

南京理工大学泰州科技学院

毕业设计(论文)外文资料翻译

学院(系): 城市建设与设计学院

专 业: 工程管理

姓 名: 陈科屹

学 号: 1904260111

外文出处: 英国皇家物理协会期刊

附 件: 1. 外文资料翻译译文; 2. 外文原文。

指导教师评语:

签名: _____

2023 年 1 月 13 日

注: 请将该封面与附件装订成册。

附件 1：外文资料翻译译文

BIM 技术在无梁楼盖结构可持续设计中应用

摘要 建筑信息模型（BIM）是建筑、工程和施工（AEC）行业的一个潜在的数字化工具，用于以三维模型表示项目。它提供了一个中央统一的数据库，可以进行查询、过滤、操作和改变分析，从而在项目的整个生命周期为项目的利益相关者提供了一个合作工具。采用 BIM 的承包商获得了良好的投资回报，同时它有助于在早期设计阶段中发现建筑构件之间的冲突。BIM 在建筑可持续发展和城市智能化发展中被证实是至关重要的。环境问题使得越来越多的可持续建筑被设计和实施。建筑设计期间 BIM 在解决日益增长的环境问题中发挥着固有作用，例如 BIM 可以减少碳排放、减少建筑废弃物、筛选绿色材料、室内环境质量监控、进行水资源保护和考虑居民的健康因素等，在目前的实践中，模拟和环境性能分析是在项目的设计阶段之后进行的，因此没有被纳入到这个阶段的决策中。在所需的参数被分配给建筑不同构件的研究需求下，催生出了无梁楼盖建筑模型的应用。本文对涉及无梁楼盖建筑模型的文献进行了研究综述。

1 引言

工程和技术在人类进步中发挥着核心作用，解决了能源、交通和气候变化、灾害管理、环境问题、自然资源管理和可持续等城市难题^[1]。众所周知，建筑业已经对环境造成了显著的影响。建筑资产在温室气体总量（GHGS）中高占比，是能源中最大的消耗主体^[2]。人们对具有最小化环境问题的可持续建筑有需求。与能源和环境问题相关的决定在设计和施工前的初始阶段影响最大^[3]。对满足气候、文化、场所、类型和资源消耗等生态问题的可持续建筑的需求日益增加^[4]。可持续发展、低碳经济和更有弹性的建筑基础设施的设计面临许多障碍^[5]。这些要求是多方面的，而且往往是冲突和不确定的，并持续在整个项目的生命周期，因此需要一个范式的转变来让他们充分参与。BIM 以其可持续进程、广阔的前景和适合的背景来应对这些难题^[6]。BIM 可以通过进行复杂的建筑性能分析来解决日益增长的环境问题^[7]。可以说，BIM 和可持续建筑是当今建筑业的两个最重要的趋势^[8]。

2 方法论

作者遵循了撰写叙述性文献综述的准则，因为这篇综述文章的主要动机是将有关 BIM 方法用于无梁楼盖建筑的可持续设计，把当前和未来问题纳入视野。因此，对于每篇评论文章的叙述性概述，不加评判。下面将介绍如何为读者准备本篇综述的提纲。除了 ASCE 图书馆之外，还使用了两个主要的电子研究数据库来源，即 Science Direct 和 Google Scholar。检索知名学术出版社来获取待综述文章。作为研究的关键概念，制定了三个主要的关键词组来进行普通和高级的在线搜索。第一组包含关键词 BIM 及其相关变体，如 "建筑信息模型"、"BIM 过程"、"BIM 工具"、"BIM "等。第二组的关键词包含 "BIM 和可持续性"、"可持续性"、"可持续建筑设计"、"可持续建筑施工"、"BIM+可持续性 "等主题内容。第三组关键词是基于类似无梁楼盖的概念 "无梁楼盖"，"无梁楼盖建筑的可持续性"，"BIM+无梁楼盖"，"无梁楼盖数字设计 "等。图 1 显示了所采用的检索方法的图示方案。收集到的文章经过筛选，出版时间范围限制在 2012 年至 2020 年之间。

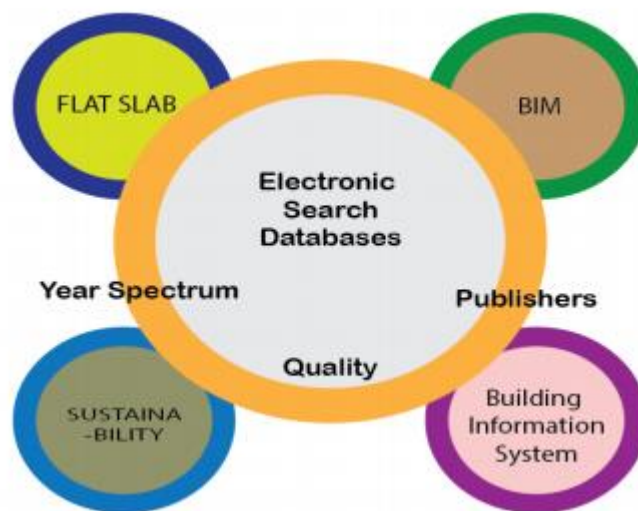


图 1. 用于电子搜索待审文章的关键词组

3 建筑信息模型(BIM): 概述

BIM 的概念最早是由 Eastman 在 1975 年使用的，当时它被构想为 "建筑描述系统"^[9]。计算机辅助设计 (CAD) 从 20 世纪 80 年代开始流行用于绘制二维 (2D) 图纸，在过去的 20 年里，它才被实践用于三维 (3D) 图纸^[10]。土木工程在建筑过程的设计、施工和运营维护阶段有了 BIM 这个越来越重要的新工具。BIM 从根本上说是对高级或简单信息和知识生成程序的协调和一致的数据存储^[11]。BIM 允许任

何建筑项目中的利益相关者进行合作，甚至在实际建筑出现之前就将建筑资产建模成计算机模型^[12]。作为这种建模的结果，任何冲突都可以在这个阶段被发现和补救，只需在领域中有一部分进行纠正。因此，成本效益是世界上许多政府强制要求在建筑活动中使用 BIM 进行审批的主要原因^[13]。建筑信息系统（BIM）是建筑、工程 and 施工（AEC）行业的一个潜在的数字化工具，用于以三维模型表示项目^[14]。它提供了一个中央统一的数据库，可以被查询、过滤、操作和改变，以进行分析。因此，在项目的整个生命周期中，为项目的利益相关者提供一个合作工具^[15]。BIM 使用户能够协作、模拟和可视化关于设施的所有信息，包括几何和非几何信息。然而，只有当 Autodesk 公司在商业上推广 BIM 以创建一个具有物理和功能信息的设施时，BIM 才受到关注^[16]。建筑项目中的利益相关者，如业主、建筑师、顾问、工程师、承包商、分包商、管理人员等，从概念规划、设计、施工、设施管理到拆除都可以相互协作。然而，建筑构件制造商的参与受到其产品目录和 BIM 模型之间缺乏动态链接的阻碍^[17]。采用 BIM 的承包商获得了正向的投资回报，因为它有助于在设计阶段早期发现建筑构件的冲突^[18]。

因此，BIM 导致了更少的信息请求（RFI）和最少的变更单（COs）。BIM 正在成为发展可持续建筑、智能和智慧城市的重要工具。BIM 被广泛认为是 "颠覆性的"、"革命性的"，是民用建筑领域中创新、效率和生产力的 "催化剂"。BIM 预计推动更多可持续建筑的应用，帮助发展中国家减轻他们的技术负担^[19]。尽管 BIM 已经在建筑施工中得到了很好的实施，但基础设施项目还没有发挥出 BIM^[20]。

4 BIM 作为可持续设计的推动者

可持续性是在管理建筑项目的同时，考虑并保持生态、经济和社会指标之间的平衡^[21]。可持续的建筑资产在一段时间内为业主提供最佳的可用性，并能满足业主、建筑管理者和整个社会的需求^[22]。客户和设计师总是关注可持续建筑项目的能源消耗和效率^[23]。文献^[24]的案例研究表明，如果在设计阶段就进行可持续性评估，特别是在可能难以或不可能收回设计决策的情况下，可以实现更好的决策和大量的节约。所有的利益相关者在决策中都至关重要，因为参与人员为了实现能源可持续利用需要考虑到能源规划程序的不同概念和必要的政策措施^[25]。

BIM 在考虑设计领域的可持续性方面发挥了重要作用，包括建筑朝向、形式和围护结构、建筑能耗模型、材料选择、场地和物流管理、水的使用等^[26]。在过去的

十年中,对 BIM 在交付可持续项目以提高效率方面所发挥的作用的认识已经成为一个优先事项^[27]。BIM 以其自身的功能价值,通过可持续的采购系统促进项目的全周期流程^[28]。显著的要点如图 2 中所示。BIM 模型可以协作并导出到各种日照和能源分析工具中。BIM 应用软件 Revit Architecture 可以将模型导出到 Ecotect 和 3D Studio Max Design 等日照分析工具。随着 BIM 在施工活动中的不断普及和使用,将日光分析无缝整合到设计过程中变得越来越普遍和方便^[29]。在过去几十年以来,从广泛建筑材料中选择合适的已经变得复杂和困难。除了基本的成本外,可持续发展方面的新内容,如提高能源效率、场地和可回收材料的选择,都必须纳入决策标准中^[30]。提出了一个 BIM 环境框架,在考虑到可持续性方面的情况下,为建筑部件提供最优组合,在选择过程中的人为干预可忽略不计。可持续发展的目标实际上是由相互关联的动态约束的,涉及能量、环境、社会和经济等多个层面^[31]。设计生命周期是对建筑资产的可持续性进行详细分析的一个依据^[32]。^[33] 旨在研究 BIM 和可持续性发展在建筑项目中的整合,以寻找进一步成功的关键因素。他们的研究集中在使用 BIM 和类似智能的建设项目上,实现项目的可持续性的。^[34]他们的研究是在维也纳技术大学和大约七家 BIM 供应商的软件开发人员或顾问的帮助下进行的,研究最后得到 BIM - Sustain 的成果。



Figure 2. Salient points of the BIM approach for sustainability

图 2. 促进可持续性的 BIM 方法的要点

参考文献

- [1] Suwal, S, Jävājā, P and Salin 2014 BIM education: Implementing and reviewing “openBIM” – BIM for teachers Computing in Civil and Building Engineering - Proceedings of the 2014 International Conference on Computing in Civil and Building Engineering (Ipcc 2007) pp 51–58
- [2] Stadel, A et al. 2011 Intelligent sustainable design: Integration of carbon accounting and building information modeling Journal of Professional Issues in Engineering Education and Practice 137(2) pp 51–54
- [3] Lee, J et al. 2013 Building Environmentally and Economically Sustainable Transportation Infrastructure: Green Highway Rating System Journal of Construction Engineering and Management 139(12) pp 1–10
- [4] Ogwueleka, A C and Ikediashi, D I 2017 The Future of BIM Technologies in Africa: Prospects and Challenges in Integrated Building Information Modelling pp 307–314
- [5] Dong, R R and Martin, A 2017 Research on barriers and government driving force in technological innovation of architecture based on BIM Eurasia Journal of Mathematics, Science and Technology Education, 13(8) pp 57–63
- [6] Watson, A 2010 BIM – a driver for change Proceedings of the International Conference on Computing in Civil and Building Engineering, (Iso 10 303)
- [7] Azhar, S and Brown, J 2009 Bim for sustainability analyses International Journal of Construction Education and Research 5(4) pp 276–292
- [8] Ahmad, T, Aibinu, A and Thaheem, M J 2017 BIM-based Iterative Tool for Sustainable Building Design: A Conceptual Framework Procedia Engineering 180 pp 782–792
- [9] Aryani, A L, Brahim, J and Fathi, M S 2014 The development of building information modeling (BIM) definition Applied Mechanics and Materials 567 pp 625–630
- [10] Ozcan-Deniz, G 2016 the Aec Students’ Perspective in the Learning Process of Cad and Bim 10th BIM Academic Symposium & Job Task Analysis Review, Orlando, FL, 4-5
- [11] Preece, J R H-Y C C 2015 Adoption of Building Information Modelling technology (BIM) Engineering, Construction and Architectural Management 22(4) pp 424–445
- [12] Doumbouya, L et al. 2017 Application of BIM technology in design and construction: A case study of pharmaceutical industrial base of amino acid building project Engineering for Rural Development 16 pp 1495–02

- [13] Antoljak, S 2020 Geotechnical BIM 2020 Geo-Congress 2020 1(2019) pp 74–82
- [14] Nandavar, A et al. 2018 Interactive Virtual Reality Tool for Bim Based on Ifc Learning, Adapting and Prototyping, Proceedings of the 23rd International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2018, 1(May) pp 453– 462
- [15] Mazairac, W and Beetz, J 2013 BIMQL - An open query language for building information models Advanced Engineering Informatics. Elsevier Ltd, 27(4) pp 444–456
- [16] Li, X et al. 2017 Mapping the knowledge domains of Building Information Modeling (BIM): A bibliometric approach Automation in Construction, 84(October 2016) pp 195–206
- [17] Costa, G and Madrazo, L 2015 Connecting building component catalogues with BIM models using semantic technologies: An application for precast concrete components Automation in Construction. Elsevier B.V. 57 pp 239–248
- [18] Barlish, K and Sullivan, K 2012 How to measure the benefits of BIM - A case study approach Automation in Construction 24 pp 149–159
- [19] Bui, N, Merschbrock, C and Munkvold, B E 2016 A Review of Building Information Modelling for Construction in Developing Countries Procedia Engineering 164(1877) pp 487–494
- [20] Popa, H, Batali, L and Berdigylyjow, M 2019 The role of BIM in geotechnical engineering with application to deep excavations in urban areas in Proceedings of the XVII ECSMGE-2019
- [21] Moradi, M, Hafezalkotob, A and Ghezavati, V 2019 Sustainability risk management in a cooperative environment under uncertainty: Iran's Niayesh tunnel case study Kybernetes 48(3) pp 385–406
- [22] Bjorberg, S et al. 2015 Optimizing building design to contribute to value creation 00(September) pp 28–30
- [23] Motawa, I and Carter, K 2013 Sustainable BIM-based Evaluation of Buildings Procedia - Social and Behavioral Sciences Elsevier B.V. 74 pp 419–428
- [24] Ugwu, O O et al. 2006 Sustainability appraisal in infrastructure projects (SUSAIP): Part 2: A case study in bridge design Automation in Construction 15(2) pp 229–238
- [25] Pohekar, S D and Ramachandran, M 2004 Application of multi-criteria decision making to sustainable energy planning - A review Renewable and Sustainable Energy Reviews 8(4) pp 365–381

- [26] Jin, R et al. 2016 BIM-based Multidisciplinary Building Design Practice-A Case Study
- [27] Ayman, R, Alwan, Z and McIntyre, L 2020 BIM for sustainable project delivery: review paper and future development areas *Architectural Science Review* Taylor & Francis 63(1) pp 15–33
- [28] Alhasan, S, Kumar, B and Thanikal, J V 2017 Effectiveness of implementing 5D functions of Building information modeling on professions of quantity surveying - A review *International Journal of Civil Engineering and Technology* pp 783–800
- [29] Moakher, E P E 2012 Building Information Modeling (BIM) and Sustainability – Using Design Technology in Energy Efficient Modeling *IOSR Journal of Mechanical and Civil Engineering* 1(2) pp 10–21
- [30] Khanzadi, M et al. 2019 Optimization of building components with sustainability aspects in BIM environment *Periodica Polytechnica Civil Engineering* 63(1) pp 93–103
- [31] Barile, S et al. 2018 People, technology, and governance for sustainability: the contribution of systems and cyber-systemic thinking *Sustainability Science*. Springer Japan 13(5) pp 1197– 1208
- [32] Zanchetta, C et al. 2014 The Role Of Building Energy Modeling To Ensure Building Sustainability And Quality In A Whole System Design 5th International Conference on Urban Sustainability, Cultural Sustainability, Green Development, Green Structures and Clean Cars (USCUDAR '14) pp 87–93
- [33] Olawumi, T O and Chan, D W M 2019 Critical success factors for implementing building information modeling and sustainability practices in construction projects: A Delphi survey *Sustainable Development* 27(4) pp 587–602
- [34] Kovacic, I et al. 2014 Assessment of BIM Potentials in Interdisciplinary Planning through Student Experiment and Practical Case Study *Proceedings REAL CORP 2014 Tagungsband*, 21-23 May 2014, vienna, Austria, 8 (May) pp 91–98

附件 2：外文原文

IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

BIM Approach for Sustainable Design of Flat Slab Buildings: A Review

To cite this article: Lovnesh Kumar Goyal and Hardeep Singh Rai 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **955** 012012

View the [article online](#) for updates and enhancements.



ECS The Electrochemical Society
Advancing solid state & electrochemical science & technology

239th ECS Meeting with IMCS18

DIGITAL MEETING • May 30-June 3, 2021

Live events daily • Free to register

Register now!

This content was downloaded from IP address 41.237.101.149 on 21/05/2021 at 03:15

BIM Approach for Sustainable Design of Flat Slab Buildings: A Review

Lovnesh Kumar Goyal¹, Hardeep Singh Rai²

¹Research Scholar, Civil Engineering Department, IK Gujral Punjab Technical University, Kapurthala, Punjab, India, 144603

²Civil Engineering Department, Guru Nanak Dev Engineering College, Ludhiana, Punjab, India, 141006

Corresponding author's e-mail address: lovnesh@gmail.com

Abstract. Building Information System (BIM) is a potential digital tool with the Architecture, Engineering, and Construction (AEC) industry that is used to represent the projects in three-dimensional models. It provides a central unified database that can be queried, filtered, manipulated and/or changed for analysis, thus providing a collaborative tool for all the stakeholders in the project throughout the life cycle of the project. Positive returns on investments are acceded by the contractors adopting BIM while it helps detect clashes of intersecting building components early in the design stages. BIM is proving of utmost importance while focusing on the development of sustainable buildings and to develop the cities smarter and intelligent. Environmental concerns warrant more and more sustainable buildings to be designed and implemented. BIM has an intrinsic role to play in building design to address the growing environmental concerns such as to reduce carbon footprint, to cut construction and demolition waste, selection of green material, quality of the indoor environment, water conservation, and health factors of inhabitants, etc. In the current practices, the simulation and environmental performance analysis follow the design phase of the project, thus not getting incorporated into the decision making at this stage. Some models of flat slab buildings are generated by some studies where required parameters were assigned to different elements of the building. This paper makes an effort to review the literature regarding the BIM approach to sustainable construction of buildings considering the flat slab models.

1. Introduction

Engineering and technology play a central role in human progress by tackling the urban challenges like energy, transportation, and climate change, disaster management, environmental concerns, natural resource management and sustainable building constructions [1]. It is a known fact now that the building industry has caused a noteworthy impact on the environment. The built assets are largely responsible for a high percentage of total greenhouse gases (GHGs), being the consumer and embodiment of the largest fraction of energy [2]. There is a demand for sustainable buildings with minimal environmental issues. The decisions related to energy and environmental concerns are most influential in the beginning stages of design and preconstruction [3]. The demand for sustainable buildings meeting ecological concerns like climate, culture, place, type, and resource consumption is increasing [4]. The design for sustainable, low carbon economy and more resilient building infrastructure is beset with a lot of hurdles [5]. These requirements are multi-faceted and often conflicting, uncertain, and lasting the whole



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

Published under licence by IOP Publishing Ltd

lifecycle of the project, thus requiring a paradigm shift to engage them fully. BIM, with its long-term process, view promises, and appropriate context for meeting these challenges [6]. BIM can address the growing environmental concerns by performing complex building performance analyses [7]. Plausibly, BIM, and sustainable buildings are the two most important trends today in the construction industry [8].

2. Methodology

The authors have followed the guidelines of writing a narrative literature review as the main motive of this review article was to bring into perspective the current and future issues regarding the BIM approach for sustainable design of flat slab buildings. Hence, there is no critique for the narrative overview for each paper reviewed. The following describes how the present outlining of the review was prepared for the readers. The two main sources of electronic research databases, namely Science Direct and Google Scholar, were used in addition to the ASCE Library. Reputed academic publishers were searched for articles to be reviewed. As the key concepts of the research, three main groups of the keywords were formulated to conduct the normal as well as advanced search online. The first group contained the keywords BIM and its related variants like 'Building Information Modeling,' 'BIM Process,' 'BIM tools,' 'BIM' etc. The keywords for the second group connoted the theme of 'BIM and Sustainability,' 'Sustainability,' 'Sustainable building design,' 'Sustainable Building Construction,' 'BIM + Sustainability' etc. The third group of keywords was based on the concept of flat slab-like 'Flat Slab,' 'Sustainability in Flat Slab Buildings,' 'BIM + Flat Slabs,' 'Flat Slab digital design' etc. Figure 1 shows the diagrammatic scheme of the search methodology adopted. The collected articles were subjected to selection criteria, and the publication time spectrum was restricted to be between 2012 and 2020.

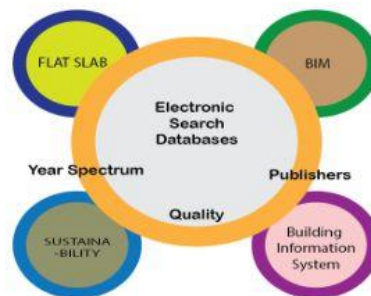


Figure 1. Keyword groups for an electronic search of articles to be reviewed

3. Building Information Modeling (BIM): An Overview

The concept of BIM was first used by Eastman in 1975 when it was conceived as "Building Description System" [9]. Computer-Aided Design (CAD) has been in vogue for drafting two dimensional (2D) drawings since the 1980s, and it has been practiced for three dimensional (3D) drawings for the last two decades [10]. Civil engineering has a new, increasingly important tool in BIM for design, construction, and operation/maintenance stages of the building process. BIM is fundamentally a co-ordinated and consistent data storage of advanced or simple information and knowledge generation procedures [11]. BIM allows the stakeholders in any building project to collaborate and model the building asset into a computer model even before the actual building comes into existence [12]. As a result of this modeling, any conflicts can be detected and remedied at this stage at the cost that is just a fraction of what it would have value to correct the real thing in the field. The cost-effectiveness is thus the main reason that many governments in the world are mandating the use of BIM in construction activities for their approval [13]. Building Information System (BIM) is a potential digital tool with the Architecture, Engineering, and Construction (AEC) industry that is used to represent the projects in three-dimensional models [14]. It provides a central unified database that can be queried, filtered, manipulated and/or changed for analysis,

thus providing a collaborative tool for all the stakeholders in the project throughout the life cycle of the project [15]. BIM enables the users to collaborate, simulate, and visualize all the information about a facility that may be geometric or non-geometric. However, BIM came to limelight only when the Autodesk promoted BIM commercially for creating a facility having physical and functional information [16]. All the stakeholders in the building project, e.g., the owners, architects, consultants, engineers, contractors, subcontractors, managers, etc. can collaborate amongst themselves right from concept planning, designing, construction, facility management to demolition. However, the participation of the building component manufacturers is hindered by the lack of dynamic links between their product catalogs and the BIM model [17]. Positive returns on investments are acceded by the contractors adopting BIM while it helps detect clashes of intersecting building components early in the design stages [18].

Consequently, BIM results in lesser requests for information (RFI) and a minimum of change orders (COs). BIM is becoming a vital tool in the drive on developing sustainable buildings, smart and intelligent cities. BIM is widely observed as 'disruptive,' 'revolutionary,' a 'catalyst' in the civil construction arena for innovation, efficiency, and productivity. BIM is expected to cause more sustainable construction activities that will help the developing countries alleviating their misery [19]. Though BIM has been well implemented in building constructions, the infrastructure projects have yet to harness the benefits of BIM [20].

4. BIM as an Enabler of Sustainable Design

Sustainability is considering and maintaining the equilibrium between the ecological, economic, and social indicators concurrently while managing the construction projects [21]. Sustainable built assets provide the best usability for owners over time and can meet the demands of the owners, building managers, and society at large [22]. The clients and designers are always concerned about energy consumption and efficiency with a sustainable construction project [23]. The case study by [24] shows that better decision making and substantial savings could be realized if the sustainability appraisal is done at the design stage, particularly in cases where it may be difficult or impossible to retract the design decisions. The role of all stakeholders in the decision making is important as altogether different conceptions of the energy planning procedures are to be considered for the truly best usage of sustainable energy, along with the necessary policy measures [25].

BIM finds a crucial role to consider sustainability in the design areas that include building orientation, form, and envelope, building energy modeling, material selection, site and logistics management, water usage, etc. [26]. Over the last decade, the recognition of the role BIM plays in delivering sustainable projects to improve efficiency has become a priority [27]. BIM, with its tools and valuable high functions, develops the delivery process of the construction project from beginning to completion through sustainable purchase systems [28]. The salient points are depicted in Figure 2. BIM models can be collaborated and exported to various daylight and energy analysis tools. The BIM application software Revit Architecture can export the model to daylight analysis tools like Ecotect and 3d Studio Max Design. With the rising popularity and use of BIM in construction activities, the seamless integration of daylight analysis into the design process is becoming more pervasive and convenient [29]. The selection of building materials from a wide range of options has grown complex and difficult since the last decades. Apart from the basic cost, new aspects as regards sustainable development like increasing energy efficiency, local and recyclable material selection have to be incorporated in the decision making criteria. [30] propose a BIM environment framework that provides the most coveted and optimal combination for the building components, considering sustainability aspects, with negligible human intervention in the selection process. The goals of sustainable development are in actual bound by very interconnected dynamics involving a myriad of energetic, environmental, social, and economic dimensions [31]. The design lifecycle is a crucial tool to perform a detailed analysis of the sustainability of a building asset [32]. [33] aim to study the integration of BIM and sustainability practices in the construction projects to search for the critical success factors (CSFs) that can help it expand further. They focus their research on construction projects using BIM and similar smart

technologies for the sustainability of the project. [34] provide the result of BIM-Sustain, their research carried out with the help of Vienna University of Technology and about Seven BIM vendors of software developers or consultants.

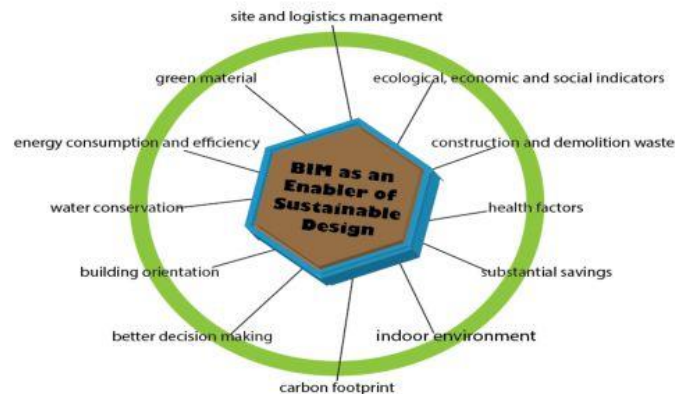


Figure 2. Salient points of the BIM approach for sustainability

4.1 Green Building Assessment (GBA) Systems

The construction industry has changed its approach to sustainability due to building rating systems [35]. Various domestic and international green building certification programs are in effect to regulate the energy efficiency of construction projects [36]. The Building Research Establishment Environmental Assessment Method (BREEAM, UK) was the first building performance assessment system introduced in 1990. Some of the GBA systems are; Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), GreenStar (Australia), Building Environmental Assessment Method (BEAM) Plus, CASBEE (Japan), Green Star, Green Building Index (GBI), HQE (France) and Green Mark. The assessment by these GBA is based on the influences affected by energy consumption and efficiency, health concerns, daylight, indoor and outdoor environment, water and air, and life cycle assessment (LCA) [37].

4.2 Life cycle Assessment

LCA is the iterative procedure and an analysis of the environmental impact of the product on the surrounding world, spanning its whole lifetime [38]. BIM is a very relevant tool to address the LCA as any single element of a building can be parametrized and modeled separately [39]. [40] provide a methodology of integrating BIM and LCA tools that can be used in designing sustainable buildings. The method explains the development and implementation of the database incorporation in the model that stores the data about sustainable material. The model is linked to BIM, LCA, certification, and cost modules. [41] recommend the inclusion of LCA data in the BIM objects rather than using external databases to enhance the stakeholders' understanding of the better alternatives about the environmental concerns in the early phases of the design process.

4.3 Site Location

It is not easy to evaluate the sustainability effects of location and distance to travel while designing green buildings. These assessments require a lot of manual calculations, experience, hard work, and time. BIM is now helping the stakeholders in getting green building certifications. However, as BIM applications lack strong mapping support, the location and transportation analysis by BIM is taken as improbable by many. [42] thus focus their research on the development of a framework that integrates technologies in

BIM and Web Map Service (WMS). They develop a BIM plugin for Autodesk Revit using Autodesk Revit and Google Maps APIs.

4.4 Lean Construction

The construction industry is witnessing fundamental changes due to its two important segments, the first being lean construction and the other BIM [43]. Much research is being done on BIM, lean construction, and construction sustainability not only singularly but in combination also. BIM has scheduling levels that help reduce cycle times. It is the outcome of several studies to indicate that BIM facilitated to implementation of both lean and green constructions [44]. The major purpose of lean construction is to maximize the customer value by reconceptualizing the construction process, to minimize, understand waste in any activity that consumes resources without creating any value, e.g., the mistakes that require rectifications, later on, unnecessary processing steps, purposeless transportation of goods and employees, etc. [45]. It is a control system for production planning that promotes all stakeholders to work in a team activity to generate a work process that results in higher productivity and dependable workflow [46]. The major contribution of [47] research is to explore the enhancement caused by lean implementation in the BIM maturity levels.

4.5 Off-Site Construction

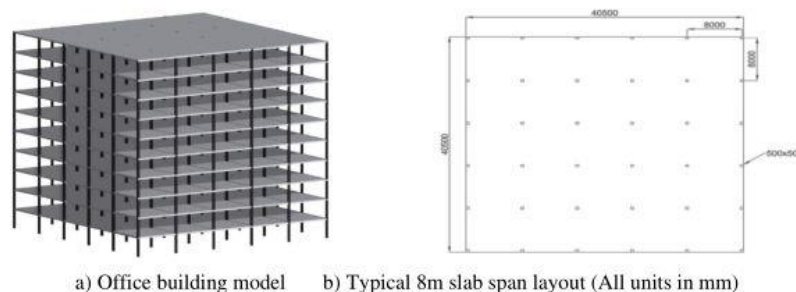
BIM can leverage the benefits of off-site manufacturing as against the traditional construction that includes improved quality, safety, economy, work conditions, construction processed, sustainability with reduced waste, time, re-works with expected sustainability performance of the built assets [48]. However, the success of BIM lies in bidirectional data exchange among the different project stakeholders and the corresponding data in the BIM model [49].

4.6 BIM Software

BIM is generally perceived wrongly as a software program requiring high skills for advanced use of BIM [50]. Autodesk, Bentley Systems, and Graphisoft are major BIM software developers and providers. BIM is a process, and the strength of BIM lies in its interoperability and coordination as it involves the use and input from a myriad of software such as Revit for design, CAD MEP for MEP, Primavera for scheduling tasks, TEKLA for structures, DesignBuilder for sustainability analysis and Candy for pricing [51]. Other examples of the leading BIM solutions include Autodesk Architectural Desktop (ADT), Bentley Systems, Graph iSOFT's ArchiCAD, among many others.

4.7 Flat Slabs

The residential, office, and other buildings in the industry extensively use the reinforced concrete flat plate slabs systems all over the world. The advantage of this lies in the reduction of the formwork cost, the time required, and the convenience of the installation [52]. The study by [53] examines the concrete structures for environmental performance by varying design parameters. The included various slab systems like flat slab and flat plates with different construction techniques and using traditional reinforcement and also post-tensioned methods. The outcome of design alternatives was considered in terms of embodied energy showing a decrease between 23.7% and 49.1% in the case of the post-tensioned construction system. Figure 3 shows a simplified building plan in their study.



a) Office building model b) Typical 8m slab span layout (All units in mm)

Figure 3. Simplified building plan [53]

[54] study the design and quantity take-off of automated virtual flat plate reinforced with S-BIM. [54] base their research on the interoperability among architectural and structural models, between structural analysis to structural analysis models and the design results that conform to the minimum thickness, deflection requirements in the concrete flat plates. Their study completes the numerical experiments for the automation of a flat plate in a 3D digital virtual model that includes reinforcement bars using structural BIM. Parametric design specifications and adoption of structural optimization during the initial stages of the workflow for better sustainability performance are expected to become more relevant as the BIM technologies are developed and adopted more and more in the design of buildings [55]. They study the automation for optimizing the reinforced concrete flat slabs for the reinforcement specifications process utilizing the data inputs from BIM and Finite Element Model (FEM) engine. The study by [56] analyses flat slab structures about their emissions and economic costs depending on the layout of columns and thickness of slabs. To assess the processes causing the equivalent carbon dioxide emissions, modeling of three different buildings with varying slab thickness was examined. They find that the permanently incorporated concrete and reinforcement material represents 85.5% of total emissions at their production stage. [57] opine that structural design implications have been ignored concerning the carbon performance of built assets in the previous studies. They address this prevalent limitation by presenting an integrated and structural analysis for sustainable building design. To achieve their goal, a BIM-based approach was devised by using embodied carbon metrics and the data from structural optimization.

5. Conclusion

This paper makes an effort to review the literature regarding the BIM approach to sustainable construction of buildings considering the flat slab models. The review in this article emphasizes the growing understanding of the integration of BIM and sustainability practices. As sustainable construction needs to minimize the waste quantities, BIM response in real-time to optimize the construction waste is the preferable option to the traditional data analysis techniques. Some models of flat slab buildings are generated by some studies where required parameters were assigned to different elements of the building. The embodied energy in these models was calculated and compared. A few benefits of using BIM approach, like the enhanced collaboration among stakeholders in the project, transparency in the design provided the visualization of the project model, data sharing, among others, have been highlighted in various overviews in this article. BIM can be used beneficially in the sustainable design of the buildings only by juxtaposing with proven prevalent project strategies. Though BIM has been there since the 1970s, BIM has yet to be exploited to its full potential even in leading contexts. Promising insights, however, signal successful embracing of BIM in the near foreseeable future. There is increasing awareness now to use modern digital tools like BIM.

Acknowledgments

The authors gratefully acknowledge the support provided by IK Gujral Punjab Technical University, Kapurthala, Punjab, India, and colleagues. The authors are also grateful to the anonymous reviewers of the paper for their careful reading and evaluation.

References

- [1] Suwal, S, Jävājā, P and Salin 2014 BIM education: Implementing and reviewing “openBIM” – BIM for teachers *Computing in Civil and Building Engineering - Proceedings of the 2014 International Conference on Computing in Civil and Building Engineering (Ipcc 2007)* pp 2151–58
- [2] Stadel, A et al. 2011 Intelligent sustainable design: Integration of carbon accounting and building information modeling *Journal of Professional Issues in Engineering Education and Practice* **137(2)** pp 51–54
- [3] Lee, J et al. 2013 Building Environmentally and Economically Sustainable Transportation Infrastructure: Green Highway Rating System *Journal of Construction Engineering and Management* **139(12)** pp 1–10
- [4] Ogwueleka, A C and Ikediashi, D I 2017 The Future of BIM Technologies in Africa: Prospects and Challenges in *Integrated Building Information Modelling* pp 307–314
- [5] Dong, R R and Martin, A 2017 Research on barriers and government driving force in technological innovation of architecture based on BIM *Eurasia Journal of Mathematics, Science and Technology Education*, **13(8)** pp 5757–63
- [6] Watson, A 2010 BIM – a driver for change *Proceedings of the International Conference on Computing in Civil and Building Engineering, (Iso 10303)*
- [7] Azhar, S and Brown, J 2009 Bim for sustainability analyses *International Journal of Construction Education and Research* **5(4)** pp 276–292
- [8] Ahmad, T, Aibinu, A and Thaheem, M J 2017 BIM-based Iterative Tool for Sustainable Building Design: A Conceptual Framework *Procedia Engineering* **180** pp 782–792
- [9] Aryani, A L, Brahim, J and Fathi, M S 2014 The development of building information modeling (BIM) definition *Applied Mechanics and Materials* **567** pp 625–630
- [10] Ozcan-Deniz, G 2016 the Aec Students' Perspective in the Learning Process of Cad and Bim *10th BIM Academic Symposium & Job Task Analysis Review, Orlando, FL*, 4–5
- [11] Preece, J R H-Y C C 2015 Adoption of Building Information Modelling technology (BIM) *Engineering, Construction and Architectural Management* **22(4)** pp 424–445
- [12] Doumbouya, L et al. 2017 Application of BIM technology in design and construction: A case study of pharmaceutical industrial base of amino acid building project *Engineering for Rural Development* **16** pp 1495–02
- [13] Antoljak, S 2020 Geotechnical BIM 2020 *Geo-Congress 2020 1*(2019) pp 74–82
- [14] Nandavar, A et al. 2018 Interactive Virtual Reality Tool for Bim Based on Ifc *Learning, Adapting and Prototyping, Proceedings of the 23rd International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2018, 1(May)* pp 453–462
- [15] Mazairac, W and Beetz, J 2013 BIMQL - An open query language for building information models *Advanced Engineering Informatics. Elsevier Ltd.* **27(4)** pp 444–456
- [16] Li, X et al. 2017 Mapping the knowledge domains of Building Information Modeling (BIM): A bibliometric approach *Automation in Construction*, **84(October 2016)** pp 195–206
- [17] Costa, G and Madrazo, L 2015 Connecting building component catalogues with BIM models using semantic technologies: An application for precast concrete components *Automation in Construction. Elsevier B.V.* **57** pp 239–248
- [18] Barlish, K and Sullivan, K 2012 How to measure the benefits of BIM - A case study approach *Automation in Construction* **24** pp 149–159
- [19] Bui, N, Merschbrock, C and Munkvold, B E 2016 A Review of Building Information Modelling

- for Construction in Developing Countries *Procedia Engineering* **164(1877)** pp 487–494
- [20] Popa, H, Batali, L and Berdigylyjow, M 2019 The role of BIM in geotechnical engineering with application to deep excavations in urban areas in *Proceedings of the XVII ECSMGE-2019*
- [21] Moradi, M, Hafezalkotob, A and Ghezavati, V 2019 Sustainability risk management in a cooperative environment under uncertainty: Iran's Niayesh tunnel case study *Kybernetes* **48(3)** pp 385–406
- [22] Bjorberg, S et al. 2015 Optimizing building design to contribute to value creation 00(September) pp 28–30
- [23] Motawa, I and Carter, K 2013 Sustainable BIM-based Evaluation of Buildings *Procedia - Social and Behavioral Sciences* Elsevier B.V. **74** pp 419–428
- [24] Ugwu, O O et al. 2006 Sustainability appraisal in infrastructure projects (SUSAIP): Part 2: A case study in bridge design *Automation in Construction* **15(2)** pp 229–238
- [25] Pohekar, S D and Ramachandran, M 2004 Application of multi-criteria decision making to sustainable energy planning - A review *Renewable and Sustainable Energy Reviews* **8(4)** pp 365–381
- [26] Jin, R et al. 2016 BIM-based Multidisciplinary Building Design Practice-A Case Study
- [27] Ayman, R, Alwan, Z and McIntyre, L 2020 BIM for sustainable project delivery: review paper and future development areas *Architectural Science Review* Taylor & Francis **63(1)** pp 15–33
- [28] Alhasan, S, Kumar, B and Thanikal, J V 2017 Effectiveness of implementing 5D functions of Building information modeling on professions of quantity surveying - A review *International Journal of Civil Engineering and Technology* pp 783–800
- [29] Moakher, E P E 2012 Building Information Modeling (BIM) and Sustainability – Using Design Technology in Energy Efficient Modeling *IOSR Journal of Mechanical and Civil Engineering* **1(2)** pp 10–21
- [30] Khanzadi, M et al. 2019 Optimization of building components with sustainability aspects in BIM environment *Periodica Polytechnica Civil Engineering* **63(1)** pp 93–103
- [31] Barile, S et al. 2018 *People, technology, and governance for sustainability: the contribution of systems and cyber-systemic thinking* *Sustainability Science*. Springer Japan **13(5)** pp 1197–1208
- [32] Zanchetta, C et al. 2014 The Role Of Building Energy Modeling To Ensure Building Sustainability And Quality In A Whole System Design *5th International Conference on Urban Sustainability, Cultural Sustainability, Green Development, Green Structures and Clean Cars (USCUDAR '14)* pp 87–93
- [33] Olawumi, T O and Chan, D W M 2019 Critical success factors for implementing building information modeling and sustainability practices in construction projects: A Delphi survey *Sustainable Development* **27(4)** pp 587–602
- [34] Kovacic, I et al. 2014 Assessment of BIM Potentials in Interdisciplinary Planning through Student Experiment and Practical Case Study *Proceedings REAL CORP 2014 Tagungsband, 21-23 May 2014, vienna, Austria, 8(May)* pp 91–98
- [35] Hu, M 2019 Building impact assessment—A combined life cycle assessment and multi-criteria decision analysis framework *Resources, Conservation and Recycling*. Elsevier, **150**(March) p. 104410
- [36] Ryu, H S and Park, K S 2016 A study on the LEED energy simulation process using BIM *Sustainability (Switzerland)* **8(2)** pp 1–13
- [37] Liu, Z et al. 2020 'Envelope thermal performance analysis based on building information model (BIM) cloud platform - Proposed green mark collaboration environment', *Energies*, **13(3)**
- [38] Jrade, A and Abdulla, R 2012 Integrating Building Information Modeling and Life Cycle Assessment Tools to Design Sustainable Buildings *Proceedings of the 29th International Conference of CIB W78* pp 173–182
- [39] Van Wageningen, H W 2012 Building Information Modeling and Historic Buildings: How a Living

- Model Leads to Better Stewardship of the Past
- [40] Jalaei, F and Jrade, A 2014 Integrating Building Information Modeling (BIM) and energy analysis tools with green building certification system to conceptually design sustainable buildings *Journal of Information Technology in Construction* **19**(2010) pp 494–519
 - [41] Jung, N, Häkkinen, T and Rekola, M 2018 Extending capabilities of bim to support performance based design *Journal of Information Technology in Construction*, **23**(January 2017) pp 16–52
 - [42] Chen, P H and Nguyen, T C 2017 Integrating web map service and building information modeling for location and transportation analysis in green building certification process *Automation in Construction* **77** pp 52–66
 - [43] Saieg, P et al. 2018 Interactions of Building Information Modeling, Lean and Sustainability on the Architectural, Engineering and Construction industry: A systematic review *Journal of Cleaner Production*. Elsevier Ltd **174** pp 788–806
 - [44] Ahuja, R, Sawhney, A and Arif, M 2014 Bim based conceptual framework for lean and green integration *22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014, 201301* pp 123–132
 - [45] Andújar-Montoya, M D et al. 2015 A construction management framework for mass customisation in traditional construction *Sustainability* (Switzerland) **7**(5) pp 5182–5210
 - [46] Bulgakov, A and Bock, T 2018 Integration of Lean Management Methods in Construction and the Building Information Modelling *MATEC Web of Conferences* **251**
 - [47] Hamdi, O and Leite, F 2012 BIM and Lean interactions from the bim capability maturity model perspective: A case study *IGLC 2012 - 20th Conference of the International Group for Lean Construction*, (512)
 - [48] Abanda, F H, Tah, J H M and Cheung, F. K. T. 2017 BIM in off-site manufacturing for buildings *Journal of Building Engineering* **14**(March) pp 89–102
 - [49] Nawari, N O 2012 BIM standard in off-site construction *Journal of Architectural Engineering* **18**(2) pp 107–113
 - [50] Hjelseth, E 2017 BIM understanding and activities *WIT Transactions on the Built Environment* **169** pp 3–14
 - [51] P Bhatija, V 2017 A Preliminary Approach towards Integrating Knowledge Management with Building Information Modeling (KBIM) for the Construction Industry *International Journal of Innovation, Management and Technology* **8**(1) pp 64–70
 - [52] Yi, W J, Zhang, F Z and Kunnath, S K 2014 Progressive collapse performance of RC flat plate frame structures *Journal of Structural Engineering* (United States) **140**(9) pp 1–10
 - [53] Miller, D, Doh, J H and Mulvey, M 2015 Concrete slab comparison and embodied energy optimisation for alternate design and construction techniques *Construction and Building Materials*. Elsevier Ltd **80** pp 329–338
 - [54] Cho, Y S, Lee, S Il and Bae, J S 2014 Reinforcement placement in a concrete slab object using structural building information modeling *Computer-Aided Civil and Infrastructure Engineering* **29**(1) pp 47–59
 - [55] Eleftheriadis, S et al. 2018 Automated specification of steel reinforcement to support the optimisation of RC floors *Automation in Construction* **96**(June) pp 366–377
 - [56] Ferreira-Cabello, J et al. 2016 Minimizing greenhouse gas emissions and costs for structures with flat slabs *Journal of Cleaner Production*. Elsevier Ltd **137** pp 922–930
 - [57] Eleftheriadis, S, Duffour, P and Mumovic, D 2018 BIM-embedded life cycle carbon assessment of RC buildings using optimised structural design alternatives *Energy and Buildings*. Elsevier B.V. **173** pp 587–600