Opportunities and limitations for integration of the Green Building Certification System in the BIM environment

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***Abstract*— With the increasing interest of the construction sector in the evaluation of existing and newly designed buildings using the principles of Green Building Certification Systems (GBCS), the scientific community is faced with the task of devising methods for their integration with Building Information Modeling (BIM) as an already established environment for managing the design process. Due to complex and comprehensive set of requirements of GBCS, covering all design stages, there are opportunities and limitations regarding integration with BIM, which represent the focus of this research. This paper examines GBCS (LEED and BREEAM) from the aspect of estimating the number and scope of issues and criteria susceptible to automation. Sections of the manual whose formulation and requirements allow parameterization can be translated into the BIM environment using visual programming language. In this paper, two methodologies for automating GBCS requirements have been proposed: the first can be applied to 28.6% of categories, and the second to 71.4%. Through the automation of GBCS requirements in practice, the time required to assess building design and prepare documentation will be reduced. Additionally, facilitating evaluation in this manner will result in using the GBCS manual not as a limitation, but as guidelines that can be quickly and seamlessly implemented. Designing new buildings or planning the reconstruction of existing ones can become more flexible, as it allows exploration of changes in order to define the best design options, ultimately aiming to improve overall building performance through the integration of GBCS in the BIM design process.**

Keywords*— Building Information Modeling (BIM), Green Building Certification System (GBCS), automation, parameterization

I. INTRODUCTION

In recent years, there has been a notable increase in the scientific community's interest in the integration of Building Information Modeling (BIM) and Green Building Certification Systems (GBCS). This is evidenced by the significant rise in the number of published scientific papers, which increased by 50% between 2019 and 2020 [1].

The GBCS provides guidance for evaluating both existing and newly designed building stock, from the perspective of sustainability and environmental impact. Due to the complexity and level of information required for certification, the evaluation itself constitutes a lengthy and intricate process. For this reason, the automation of certain aspects of this process is a highly beneficial circumstance for experts in this field. On the other hand, BIM has become a standard tool in the Architecture, Engineering, Construction, and Operations (AECO) industry. The industry has shown significant interest in both GBCS and BIM, due to the significant benefits they bring. Therefore, their integration is currently a highly relevant area, being addressed by both the scientific community and professionals in practice [2].

Most researchers consider that the primary challenges and limitations of using BIM tools lie in data exchange and interoperability with other software, despite the theoretical existence of methods for interacting with BIM files, such as Industry Foundation Classes (IFC) [3]. Interoperability with other software leads to the loss of a significant amount of data and also prolongs work processes [4]. Therefore, it is important to develop new tools within the framework of BIM technology or enhance existing software to minimize or completely eliminate the need for other software (e.g., for building performance simulations).

A. Previous research

This study represents a continuation of research into the integration of GBCS and BIM, specifically focusing on the integration of the LEED and BREEAM manuals into the BIM design process. During the research, two papers were published: the first addressed newly designed architectural objects, while the other one focused on existing ones.

1) LEED to BIM methodology

In the first paper [5], the authors explored methods for automating insights into credit achievement from the LEED Reference Guide for Building Design and Construction (LEED BD&C) v4 manual [6]. To implement the proposed workflow, Autodesk Revit 2023 BIM software was utilized. Visual programming tool Dynamo, integrated into the aforementioned software, was employed to create an algorithm for analysis and calculation of credit achievement.

Excel was utilized to create a database of materials, which was populated with data sourced from various declarations (e.g. EPD - Environmental Product Declaration).

2) BREEAM to BIM methodology

The second paper [7] investigated the Technical Manual SD225 1.4 – BREEAM International Non-Domestic Refurbishment 2015 [8] and the potential for its parameterization to facilitate the implementation of its requirements into BIM. By employing Autodesk Revit 2023 for building modeling and Dynamo for parameterizing requirements, once again, insight into whether the analyzed credit has been achieved or not is facilitated.

Each GBCS provides many different manuals depending on the type of buildings, project, and development, as well as whether they are existing or newly designed buildings. The proposed methodologies can be applied independently of the type and purpose of the building, the type of project, as well as the design phase. Through explained methodologies and software combination, automated, real-time insight into the achievement of specific credits is enabled, rendering it accessible throughout all stages of the design process. In the previous research, the methodologies were applied to one category each from the LEED and BREEAM manuals. Both studies demonstrate significant time savings in the evaluation and certification process of newly designed and existing buildings, as the automation has eliminated the lengthy and exhaustive manual work.

In order to move toward a holistic approach of assessing buildings for the purpose of obtaining green building certification, this article aims to explore and analyze the potential opportunities and limitations of automating all GBCS categories. The applicability of the proposed methodologies for automation was analyzed in seven common categories of the LEED and BREEAM manuals.

II. GBCS CATEGORIES

This study aims to examine the requirements established by LEED and BREEAM GBCS, which, notwithstanding variances in specific prerequisites, share common environmental objectives. The categories primarily pertain to the subsequent subjects:

A. Management (BREEAM) / Integrative design (LEED) and Sustainable Sites (LEED)

Categories encompass a holistic approach throughout the building development process, encouraging the involvement of all relevant stakeholders during the initial design phases and guiding the management process in the later stages (construction, commissioning, post-occupancy)

B. Health and Wellbeing (BREEAM) / Indoor Environmental Quality (LEED)

Categories focus on the aspects of the building environment that influence the occupant's health and wellbeing including visual and thermal comfort, air quality, acoustic qualities of the development, access to basic amenities.

C. Energy (BREEAM) / Energy and Atmosphere (LEED)

Categories encourage energy efficient and responsible building developments by using extensive analysis during the design process and setting criteria for various energy efficient building features

D. Water (BREEAM) / Water Efficiency (LEED)

Categories represent a group of requirements which provides guidelines and recommendations for efficient and sustainable water use.

E. Transportation (BREEAM) and Land use and ecology (BREEAM) / Location and transportation (LEED)

Categories focus on the methods through which development can contribute to a more sustainable local transportation infrastructure by analyzing the site location and surroundings. Choosing building locations in already developed and compact urban environments is encouraged. Additionally, BREEAM introduces ecology criteria aimed at enhancing and improving site ecology.

F. Materials (BREEAM) and Waste (BREEAM) / Materials and Resources (LEED)

Categories provide guidance for making responsible choices regarding materials, encouraging material efficiency aiming to reduce the amount of construction and operational waste and improving waste management.

G. Pollution (BREEAM) category

Category focuses on the prevention of potential pollution that the development may cause to the surrounding environment. It provides guidance on the selection of systems for water pollution prevention, noise reduction, and controlling light pollution.

Innovation (BREEAM and LEED) category which awards innovation and creative solutions coming from the project teams and aims to push the boundaries of the standard criteria set by GBCS, as well as *Regional priority* (LEED) which prioritizes enhancement of the local environment in terms of environmental protection, social equity and public health, due to their complexity and specificity are not examined in this study.

III. METHODOLOGY

In this study, the potential opportunities and limitations regarding integration with BIM were examined in relation to the previously mentioned researches.

In the mentioned studies, two methodologies were presented for automating the assessment of compliance with GBCS requirements. The *LEED to BIM methodology* utilizes a previously created database in Excel format, which is integrated into the BIM project process using Dynamo visual programming tools, enabling calculation, analysis, and notification of the number of achieved credits. On the other hand, the application of the *BREEAM to BIM methodology* involves parameterizing the requirements of the selected GBCS manual category. Subsequently, using Dynamo, these requirements are analyzed and compared with the BIM model data. As a final result, information is obtained regarding whether a requirement is fulfilled or not, thereby determining the number of achieved credits.

Studying each category from the perspective of the applicability of the two methodologies, opportunities and limitations for automating the requirements were analyzed.

IV. RESULTS

The Results section entails defining the level of applicability of the proposed methodologies to GBCS

categories, that is analyzing the opportunities and limitations for integration into the BIM environment.

A. Management (BREEAM) / Integrative design (LEED) and Sustainable Sites (LEED)

While BIM modeling serves as an integrative design tool that promotes collaboration and aids in incorporating multiple stakeholders into the design process, it alone is insufficient to meet the requirements of the Management section. These criteria primarily involve activities beyond the design process, including internal and external consultations, construction site management, and post-construction activities such as commissioning and handover. In this context, BIM can facilitate project communication tracking by incorporating various inputs and comments into the model, thereby contributing to the preparation of evidence for the criteria and demonstrating the outcomes of collaboration. In the context of this study, the proposed methodologies for automation are not applicable to this category.

B. Health and Wellbeing (BREEAM) / Indoor Environmental Quality (LEED)

Since occupants' health and comfort often depend on building properties and materials, a significant portion of the criteria in this category could potentially be automated using the *BREEAM to BIM methodology* (parametrization). Requirements aimed at achieving optimal visual comfort for occupants can be met by assessing factors such as daylight availability, presence of glare prevention elements, views from room windows, and evaluation of internal and external artificial lighting features. Additionally, occupant comfort concerning accessibility (both exterior and interior communications, traffic solutions, etc.) and access to outdoor space can be analyzed during the design process by examining the physical properties of the building. A detailed BIM model with integrated HVAC and plumbing designs could further automate the assessment of criteria related to thermal air and water quality, as well as thermal comfort.

C. Energy (BREEAM) / Energy and Atmosphere (LEED)

The set of criteria in this section focuses on assessing the energy efficiency properties of the building. Therefore, integrating detailed electrical and HVAC designs, which encompass the chosen systems' details and characteristics, would significantly contribute to the possibility of automation through the combination of the *LEED to BIM* and *BREEAM to BIM* methodologies. The limitations of this section's criteria pertain to passive design and low and zero carbon analysis, which require specialized knowledge and experience and are unlikely to be achieved through the use of parametrization.

D. Water (BREEAM) / Water Efficiency (LEED)

Reducing water consumption and implementing sustainable solutions can be achieved through the specification of efficient sanitary components and solutions that prevent unnecessary water use through careful monitoring systems. This feature could be automated using the *BREEAM to BIM methodology*, which could analyze the system properties included in the BIM model.

E. Transportation (BREEAM) and Land use and ecology (BREEAM) / Location and transportation (LEED)

Although most of the criteria related to transportation depend on external factors not included in the BIM model (such as surrounding traffic and public transportation systems), several criteria could still be automatically assessed using parametrization. Criteria that promote the use of alternative means of transport and require the provision of suitable bicycle parking, electric car chargers, etc., could be assessed by checking the quantity and suitability of these amenities via parametrization (*BREEAM to BIM methodology*).

Land use, which pertains to site location and the existing ecological condition of the site, cannot be automated through the use of BIM, as they require a much wider scope of assessment than is typically provided by the model.

F. Materials (BREEAM) and Waste (BREEAM) / Materials and Resources (LEED)

As demonstrated in the previous study, assessment aligned with requirements pertaining to materials possessing suitable characteristics is closely tied to BIM and can be evaluated using the *LEED to BIM methodology*. Limitations in this section pertain to specialized studies involving life cycle assessment (LCA) and the efficient utilization of materials.

The waste section, which is presented as a separate category in BREEAM, primarily addresses criteria concerning waste management methods and recycling, which are unlikely to be incorporated into the BIM model.

G. Pollution (BREEAM) category

The aspects of the Pollution category that could be subject to automation relate to the analysis of HVAC and lighting systems, which are associated with various types of pollution. Accordingly, *BREEAM to BIM methodology* is applicable. However, the remaining criteria, which address surface water pollution and noise, cannot be integrated into BIM as they necessitate the involvement of different specialists and a more intricate analysis. The Table I. serves to illustrate potential opportunities for implementing one or both methodologies on specific requirements within a category.

TABLE I. APPLICABILITY OF THE PROPOSED METHODOLOGIES TO GBCS CATEGORIES

Category	***LEED to BIM methodology***	***BREEAM to BIM methodology***
Management (BREEAM) Integrative design (LEED) and Sustainable Sites (LEED)		
Health and Wellbeing (BREEAM) Indoor Environmental Quality (LEED)		✓
Energy (BREEAM) Energy and Atmosphere (LEED)	✓	✓
Water (BREEAM) Water Efficiency (LEED)		✓
Transportation (BREEAM) and Land use and ecology (BREEAM) Location and transportation (LEED)		✓
Materials (BREEAM) and Waste (BREEAM) Materials and Resources (LEED)	✓	
Pollution (BREEAM) category		✓

V. DISCUSSION AND CONCLUSION

This study analyzed LEED and BREEAM GBCS from the perspective of the applicability of methodologies for automation in the BIM environment proposed in previous research.

Integrating GBCS requirements into BIM software offers several benefits, including easier and faster implementation

and enhancement of design qualities in the field of sustainability. However, the automation between the BIM model and GBCS requirements is directly dependent on the scope and level of detail within the model itself. This implies that the more information and detail incorporated into the model, the more requirements can be effectively assessed. Therefore, the model should not merely include basic information regarding materials, building elements, or components, but should also encompass details such as origin, relevant standards, system design specifications, and component performance. For the application of the two proposed methodologies, an important prerequisite is that the BIM software is used at an advanced level and to its full capacity. Given that the model contains the highest level of information, the limitations of BIM in this context primarily pertain to external processes and factors beyond the design process.

Considering the results of this research, a significant opportunity for automation is observed when it comes to the evaluation of buildings from the perspective of GBCS. Table 1 shows that the *LEED to BIM methodology* can be applied to 2 out of 7 categories of the LEED and BREEAM manuals, accounting for 28.6%. The *BREEAM to BIM methodology* can be applied to 5 out of 7 categories, accounting for 71.4%.

On the other hand, limitations in the application of the proposed methodologies have also been identified. Certain categories or requirements cannot be automated using the proposed methodologies due to some of the processes involved in sustainability assessment and the impact of buildings on the environment being associated with activities and analyses that cannot be linked to the BIM model.

To clarify, if a GBCS category in this study is indicated as capable of accommodating one of the automation methodologies, it doesn't imply full automation is feasible. The author's previous research [5], [7] has highlighted automation limitations, indicating that manual verification is still necessary for certain stages of the process.

Various research gaps can limit comprehensive automation, such as software constraints, which necessitate certain calculations to be performed manually. In some cases, automation requires prior manual work, such as forming a database, which serves as the starting point for further automation.

Future research will focus on defining and specifying which requirements can be automated, in order to determine the degree of automation of an individual category more precisely. Accordingly, the authors will make efforts to modify the proposed methodologies and create new ones that will address the holistic automation of requirements in GBCS.

Working on the challenges of integrating BIM and GBCS, from a broader perspective, will lead to the definition of a holistic sustainable approach to evaluating both existing and newly designed building stock.

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