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A Research Study Done on the Adaptation of Building Information Modelling in Various Fields of a Construction Project

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Abstract

The growing use of Building Information Modelling in the construction as an emerging concept is a digital approach replacing traditional approaches gradually. With the changing scenario in the industry with the introduction of technology, the adoption of BIM has brought forth many a debates among professionals. With the growing technological advancements, there is also a growing need for knowledge; hence many professionals and researchers are working on various aspects of research in various fields of BIM. The paper aims to review the amount of research done on the use and adoption of BIM in various fields of construction project. By examining 130 publications from various sources, a cumulative analysis of the fields of research and progression in publication has been studied and established. The results got henceforth from the paper indicate a progressive increase in the research done in various fields of construction projects.

Keywords: Building Information modelling • Construction project • Design • Construction • Operation and management • Sustainability and energy • Project lifecycle

Introduction

Building information modelling is a digital form of recording the entire project lifecycle including all the phases from conceptual designing till the construction also including the operation [1] and production management [2]. Breaking through manual working approaches, it provides more information flow between all work-sectors involved in the project. Despite its recent entry into the construction industry, the use of BIM in project helps create a language among the parties involved in the project helping the project manager in various disciplines and phases [3], revolutionising the building design, construction and day-to-day operations, enhancing the efficiency of project [4]. Creating a virtual and reliable source of information with respect to various parameters, BIM is the emerging technology handling information in the AEC industry [5].

In context to the varied application of BIM by various public and private investors involved in the construction industry, are investing on a large scale into BIM [6].

Despite its advantages and use in many construction projects, the industry itself obstructs its full use [1] and effective application [7]. Hence government initiatives to increase the role of BIM can change the practices in the industry [1], with various initiatives like policy formation, BIM organisation, research areas identification etc. having been formulated by various BIM fields in USA, Norway, Finland, Denmark, Singapore and Hong Kong [8], resulting in an increase in its use over past few years in various countries like North America, U.K., Scandinavia etc. [7].

Although BIM in developed nations is well established, the construction companies in developing nations are facing many hurdles with respect to technological, social and economic aspects [9]. The rate at which BIM is being adopted is relatively slow in Chinese construction industry [10] and also in Pakistan industry [11].

Despite its varied uses BIM's hands have not yet extended completely to certain aspects like sustainability, renovation and re-construction, energy simulation tools and adaptation of social sustainability into a project [12]. The need of technical support, reduced construction cost benefits and software package with the use of BIM are also yet to be addressed [13].

In the Architecture, Engineering, Construction and Operations (AECO) industry the use of BIM has been explicit with an expansive knowledge base [14] but few of the areas in which BIM is lagging behind have come forth after extensive research in the field [12]. Considering the positives and negatives, advantages and drawbacks that are faced due to the use of BIM in a construction project, various professionals have contributed researches on various platforms. The paper aims to examine 130 publications on the adaptation of BIM in construction project during various phases. Categorising into 6 broad aspects - BIM, Design, Construction, Operation and Maintenance, Sustainability and Energy and Project Lifecycle. Firstly extensive research done on BIM with respect to relevance, use, software, benefits, and adoption; Design stages of macro and micro level planning, building, landscape, renovation and conservation, heritage buildings etc; Construction with the broad aspects of construction management, conflict management, information management, etc; Operation and Management from project delivery to the end of building; Sustainability and Energy and the overall Project Lifecycle Assessment. The paper elaborates further on the fields mentioned above.

Study Area

BIM is widely used for designing, construction and management of the project involving a digital representation of the project also changing the way in which the building looks, functions, designed and built. Calculating and documenting the time, cost and labour required it acts as a source for better construction management and practices [15]. Integrated construction environment backs up the effective use of BIM in the growing trends of energy efficient and sustainable building construction [16] and project lifecycle [17].

BIM

BIM software is a computer programming language that enables the users to build models provided with necessary information that has multiple visual programming languages providing operators with specific languages that can be used for Industry foundation classes models and code compliance checking

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[18] a standard semantically rich 3D modelling tool that is one of the most popular schema model currently used in the industry [19].

Design

Considering the technology driven transformation, various core aspects with respect to design i.e., understanding, collaboration, decision making etc can be addressed to and integrated with the help of BIM [20,21]. With the emerging concept of smart city, the integrated application of BIM and GIS has taken a new direction and is in the stage of early exploration [22]. Aiding smart city initiatives, BIM-GIS based systems for energy planning is proposed as a solution to optimally and technically integrate the emerging smart city concept [23]. With respect to the professional's interaction with the client in connection to design, construction and maintenance process on a functional level. The integrated use of BIM with a gaming engine has been proved to be a promising potential support that enables functional collaboration and interaction of both the parties providing a practical solution to the little addressed issue [24]. Heritage Building Information Modelling tools are used in restoration of buildings in a retrofitting and conservation framework [25]. Extending further, the use of BIM for landscape projects enables the designer to establish a more informative working environment increasing fields for designing and managing the project and schedule backed up with managerial, scientific, professional and practical approach [26].

Construction

Various project management benefits with the help of BIM can be achieved making use of BIM as a feasible and promising source of identifying the progress, conflict checks, construction resource management and cost benefits [27,28]. BIM can be used by project managers to avoid unnecessary works and save time and cost [29], improving work flow with visual base of the project [30], providing for a successful project delivery [29]. With the use of BIM, construction conflicts can be predicted and rectified or eliminated improving the efficiency of project delivery [31]. Ensuring practical understanding of the whole project, BIM ensures a check and helps predict probability of accidents [32]. Safety planning and management at construction sites can also be improved with the help of BIM, 3D and 4D simulations and other visualisation technologies [33-35].

Operation and Management

Integration of BIM with facility management, BMS and front-end sensor data visualisation aided environmental sensing helping the operation and maintenance stages [36,37]. The information stored in BIM while construction if retrieved during the operation stage can significantly increase the service life of the project also making the maintenance easy [38]. Furthermore BIM can also be used to ensure fire safety with respect to evacuation assessment and route planning, safety education and equipment planning [39]. BIM with the involvement of the client, with his/her maturity levels as a potential ability to interact with the BIM can help monitor the benefits of BIM in building disaster management as well [40].

Sustainability and Energy

BIM's ability to serve as a multidisciplinary has made it feasible to explore its sustainability value [41]. With the growing importance and need of BIM in the construction industry, most construction companies are adopting BIM technologies in adaptation to the changing context, towards more sustainable environment [42]. Recent advancements have seen the integration of Building Information Modelling and Building Energy Modelling in the light of achieving growing energy conservation needs leading to updates in environmental policies [43]. When plugged in with an energy performance analysis tool, BIM can also act as an energy simulation tool providing the designers with greater fields with respect to sustainability and energy efficient factors [41].

Project Lifecycle

The innovations of BIM have continuous adaptation 3D model that provides information, data and a series of steps with respect to optimization and preparation of design requirements, construction, processing and pulling down covering the process of building lifecycle management [44,45].

People, process and technology form a basis for resistance in adoption of BIM in most of the newly entering construction companies, while on the contrary experienced and advanced construction companies are increasingly adopting BIM for its efficiency and competitive advantages [46]. BIM, even though being of great advantages with respect to project quality and costs, it requires certain changes to be adopted with its current practices in terms of its use in processing and technology for project management. Hence emphasizing the roles and responsibilities of the construction players using BIM might differ from conventional practices [47]. The role of sufficient information to be acquired from contractors and operators to facilitate the BIM software is very crucial. It is well known that BIM helps in various decisions making and project delivery aspects but its full benefits cannot be exploited unless the relation between site and model is linked correctly [13].

The divergent application of various fields within BIM has also been explored with a set of defined components and boundaries outlined providing a set of guidelines and BIM framework [14]. The integration of BIM and off-site construction are increasingly being applied in the AEC industry with its advantages in aiding the project stakeholders with visualization, waste management etc., and lot of research is also being done to bring out advantages and applications of BIM [48].

Research Methodology and Data Analysis

Methodology

To review, a three step model examines journal articles, conference papers and books. The first step, journal articles, conference papers and books are classified according to the fields. The found journals were further categorised under a table dealing with:

- BIM
- Design
- Construction
- Operation and Management
- Sustainability and Energy and
- Project Lifecycle (Table 1).

The second step included the year of publication of the articles, conference papers and books. The third step involved the cumulating of both first and second steps (Table 2).

Over 130 publications (journal articles, conference papers and books) were examined with 111 journal articles, 10 books and 9 conference papers. Figure 1 elaborates the percentage of research done in various fields of project life. Figure 2 represents the research done in various years starting from 2007-2019. Figure 3 is a cumulative analysis of the amount of research done in various fields from 2007-2019. These figures indicate the increase in research with respect to the fields, with the highest contribution of research being done for construction phase of the project. Design phase stands next highest. While there is still research going on with respect to operation and management stages, the research on sustainability and energy is progressive. Research on BIM is increasing day-by-day with its increasing adaptation; research in specific fields is on a varied scale.

Discussion and Inferences

From visualization of the project enhancing the decision making process and tracking digital project documents [49], the early architectural design stage [50], the planning and preplanning stages [51], micro and macro level planning [17], construction safety [52], Facility management [53], Construction Waste

Table 1. Examined articles classified according to fields.

Keywords	Journal – Publication	#
BIM (software, benefits, use and adoption)	• Architectural Engineering and Design Management – T&F Online • Automation in Construction – Science Direct • BIM Design: Realizing the Creative Potential of Building Information Modelling – Wiley • BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers, 3rd Edition – Wiley • Building Information Modeling: BIM in Current and Future Practice – Wiley • Building Information Modelling Technology Foundations and Industry Practice – Springer-Link • Enhanced Building Information Models-Introduction – Springer-Link • Enhanced Building Information Models-Using IoT Services and Integration Patterns – Springer-Link • Frontiers of Engineering Management - Springer-Link • IFAC-Papers OnLine – Science Direct • International Conference on Web Information Systems and Technologies – Springer-Link • International Journal of Advanced Robotic Systems – Sage • International Journal of Construction Management – T&F Online • International Journal of Project Management – Science Direct • Journal of Building Pathology and Rehabilitation – Springer-Link • Journal of Computational Design and Engineering – Science Direct • Procedia Engineering – Science Direct	25
Design (macro and micro level, building, landscape, renovation and conservation)	• Archives of Civil and Mechanical Engineering • Automation in Construction – Science Direct • BIM for Landscape – T&F Online • Computer-Aided Architectural Design Futures (CAAD Futures) – Springer-Link • Energy – Science Direct • Energy Procedia – Science Direct • Frontiers of Engineering Management – Springer-Link • Heritage Science – Springer-Link • International Journal of Architectural Heritage – T&F Online • Journal of Computational Design and Engineering - Science Direct • KSCE Journal of Civil Engineering – Springer-Link • Procedia Engineering – Science Direct • Procedia Environmental Sciences – Science Direct • Tsinghua Science & Technology – Science Direct • Visualization in Engineering – Springer-Link	30
Construction (construction management, project management, conflict management)	• Automation in Construction – Science Direct • Chinese Journal of Population Resources and Environment - T&F Online • IFIP International Conference on Product Lifecycle Management – Springer-Link • International Conference on Applied Economics – Springer-Link • International Journal of Advanced Robotic Systems – Sage International Journal of Computer Integrated Manufacturing – T&F Online • International Journal of Engineering Business Management - Sage • International Journal of Sustainable Built Environment - Science Direct • Journal for Education in the Built Environment - T&F Online • Procedia Engineering – Science Direct • Procedia Economics and Finance – Science Direct • Procedia - Social and Behavioral Sciences - Science Direct • Procedia Technology - Science Direct • Renewable and Sustainable Energy Reviews – Science Direct • Safety and Health at Work- Science Direct • Safety Science – Science Direct • The Impact of Building Information Modelling-Transforming Construction – T&F online • Visualization in Engineering – Springer-Link	40
Operation and Maintenance	• Automation in Construction – Science Direct • Energy and Building – Science Direct • IFAC-Papers Online – Science Direct • International Journal of Sustainable Built Environment – Science Direct • Journal of Building Engineering • Procedia Economics and Finance – Science Direct • Procedia Engineering - Science Direct • Procedia Environmental Sciences • Procedia - Social and Behavioral Sciences – Science Direct	17
Sustainability and Energy	• 26th IPMA World Congress, Crete, Greece, 2012- Science Direct • Ain Shams Engineering Journal – Science Direct • Automation in Construction – Science Direct • Building Information Modelling, Building Performance, Design and Smart Construction – Springer-Link • Energy and Buildings – Science Direct • Energy Procedia – Science Direct • Frontiers of Architectural Research – Science Direct • IFIP International Conference on Product Lifecycle Management – Springer-Link • International Journal of Sustainable Built Environment – Science Direct • Procedia Engineering - Science Direct	13

Lifecycle	• Building and Environment – Science Direct • IFIP International Conference on Product Lifecycle Management – Springer-Link • Procedia Engineering - Science Direct	5

Table 2. Examined articles classified according to year of publication and fields.

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
BIM			1	3			1	5	3	2	4	2	4
Design	1	1						4	2	5	4	4	9
Construction				1		1	5	6	7	8	8	1	3
O&M								1	1	5	6	1	3
S&E						1	1		3	1	5	1	1
Lifecycle							2		1		1		1
	1	1	1	4		2	9	16	17	21	28	9	21

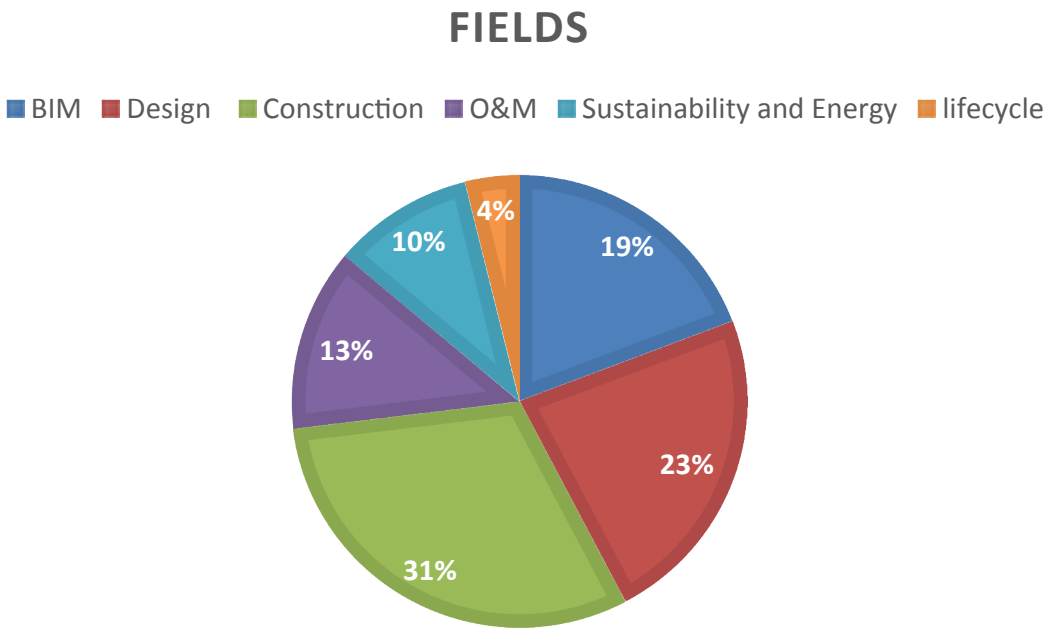

Figure 1. Fields.

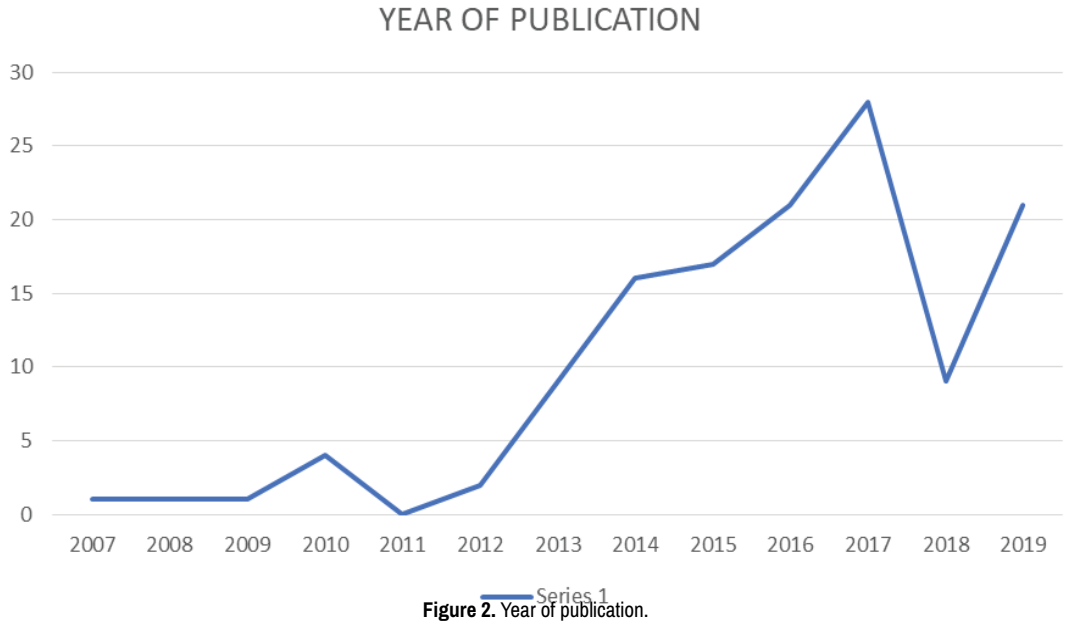

Figure 2. Year of publication.

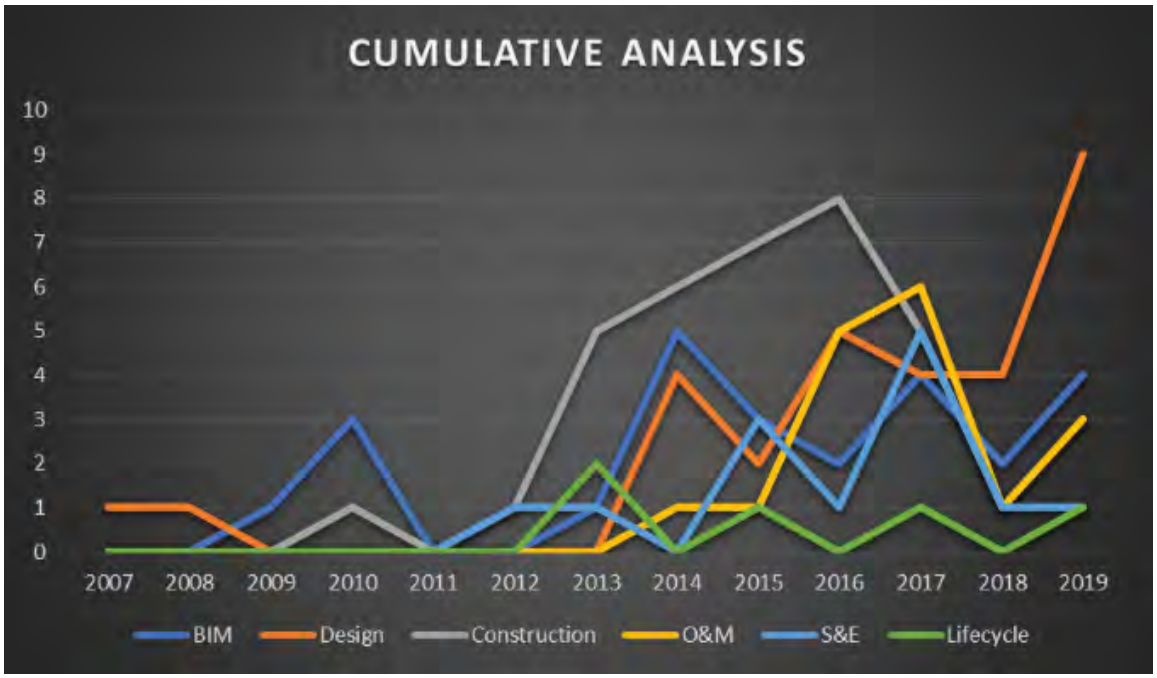

Figure 3. Cumulative analysis of the fields and year of publication.

Management [54], building performance management [55], eco-feedback systems engaging the end users [56], with respect to technology, urban governance, life cycle and energy management [17] BIM acts as a mediator creating a relationship that conflicts the existing work practices and provides a new dimension to work environment [57].

Solutions provided to overcome [58] the on-site implementation [59], data accumulation and exchange [60], semantic web technologies to track uncertainties and risks [61], research prevent design hindrances in renovation projects [62] have provided scope for better implementation of BIM [63].

Conclusion

Despite the many advantages of using BIM, there is a stigma surrounding it to be a disruptive force that is changing the way of designing, building and managing the built structures. But insights into the essays composed by leaders from professional sources provided the potential benefits of using BIM speculating its future.

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