An Italian BIM-based portal to support collaborative design and construction

A case study on an enhanced use of information relying on a classification system and computational technical datasheets

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A great amount of information needs to be managed along the building life cycle in order to fulfil building codes, standards and regulations, client and user requirements. However, a lack of transparency in the information management and a lack of communication between stakeholders often bring to the adoption of solutions in the design process that do not meet the original requirements. Therefore, an ordered structure for information improves its storage, enhancing its visibility, traceability, usability and re-usability. In addition, for public works contracts and design contests, the use of specific electronic tools, such as building information electronic modelling tools, is often required for the information management. The paper presents the efforts devoted within the Italian building sector for proposing a standardized structure and developing tools for collecting, sharing and exchanging information between stakeholders involved in different stages of the building process. An enhanced use of information relying on the adoption of the standardized structure of information is presented, proposing dedicated applications for automating the process of information fruition.

Keywords: *BIM-based portal, Standardized information, Computational technical datasheets*

INTRODUCTION

The fulfilment of building codes, of standards and regulations, of clients' and users' requirements also depends on an improved management of the great amount of information produced along the building life cycle. Therefore, an ordered structure for information is needed to store and use all the required data. This is even truer nowadays, when data and information tend to dissolve in a digital ecosystem more and more volatile.

In fact, for enhancing visibility and traceability of information, it is essential to adequately manage requirements from the Strategic Definition stage to the In Use stage [1]. A lack of transparency in the information management and a lack of communication between stakeholders often bring to the adoption of solutions in the design process that do not meet the original requirements (Jallow et al. 2008; Kiviniemi 2005). Therefore, the process results in design iterations, rework, and, consequently, low efficiency (Jansson et al. 2013). Furthermore, the operational islands between different disciplines cause ineffective coordination (Schade et al. 2011). All those barriers affect the fulfilment of the multiple requirements, impacting in turn on the performance of buildings.

In addition, for public works contracts and design contests, there is an increasing demand in the use of specific electronic tools, such as building information electronic modelling tools [2, 3].Therefore, great efforts have been devoted by corporations, organizations, and working groups at different levels, dealing with BIM-related issues. That highlights another dimension of the information management, that is the usability and re-usability of data and information in order to create value in the process.

The paper focuses on some preliminary efforts within the Italian building sector for proposing a standardized structure and developing tools for collecting, sharing and exchanging information between stakeholders involved in different stages of the building process.

The paper presents the main aspects emerged during the development of: a) a standardized structure for collecting, sharing and exchanging information concerning technological solutions; and b) a national database for the fruition of information from different stakeholders through a web-portal. Furthermore, usability of the information is explored and compared to what is provided by the existing market through digital-based applications. In fact, an enhanced use of information, relying on the adoption of the standardized data structure, is presented for the assessment of environmental sustainability. Dedicated applications are presented in the paper for automating the process of information fruition, especially establishing a link between information in the structured database and information provided by BIModels. Information is then adopted within algorithms for the estimation of selected indicators.

APPROACH

An analysis of the Italian building sector has been performed for identifying main criticalities to be solved and essential information to be collected, shared and exchanged. Therefore, several stakeholders (e.g., universities, research centres, construction companies, designers, associations and federations of product manufacturers, software houses) have been involved during the research for identifying informational requirements and information technologies to be adopted for the definition of a standardized structure and for the fruition of information through a web-portal. The points of view of different actors have been analysed through the establishment of working groups (Figure 1) at the Italian standardization organization (UNI) and through the participation at a national research project (INNOVance project).

After the definition of the information content and structure, different applications have been explored in order to demonstrate how the developed structure affects the current use of information in the construction sector, using information for the assessment of environmental impacts applying a LCA approach.

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The collaboration between several stakeholders through the Italian standardization organization and the involvement of different teams in INNOVance project result in the definition of criteria for the unification of terminology, organization, collection and exchange of information for the construction sector.

Figure 1
WG 9 "Codification criteria for construction products and processes"

UNI 11337	Topic	Status
Part 1	Models and informative objects for products and processes	UNI 11337-1
Part 2	Criteria for the classification of models, products and processes	pr UNI 11337-2
Part 3	Models for collecting, organizing and storing technical information about construction products (digital datasheets for products and processes)	pr UNI 11337-3
Part 4	Evolution and development of information for models and objects	UNI 11337-4
Part 5	Information flows in digital processes	UNI 11337-5
Part 6	Guidelines for information requirements	pr UNI 11337-6
Part 7	Requirements for knowledge, skills and expertise of stakeholders involved in digital information management processes	pr UNI 11337-7
Part 8	Construction project management, information modelling and management	pr UNI 11337-8

Two main results have been achieved:

- an unambiguous classification system;
- models for performance-based computational digital technical datasheets.

Both the classification system and the models for technical datasheets have been proposed for different technical solutions adopted in building processes.

The criteria identified for the definition of an unambiguous classification system allow to identify families of objects considering different aspects. Namely, those aspects are: category, typology, reference standard or function, main performance, geometry, dimensions and physical-chemical characteristics (Pavan et al. 2014). By selecting a specific choice for each field, a unique code is created for each object.

Furthermore, models have been defined for collecting, organizing and archiving technical information about construction products and technological solutions. Particularly, standard criteria have been identified to describe construction products, in identificative, qualitative and quantitative terms. The structure has been defined in accordance with harmonized standards for CE marked products or in agreement with other relevant reference standards (if available and/or applicable) for non-CE marked products. Once defined the models for construction products, a comparable structure has been developed also for technological solutions and technological systems. As demonstrated through the exploration of uses proposed in the paper, such structure is essential to provide an easily accessible source of data, directly usable from machines.

The models for the collection of technical information have been organized into informative blocks of homogeneous data. The structure collects information into classes and provides guidance on how to fill datasheets, standardizing the process of description and characterization of those ones. The informative blocks, differentiated for CE and non-CE marked products, are related to: identifying manufacturer information; identifying product information; technical information; information about packaging, movement, storage in factory and transport; commercial information; additional technical information; information about laying/installation, maintenance and disposal of products, description of the main components of products; attachments; information on data reliability.

Beyond the definition and development of the classification system and computational technical datasheets, a web-portal has been created for the fruition of information. The web-portal is composed of four main sections for:

- the collection of information related to technological systems, MEP objects and construction works;
- the fruition of information related to technological systems, MEP objects and construction works;
- the collection of BIModels linked to the standardized structure of the database;
- the collaboration among several stakeholders through a BIM Server.

Particularly, a link among information collected within the standardized structure and BIModels have been established, considering the approach adopted in the development of the BIM library, as presented in (Pasini et al. 2017).

Moreover, interoperability has been guaranteed thanks to the development of scripts for enriching the IFC schema with information stored in an external database. In fact, an automated process can be developed in a Python-encoded environment for reading the information of all the objects both in the native BIModel and in the IFC model, detecting the missing information and writing those ones in a structured database, as described in (Mirarchi et al. 2017).

PRACTICAL IMPLICATIONS

Background

The whole supply chain can take advantages from the availability of a standardized information structure and from its implementation in a BIM-based portal to support web-based collaborative design and construction. Particularly, for what concerns the section of the portal for the collection of information related to technological systems, different manufacturers have the possibility to upload complete information of their products, designers can easily compare characteristics and performances of similar products, construction companies have access to information concerning the installation and the maintenance of selected products. Moreover, such structure can promote the development of dedicated applications for using and re-using information through automated processes. Those applications can be developed because data collected following the proposed structure and stored in the portal are accessible in an electronic way, in line with the growing demands in that direction [2].

The development of automated processes is often bounded to the rules defined for a specific project. Generally, if information is not orderly collected, a specific application cannot be reused in different projects and by different subjects (Held et al. 2016). Instead, thanks to the standardized structure of the database behind the portal, applications can be developed following defined rules that are applied to each project supported by the portal itself. That means that a defined application can be developed by a third subject and then used directly in each project.

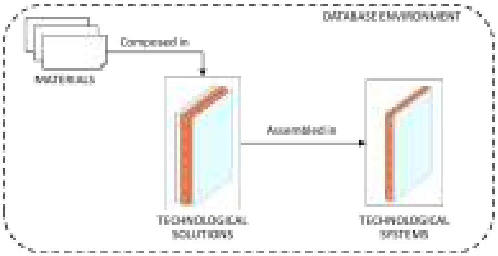

Figure 2
Database environment

Authors present specific applications focusing on the usability of information concerning environmental sustainability. Particularly, environmental issues are gaining attention within the building sector, so that standardized methods have been developed for the assessment of environmental impacts [4]. Consequently, stakeholders as manufacturers are putting great efforts in the collection of information describing those aspects concerning their products. However, that information is often not collected in a standardized way and in open and query-able formats. As an example, several Environmental Product Declarations (EPDs) can be retrieved from different websites. However, information is often stored within a PDF and, consequently, information of different products cannot be directly compared or queried. Within that context, the research presents an improved use of that information, when orderly collected in a database, as that developed within INNOVance project. Indeed, information stored in the database can be easily compared and queried. Moreover, linking information in the database and information provided by BIModels, environmental impacts of technological solutions and buildings can be easily assessed through automated processes.

Logical definition

The paper reports a case study related to the assessment of global warming potential (GWP). The GWP impact information is commonly related to a specific material referred to a functional unit. In a BIModel, objects represent construction elements (technological solutions and/or technological systems) that usually are constructed using one or more materials. The database can store all the information related to the specific material; then, materials can be used for virtually construct each technological solution that can be assembled in technological systems (Figure 2).

Technological solutions and technological systems are characterized by specific geometrical information (e.g., the thickness of the wall) that are reported both in the database and in the geometrical model. That could lead to the generation of discrepancies and inconsistencies between the model and the information related to the objects contained in the database. Thus, the coherence between the database and the geometrical model must be verified. The geometrical model contains all the information related to the geometrical characteristics of the elements (e.g., area, volume, thickness), while the database collects all the size features (e.g., thickness for walls, height and width for windows) and the non-geometric information. By coupling those kinds of information and by applying specific algorithms, the environmental impact of a technological solution and/or a technological system can be evaluated in an automated way. Consequently, obtaining the quantities of each technological solution and/or technological system within a project and coupling them with information stored in the database, the environmental impacts of a whole building can be assessed.

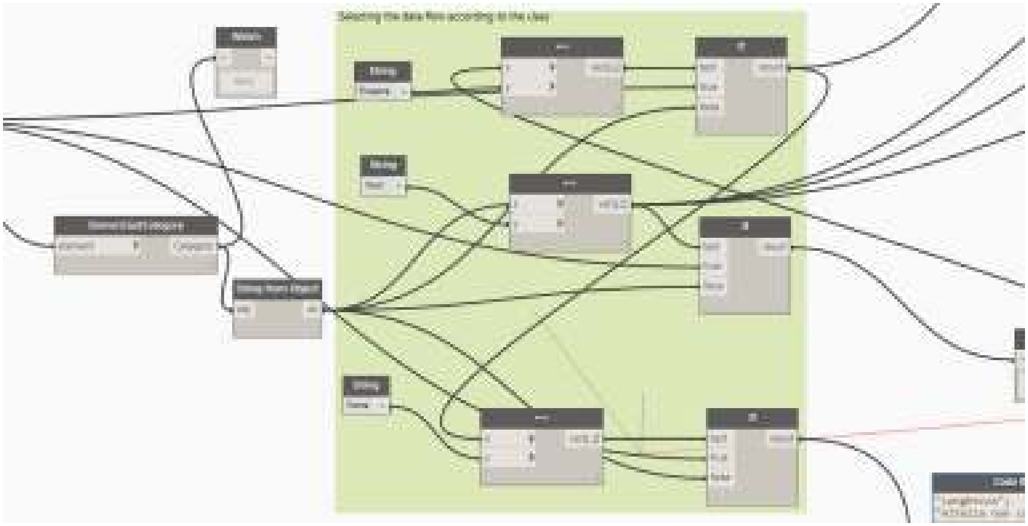

Figure 3
Rules to filter element classes

The definition of the link between the geometrical model and the database is allowed through the unique code associated to the classification systems and defined within the portal, as previously presented. Thus, including that code as informative content of the objects in the BIModel, it is possible to directly retrieve the related information from the database. Using a standardized structure allows to define stable rules, specific for each element class. In a BIM environment, a class can be defined as a set of relations and rules to control the parameters by which singular specific element of the class (called element instances) can be generated (Eastman et al., 2011). Thus, for each element class, different rules must be defined also in the algorithm for the assessment of environmental indicators for several reasons, as:

- the extraction of information from the database: in fact, different information has to be accessed in relation to the considered element class. For example, the number of leaves is required for windows but not for walls;
- the calculation rules to be applied to that information. As an example, when evaluating the environmental impact of windows, the weight (in kg) of a profile needs to be considered using its linear dimensions; whilst, evaluating the environmental impact of walls, the volume (m3) and the density (in kg/m3) of an insulation panel needs to be considered.

Therefore, after defining the information required for the environmental assessment of each technological system, a set of rules has been created for matching the information in the database to the right object in the BIModel. For reaching that purpose, a specific application has been developed through Dynamo, a visual programming environment, integrated with customized Python scripts (Figure 3).

Therefore, a workflow (Figure 4) has been proposed for enhancing an automated process for the evaluation of environmental indicators, coupling information in BIModels and in the database on the web-portal (structured within INNOVance project) and creating customized rules for different element classes.

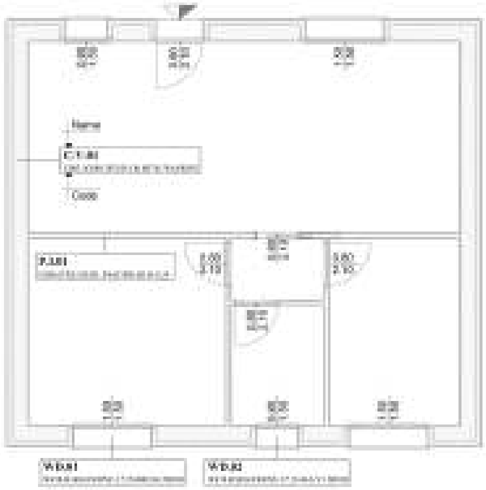

Figure 4
Name and code describing each element in a BIModel

Case study application

The workflow has been validated on a test model that contains basic objects (doors, windows, walls) defined through the portal. Each element is characterized by its fundamental information (the set of information that are provided by the BIM authoring tool, i.e. Autodesk Revit in the presented case) enriched by the code that links each element type to the correct information stored in the database. A type can be defined as a subset of a specific class which groups elements with the same characteristic features (e.g., thickness and number of layers for a wall). As shown in Figure 5, elements in the BIModel are described through:

- a specific name, that is defined at the project level and can be used in the project environment;
- a code, that remains the same for every project that uses the same element type.

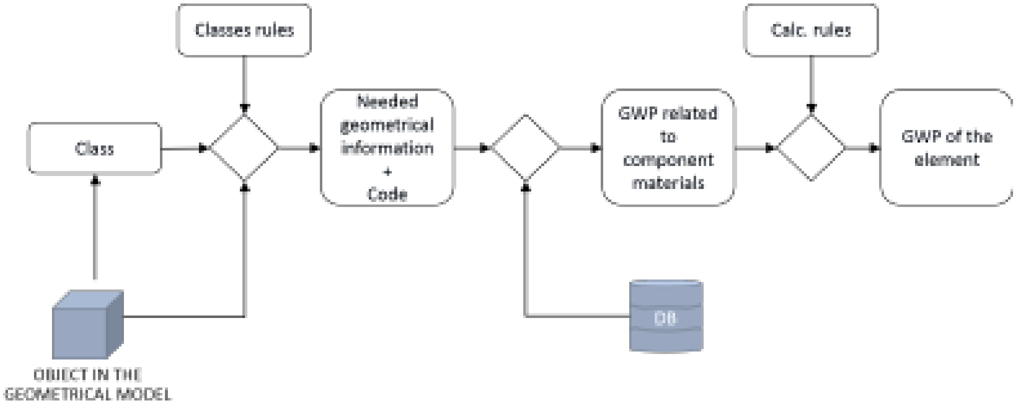

Figure 5
Workflow for automating the evaluation of environmental indicators

For example, in different projects the name C.V.01 can be associated to element types that are different to each other, whilst the code (C003.5OJ89.JFGHV.O0.8R74J.W6.8RE92) is unique for each element type, as it is the result of the choices made in the classification system (those choices are always the same, even when the same element type is used in different projects).

The objects used in the test model are defined with a Level of Development (LOD) that is reasonably high because the evaluation of the GWP needs the definition of the specific materials and layers that compose each element. In accordance with the Italian standard UNI 11337:2017 [5], the reached LOD for all the objects (doors, windows and walls) is LOD E. The informative content required for reaching LOD E is intended combining the information provided by the geometrical model and by the database.

The proposed application has been developed through the following steps:

- considering that different algorithms and calculation rules need to be applied and associated to different elements, the first step of the workflow analyzes the element classes defined in the geometrical model and directs the data in the correct data flow, through rules (as shown in Figure 3);
- in a second step, geometrical information and the code are extracted from the BIModel and stored in a temporary list (Figure 6). Using the code, the dataset related to the specific object is isolated and the useful data are extracted (selecting the data accordingly to the specific element class). The extraction of the only data related to the specific application on which the script is focused is possible because the data field is every time in the same position and is called with the same name in the database;
- the final step combines geometrical data extracted from the model and GWP information referred to the component materials provided by the database, calculating the GWP of the selected element.

Extending that process to each element of the model, it is possible to evaluate the global GWP impact referred to technological solutions and systems and, thus, to the whole building (Figure 7).

The automated system includes also a verification process for validating the information extracted from the geometrical model and the ones provided by the database. In particular, geometrical information of the same element is compared between the two sources (geometrical model and database) and

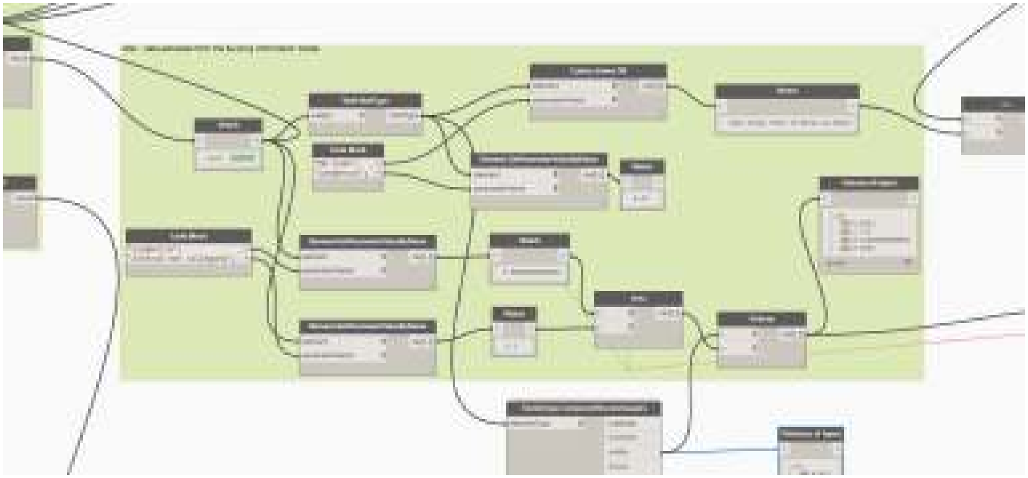

Figure 6
Extraction of geometrical information from BIModels

an error message is shown if some discrepancies or inconsistencies are revealed (Figure 8).

The development of the case study highlights an important aspect characterizing the data structure proposed by the portal. In a BIModel, usually, there are several kinds of information that are represented using the geometrical representation without any relation with the informative content. For example, in the proposed model, doors have a graphical representation of their open direction but no information related to it. Therefore, an automated process cannot use that information in order to perform calculation or other activities on the specific object. In the specific case study, the number of leaves of windows is a fundamental information for the calculation of the GWP of the specific element type. That information is well represented in a geometrical way in the BIModel but no informative fields are commonly defined. In a traditional process, that lack of informative fields could hinder the definition of automated scripts. Instead, in the proposed structure, the number of leaves are identified in the database. Consequently, that information can be used in the automated process allowing a correct calculation of the required data fields.

DISCUSSION

The proposed solution aims to overcome barriers and difficulties derived from the fragmentation of information among actors and along building stages.

The application presented in the paper concerns environmental aspects. However, the same considerations can be extended to other sectors, characterized by the same issues, as:

- each stakeholder (especially manufacturers) collects their information (not only environmental information) and promotes their use through personal webpages; instead, having a standardized structure adopted at national level enhances their visibility and competition;
- information stored in PDF cannot be reused in an automatic way, e.g. applying algorithms; instead, the research demonstrates how information can be re-used if orderly stored in a database;
- generally, there is not a direct link among information provided by manufacturers and objects (especially, BIM objects) in a project; instead, the code proposed in INNOVance project allows to create that link and enhances

Figure 7
Estimation of environmental indicators

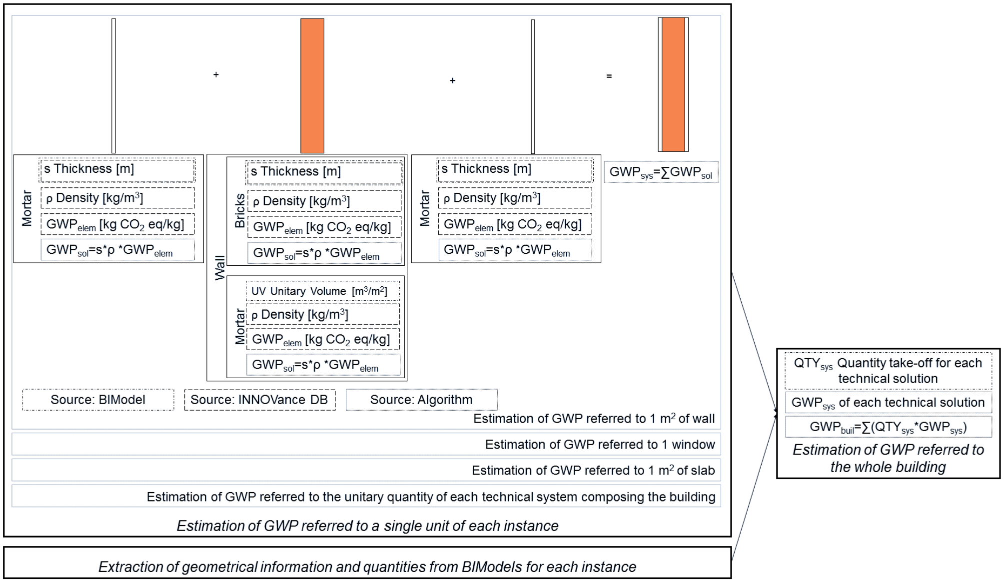

Figure 8
Verification process of inconsistencies

the fruition of information stored in different databases, also through applications that are not related to one sigle project;

- it is often difficult to compare objects belonging to the same element class, but described by different manufacturers (e.g., information is provided with different units of measure); instead, collecting information in a standardized structure enhances comparisons because information is always expressed in the same way and stored in the same section of the database.

A direct and easy fruition of information is possible through a BIM-based portal. The presented portal has been developed for enhancing the collection, sharing and exchanging of information, according to the standardized structure. However, nowadays, the portal has been released only as a prototype. Additional resources are required for optimizing and increasing the diffusion of the tool. However, the background data structure implemented in the portal represents a challenging point in the project and allows the further development of automated procedures for the use of stored information.

CONCLUSION

The development of a classification system and computational technical datasheets accessible through the BIM-based portal aims to improve actual building processes through a standardized structure for collecting building-related information, that is still lacking in the Italian construction sector.

The standardized structure applies to the information flow of the construction process and affects all subjects and phases related to it (such as planning, procurement, production, purchasing/supplying, construction, usage, maintenance and disposal).

Therefore, the results of the project support collaborative design and construction, providing a shared database and promoting the usability of data and information through dedicated applications.

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