM libraries can be developed considering features for reuse and configuration of components, either from generic or manufacturer-specific libraries [18].

2.4. Interoperability

To facilitate collaboration in the AEC industry, for decades it has been a common practice to provide one-to-one interaction between heterogeneous software applications. However, this approach provides inefficient collaboration due to numerous data interfaces and different data formats. With the exploitation of Building Information Modelling (BIM), the Industry Foundation Classes (IFC) have been used for exchanging data with the expectation of fostering interoperability among heterogeneous BIM software. Despite this, there are some issues regarding different interpretation techniques of these heterogeneous software tools [19], leading to inconsistent data models. Several researches have been conducted to solve the interoperability issues [20][21][22][23], suggesting a common IFC-based BIM platform and different IFC-based formats such as IFCXML, IFCOWL etc. To support data interoperability and flexible data exchange, it has been a trend for the information exchange applications in the AEC industry to use semantic web technologies or tools from the Linked Open Data (LOD) domain. To connect the well-established IFC standard with the semantic web technology, ifcOWL has been introduced. ifcOWL is represented by an agreed Web Ontology Language (OWL) ontology [24][25].

IFC-based formats are more focused on models of construction objects such as wall, building, apartments etc. While this paper focuses on the Product data such as properties of windows, cements, plasters etc., a common and reliable format (i.e. XML) in the Software development field has been used for exchanging product data information.

Software developers often face the problem of having systems and databases containing data in incompatible formats. Thus, they lack of having a reliable format for exchanging data among incompatible systems over the internet. XML is the Extensible Markup Language, that provides rules for creating, structuring, and encoding documents. XML can be used to store data in files or databases. It is possible to write applications to store and recover information from the XML documents, and write generic applications to display certain types of data. XML means a language-agnostic programming - all of the major programming languages provide mechanisms for reading and writing XML documents, either as part of the core or in external libraries. Moreover, the strict definition of the Markup-Language resulted in a variety of tools and every XML instance (given it is well-formed) can be processed by of-the-shelf tools. Converting to XML data reduces the complexity of incompatible formats, and also

creates data that are easy to read by any kind of application. In this way, it allows communication between applications thus foster interoperability.

3. Structure of Product Data
This section is intended to provide a description of the structure of the product data through the process, performance and sustainability related information, that helps to understand the structure of the information that has been considered in the presented work.

3.1. Process
In the domain of Construction Engineering, a technical datasheet is usually adopted to describe technical characteristics of an item or product. It is published by manufacturers to help people in choosing products or using them in the right way. Usually, a technical sheet may offer an average value, a typical value, a typical range, engineering tolerances, or a nominal value. For some of the characteristics of the specific product, descriptions and reference standards (if there are any) are represented. For other characteristics the value, unit of measure and dependencies on different standards (if there are any) are specified in the technical sheet. By contrast, a technical specification is an explicit set of requirements to be satisfied by a material, product, or service which is termed as "Norm".

Product libraries gather product-related data, listed in a set of attributes. The presented research defines groups of attributes for describing products through information related to:
- the manufacturer who is responsible for the description of the product;
- the product factory where the product is realized;
- the main information required for identifying a product;
- the description of performances and characteristic of the specific product;
- conditions for transport and commercial information.

All the groups of attributes are part of a technical datasheet.

For creating a consistent product library, the presented research relies on:
- the definition of a first set of attributes compliant with standards and European directives (e.g. with reference to CE marks and DOP);
- the selection among different attributes for defining different levels of information according to each stage of the building process.

3.2. Performances – related information
For making the trade of products possible within the European community, some information and documents are strictly required to manufacturers. In detail, construction products can be commercialized if combined with CE mark and DOP.

Hence, as great efforts are required to manufacturers for creating massive BIM libraries for describing their products, a standardised structure collecting all the performances for their specific products can be helpful. For collecting this kind of information, a standardized structure could be organized according to the information defined in Construction Products Regulation EU 2011/305 [12] and in Commission Delegated Regulation (EU) 574/2014 [26].

Furthermore, for describing products according to their performances, harmonised standards could be used as sources for essential characteristics and properties that are strictly required for the CE-marking of a product. As performances-related information could be ordinately stored in a digital environment, a solution for a digital CE marking for construction products could be set.

3.3. Sustainability – related information
Besides information concerning performances, the increasing attention towards sustainability is enriching the description of products with environmental aspects. For defining a standardised structure for collecting sustainability-related information, the research identifies European and national standards as possible sources of attributes.

A list of indicators for sustainability is provided by EN 15804 [27]. Furthermore, according to the Italian regulation [28], additional information can describe products in relation to minimum criteria for environmental inspections (e.g. with reference to the content of materials to be reused).

4. Conversion of Product Data collection into a Digital Product Library

The discussion from the *Literature Review* presented in section 2 shows the need to develop a digital product library for the construction products. To accomplish this purpose, the presented work analyses the complex structure of the construction product data and a conceptual model together with a meta-model have been developed in the design phase. These developed models have been followed during the implementation of the product library.

4.1. Conceptual Model

To realize a phenomenon, there is the need to capture ideas in a specific problem domain. A conceptual model is a representation of a system that uses concepts and ideas to form a representation.

In the overall system development along the life cycle, the conceptual model plays an important role by providing a point of reference for system designers to extract system specifications, facilitating an efficient conveyance of system details between stakeholders, enhancing an individual's understanding of the representative system and documenting the system for future reference to provide a means for collaboration [29].

There are various ways to describe a conceptual model such as UML, ORM, Entity Relationship Modelling etc. The work presented in this paper adopted the Entity-Relationship Modelling to show the conceptual model of the product data by using Entity-Relationship (ER) notation, in which entities represent concepts, while cardinality and optionality represent relationships between concepts [30]. To form this system process, the relationships are combined with the entities, then attributes are added to further describe the process.

For describing a construction product (i.e. in compliance with UNI 11337), different entities have been identified in the conceptual model. The presented work considers that the *Entity* is an object with an independent existence (e.g. Manufacturer, Technical sheet etc.), which is represented by a set of *Attributes* (its descriptive properties, e.g. ID, Name, Address etc.) and the *Attribute values* that describe each entity become a major part of the data eventually stored in a Product data library. The developed conceptual model (figure 1) has the following entities:

- Technical Sheet;
- Manufacturer;
- Product Factory;
- Product Identification Information, consisting of 3 sub entities:
  - Characteristics for CE Marking / Referenced Norm;
  - Fixed characteristics;
  - Variable characteristics;
- Transport;
- Commercial Information;
- Sustainability.

As the manufacturer can input new characteristics on the technical datasheet of the specific product, this part has been generalized by introducing the entity "Row" which means a row that has at least 1 to n "Sub row" and at least 1 to n "Column". The same method has been adopted for managing attachments, introducing the entity "Attachment" and providing users the possibility to specify different properties, as the type and the name of the attached file.
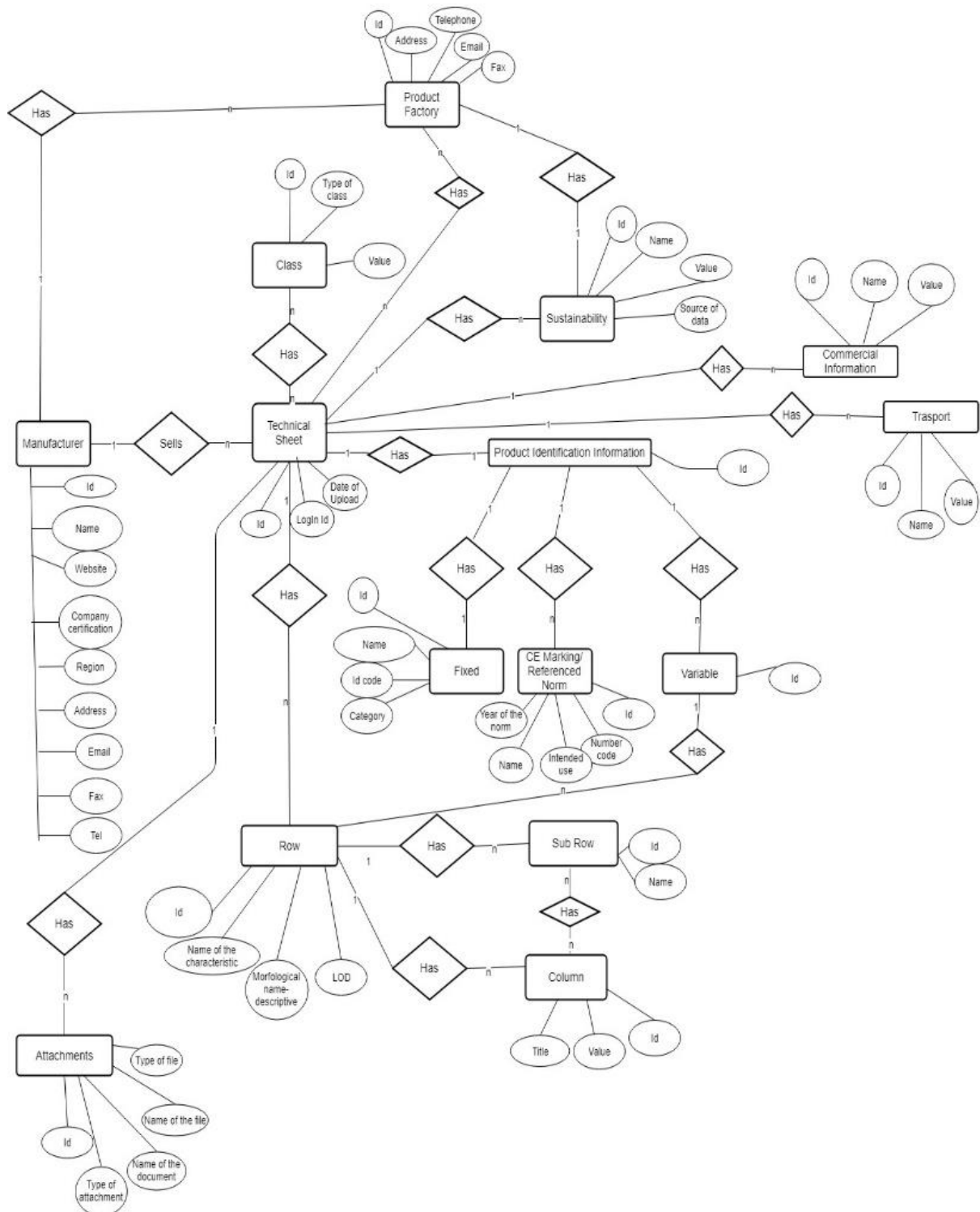
Figure 1. Conceptual model of a construction product

Moreover, the presented conceptual model (figure 1), incorporates representations of both behaviour and data at the same time by illustrating 1-to-1, 1-to-many, and many-to-many relationships within the system. Indeed, entities are related through different relationships. Particularly:

- technical datasheets are sold by manufacturers, that have product factory;
- technical datasheets describe product identification information;

- technical datasheets are composed of different sections, represented by different entities, as sustainability, commercial information, transport.

Relationships allow also to describe different aspects of a product. As an example, by linking product factory and sustainability through a relation, it is possible to declare different environmental indicators for the same product when it is produced in different factories.

4.2. Conceptual Meta-model

This work also emphasizes on the meta-modelling approach [31] to provide an explicit description of how the domain specific model or conceptual model for the product data has been built. On one hand, the meta-model provides the abstraction of the model by highlighting properties of the model itself. On the other hand, it facilitates applicable and useful construction of models by providing constructs and rules. For example, in figure 2, to represent the values of different characteristics of the product data, the entity Value has been explicitly defined by 4 types of data, such as List, Range, Text, Single number.

To explicitly define the constructs and rules of the properties presented in the conceptual model, a meta-model has been developed as represented in figure 2. This meta-model considers the characteristics specified in the technical sheet of a specific product. The characteristics represented in the technical sheet are:

- Geometry and Form
- Dimension
- Visual and constructive aspects
- Chemical Physics-Qualitative
- Chemical Physics-Quantitative
- Tolerances
- Main components of the product
- Declared performances

In the meta model, the consideration has been taken to the fact that the producer can insert different types of values for each of the above-mentioned characteristics. The value can be a list, range, text or single number. Moreover, other considerations have been taken following the real-world phenomena, such as a producer can insert 1 to n characteristics, each category of the specific product can have n typology and each typology can have 0 to n characteristics. Also, one category of a product may have no typology but it can have 0 to n characteristics. In addition, product, typology and characteristic can have up to n reference norm or marking CE.

4.3. XML Structure

As one of the aims of this work is to share the product data automatically, an eXtensible Markup Language (XML) structure has been developed in order to allow a machine-readable exchange of information. The developed of the XML structure follows the structure of the Technical sheet and Declaration of Performances (DOP) of a construction product. An XML Schema Definition (XSD) has been developed for formally describing the elements in the developed XML document for the construction product.

Both HTML and XML are markup languages: XML is used to describe data focusing on what the data represent, while HTML is used to display data focusing on the way data look. XML can store data separately from HTML or inside the HTML documents. It is possible to design a HTML form structure so that it embeds all data content and structure of some XML data such that the XML data are displayed in the fields of the HTML form.
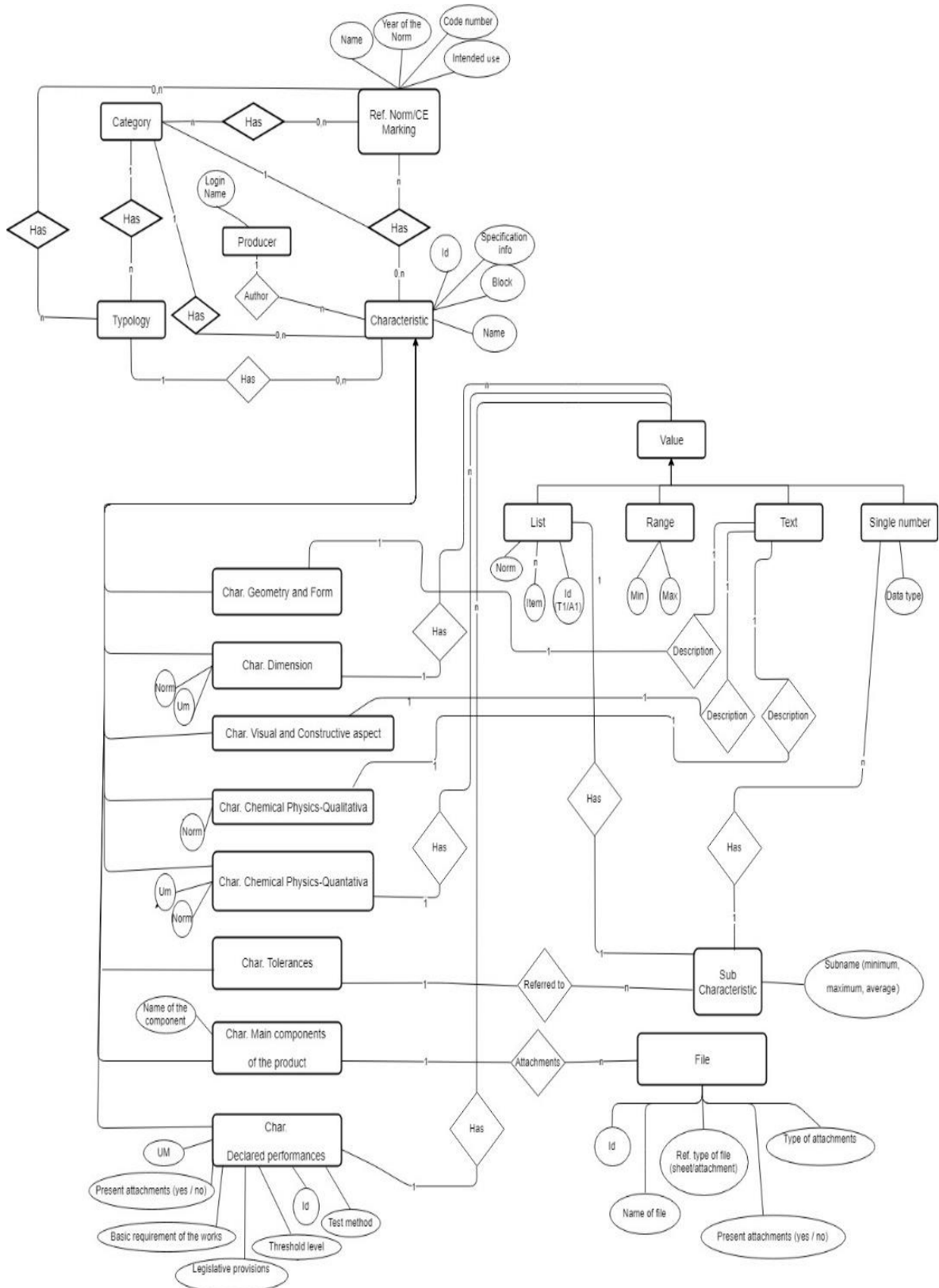
Figure 2. Conceptual meta-model of a construction product.

To facilitate the manufacturer in inserting different characteristics and related attribute values, an HTML form (figure 3) has been developed. This has been possible by using the developed XSD and XML file in an HTML form generator editor[1]. In this way, the HTML form and the XML data are logically equivalent in terms of the contents of the XML data.

Figure 3. XML structure in HTML form

After the manufacturer enters the values in the attribute fields, this editor can create the XML document with the inserted values as depicted in figure 4 and can be saved for sharing with other applications.

```
 1 ▾  <Declared_performances>
 2 ▾      <Essential_characteristic>Thermal properties
 3 ▾        <Requirement_clauses>
 4 ▾          <Requirement_clause>
 5              <name>Thermal transmittance</name>
 6              <value>0.7</value>
 7              <unit>W/m2K</unit>
 8              <referenced_norm>EN 10077-2</referenced_norm>
 9            </Requirement_clause>
10 ▾          <Requirement_clause>
11              <name>g value</name>
12              <value>0.53</value>
13              <unit>-</unit>
14              <referenced_norm>EN 14351-1</referenced_norm>
15            </Requirement_clause>
16          </Requirement_clauses>
```

Figure 4. XML structure

---

[1] http://www.datamech.com/XMLForm/

5. Conclusions

Defining a common data structure for describing products and using existing technologies to share product-related data allows to define the requirements for developing an online library. Accessing information stored in such a consistent library brings benefits to:

- manufacturers, who have the possibility to share information about their products and promote their objects, even if a great effort is required to manufacturers for creating "complete" objects, rich of information;
- clients and users, who have the possibility to access information about different products becoming aware of provided information.
- Identified requirements for sharing information about construction products are:
- performance-related information and sustainability-related information:
- interoperable exchange of information;
- standardized format always updated.

The described research activity shows the definition of requirements for developing an online product library that permits a user-friendly consultation by stakeholders and an automated extraction of data by software.

References

[1]   BSI PAS 1192-2 2014 Specification for information management for the capital/delivery phase of construction projects using building information modelling
[2]   Eastman C, Teicholz P, Sacks R, Liston K 2011 *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors* (John Wiley & Sons)
[3]   Mayouf M, Cox S, Boyd D 2014 Exploring different information needs in Building Information Modelling (BIM) using Soft Systems. *Proc. International Data and Information Management Conference*
[4]   Pasini D, Caffi V, Daniotti B, Spagnolo SL and Pavan A 2017 The INNOVance BIM library Approach, *Innovative Infrastructure Solutions* **2**(1) p15
[5]   Duddy K, Beazley S, Drogemuller R and Kiegeland J 2013 A platform – independent product library for BIM. *Proc. the 30th CIB W78 International Conference(Beijing, China)* WQBook (ed Ma Z, Zhang J, et al)
[6]   Kim JB, Jeong W, Clayton MJ, Haberl JS and Yan W2015 Developing a physical BIM library for Building thermal energy simulation *Automation in construction* vol **50** pp16-28
[7]   Gudnason G and Pauwels P 2016 SemCat: Publishing and Accessing Building Product Information as Linked Data *Proc. 11th European Conference on Product & Process Modelling (ECPPM)* pp. 659-666
[8]   *What is a product data template? Advancing the industry through standards* Cobuilder [Online] available: https://cobuilder.com/en/what-is-a-product-data-template/#what-is-a-pdt
[9]   *Product Data Template* CIBSE [Online] available: https://www.cibse.org/knowledge/bim-building-information-modelling/product-data-templates
[10]   *Product data templates for manufacturers* NBS BIM Toolkit [Online] available: https://toolkit.thenbs.com/articles/pdts
[11]   Lupica Spagnolo S, Pasini D, Daniotti B, Pavan A, Mazza N, Valra A 2017 A BIM-based platform for managing the whole building life cycle. *Proc. ISTeA 2017 conference (Florence, Italy)* Reshaping the construction industry (ed Ciribini A, Alaimo G, et al) pp. 112-121
[12]   European Commission, 2011 Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC
[13]   EN 14351-1:2006+A2:2016 2016 Windows and doors - Product standard, performance characteristics - Part 1: Windows and external pedestrian doorsets
[14]   Eynard B, Gallet T, Nowak P and Roucoules L 2004 UML based specifications of PDM product structure and workflow *Computers in industry* vol **55**(3) pp301-16
[15]   Gu N and London K 2010 Understanding and facilitating BIM adoption in the AEC industry

Automation in construction vol **19**(8) pp988-99

[16] Huhtala M, Lohtander M and Varis J 2013 The role of Product Data Management (PDM) in engineering design and the key differences between PDM and Product Lifecycle Management (PLM) *Proc. The 1st PDM forum for Finland-Russia collaboration* (ed Merja Huhtala, Harri Eskelinen) p 99

[17] Palos S, Kiviniemi A and Kuisto J 2014 Future perspectives on product data management in building information modeling *Construction Innovation* vol **14** (1) pp 52-68

[18] Fortineau V, Paviot T and Lamouri S 2019 Automated business rules and requirements to enrich product-centric information *Computers in Industry* vol **104** pp 22-33

[19] Tarandi V and Vahenurm C 2016 BIM Product Libraries for Life Cycle Support *Proc. CIB World Building Congress 2016* volume 3 pp 153-164

[20] Lee YC, Eastman CM and Solihin W 2018 Logic for ensuring the data exchange integrity of building information models. *Automation in Construction* 1;**85**:249-262

[21] Lee YC, Eastman CM and Solihin W 2016 An ontology-based approach for developing data exchange requirements and model views of building information modeling *Advanced Engineering Informatics* vol **30**(3) pp 354-367

[22] Lai H and Deng X 2018 Interoperability analysis of IFC-based data exchange between heterogeneous BIM software *Journal of Civil Engineering and Management* vol **24**(7) pp 537-555

[23] Masior J 2019 Design requirements on the integration of technology databases *Measuring Business Excellence*

[24] Pauwels P and Terkaj W 2016 EXPRESS to OWL for construction industry: Towards a recommendable and usable ifcOWL ontology *Automation in Construction* vol **63** pp100-133

[25] Godager B 2018 Critical review of the integration of BIM to semantic web technology *Proc. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* vol **XLII** (4) pp 233-240

[26] Commission Delegated Regulation (EU) No 574/2014, 2014 *amending Annex III to Regulation (EU) No 305/2011 of the European Parliament and of the Council on the model to be used for drawing up a declaration of performance on construction products*

[27] EN 15804:2012+A1:2013 2013 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products

[28] Ministero dell'ambiente e della tutela del territorio e del mare 2017 Decreto 11 ottobre 2017 – Criteri ambientali minimi per l'affidamento di servizi di progettazione e lavori per la nuova costruzione, ristrutturazione e manutenzione di edifici pubblici (Decree of January 11, 2017– Minimum Environmental Criteria for the assignment of design services and works for the new construction, renovation and maintenance of public buildings)

[29] Kung CH and Soelvberg A 1986 Activity modeling and behavior modeling. *InProc. IFIP WG 8.1 working conference on Information systems design methodologies: improving the practice* (North-Holland Publishing Co.) pp. 145-171

[30] Embley DW and Thalheim B 2012 *Handbook of conceptual modeling: theory, practice, and research challenges* (Springer Science & Business Media)

[31] Van Gigch JP 2013 *System design modeling and metamodeling* (Springer Science & Business Media)