IFC-Based Sustainable Construction: BIM and Green Building Integration

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Abstract
There has been an increasing awareness of BIM use in sustainable construction projects due to its powerful handling of multidisciplinary information within one model. Despite the benefits of BIM and sustainable data incorporation in the design stage, there are some barriers to BIM adoption in sustainable construction such as lack of practical tools. The integration requires considerable effort and time such that sustainable data assessment remains an after design stage process for most of the cases. Therefore, a functional inclusion of sustainable data into BIM is essential for the improvement of the current practice. This paper focuses on an IFC-based approach for construction projects aiming green building certification. The proposed method includes developing property sets, determining minimum model view definitions, generating BIM model and evaluating sustainable data. In this study, extended property sets according to BREEAM International scheme are presented as the basis of the proposed approach and further steps are discussed.

Keywords: BIM, BREEAM, IFC, integration, sustainability

1 Introduction

Building Information Modeling (BIM) as a growing movement in the architecture, engineering, construction and facility management (AEC/FM) domains, is a new approach to manage the processes in the whole life cycle of a building and project data in digital format that provides the exchange and interoperability of information through Industry Foundation Classes (IFC) (Ilhan 2014). Due to its benefits such as improved productivity, collaboration, cooperation, spatial coordination, better control of time, cost and scope, the utilization of BIM has increasingly become widespread throughout the building production process. BIM adoption rate in the US AEC industry has surged from 28% in 2007, 49% in 2009 and 71% in 2012 (McGraw-Hill Construction 2012). Sustainability concept, moreover, has had a notable impact in the AEC industry as in many other industries over the last two decades. Green building rating systems such as Building Research Establishment Environmental Assessment Methodology (BREEAM 2010) and Leadership in Energy and Environmental Design (LEED) (USGBC 2011) are of great importance for dissemination of sustainable construction in the face of the increased demand for sustainability.

BIM has the potential to model and manage the information embedded in a project, from its conception to end-of-life and its expansions have been studied for extending its scope. Sustainability is one such modeling extension that is in need of development (Oti & Tizani 2015). BIM-based technologies are regarded as a potentially useful instrument for aiding project stakeholders to capture complete design and project information, and to make the best use of the available design data for sustainable design and sustainability rating analysis (Wong & Kuan 2014). Lack of interoperability of sustainable data limits the use of BIM in building design and needs to be considered earlier in the planning stage. The design stage presents the best opportunity to influence cost and sustainability impacts covering the whole life cycle stages of a building (Ding 2008). Including more sustainable data in the early stages of the building design process provides more successful results. The situation, therefore, creates demand on the development of decision support tools to guide designers in the early design stage when changes can easily be accommodated with very minimal consequences (Oti & Tizani 2015).

This work presents the steps of an integrated BIM and sustainable data model for green building certification. The purpose of the model is to guide design team on assigning the accurate and reliable sustainable data in early design stage so as to achieve certification goal on time and within budget. Due to the area of usage in Turkey and lack of BREEAM-BIM studies in the literature, the model focuses on BREEAM materials category. This study aims to take the efforts made by Ilhan & Yaman (2013) and Ilhan (2014) a step further adapting BREEAM International New Construction (NC) 2013 as the current scheme for registration and certification of new construction projects in Turkey.

2 BIM and Sustainability

The potential of effective BIM involvement in sustainable construction has been realised (Bynum et al 2013) and discussed in the literature. Krygiel & Nies (2008) suggested several innovations within BIM such as improvements in software interoperability and integration of a carbon accounting tracker and weather data in order to provide for the next steps in enhancing its capabilities with sustainability. Stadel et al (2011) suggested the use of BIM capabilities with life-cycle cost analysis (LCCA) to perform carbon accounting based on exporting the material schedule for the building and the use of BIM software plug-ins for calculating operational energy use and carbon emissions.

2.1 Background

There are various studies concerning BIM and sustainability integration (Alwan et al 2015, Azhar et al 2011, Bynum et al 2013, Ham & Golparvar-Fard 2015, Ilhan 2014, Ilhan & Yaman 2013, Inyim et al 2014, Kim & Anderson 2013, Kim et al 2015, Lee et al 2011, Lewis et al 2015, Motawa & Carter 2013, Oti & Tizani 2015, Wong & Fan 2013, Wong & Kuan 2014, Wu & Issa 2011, Wu & Issa 2015, Zanni et al 2014, Zhang et al 2014 and Zhang et al 2015).

Studies regarding to relationship between BIM and the leadership in energy and environmental design (LEED) have been carried out. For instance, Azhar et al (2011) developed a conceptual framework to establish the relationship between BIM-based sustainability analyses and (LEED) certification process and validated it via a case study. The results show that BIM-based sustainability analyses software can provide documentation supporting LEED credits directly or indirectly. Wu and Issa (2011) propose a 3rd party web service relying on BIM as the information backbone to facilitate the LEED documentation generation and management. Wu and Issa (2015) develop an integrated green BIM process map for LEED projects. Furthermore, Alwan et al (2015) aim to examine the feasibility of using 3D simulation transfer processes to streamline the environmental assessment of buildings that have been designed digitally using BIM. A case study for LEED evaluation within the BIM process is presented.

On the other hand, Wong & Kuan 2014 use a two-stage method (a Delphi study and a case study) to explore the potential use of BIM in the case of a residential building project seeking BEAM Plus sustainable building certification in Hong Kong. Oti & Tizani (2015) propose a modelling framework combining the indicators of sustainability of buildings, which are life cycle costing, ecological footprint and carbon footprint for providing sustainability assessments of alternative design solutions, based on the economic and environmental sustainability pillars. Inyim et al 2014 introduce a simulation of environmental impact of construction (SimulEICon), which is an add-on to the Autodesk Revit Architecture software, designed specifically to aid in the decision-making process during the design stage of a construction project.

Zanni et al (2014) discuss the need for a structured process for sustainable building design for BIM execution with the aim to develop a BIM-enabled sustainable design process model that identifies critical decisions actions in the design process along with the information and level of detail that facilitate an informed and timely decision. Ilhan (2014) proposes a framework for providing an integrated platform to work on and facilitating the green documentation generation in order to get green building certification. The proposed model, which is based on IFC, helps the design team assign the sustainable properties and assess the sustainability performance of the project during the design stage so that the decisions can be made on time for BREEAM certification.

2.2 IMPACT compliant suite

The green building rating systems attempt to achieve continuous improvement to optimize building performance and minimise environmental impact, provide a measure of a building's effect on upon the environment and set credible standards' by which buildings can be judged objectively (Reed et al 2011).

BREEAM, the oldest assessment method developed by BRE in the United Kingdom as a tool to measure a building's environmental performance, addresses wide-ranging sustainability issues and enables developers, designers and building managers to demonstrate the environmental credentials of their buildings to clients, planners and other initial parties (BREEAM 2010). BREEAM International including new construction, refurbishment & fit-out, in-use and communities bespoke schemes, is developed for using across the world. BREEAM International NC 2013 of those is used to assess the sustainability of new buildings over their life cycle at the design and construction stages of a project. It includes Management, Health and Wellbeing, Energy, Transport, Materials, Waste, Water, Land Use and Ecology, Pollution and Innovation categories. When considered in terms of the materials category, focusing on the life cycle impacts of the materials rather than the green rating points is the key issue of the new scheme. It aims to encourage the use of life cycle assessment tools and measure the environmental impact (including embodied carbon) of the materials over the full life cycle of the building.

An appropriate life cycle assessment tool should be used to calculate the number of credits achieved. In this sense, IMPACT, which is BIM integrated material profile and costing tool, can be operated for measuring the embodied environmental impact and the results are assessed for this BREEAM issue. IMPACT aims to facilitate improvement in design and decision making for both new design and retrofit projects by allowing users to quantify the embodied environmental and cost implications of material and product choices on a whole-building basis (IMPACT 2014). As IFC is the major enabler of BIM for providing to share and collaborate across the platforms and applications, IFC format of the projects are used in IMPACT. The other issues of the materials category are listed as: Hard landscaping and boundary protection, responsible sourcing of materials, insulation and designing for robustness.

3 IFC-Based Approach for Green Building Certification

The proposed framework for BIM and sustainable data integration comprises developing the property sets in the IFC standard, defining minimum model view definitions, generating BIM Model and its IFC format and calculating the data for green documentation processes.

Figure 1 presents an IFC-based sustainable data approach in which BIM can potentially facilitate and benefit sustainable design in the very early stage. From start to end of the design stage, the users can provide the related data for BREEAM certification by specifying the project and building element and material information.

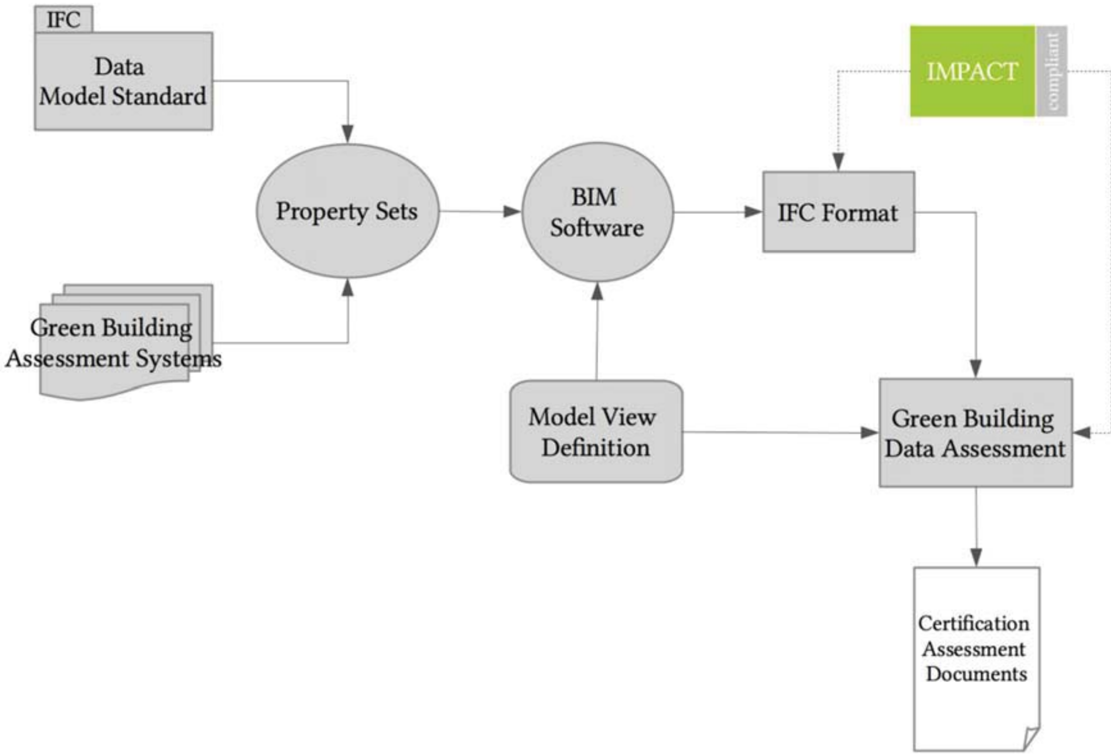

Figure 1 IFC-based approach for green building certification

3.1 Property sets for IFC model schema

To effectively determine the property sets, the process includes three main steps, which are examining the green building assessment system, the analysis of the major category areas of that assessment system and determining the property sets for IFC model schema respectively (Ilhan & Yaman 2013). In this study, BREEAM International NC 2013 is examined and each category for certification process is intended to be a property set with the criteria as their properties. The proposed property sets are listed as Pset_BRManagement, Pset_BRHealthandWellBeing, Pset_BREnergy, Pset_BRTransport, Pset_BRWater, Pset_BRMaterials, Pset_BRWaste, Pset_BRLandUse, Pset_BRPollution, Pset_BRInnovation. Within the scope of this work, Materials category of BREEAM International NC 2013 is proposed as given in Table 1. The property set is generated for schema IfcArchitectureDomain in the domain layer of the general IFC architecture and applicable to IfcProject entity.

Table 1 Proposed BRPset_Materials (IFC2x3 property set definition reference)

PropertySet Definition:

PropertySet Name	BRPset_Materials
Applicable Entities	IfcProject
Applicable Type Value	
Definition	Material properties for BREEAM certification

Property Definitions:

Name	Property Type	Data Type	Definition
Mat 01_Life Cycle Impacts	IfcPropertySingleValue	IfcBoolean	Identifies if appropriate life cycle assessment tools are

			used (= TRUE) or not (= FALSE)
Mat 02_Hard Landscaping and Boundary Protection	IfcPropertySingleValue	IfcBoolean	Identifies if appropriate life cycle assessment tools are used (= TRUE) or not (= FALSE)
Mat 03_Responsible Sourcing of Materials	IfcPropertySingleValue	IfcBoolean	Identifies if sourced materials are used for key (main) building elements (= TRUE) or not (= FALSE)
Mat 04_Insulation	IfcPropertySingleValue	IfcBoolean	Identifies if the thermal insulation has been responsibly sourced (= TRUE) or not (= FALSE)
Mat 05_Designing for Robustness	IfcPropertySingleValue	IfcBoolean	Identifies if the protection of exposed parts of the building and landscape are adequate (= TRUE) or not (= FALSE)

Due to the required specific calculations for each property, all data types are set as IfcBoolean. The definitions, therefore, are addressed in the question form. According to the answers of the properties, further calculations will be made based on the BREEAM assessment for each criterion. In order to gather the data related to project and responsibly sourced materials, BRPset_ProjectInformation and BRPset_ResponsiblySourcedMaterials are developed respectively. BRPset_ProjectInformation is applicable to IfcProject entity and has ProjectType and BuildingType properties, which are enumeration (Table 2).

Table 2 Proposed BRPset_ProjectInformation (IFC2x3 property set definition reference)

PropertySet Definition:

PropertySet Name	BRPset_ProjectInformation
Applicable Entities	IfcProject
Applicable Type Value	
Definition	Project information for BREEAM certification

Property Definitions:

Name	Property Type	Data Type	Definition
ProjectType	IfcPropertyEnumeratedValue	PEnum_ProjectType • Fit-Out • Refurbishment • New Construction	The type of project
BuildingType	IfcPropertyEnumeratedValue	PEnum_BuildingType • Commercial • Court • Domestic • Education • Health • Housing (HighRise) • Industrial • Office • Retail	The type of building

The properties of responsibly sourced materials for calculating the related issue are derived from BRPset_ResponsiblySourcedMaterials. The materials should be first checked if they are responsibly sourced and then the tier level of responsibly sourced ones should be extracted. Thus, the property set for responsible sourcing of materials is applicable to IfcBuildingElement entity and has two properties including ResponsiblySourced and TierLevel. While IfcBoolean data type is used for ResponsiblySourced, TierLevel has an EnumList (Table 3).

Table 3 Proposed BRPset_ResponsiblySourcedMaterials (IFC2x3 property set definition reference)

PropertySet Definition:

PropertySet Name	BRPset_ResponsiblySourcedMaterials
Applicable Entities	IfcBuildingElement
Applicable Type Value	
Definition	Responsibly sourced material properties for BREEAM certification

Property Definitions:

Name	Property Type	Data Type	Definition
ResponsiblySourced	IfcPropertySingleValue	• IfcBoolean	Identifies if the material is responsibly sourced (= TRUE) or not (= FALSE)
TierLevel	IfcPropertyEnumeratedValue	PEnum_TierLevel • Excellent • Very Good • Good • Pass • Certified EMS • Verified	The tier level for the responsibly sourced material.

3.2 Minimum model view definition (MVD)

Even though IFC is a rich product-modeling schema, it is highly redundant, offering multiple ways to define objects, relations, and attributes (Venugopal et al 2012). Thus, data exchanges are often unreliable due to inconsistencies in the assumptions different implementers of exchange functions make about how information should be expressed (Sacks et al 2010). There are often unpredictable differences in the ways in which export and import functions treat the same data, posing a barrier to the advance of BIM (Eastman et al 2010, Olofsson et al 2008).

Defining model view definitions, which require principal decisions and workarounds, is needed since the IFC itself does not address a number of semantic issues comprehensively. The minimal set of IFC aspects must be exported to the IFC file for it to be a valid input for green building data assessment. The minimum MVDs of the project entity and main building elements that are necessarily discussed for BREEAM certification should be included.

3.3 Green building data assessment

The assessment of green building data for certification during the design stage aims to calculate the available points for each BREEAM Materials category issue. The input of the assessment is the IFC file exported from BIM software with the minimal MVDs includes the extended property sets. The calculation is made according to the building and project type and depending on the BREEAM guide. The requirements, work flow diagrams and IFC algorithms, therefore, of each issue should be addressed in detail (for further details see Ilhan 2014).

Early design stage data assessment facilitates the decision-making whether the selected building elements and materials should be reviewed. A comparison of the elements according to their quantities and green ratings is made and in the case of lacking credits, other alternatives are experienced.

4 Conclusion and Further Research

BIM has been growing to play a significant role in building performance throughout the whole life cycle due to its benefits. IFC, additionally, as an industry-wide open and neutral data format, provides an independent environment for BIM. BIM incorporated design process with sustainable data has a beneficial impact on sustainable decisions and simplifies the certification process in terms of time and cost due to early stage interactions and improved outputs.

In this study, an IFC-based approach for green building data assessment is presented in order to provide a basis for adapting the proposed model (Ilhan 2014) to new BREEAM scheme by developing the property sets. The IFC algorithms for the calculation of each issue should be rewritten according to the new requirements and criteria by using the proposed model as the substrate. Also the involvement of IMPACT compliant into the proposed model should be examined so that an integrated solution for life cycle impacts can be offered. IMPACT's based on IFC standard also shows that the proposed model is on the right lines.

The examination of other categories of BREEAM and other green building assessment systems, their development as property sets in the IFC standard and algorithms for the calculation are the initial concerns for further research. The scope of the model can be developed in a broader perspective depending on the targeted necessities. Finally, the implementation of the proposed model can be considered as an add-on that enhances BIM-based applications. Even though this canalise the users to specific BIM software, it may increase the usage of the assessment tool due to the ease of use.

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