Sustainability certification of construction products through BIM

To cite this article: F Re Cecconi *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **296** 012054

IOP Conf. Series: Earth and Environmental Science **296** (2019) 012054 doi:10.1088/1755-1315/296/1/012054

Sustainability certification of construction products through BIM

F Re Cecconi[1], N Moretti[1], A Mannino[1*], M C Dejaco[1]

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

*antonino.mannino@polimi.it

Abstract. Sustainability certification of construction products is a key issue to be managed and controlled during the construction phase, in order to implement design choices and reduce buildings impact on the environment. Within this context, sustainability assessment protocols play an important role, since they provide a systematic approach for the sustainability rating of the building. The aim of this research is to define a BIM-based methodology to automate the sustainability certification process in construction phase. According to the proposed methodology, the contractor proposes a building component whose technical data are uploaded to a Document Management System (DMS) used as Common Data Environment (CDE). If the component passes a set of semi-automated authorisation steps, compliant with the work supervisor's, client's, and sustainability accredited professional's needs, then it is uploaded to the BIM Model. The case study (an office building in Italy) confirmed that the proposed methodology allows to achieve a higher efficiency, minimizing the certification times and efforts. Nevertheless, this methodology should be validated in further case studies. Moreover, it may be improved and further automated to cope with product dictionaries and templates under development in CEN technical committee 442.

1. Introduction

Sustainability in the Architecture, Engineering, Construction and Operation (AECO) is one of the most important issues to be considered, in order to achieve a high quality built environment [1]. Buildings, during their life cycle, have a significant impact on the environment: on one hand they are responsible for the consumption of a great amount of energy, water, materials; on the other side they produce waste and harmful atmospheric emissions [2] [3]. In the European Union, buildings' energy consumption is about 40% and the CO2 emissions account for the 35% of the total amount [4].

These factors led to the creation of green building standards, certifications and rating systems with the aim of reducing the impact of buildings on the environment through sustainable design [5]. Although the parameters considered are quite similar (e.g. energy consumption, water efficiency, building location) there are different types of certification. The most used sustainability rating systems are:

- Building Research Establishment Environmental Assessment Method (BREEAM);
- Leadership in Energy and Environmental Design (LEED);
- Sustainable Building Tool (SBTool) [6].

LEED and BREAM can be included among the most used and interdisciplinary rating systems [7]. These two rating systems share many indicators even if sometimes, parameters that describe the same performance, are calculated differently [8]. An attempt to harmonize built environment assessment has been carried out with the Common European Sustainable Built Environment Assessment (CESBA). Despite they can be considered as complex tools for assessment of the sustainability performance of the buildings, these rating systems are sometimes employed to justify increases of the market value of the physical asset rather than for the effective achievement of sustainability objectives [24].

Moreover, the idea of a green product standards, developed as a result of growing concerns about product toxicity and the impact on indoor environmental pollution, also started to arise in the 1980s, increased in the 1990s and became more prominent in the 21st century when the number and type of green product standards and certifications grew [5].

Some attempts to partially automate the sustainability certifications of buildings in the design phase can be found in literature [1], [9] [10] [11]. Nevertheless, very few efforts have been accomplished to automate the certification process during the construction phase. Through this article, a methodology for semi-automated LEED sustainability certification of buildings is presented focusing on the construction stage. The methodology is enabled by the use of Building Information Modelling (BIM) tools for design and management of the information, in compliance with the workflow proposed by the ISO 19650-1:2018 [12]. The proposed approach has been validated through a demonstration on an office building in Lombardy region, Italy, showing good preliminary results.

2. State of the art

LEED is a voluntary consensus-based rating system. The calculation of the sustainability ranking is allowed by the use of a checklist. This checklist comprises credits about several sustainability categories (regional priority, indoor environmental quality, innovation, location and transportation, energy consumption, water efficiency, sustainable sites, waste, integrative process, materials and resources) [13]. The United States Green Building Council (USGBC) established four different levels for LEED certification: Certified, Silver, Gold and Platinum. The achievement of the different ranking level is based on the assessment of the project using a scoring system [13]. However, these rating systems are getting more and more complex: the increased demand of clients and users pushed also for different versions of protocols, able to assess different parts or life cycles of the building (e.g. new construction, existing buildings, operation, site, core & shell) and of the neighborhood [8].

BIM allows the digital modelling of the physical asset, where different semantics can be related to the building components, group of components and spaces. One of the most innovative application is called Green BIM. This application concerns the employment of BIM-based models and processes for the achievement of sustainability objectives (energy performance analysis, sustainable retrofit, etc.) [14]. The use of BIM provides an effective framework for information management throughout the building life cycle, therefore many efforts have been made in order to use this approach to facilitate the development of Green Buildings [3], [15], [16] and their sustainability assessment [8]. Moreover, in order to foster interoperability and standardization, the exchange of information between BIM software and the rating system can be based on Machine View Definitions (MVD) of standard protocols (the Industry Foundation Classes [17]), such as Construction to Operation Building information exchange (COBie) [18].

Nevertheless, a standardized approach for sustainability assessment during the construction phase, using BIM approaches still cannot be found in literature. Therefore, an innovative methodology which employs a BIM-based process management approach, to facilitate the sustainability certification of building products during the construction stage, is proposed through this research.

The implementation of the BIM workflow involves the use of a Common Data Environment (CDE): the virtual place where federation of models is created and managed. The federated model can be intended as the starting point from which the digital twin could be developed [19]. ISO 19650-1: 2018 suggests that the CDE can assume four different connotations (Work in Progress, Shared, Published Documentation, Archive) according to the status of the information managed. The ISO standard describes also the modalities allowing the exchange of information within different parties.

The employment of a CDE allows the creation of a truly shared work environment, through which information quality could be improved and data are up-to-date. Accordingly, the development of the proposed BIM-based methodology for sustainability certification of building, has been developed around these principles.

3. Methods and tools

The LEED protocol requires the assessment of the sustainability criteria, both in the design and in the construction phase. The proposed methodology allows to improve the assessment of the LEED protocol criteria in the construction phase. Usually these operations are carried out through a non-automated process which employ a lot of paper works. Within the wider context of achievement of an increased synergy between BIM and sustainability certifications, the research aims at proposing a framework to improve and make the certification process efficient and automated in the construction stage. Therefore, the workflow has been developed according to the information management framework proposed (Figure 1).

More in detail, a semi-automated BIM-based methodology has been developed for the sustainability certification of the construction products. In this work, the reference stage in the life cycle of the asset is the construction one, stages number 5 in the RIBA Plan of Work [20]. During this stage a lot of information about products and systems is created and distributed among the stakeholders. Typical construction documentation includes an owner's set of files eventually transferred from the contractor at the end of the project in a number of file drawers or boxes [21]. Ineffective information communication on construction sites can lead to neglect important issues that require a quick response [22]. This article shows that BIM can be used effectively to ease communication during the construction stage, although the existing parameters in BIM software do not facilitate integration of the construction process documents [21]. In order to foster the collaboration among the parties and the development of a federated model, the proposed methodology is compliant with the CDE rules and characteristics proposed in the ISO standard, therefore information reliability increases along the steps of the process. Figure 1 represents the main procedural steps to be accomplished.

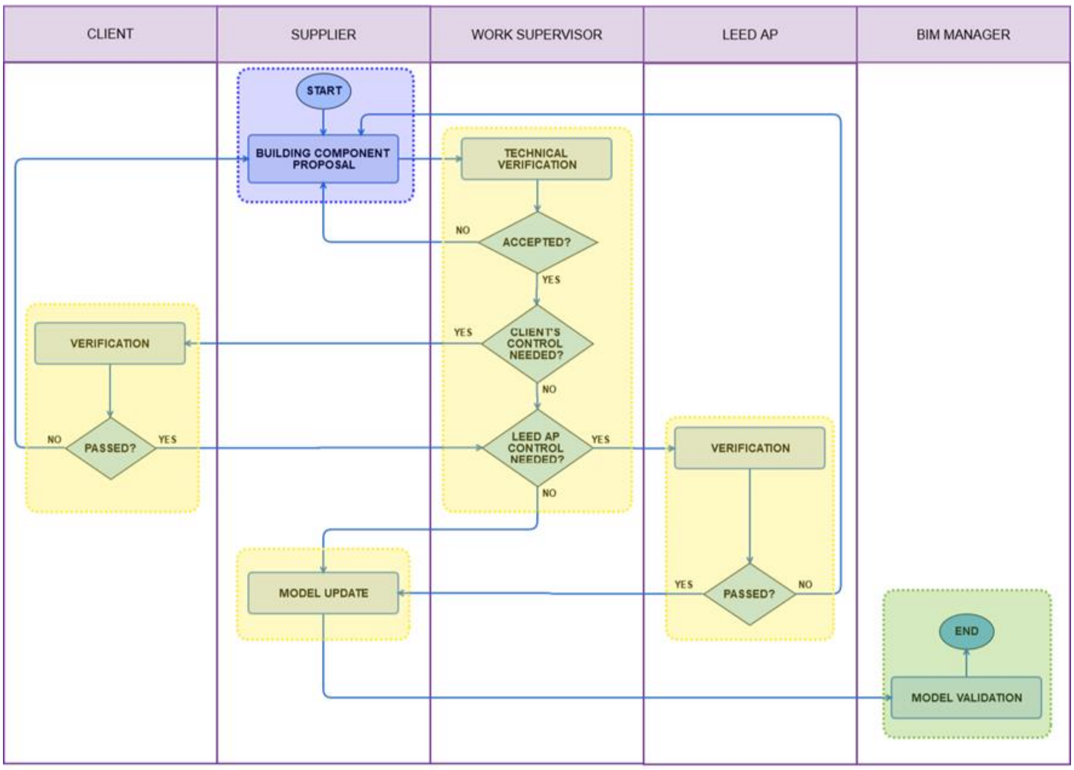


Figure 1. BIM based LEED certification process – [Colour code according to CDE stages, Work in Progress (blue) – Shared (yellow) – Published (green)].

It is assumed that the BIM model has been developed, during the design stage, carefully and the level of geometric and semantic detail is suitable with the development of the construction site. Accordingly, the process can start:

1. the supplier appointed to realize a specific part of the project proposes a product, compliant with the requirements stored in the BIM model. The product must undergo a first review and authorization step by the work supervisor.
2. If the first authorization is obtained, the work supervisor must check if a client's authorization is needed (e.g. in the case of very critical equipment or if the product is highly expensive).
3. Once the client's check is passed, the element must be passed to the verification of the LEED AP that check the technical specifications of the proposed component and assigns a score according to the LEED's procedures.
4. Once the LEED AP provide the authorization, the supplier must update the model, which is validated by the BIM manager.

It must be highlighted that not all the authorization steps are compulsory. It may happen that the Client's authorization is not needed or that the component does not have a crucial role for the sustainability rating of the building. The process in this case, will be developed slightly differently to the one represented in Figure 1: the authorization will only pass by the work supervisor, while the BIM manager always validate the updated model.

4. Application of the proposed approach

In order to test the proposed approach and verify its efficiency we have applied this methodology on a case study concerning the LEED certification of a building component in an office building in Erba (Como), Italy (Figure 2).

4.1. The case study

The building consists in a single block (20 x 93 m) with a glass curtain wall. It has an underground parking and three floors above the ground: offices of a construction company on the first and second floor, a clinic on the ground floor. The structure is made by concrete pillars and beam with a steel stiffening structure. Two stairwells divide all the floors into three parts. For the case study, as building component, we used a second-floor window into curtain wall panel.

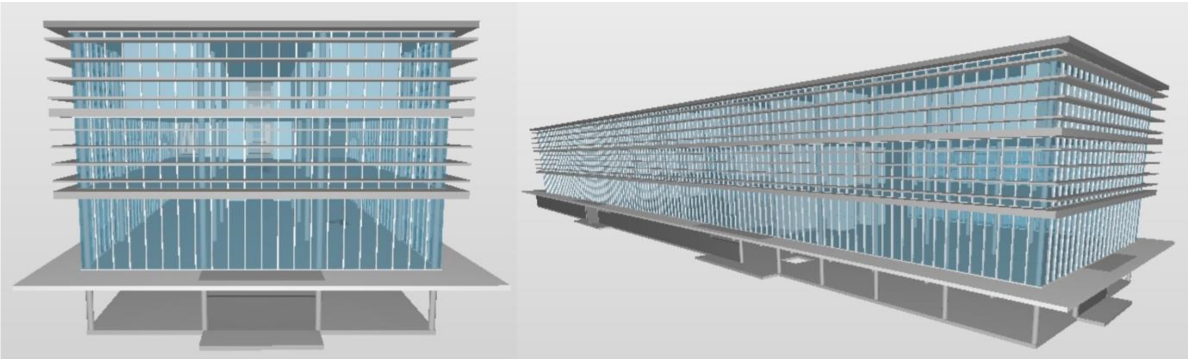


Figure 2. East facade view (left) and North/East facade view of the office building IFC model.

4.2. Validation of the proposed approach

Autodesk BIM 360 DOCS has been employed as DMS and Autodesk Revit 2018 as BIM authoring software. For the validation of the proposed methodology, a DMS has been employed to store the relevant information and to optimize the sharing among the stakeholders. BIM360 DOCS has been chosen for two reasons:

- the BIM model has been created with the BIM authoring software Autodesk Revit;
- BIM360 DOCS allows the visualization of a 3D model, both in proprietary and in IFC format. Therefore, it allows the visualization and extrapolation of information not only from digital data sheet (PDF), but also from a building component.

The DMS is structured according the Work Breakdown Structure (WBS) used for the development of the BI model. This has allowed to load data sheets of each component in the related section (Figure 3).

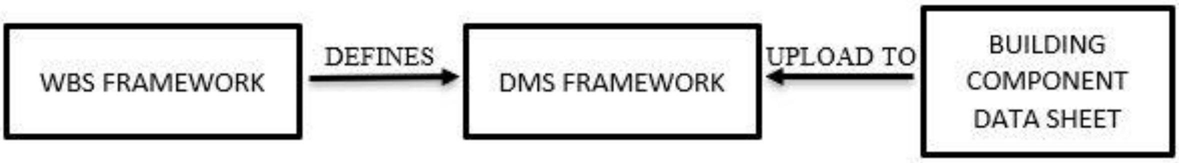


Figure 3. Working on a DMS.

The proposed process has involved the interaction of five stakeholders:

1. Client
2. Supplier
3. Work Supervisor
4. LEED AP
5. BIM Manager.

The folders of the DMS where the data sheets are loaded, are created and customized (Figure 4) in order to allow the easy visualization of the technical specifications of the component (e.g. Thermal Transmittance for windows). In this way the stakeholders were able to provide their feedback on the element.

The folders' customization, for this case study, has been accomplished manually. Once the customized folders have been created, the BIM Manager, who has been the administrator of the DMS, has set the login credentials and the access permissions for all the stakeholders of the process.

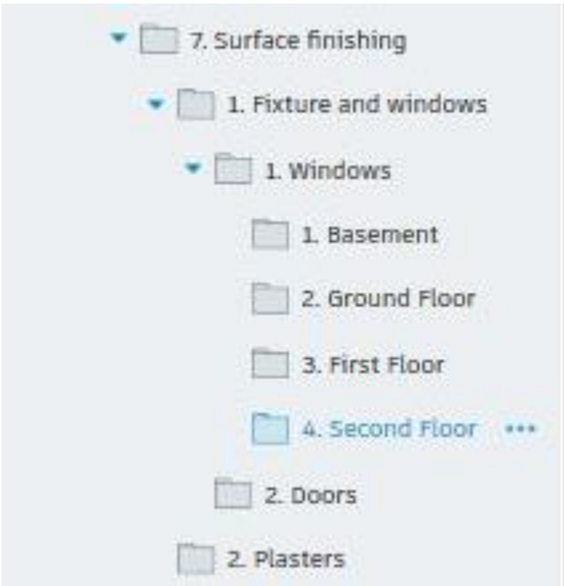


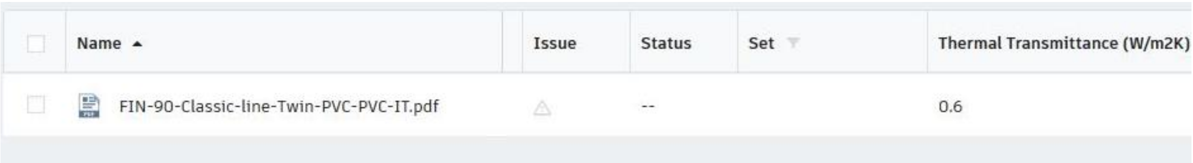
Figure 4. WBS Structure.

The process started with the proposal of the building component (in this case, as mentioned before, a window to be installed at the second floor) by the supplier through the update of the data sheet to the DMS. As mentioned before, since the DMS also allows the visualization of both Autodesk proprietary files and the open format IFC, the supplier could even upload in the DMS the 3D model of the building component to be verified, from which the data needed for the validation are extracted.

IOP Conf. Series: Earth and Environmental Science **296** (2019) 012054 doi:10.1088/1755-1315/296/1/012054

Moreover, the property field previously set by the BIM Manager are compiled with the data useful for LEED evaluation, extracted from the data sheet (e.g. Thermal Transmittance, Sound Proof, Materials, etc.) as shown in Figure 5.

In this case the thermal transmittance extracted from the technical specification is employed for the calculation of the LEED score in the "Energy and Atmosphere Credit: Optimize Energy Performance" section; in this section, up to 18 points are awarded according to the percentage improvement in energy performance of the new building.



Name	Issue	Status	Set	Thermal Transmittance (W/m2K)
FIN-90-Classic-line-Twin-PVC-PVC-IT.pdf		--		0.6

Figure 5. Upload Data sheet in the appropriate folder.

Once the data sheets are uploaded to the folder, the next step concerned the review of the building component by the appointed professionals. In order to make possible the authorization by the Work Supervisor, the Client and the LEED AP, the BIM Manager created a multi-approval steps workflow within the DMS and assigned it to the building component taken into consideration. In this case the workflow is based on 3 approval steps which correspond, respectively, to the decision of the Work Supervisor, the Client and the LEED AP.

The work supervisor approved the building component, and the review task is forwarded to the next stakeholder (the Client) who, with the same Work Supervisor procedure but considering different parameters (e.g. costs), approved the component and forwarded it to the next stakeholder (LEED AP). The latter, using the technical properties of the building component extrapolated from the data sheet by the supplier, verified that the component has met the LEED requirements (Figure 6).

IOP Conf. Series: Earth and Environmental Science **296** (2019) 012054 doi:10.1088/1755-1315/296/1/012054

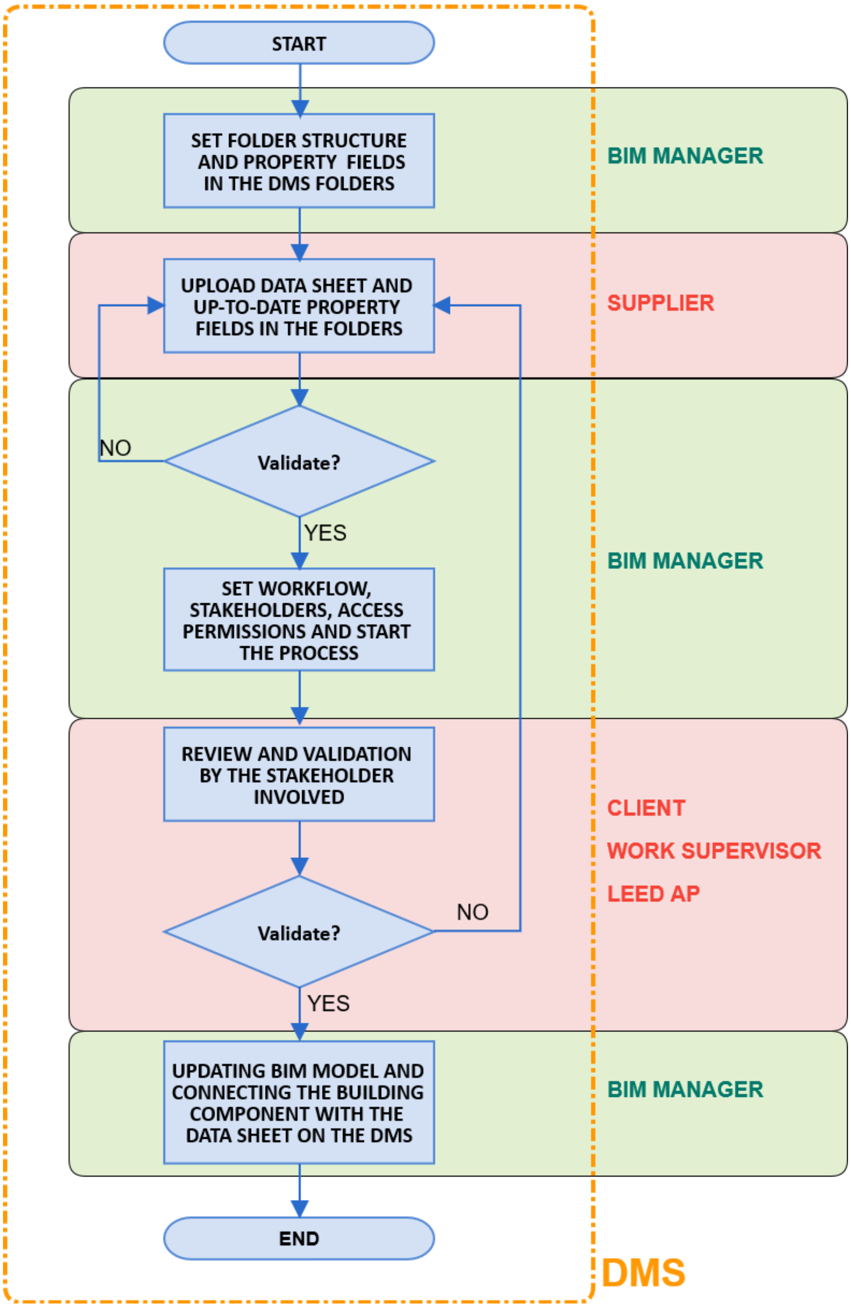


Figure 6. Three step approval workflows.

Once the LEED AP approved the building component, the review can be defined closed and the BIM Manager updated the BIM model.

The direct connection between the 3D representation of the component within the Revit model and its technical data sheet within the DMS is carried out through a link in the URL field "type properties" (Figure 7).

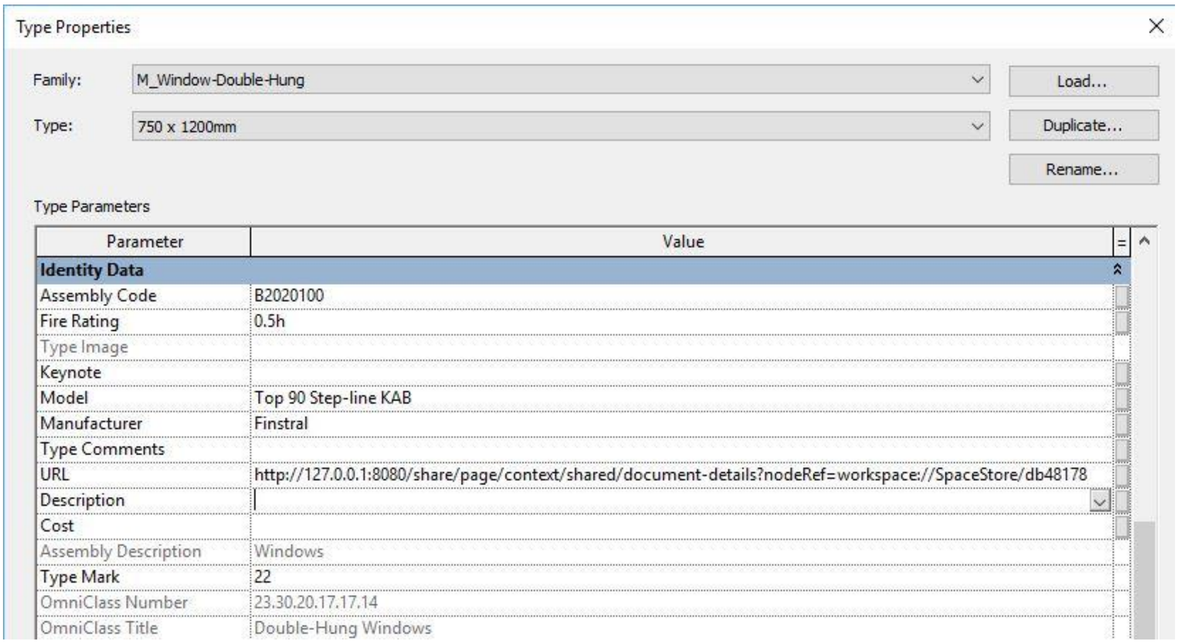


Figure 7. DMS link in Revit.

5. Results and Discussion

Through the implementation of the methodology in BIM360 the effectiveness of the methodological approach has been demonstrated. The strength of this methodology concerns the definition of an environment in which the process is managed. Currently, the process is managed in a fragmented way and without a predefined scheme. Furthermore, the process leading from the proposal of the technical specification of the construction products and building elements until the approval and LEED certification has been semi-automated: once the workflows are defined and assigned to the building components, the approval by a stakeholder implies the automatic assignment of the task to the next stakeholder defined by the pre-set workflow.

In this paper the procedure concerning the calculation of the final ranking of the LEED building design and construction has not been described. Nevertheless, the possibility to partially automate the computation of the sustainability ranking through the Industries Foundation Classes (IFC) protocol has been investigated [23]. Therefore, the approach proposed in this paper can be considered as a step toward the achievement of the automated sustainability certification of buildings. The certification is achieved through the use of the BIM approach, within the context of the Green BIM.

Another strength is the software integration: both BIM360 and Revit 2018 are developed by Autodesk. BIM 360 is not only compatible with IFC files, but also compatible with native Revit files. These tools offer good data organization and visualization of process information and have an efficient notification system. Finally, no installation is required for the DMS BIM360, since working in the Autodesk cloud is sufficient and makes the process even easier. Moreover, the DMS allows to view the open IFC format and therefore the method is replicable even by those who use other BIM authoring software.

Unlike other open-source DMS (e.g. Alfresco), viewing the 3D model of the building component is allowed by the employed software platforms. On the other hand, a weakness of the DMS we used is that the free version allows to manage just only one project at a time and it still includes many steps to be completed manually: The BIM manager must set and insert into the folders the fields to be filled in for each building product and this requires a further effort in terms of time; moreover, the supplier must also manually enter the component data within the fields and this procedure could be subject to avoidable errors with a fairly automated process. However, this is a first step towards further process automation and a further development to reduce approval times for building components is required. The methodology presented here concerns the construction of a new building. For existing buildings, where there is no 3D model and its development is too onerous, the COBie standard could be used. This MVD is characterized by the possibility to be both human and machine readable and it is provided in the form of a spreadsheet. Therefore, while it is easy to handle and understand even for non-BIM-skilled professionals, it is compliant with the most advanced standards and can be used as part of a modular implementation of a detailed 3D BIM model. Once the COBie spreadsheet has been filled with the building data, it is possible to proceed with the sustainability assessment [1].

6. Conclusions

In this paper a semi-automated methodology for sustainability rating of construction products has been proposed. Despite the methodology is still in its early stage, through the case study it has been demonstrated its effectiveness and the possibility to carry out a semi-automated sustainability assessment, during the construction phase. Moreover, a reduction of both times and the efforts of the stakeholders involved can be achieved. The implementation of the methodology provides a further step in the definition on the potentiality offered by the Green BIM, intended as the integrated use of BIM-based processes for the achievement of sustainability objectives.

To conclude, the case study demonstrated that the process can be implemented through the use of a commercial DMS. The participants to the authorization process can visualize the data needed for the validation / rejection of the building component. Once the new building component is approved, the BIM model is updated and can be delivered as an as-built of the physical asset. Nevertheless, this methodology must be validated in further case studies and the automation of the process can be further improved.

References

[1] Maltese S, Moretti N, Re Cecconi F, Ciribini A L C and Kamara J M 2017 A Lean Approach to Enable Sustainability in the Built Environment through BIM *Techne-Journal Technol. Archit. Environ.***13** 278–286
[2] Eberhardt L C M, Birgisdóttir H and Birkved M 2019 Life cycle assessment of a Danish office building designed for disassembly *Build. Res. Inf.* **47-6** 666–680
[3] Wong J K W and Zhou J 2015 Enhancing environmental sustainability over building life cycles through green BIM: A review *Autom. Constr.* **57** 156–165
[4] European Parliament and European Council 2010 Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast) *Off. J. Eur. Union*, pp 13–35
[5] Vierra S 2016 Green building standards and certification systems *Building*
[6] Sanhudo L P N and Martins J P da S P 2018 Building information modelling for an automated building sustainability assessment *Civ. Eng. Environ. Syst.* **0-0** 1–18
[7] Tagliabue L C and Manfren M 2016 Sustainability indicators for buildings: network analysis and visualization *Sustainable Built Environment (SBE) Re- gional Conference*
[8] MalteseS, Tagliabue L C, Re Cecconi F, Pasini D, Manfren M and Ciribini A L C 2016 Sustainability Assessment through Green BIM for Environmental, Social and Economic Efficiency *Procedia Eng.* **180** 520–530
[9] Soubra S, Huovila P, Scientist P, Scientist S, Palos S, and Fies B 2012 Linking IFCs and BIM to Sustainability Assessment *Proc. CIM W78 2012 29th Int. Conf. Lebanon*, pp 17–19
[10] Jalaei F and Jrade A 2015 Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings *Sustain. Cities Soc.* **18** 95–107
[11] Ilhan B and Yaman H 2016 Green building assessment tool (GBAT) for integrated BIM-based design decisions *Autom. Constr.* **70** 26–37
[12] ISO 2018 BS EN ISO 19650-1:2018. Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling. Part 1: Concepts and principles
[13] USGBC 2019 *LEED v 4 for building design and construction* p. 161
[14] Wong J K W and Zhou J 2015 Enhancing environmental sustainability over building life cycles

through green BIM: A review *Autom. Constr.* **57** 156–165
[15] Lu Y, Wu Z, Chang R and Li Y 2017 Building Information Modeling (BIM) for green buildings: A critical review and future directions *Autom. Constr.***83-August** 134–148
[16] Spatari S, Eboli J, Stadel A, Mitchell J and Ryberg A 2011 Intelligent Sustainable Design: Integration of Carbon Accounting and Building Information Modeling *J. Prof. Issues Eng. Educ. Pract.* **137-2** 51–54
[17] ISO 2013 *ISO 16739:2013. Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries*
[18] BSI 2014, *BS 1192-4 : 2014 Collaborative production of information Part 4 : Fulfilling employer' s information exchange requirements using COBie - Code of practice* p. 58
[19] Centre for Digital Built Britain 2018 *The Gemini Principles*
[20] RIBA 2013 *RIBA Plan of Work 2013: Overview* (London)
[21] Goedert J D and Meadati P 2008 Integrating Construction Process Documentation into Building Information Modeling *Constr. Eng. Manag.* **134-7** 509–517
[22] Chen Y and Kamara J M 2011 A framework for using mobile computing for information management on construction sites *Autom. Constr.* **20-7** 776–788
[23] Re Cecconi F, Tagliabue L, Ciribini A, Maltese S, and Kovacic I 2017 Green BIM-A lean methodology to support sustainability assessment protocols *17th International Multidisciplinary Scientific Geoconference, SGEM 2017* pp. 889–896.
[24] Wangel J, Wallhagen M, Malmqvist T and Finnveden G Certification systems for sustainable neighbourhoods: What do they really certify? *Environ. Impact Assess. Rev.* **56** 200–213