BUILDING INFORMATION MODELING (BIM) AND GREEN BUILDING INDEX (GBI) ASSESSMENT FRAMEWORK FOR NON-RESIDENTIAL NEW CONSTRUCTION BUILDING (NRNC)

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DEDICATION

Specially Dedicated to

My Parents

My Lovely Brothers and Sisters

My love to you will always remain and thank you for your Support, Guidance, Patience, Joyfulness to make this experience complete.

Thank you for your Sacrifices, Prayers, Understanding, and Continuous Support I wouldn't Make it Without you.

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“ May ALLAH Bless Us All To Achieve Excellence in Life

ABSTRACT

The global construction industry endorsed Building Information Modeling (BIM) and its many advantages. However, despite this endorsement, BIM still failed to attract Malaysian companies to use BIM in green building assessment, especially for the assessment of Green Building Index (GBI), and maintain GBI certification during building occupancy using BIM features. The main issue of utilizing BIM as a GBI assessment tool is the applicability of BIM Tools to digitalize GBI credit by design team, which results in the digitization of GBI criteria into BIM Model. This study aims to identify common components related to the capability of BIM to digitalize and assess GBI criteria. These components include BIM uses and tools and GBI criteria and processes. This study applied quantitative and qualitative approaches to collect data. The quantitative approach used questionnaires, which were distributed to 900 GBI members, i.e. GBI certifiers and facilitators. The survey generated a response rate of 32% during eight months of data collection. The results were analyzed using SPSS and SmartPLS. Four model categories were identified, namely, BIM uses, BIM tools, GBI criteria and GBI certification process. These categories were used to assess the BIM–GBI framework. The results obtained from the questionnaire showed that only 16 BIM uses must be included in the BIM execution plan of the GBI project for assessment purposes. The results also showed that the BIM tools present different levels of effect on the GBI criteria. The capability of BIM to assess GBI could be stronger in the design assessment (DA) than in the operation assessment, which supports the suggested BIM–GBI assessment framework. The second data collection was conducted through a focus group interview with BIM and GBI experts. Two interview sessions were conducted. Results show that the assessment method has a significant correlation in the BIM–GBI framework. The following categories were identified for the BIM assessment framework: BIM uses, BIM tools, and control, which were based on the GBI criteria for scoring and certification. Findings from the BIM and GBI assessment method framework show that GBI credits can be digitalized using different BIM uses directly and indirectly assessed by BIM tools for each GBI credit in both GBI assessment process. Based on the qualitative result of this research showed that BIM can help the design team to achieve 55% point in design assessment (DA) only and this helps the building to achieve GBI certification in level 4 of certified rating. On the other hand, 45% points of GBI credits can be digitals in completion and verification assessment (CVA). The framework provides a guide for the design team and facility management in digitalizing and assessing GBI criteria using BIM application during design assessment (DA) and completion and verification assessment (CVA) for new nonresidential constructions. The framework also offers and provides insights that will enable designers to understand the relationship between BIM and GBI criteria, which will contribute to BIM integration in Stage 3 and automate GBI assessment for the Malaysian construction industry.

ABSTRAK

Building Information Modeling (BIM) telah mendapat pengiktirafan oleh industri pembinaan di peringkat global. Namun, ia gagal untuk menarik minat syarikat-syarikat di Malaysia untuk menggunakan model ini dalam penilaian bangunan Hijau, terutamanya untuk penilaian Indeks Bangunan Hijau (Green Building Index – GBI) dan mengekalkan pensijilan GBI semasa menggunakan bangunan siap bina menggunakan ciri-ciri BIM. Tujuan utama penggunaan BIM sebagai perisian penilaian GBI ialah kebolehgunaan Peralatan BIM ke kredit GBI digital yang menghasilkan pendigitalan kriteria GBI kedalam Model BIM. Tujuan kajian dilaksanakan untuk mengenalpasti komponen biasa yang berkaitan dengan keupayaan BIM untuk mendigital dan mengakses kriteria GBI. Kaedah mod campuran iaitu pendekatan kuantitatif dan kualitatif digunakan dalam pengumpulan data, borang soal selidik (kuantitatif) dihantar kepada 900 fasilitator dan ahli GBI yang diiktiraf. Kajian ini mendapat kadar sambutan sebanyak 32% dalam tempoh lapan bulan pengumpulan data dan dianalisis menggunakan SPSS dan SmartPLS untuk pengukuran. Empat kategori model telah dikenal pasti iaitu penggunaan BIM, alat BIM, kriteria GBI, dan proses pensijilan GBI bagi penilaian rangka kerja BIM-GBI. Keputusan soal selidik menunjukkan hanya 16 penggunaan BIM yang diperlukan dalam pelan pelaksanaan BIM untuk projek GBI bagi tujuan penilaian dan alat BIM menunjukkan kesan yang berbeza pada kriteria GBI. Keupayaan BIM untuk menilai GBI mungkin lebih baik dalam penilaian reka bentuk (DA) berbanding penilaian operasi yang menyokong rangka kerja penilaian BIM-GBI yang disarankan. Secara kualitatif, dua sesi temu bual bersama pakar-pakar BIM dan GBI dijalankan menunjukkan bahawa kaedah penilaian merupakan satu perkara penting dalam BIM dan GBI. Berikut merupakan rangka kerja penilaian BIM iaitu; (Input) penggunaan BIM, kaedah penilaian alat BIM, dan kawalan berdasarkan kriteria GBI untuk pemarkahan dan pengesahan (output). Hasil daripada kaedah penilaian BIM dan GBI menunjukkan bahawa kredit GBI boleh didigitkan menggunakan BIM yang berlainan secara langsung atau tidak yang dinilai oleh alat BIM untuk setiap kredit GBI dalam kedua-dua proses penilaian GBI. Berdasarkan keputusan kualitatif menunjukkan BIM boleh membantu perekabentuk mencapai 55% mata dalam penilaian rekabentuk (DA) dan mungkin pensijilan GBI ini adalah pada peringkat 4 dengan taraf yang disahkan. Manakala, 45% mata boleh dilakukan secara digital dalam penyelesaian dan penilaian pengesahan (CVA). Ia menyediakan panduan kepada perekabentuk dan pengurusan kemudahan dalam proses digitalisasi dan menilai kriteria GBI menggunakan aplikasi BIM semasa penilaian rekabentuk (DA) dan penyempurnaan serta penilaian pengesahan (CVA) untuk pembinaan bukan-kediaman baru. Rangka kerja ini turut menawarkan dan menyediakan pandangan yang membolehkan perekabentuk untuk memahami hubungan antara kriteria BIM dan GBI, yang akan menyumbang kepada integrasi BIM dalam Tahap 3 dan mengautomasikan penilaian GBI untuk industri pembinaan Malaysia.

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BIM	-	Building Information Modeling
GBI	-	Green Building Index
DA	-	Design Assessment
CVA	-	Completion and Verification Assessment
SPSS	-	Statistical Package for the Social Sciences
PLS	-	Partial Least Square
AEC	-	Architecture, Construction and Engineering
ODBC	-	Open Database Connectivity

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Presently there is a huge demand for sustainability and green buildings. Therefore, it is important to make decision of design regarding sustainable building features at the stages of design and preconstruction [1]. For Green Building projects and certification procedure, the design team has to conduct in-depth sustainability analyses based on building shape, context, materials and mechanical electrical plumbing (MEP) systems. Since the Building Information Modeling (BIM) has a huge information on the models' capability which provides opportunity to produce more effective and comprehensive analysis with a traditional method of comparison [2].

Malaysian Institute of Architects over the years has been developing towards a more sustainable and green architecture. In 2008, the need for a localised Green Building rating tool became more evident especially in the light of increasing demand from building end-users for Green-rated buildings that would not overly and adversely contribute to the destruction of the environment. In August 2008, PAM Council endorsed and approved the formation of the new Sustainability Committee who was tasked primarily to develop and setup the Green Building Index and the accompanying Panel for certification and accreditation of Green-rated buildings [3]. The Green Building Index (GBI) was developed in 2009 and MyCrest was established in 2013 to promote sustainability in the built environment and raise awareness among industry players [4]. Also GreenRE was set up by Real Estate and Housing Developers' Association (REHDA) in 2013 to promote sustainability in the property industry and Green PASS (Green Performance Assessment System In

Construction) developed by Construction Industry Development Board of Malaysia (CIDB) to promote construction phase and operational phase of the building [5]. GBI is an environmental rating system for buildings developed by PAM (Pertubuhan Arkitek Malaysia / Malaysian Institute of Architects) and ACEM (the Association of Consulting Engineers Malaysia). It is Malaysia's first inclusive rating system for evaluating the environmental design and performance of Malaysian buildings [6].

Building Information Modeling (BIM) is a new approach to design, construct and facility management in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in a digital format [7]. Chen and Hsieh [8] developed a BIM-assisted rule-based approach to automatically check greenhouse gas emission of buildings. However, most of these applications are limited to the design stage.

Using BIM is also changing the manner of constructing buildings in the construction industry. The relationship of space and time can be accurately described in a systematic way in 4D modeling. Several approaches have been proposed to analyse spatial conflicts and to improve safety and efficiency on site based on the spatiotemporal information provided by BIM [9].

BIM in sustainability is relatively new concept within the Architecture, Construction and Engineering (AEC) industry. Therefore their relationship is just beginning to realise its potential. Krygiel and Nies [10] 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 the next steps in enhancing it is capability with sustainability. Azher *et al.,* [11] described the use of BIM to select building orientation, evaluate various skin options, and perform daylight studies for its positioning on the selected site during the design phase, thus enhancing its sustainability. Bynum and Issa [12] noted that because of the trend in sustainability toward net-zero-energy buildings and carbon emissions reduction, designers need to analyse the building as a fully integrated dynamic design and construction process. Stadel *et al.,* [13] suggested the use of BIM capabilities with life cycle cost analysis (LCA) 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.

The development of Building Information Modeling (BIM) technology, complex building modeling can be digitally constructed with precise geometry and accurate information in order to support various project stages. Many researchers had stated the benefits of BIM in AEC industry, such as accurate data environment, effective design process, accurate project cost estimation, time saving and other benefits [14].

The applications of BIM for sustainable building design or Green BIM model had been investigated widely recently. For instance, the data of BIM model can be utilised for green rating evaluation. BIM-based model can also be used for post occupancy evaluation process and waste reduction of renovation projects [15].

1.2 Problem Statement

The pre-construction phase of GBI building projects is the most critical time to make decisions regarding its sustainability features. Building information modeling (BIM) enables this information to be multidisciplinary in one model, thereby providing an opportunity to incorporate GBI criteria in the design process [16]. BIM has many uses throughout the life cycle of a project and can be used during the pre-, actual, and post-construction phases with different BIM tools in each of the project development while conducting technology and management process for the BIM and green building projects [17].

BIM applications are generally implemented for clash detection and 3D coordination in the Malaysian construction industry. Moreover, BIM application remains low for sustainability evaluation, engineering analysis, and GBI coding. The reason is the personnel's continuing indefinite ability to use the BIM tools for all the pursued GBI points to process the GBI certification in the design and operation assessment. Accordingly, these issues originate from the fact that many GBI buildings fail to maintain the final GBI certification after the operation stage [6].

The actual issues of the BIM application in the GBI assessment occur in two stages in the GBI certification process, namely, (1) design assessment and (2) completion and verification assessment. The design team experiences difficulty in assisting the GBI criteria for the design assessment, which is the same as the operation assessment. This problem occurs because the BIM application remains in the low stage of collaboration and integration, thereby resulting in a few problems on

the BIM application to digitize and assess each GBI credit for evaluation design and operation assessment. These issues are anticipated because of the difficulty in finding engineers, architects, facility managers, and project managers who are familiar with the GBI criteria, its assessment, BIM tools, and its process. Consequently, the design team and facility management should address the following problems:

i- The BIM team is unfamiliar with each GBI criterion that contains the entire requirement for the design and operation assessment. Accordingly, the BIM team must formulate a BIM Project Execution Plan to ensure that all parties are substantially aware of the GBI credit by identifying the BIM uses during the design and operation assessment for each GBI credit.

ii- The BIM team does not utilize the features of the BIM tools because these tools assess the GBI criteria from the BIM model using an external parameter while exporting files to different tools either in the design or operation stage.

iii- Digitizing the data in the BIM model is difficult during the operation stage because the designed BIM model does not follow the criteria of the GBI assessment. Accordingly, this assessment requires further information for each design and operation assessment.

iv- The project managers of the BIM and GBI projects experience difficulties in defining the responsibility of providing data and the roles for each GBI assessment process.

BIM has been implemented recently in the Malaysian construction industry. In addition, many projects are undertaken by BIM in the country, particularly the GBI project. However, construction players in Malaysia fail to use the BIM tools for GBI assessment in the design assessment. The reason is that having the final BIM model require considerable time and drawing the model using non-BIM tools for the design assessment. This long process will affect the operation assessment and incur loss of database for assessment, which BIM can provide for the long-term operation. Moreover, the BIM model can enable the design team to achieve the project goals of green building within the project life cycle [10].

The BIM data can be used to ensure the most efficient maintenance, scheduling, and use of space during the management and maintenance operations. This process can maintain the occupancy of a green building [18]. Many areas of adoption issues and know-how of BIM were investigated. However, no prior

research has considered the application of BIM in Green Building Index (GBI) assessment tools with whole of GBI criteria and its certification process. Therefore, the current research focuses on the applicability of the BIM application for GBI assessment in the Malaysian construction industry. This research focused on the use of BIM data to digitals GBI criteria for both design and operation assessment to achieve GBI certification even during the reassessment after operation stage.

1.3 Research Questions

The use of BIM has provided a means of increasing deliverable projects with many BIM uses in green building projects and ability of BIM tools for green building certification assessment. Although BIM is a recent development in construction, a lot of researches conducted the BIM for sustainability and in order to further enhance the BIM in planning, design, construction and operation.

In regards to the use of BIM with green building project, especially when it is implemented in order to obtain GBI certification, some of the most important issues will include:

- What is the capability of BIM application for Green Building Index assessment process?
- What is the BIM assessment method for Green Building Index assessment process?
- How is the process of BIM-GBI assessment for the Green Building Index project?
- What is the validation of development BIM-GBI assessment framework?

1.4 Research Objectives

This research seeks to assess the ability BIM application in green building assessment and demonstrates the process that the project team might use for assessment method in pursuing for green building certification and maintain the occupancy of green building. Therefore the research objectives are:

1. To assess the capability of BIM application for Green Building Index assessment process.
2. To analyse the BIM assessment method for Green Building Index assessment process.
3. To develop a BIM-GBI assessment framework for Green Building Index project.
4. To validate the BIM-GBI assessment framework for Green Building Index project.

1.5 Scope of Research

The scope of the research is limited to BIM and Green Building Index projects for Non-Residential New Construction (NRNC) in Malaysia. The Green Building index is divided into two rating tools for the assessment; Residential and Non-residential.

Non-residential building is the most GBI certificated projects and that is the reason for being the focus of research and there are some of projects have been in construction are BIM and GBI projects as Non-Residential New Construction, where the researcher plans to investigate the importance of BIM Uses for GBI assessment process in green building and the ability of BIM application tools to assist green building criteria for GBI competency. This research assessed the capability of BIM application for Green Building Index assessment process in order to develop a framework to link BIM based on the GBI rating system with level 2 of BIM maturity and GBI criteria for green building project.

The quantitative method in this research used questionnaire by online survey and the Green Building Index (GBI) members was respondents to achieve the research objective because as GBI member, they are responsible for providing services for green building project assessment. There are 900 GBI Certifier and Facilitators who were given certificates upon their completion of the course and examinations of GBI rating system, which made them familiar with GBI criteria and assessment process. The qualitative method was deeply focused on BIM-GBI assessment method which the respondents are experts of.

1.6 Significance of Research

This research attempt to help the design team to achieve deliverable goals for green building due to the demand of marketing for design team, contractor and facility manager to integrate BIM in the green building delivery and certification process, with design and operation stage to ensure the occupancy of building follows the design. This help for the client of Green Building project to maintain the building occupancy during the operation and getting, digital data for assessment of building for GBI certification.

This research is useful for academicians when studying the basics of full integration of automatic green building assessment that may be implemented for system design specification in green industry, where more green building projects in BIM integration delivery project with high stage of BIM level application can be executed. The problems have been identified in previous section (1.2) and the main objective of this research is to find solutions to those issues.

1.7 Thesis Outline

This thesis is structured so as to provide a critical review of relevant information about the topic of research and to discuss relevant literature, thereby providing a research framework and a plan for conducting the research. Next, data gathered are analysed to provide evidence in support of the research objective. The research findings, together with the theoretical framework are generated, then used to suggest BIM-GBI assessment framework. The research consists of six chapters, and its framework is as follows:

Chapter 1: This chapter introduces the research, the necessity of this research, problem statement of this research, aims and objectives of the study, scope of the research and significance of the research.

Chapter 2: Reviews the existing literature and covered some areas including: an overview Building information Modeling for sustainability, BIM Uses and Tools, Green Building assessment tools, BIM software analysis in sustainability and BIM assessment method in Green Building Tools.

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