Towards Automated Process to Manage Buildings' Environmental Sustainability- A BREEAM Application

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Abstract
Building Information Modelling (BIM) promotes effective information and process integration across lifecycle and supply chain. This integration should comply with an increasingly complex regulatory environment and statutory requirements. This paper presents a valid approach for BIM-based solution to promote environmental sustainability. To achieve this, a methodology has been developed and examined to integrate ICT-based information management systems with environmental sustainability assessment methods. The methodology has been applied to BREEAM assessment method to examine the possibility for automating compliance checking. Although the system performed well in assessing some BREEAM requirements, the aim of fully automating BIM based sustainability compliance checking is currently difficult to achieve. This is due to the fact that many assessment data requirements cannot be processed from a BIM model without human interaction.

Keywords
BIM, Environmental sustainability, BREEAM assessment, Compliance checking, IFC Extension

1. Introduction

Current practice within the construction industry demands more effective tools to design sustainable and high-performance buildings that are able to achieve low carbon footprints (Everett et al., 2012). To achieve this, professionals throughout the construction industry are increasingly required to use environmental assessment systems to evaluate building performance during the design, construction and operation stages (Singh et al., 2012). Never the less, the traditional assessment methods have been criticized for being tedious and long processes. This lack of tools has raised several important issues that need to be considered while assessing the sustainability performance of buildings. This includes the large amount of data and information across the project lifecycle and supply chain, the nature and the number of the performance criteria and their divergent influence on the different stages of construction projects (Jaffe et al., 2005).

While a plethora of environmental assessment methodologies and frameworks are currently available to enforce the delivery of low carbon buildings (Trusty, 2000) (e.g., BREEAM and LEED), there is a clear gap in the provision of design-friendly tools and services that support and implement these methodologies and facilitate the process of environmental assessment. Moreover, the current manual practice of conducting an environmental assessment is not effective, as carried out during the later stages of the construction process. Hence, any improvements in achieving the desired sustainable performance have often proved too expensive and time consuming (Kibert, 2008). A comprehensive assessment process of regulatory compliance has not yet been achieved to-date. In the UK, BREEAM assessment is conducted manually by professional BREEAM assessors. To resolve that, the construction industry needs a fundamental change in the assessment culture and methodology in order to provide the opportunity to address holistically and in an integrated way, the required life cycle performance assessment (Lee and George, 2013).

The relatively recent emergence of BIM technologies provides a key opportunity to optimise the process of environmental assessment and regulatory compliance checking. The UK government has announced that the use of Building Information Modelling (BIM) is now mandatory for all public sector projects (Counsell, 2012). The focus has since shifted from the encouragement of adoption, to practical BIM implementation and hence to effectively integrate the power of BIM to facilitate sustainability assessment of buildings (Jung and Joo, 2011, Singh et al., 2011).

The approach presented in this paper will address the challenge of automating the highly-complex and technically-rigorous BREEAM assessment process. The availability of such a system will prove invaluable in increasing the functionality of BIM solutions to allow building designers to manage the sustainability performance of their design during the early stages of a construction project. In addition, such a solution will have the significant advantages of reducing the time required for the assessment process, and conducting the work at a minimum cost.

2. Background

BIM tools allow efficient sustainable construction by providing the information required for sustainable design analysis and analysis available throughout the design stage as by product of design activities. This has been reported by many researchers and software venders such as Autodesk (Azhar et al., 2009). For example, the energy performance of a building could be directly influenced by the building features such as massing, orientation, openings, space layout, insulation specifications and so on. By using BIM, designers are able to consider these aspects and their impacts in a more integrated and informed way to achieve an optimized design which meets sustainable building regulations.

In order to practically conduct building performance assessment in the early design and preconstruction stage, the access to a comprehensive set of information and knowledge regarding building form, component behaviour, management system, location, materials, context, and technical systems are required. Therefore, the integration between BIM and sustainability tools to develop an automated assessment process has been studied by many researchers (Biswas and Wang, 2008). Furthermore, there are many practical attempts to consider sustainability assessment process using information modeling tools.

BIM software companies such as Bentley Systems, Autodesk and Graphisoft have developed their integrated BIM solutions where the regulation compliance checking has become a differentiating and marketing feature. This is reflected in Bentley System's AECOsim Compliance Manager; a project management and collaboration service to automate the LEED certification process for the United States

Green Building Council's (USGBC) (Bentley, 2016). The system is based on a centralized online LEED data repository and a record for project information. The system checks building's LEED rating using checklists, wizards and calculators. However, this state-of-the-art service fails short in providing an integrated solution that extracts seamlessly the necessary data from the BIM taking into account the lifecycle and supply chain complexity. This is the clear gap addressed by the present paper.

There is a considerable number of software tools used for sustainability analysis, energy analysis and CO2 emission calculations. For example IES<VE> has the ability to conduct energy analysis and examine building compliance with part L of the English building regulations and check against the LEED rating system. The process is managed by BIM and the capability of data exchange between BIM design tools and energy simulation tools (Crawley et al., 2001). Different formats for data is used to achieve the exchange and the most popular ones are gbXML and Industry Foundation Classes (IFC). However, there are some limitations in their usage; gbXML is not comprehensive and it lacks lifecycle consideration and IFC does not include all of the information needed for sustainability compliance checking.

Beyond building simulation tools which mainly focus on energy efficiency of the building, and this only represents a part of the comprehensive BREEAM environmental assessment process, there are several attempts to consider building model checking systems. These were well studied by the author to facilitate the development of the current methodology.

One of the most popular model checking systems is Solibri Model Checker (SMC). Solibri has been designed to achieve continuous quality control for the building model during its life cycle. Its functionality is based on an information take-off (ITO) capability, which allows users to collect information from the BIM, organise it, visualize it, read the IFC file, map it to its rules structure, and report results instantly. The information that can be checked with SMC includes areas and spatial calculations, the envelope of the building to be used for energy calculations, volumes, and quantities. Furthermore, there are many other systems to conduct design rule checking of the building information model such as Jotne Express Data Manager, EDM Model Checker, and E-plan Check of the Singaporean CORNETE project (Eastman et al., 2009)

The methodology applied in the aforementioned compliance checking approaches was to create IFC models and then process the IFC files to facilitate information exchanging and processing (Salama and El-Gohary, 2011). Most of the previous developments focused on the architectural and structural design domain, where efforts were exploited only to examine compliance with relatively simple form of rules such as dealing with geometrical or special attributes (Khemlani, 2002). For example, checking access dimensions, doors sizes, or wall thickness (Yang and Xu, 2004). It can be concluded from literature review findings that BIM integrated solutions for sustainability checking is still in its early stages (Kasim, 2013). Therefore, this paper presents the methodology that has been developed for a more comprehensive assessment process.
This methodology paves the way to a design management approach. It can be used iteratively to simulate the performance criteria against targeted regulations as design develops. This helps designers manage the compliance checking process over the life cycle of the construction project and equally the tool provides the designer with constant feedback on how to improve the performance of the design as needed.

3. Automation of Environmental Assessment Method

The stages of BIM- based sustainability compliance checking described in this paper are in line with the previously reported efforts by (Eastman et al., 2009), where code compliance checking is structured into four major phases: (a) rule interpretation and logical structuring, (b) building model preparation, (c) the rule execution phase, and (d) the reporting of the checking results. However, there are some significant differences in terms of the functional issues presented in each phase. Figure 1 illustrates the overall structure of the developed approach, and the details are explained in the following sub-sections.

Figure 1 shows how the regulations (BREEAM in the current paper) has been converted into rules to facilitate compliance checking. Within Figure 1, label (1) shows how rules are extracted using decision logic and a metadata language called RASE (Hjelseth and Nisbet, 2011). This process creates formalized business rules that can be further integrated into automated services as shown in label (2). The output of this process is a taxonomy of the domain of compliance requirements and their required data for the particular regulation. This taxonomy describes all objects and attributes that are needed for the assessment.

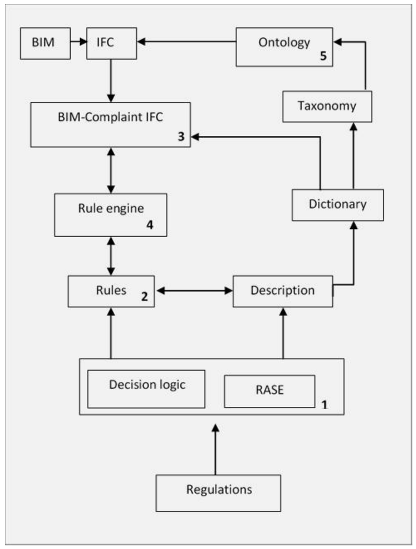

Figure 1 Methodology overview

Based on this taxonomy, a list of data items has been identified to generate a dictionary of compliance data requirements. The advantage of having this dictionary is to perform an enhancement of the current IFC standards (Label 3). From this analysis, a set of improvements have been identified in order to make an IFC extension for sustainability compliance checking. Finally, a rule engine is used to perform the compliance check against an IFC model (Label 4).
The rule based system is then integrated in the form of a plug in with an industry standard design package. In the current case implementation, the rules checking system was integrated with Bentley Microstation (Figure 2). However, the generic so that a similar plug in for Autodesk Revit or any other BIM design tool could easily be created.

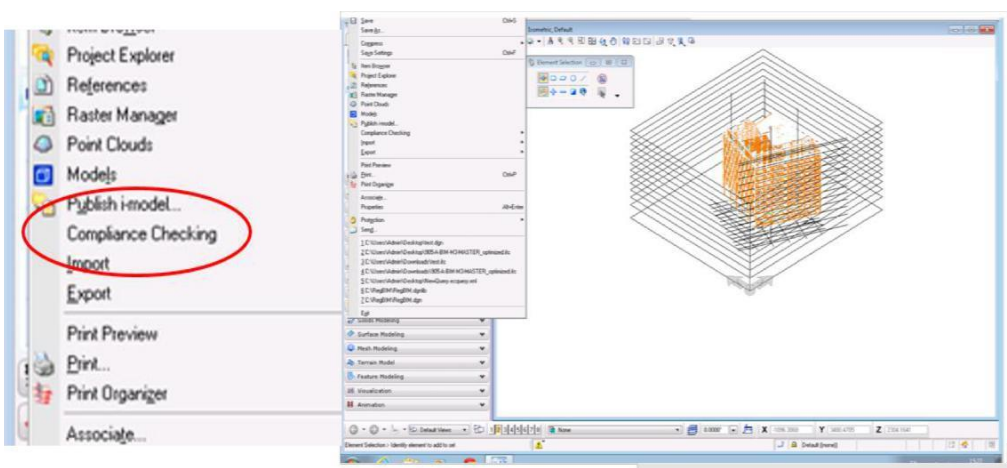

Figure 2 Bentley Microstation interface for compliance checking

This ability to integrate a regulatory compliance system together with design tools has many advantages for designers. It allows them to visualize and preview the sustainability performance of a building and its regulatory compliance during the modelling phase, enabling them to achieve the optimized design. In addition to this, we believe it can reduce the time and cost and release human assessors from such a repetitive and tedious task

4. Implemntation and results validation

The developed methodology has been validated by applying it to a real case study. A BIM model of a pre-designed and pre- BREEAM assessed building has been imported to Bentley microstation where the plugin for the compliance checking was added.

Then BREEAM assessment has been conducted using the developed methodology to verify the accuracy of the system and to reflect the differences between the compliance checking results obtained from the actual manual process and the automated computer-based approach. Results for the overall BREEAM assessment of the building is given in table 1. In this paper, validation results for BREEAM-Management category is illustrated.

Table 1 BREEAM Assessment results

BREEAM Category	Credits Achieved	Credits Available	% of Credits Achieved	Category Weighting	Category Score
Management	22	22	100.00%	0.12	12.00%
Health and Wellbeing	14	15	93.33%	0.15	14.00%
Energy	8	31	25.81%	0.19	4.90%
Transport	7	11	63.64%	0.08	5.09%
Water	7	9	77.78%	0.06	4.67%
Materials	4	13	30.77%	0.125	3.85%
Waste	7	7	100.00%	0.075	7.50%
Land Use and Ecology	6	11	54.55%	0.1	5.45%
Pollution	11	13	84.62%	0.1	8.46%
Innovation	5	10	50.00%	0.1	5.00%
Final BREEAM score					70.92%
BREEAM Rating					EXCELLENT

The implementation results shows that the developed system correctly calculates the correct results, as judged by a comparison with the traditional assessment method. Most of the BREEAM requirements concerning the sustainable management of the building design are subjective; this information can seldom be presented directly by the information model. However, the model was enriched by these information and BREEAM assessment was then conducted.

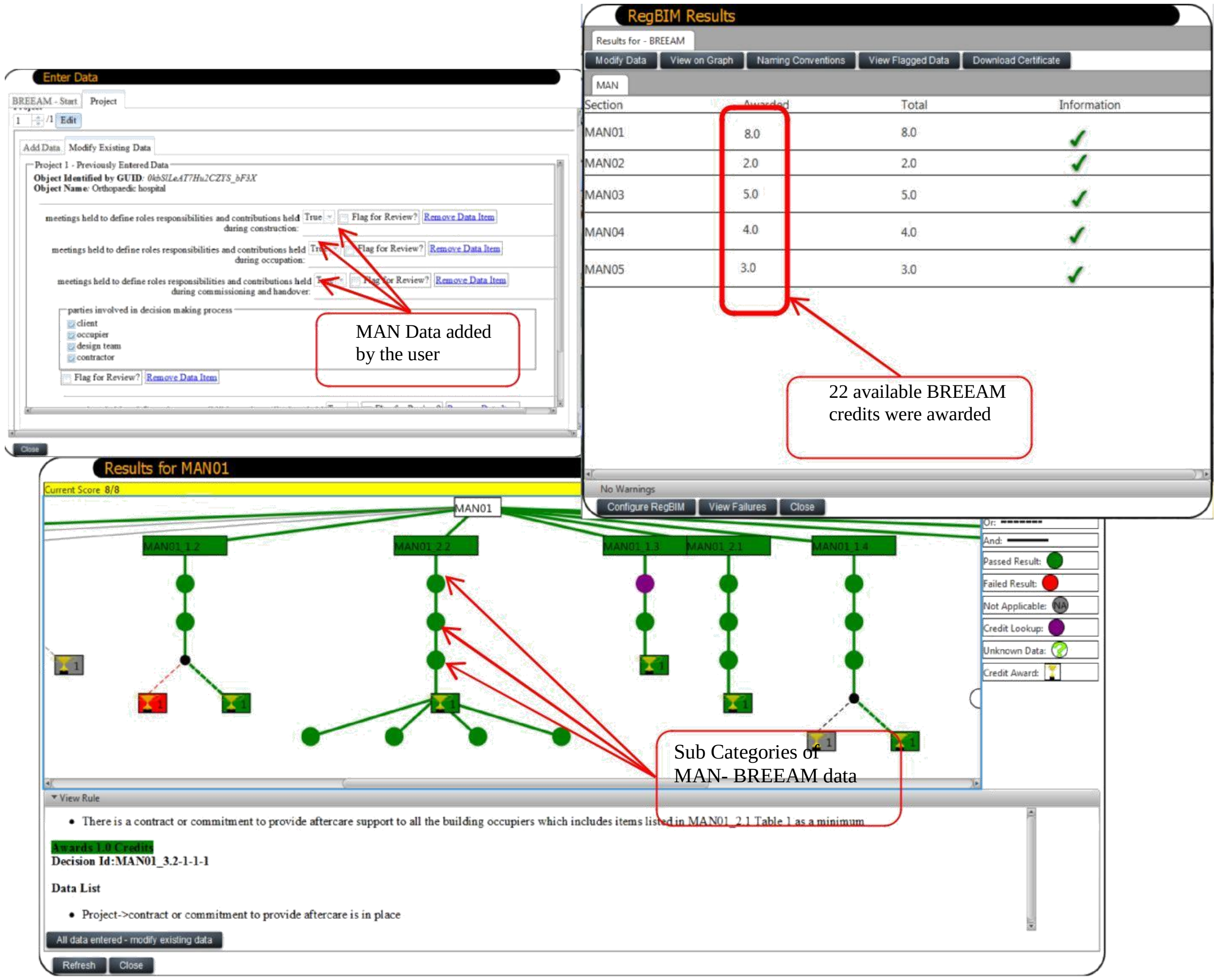

Figure 3 BREEAM assessment results

4. Conclusion

This paper has presented a generic valid methodology for sustainability assessment checking using BIM integration solution. The system can facilitate automating sustainability assessment process by using Building model data to examine sustainability performance. The methodology has been applied to BREEAM assessment method and it involved extracting the relevant information for BREEAM assessment using the concept of BIM through the several stages; (a) extracting information requirements from BREEAM textual format; (b) converting these into BIM-friendly rules; (c) processing these rules through a dedicated rule-based service; and (d) performing BREEAM assessment performance analysis underpinned by the BIM concept. The methodology relied on using IFC data model which lacks the comprehensive representation of the data needed for the assessment, nevertheless, the developed system has address this issue and involve the enhancement of IFC files to include the required data for sustainability assessment and make it available in the Building information model.

Although the methodology that has been developed and the resulting BREEAM compliance checker have both performed well, the aim of fully automating BIM based sustainability compliance checking is currently difficult to achieve. This is due to the fact that many assessment data requirements are subjective and cannot be obtained from a BIM model without human interaction.

The approach presented in this paper is a management approach which can support a design performance review over time, as the design is developed and new details are added. The approach is generic and applicable to other regulatory compliance domains. The challenges of its implementation depend on the level of information of the building model and the complexity of the applied regulations. Finally, it is worth noting that the developed system presented in this paper is tested by the RegBIM project and is currently in the process of being exploited as an online service by the Building Research Establishment (BRE) in the UK.

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