

# Meta-Analysis of Building Information Modeling Literature in Construction

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**Abstract**— *Building Information Modeling (BIM) as a growing movement in the construction industry is rapidly gaining acceptance by incorporating different tools and processes. It is a new approach to manage building design and project data in digital format throughout a building's life cycle that provides the exchange and interoperability of information among the stakeholders. One of the key advantages of BIM over drawing methods, either manual or computer-aided, is its ability to prevent possible conflicts during construction process by providing accurate project drawings and construction documents on time and fast. Moreover, BIM provides users with a consistent method of conveying project information, which prevents errors or conflicts caused by lack of coordination within the project teams. Due to these benefits, BIM related studies have gradually increased recently. Accordingly, there is a need of determination for research tendency and gap analysis within BIM discipline. This study aims to analyze BIM related studies and classify them via meta-analysis. A Meta-classification system including four dimensions and their sub-categories is used. For this purpose, refereed journal articles are examined in terms of the area within the construction industry, subject, the stage of the building production process, study level, methodology, contribution, starting point, BIM tools, results, country and institution. Moreover, BIM and sustainability relationship is especially discussed due to the importance of green BIM as an emerging trend in the construction industry. Finally, according to the obtained results from the analysis, the potential areas for future studies are suggested in conclusion.*

**Index Terms**—Building Information Modeling (BIM), Construction Industry, Meta-Analysis, Sustainability.

## I. INTRODUCTION

Studies of publication patterns are useful indicators of scientific productivity, trends, emphasis of research in various disciplines and of researchers' preferences for publication outputs [1]. Publication examination studies related to a specific area, also known as meta-analysis studies are beneficial in decision-making processes of academic researches from planning to management [2]. Moreover, academic journals, one of the most important communication channels of knowledge sharing, provide the examination of research findings and realization of the academic debates. In academia, communication is central to the promotion of knowledge and while there are many forms of communication channels, the most permanent and durable are the published literature, especially refereed academic journals [2]. An established refereed journal is a repository of good and novel insights gained from data based research, scholarly enquiry, rigorous analysis of experience and careful logical debate

about an issue or phenomenon [3]. While analyzing of a single journal as a case study provides a historical record, describes the characteristics of a journal and gives an opportunity to assess the editorial policies or develop recommendations for future policies and publication gaps to be filled; the analysis of a broader sample provides a map of a discipline reflecting important patterns [2], [3]. The meta-analysis studies concern the ways in which an academic discipline develops, the main dimensions of the subject matter and the ways relevant research methods and tools are used [2]. On the other hand, Building information modeling (BIM), one of the most promising recent developments in the construction industry, is developed for the needs of collaboration, getting improved outputs, minimizing the risks, time loss and cost. It also aids in the development of buildings less harmful to the environment in addition to providing better visualization and project integration. The term BIM was coined in the 1970s by Charles Eastman and has been used in academia in various studies [10], [11], [12]. The value of BIM technology has been understood since the early 2000s in the construction sector and in academic studies related to construction. This study presents BIM related studies and a general overview of the aspects discussed. The aim of the study is to examine the research tendency as well as the gaps for potential fields of BIM as future studies. Furthermore, it is also intended to find out the relation between BIM and sustainability, which are the two emerging concepts in the construction industry. It examines the characteristics of the papers in BIM literature. Accordingly, articles published in refereed journals are classified from the point of the content, style/input-output, purpose/outcome relationship and author of the study.

## II. DATA AND RESEARCH METHODOLOGY

BIM related studies are accessed through various sources including journal articles, conference papers, academic dissertations and reports. Within the scope of this study, articles published in refereed journals are analyzed exclusively to ensure a certain academic standard. Leading international refereed journal publishers in construction and information technologies, therefore, are determined. These are American Society of Civil Engineers (ASCE), Emerald and Science Direct. Keywords limited to "Building Information Modeling" and "BIM" were searched for among the title and keywords sections of the articles via the databases of the determined journal publishers. As of 10.10.2013, when "Building Information Modeling" is searched for title and keywords of the articles, it gave the 101 and 295 results respectively. On the other hand, 126 results took place in the

title of articles for “BIM” while the number is 355 for the keywords. The articles about construction industry are included after the elimination of the repeated publications from the obtained results. Studies related to electrical and mechanical systems, book reviews and editorials are excluded. Determination of the classification method is of great importance for meta-analysis studies that examine a discipline, inter-relate different areas of the study and identify emerging and neglected themes [3]. The rationale for the use of meta-models arises out of a theoretical understanding that the main determinants of the nature of construction management research come from the multi-disciplinary background of its knowledge bases, the many organizational levels within the industry, the multiple stages through which construction projects move in their life-cycle, the professional differentiation that exists between parts of the sector and the distinctions within different types of research process [2]. Meta-classification system used in this study is adapted from previous studies. It consists of four main dimensions that are content, style/input-output, purpose/outcome relationship and author respectively. Each dimension has its own sub-categories. While area, subject, process and study level sub-categories are addressed in the content dimension; style examines the articles in terms of input and output. In the purpose/outcome relationship, the starting point of the articles, BIM tools used and the results of the studies are analyzed. Finally, the last dimension concerns the author in country and institution aspects. Table I shows the meta-classification system used in this study. The content dimension firstly concerns about the professional area related to the construction industry. Area analysis designates a professional boundary. The second sub-category of the content dimension examines the articles on which subject based. This sub-category is accepted as one of the most important means for gathering the body of knowledge in a discipline and determining the frequently published or neglected themes [3]. Whereas process sub-category of the content dimension analyses the stage focused within the building construction process, in the last sub-category the study level of the articles is examined. The second dimension of the meta-classification system is style/input-output which addresses the methodology used in the study first and then the contribution to the field. In the next dimension purpose/outcome relationship of the articles is analyzed. Firstly, starting point of the study is discussed in order to find out the triggering factors of BIM. After the determination of the BIM tools used for generating the study, the results are discussed. Country and institution sub-categories are examined in the author dimension in order to bring out which countries contribute to BIM field most. Country is considered as the country affiliated with the author’s institution, in other words, the country where the research is generated. On the other hand, the type of the institution is identified in the institution sub-category.

Table I. Meta-Classification System

Dimension	Sub-Category	
Content*	Area	Architecture, AEC Industry, AECO Industry, Building/Construction, Civil Engineering, Construction Management, Education, Facility Management
	Subject	Impacts of BIM, Benefits of BIM, BIM Adoption, BIM Usage, Implementation of BIM, Communication, Collaboration, Coordination, Data Exchange, Enhancement of BIM, Interoperability, Integration
	Process	Planning, Design, Procurement, Construction, Operating, Whole Life Cycle, N/A
	Study Level	Sector, Firm, Project, Product
Style/Input-Output*	Methodology	Theoretical, Practical, Case Study, Survey, Interview
	Contribution	General Evaluation, Model Building, Statistical Results, System Development
Purpose/Outcome Relationship	Starting Point	
	BIM Tools	Module Addition, Common File Usage, Software Usage, Software Development
	Result	
Author	Country**	Country where Research is Generated
	Institution	University, Research Centre, Private Sector

\* Adapted from [3], \*\* Adapted from [2].

### III. ANALYSIS AND RESULTS

The results of the analysis show that there are 130 articles published on the subject of BIM until the third quarter of 2013 within the construction related limitations. The number of articles from each journal publisher by their publication years is presented in Table II. The literature review made without any time restriction shows that BIM related academic studies started since 2004. Nevertheless, the number of the articles published in recent years has gradually increased. Excluding 2013, most articles were published in 2011. It should be also noted that the articles regarding to 2013 cover the third quarter of the year. Another noteworthy point is that there is no study carried out in the years of 2005 and 2007. This can be interpreted with the lack of functionality before 2007 and widespread use of BIM software such as Autodesk Revit, ArchiCAD and Nemetschek

Tablo II. Analysis Results by Publisher/Database and Years

Publisher/Database	2004	2006	2008	2009	2010	2011	2012	2013*	Total
ASCE			1	1	5	6	7	21	41
Emerald	1		1	1	1	4	3	2	13
Science Direct		1	6	4	7	17	12	29	76
<b>Total</b>	<b>1</b>	<b>1</b>	<b>8</b>	<b>6</b>	<b>13</b>	<b>27</b>	<b>22</b>	<b>52</b>	<b>130</b>

\* 2013 includes the third quarter of the year.

Allplan after 2007. When the publishers/database is examined in terms of the number of articles published, Science Direct has the most articles in each year and total except 2004. ASCE and Emerald respectively follow Science Direct. 130 articles obtained from the analysis are published by 23 different refereed journals. Automation in Construction has the highest number with 59 articles whereas Advanced Engineering Informatics and Journal of Computing in Civil Engineering published 12 articles each. Journal of Construction Engineering and Management and Journal of Professional Issues in Engineering Education and Practice follow them with 9 and 5 respectively.

The results obtained from the analysis used meta-classification system are discussed in detail below.

**A. Content**

Area, subject, process and study level sub-categories are discussed in the content dimension.

In the area sub-category, the professional areas are grouped as Architecture, Architecture, Engineering and Construction (AEC) Industry, Architectural, Engineering, Construction and Operation (AECO) Industry, Building/Construction, Civil Engineering, Construction Management, Education and Facility Management. Fig 1 shows the distribution of the articles according to their area within the construction industry. While 39 of the analyzed articles are intended for AEC Industry, 37 of them are related to AECO Industry. Construction Management in 16 of the articles is the following most frequent area. Results also show that BIM is argued in 9 studies for Education in the construction industry. BIM is analyzed from the perspective it is discussed in the subject sub-category. It concerns the aspects of BIM. Even though theme of each article is specific, subject sub-category can be generalized according to the content of the articles. Therefore, the main subjects are Impacts of BIM, Benefits of BIM, BIM Adoption, BIM Usage, Implementation of BIM, Communication, Collaboration, Coordination, Data Exchange, Enhancement of BIM, Interoperability and Integration as shown in Fig. 2. The majority of the articles examine the impacts of BIM on various topics including data extraction, information gathering, documentation, advanced decision making, career, education, sustainable design, design review systems, quantity takeoff, cost estimation, contractual issues, supply chain, 4D scheduling. Integration is the next discussed subject in 23

articles. Integrated BIM solutions for different topics are suggested.

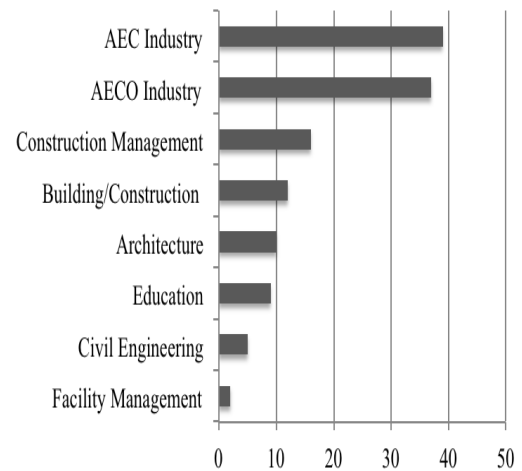


Fig. 1 Articles by Area

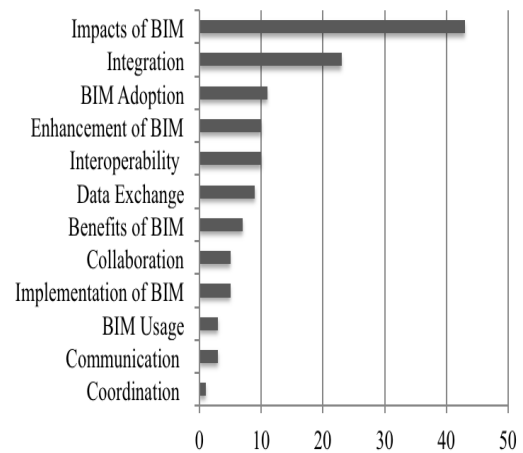


Fig. 2 Articles by Subject

These are included but not limited to visualization, energy analysis, laser scanning, construction safety, procurement process, information flow, simulation, augmented reality (AR), ontology, social networking systems (SNS) and radio frequency identification (RFID). BIM adoption, enhancement of BIM, interoperability, data exchange and benefits of BIM are the other prominent subjects. in the third sub-category of content dimension, the process within the building production system is analyzed. Fig. 3 presents the results of the studies by their process intended for. Except 22 articles, the process of the studies is specified.

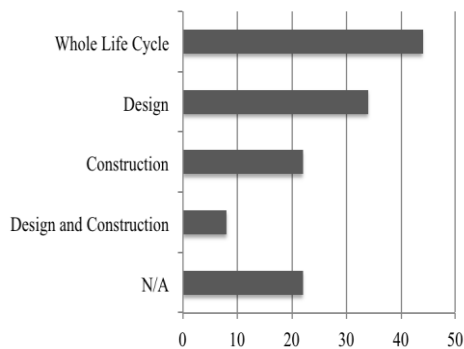


Fig. 3 Articles by Process

While 44 articles of 130 are regarding the whole life cycle, design stage is referred in 34 studies. Then, construction stage comes. Besides, there are studies concern both design and construction stages, resulting from integration, collaboration and coordination related subjects. In addition, studies regarding the design stage emphasize the importance of design stage of the building production process due to the effect of decisions made during design stage on cost, time and quality. Study level of the articles is discussed in the last sub-category of content dimension. As shown in Fig. 4, the vast majority of the studies are carried out at Project level. Even though the project level is the dominant level in the project-based recognized sector; sector, firm and product levels are the other levels discussed respectively. Moreover, 2 articles pertain to both project and firm and one of the studies is applied for product, project and sector level.

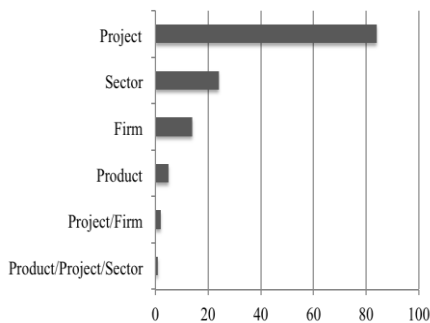


Fig. 4 Articles by Study Level

**B. Style/Input-Output**

In the second dimension of the meta-classification system, the articles are primarily evaluated by their methodology. In this context, studies are analyzed in terms of the methods including case study, practical, theoretical, survey, interview or the combination of them. The results are presented in Fig. 5. Case study is the most used method. Practical studies also take an important place in BIM related articles. 51 of the analyzed 130 articles conducted case study and 40 of them are practical while 16 articles are theoretical. Survey and interview based studies are generally conducted for measuring the impacts of BIM, understanding its benefits or identifying the preventing factors of BIM usage.

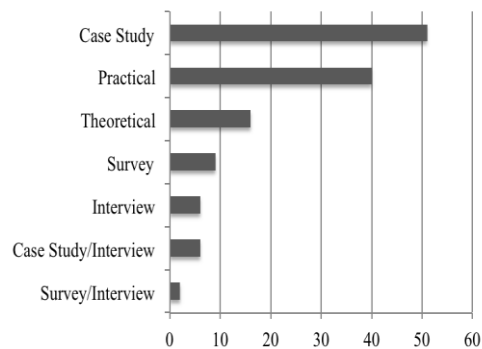


Fig. 5 Articles by Methodology

Contribution sub-category of the style/input-output dimension examines the articles in terms of the output they produce. The contribution to the field is evaluated via general evaluation, model building, statistical results and system development. Fig. 6 indicates the analysis results of the examined 130 articles. Model building comprises the majority with 82 articles. General evaluation, system development and statistical results follow it respectively.

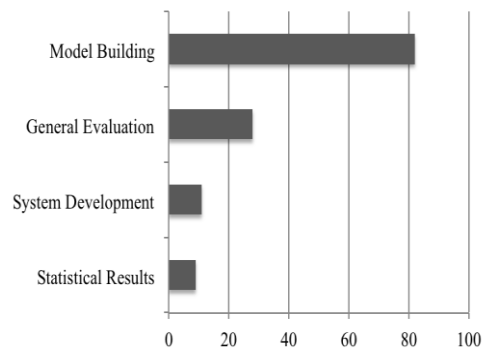


Fig. 6 Articles by Contribution

**C. Purpose/Outcome Relationship**

The third dimension of the meta-classification system has three sub-categories, which are starting point, BIM tools and result. Firstly, the causative factors are examined in the starting point. These can be listed as development of new technologies, opportunities of BIM, need of 3D model, lack of BIM utilization, the benefits of collaboration, integration, data exchange and interoperability and their difficulties in usage. BIM tools are examined next as the second sub-category. It concerns how BIM is used in order to achieve the purpose of the study. Common file usage, software usage, software development and module addition into existing software are classified as the tools in BIM related studies. Even though there is no tool used in some studies, software usage is the most common tool with 46 articles as indicated in Fig. 7. On the other hand, in 21 articles software is developed for BIM enhancement, integration, data exchange and interoperability. Common file usage and module addition follows them respectively.

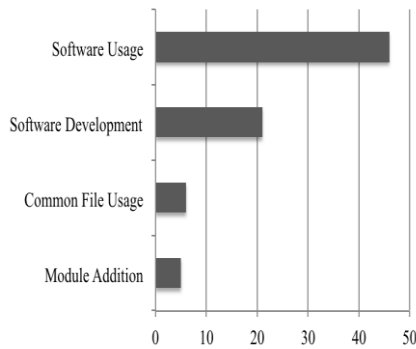


Fig. 7 Articles by BIM Tools

The results of the studies are determined in the last sub-category of the purpose/outcomes relationship dimension. The necessity of accurate BIM usage and integrated solutions to improve the performance in construction projects, the importance of BIM, potential advantages of BIM, factors affecting BIM adoption and implementation, positive BIM impacts on education are the outstanding results.

**D. Author**

In the last dimension of the meta-classification system, the author/s of the articles are examined in terms of their country and institution. The country sub-category refers to the country where the research is generated. In the articles that have more than one author, the first author’s background is discussed. However, in the institution sub-category, the studies are evaluated by the type of the research. The examined articles in this study are carried out in 21 different countries. The results show that studies related to BIM are discussed most in USA as in many other areas. Fig. 8 presents the articles by country.

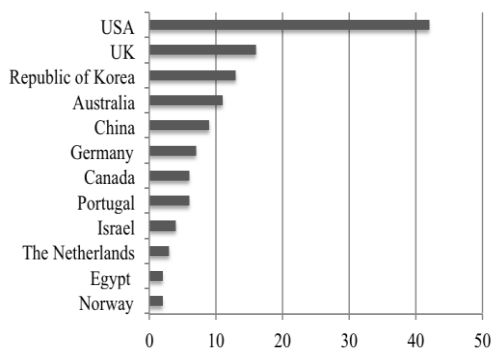


Fig. 8 Articles by Country

More than 40 articles are generated in USA. UK, Republic of Korea, Australia, China, Germany, Canada, Portugal, Israel, The Netherlands, Egypt and Norway are the following countries respectively. Besides, there are 9 countries not shown in the figure that have one article. These are Finland, France, Hong Kong, Ireland, Slovenia, Spain, Sweden, Taiwan and Turkey. While 15 articles are single-author article, 38 articles have two authors and the rest of the articles are published by more than two authors. The collaboration of the authors is important in terms of

gathering different perspectives and contribution to the field. Fig. 8 shows the results of the institution sub-category. Majority of the articles are generated within university and 15 articles are sector-university collaboration. This can be explained by the limited sector-university collaboration so that most studies remain in academic environment. However, collaboration with participants operating in the industry is of great importance for BIM studies, which are practical.

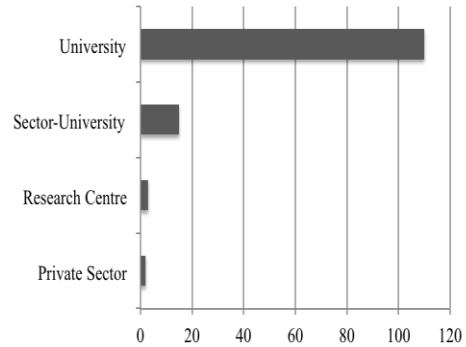


Fig. 8 Articles by Institution

**IV. BIM AND SUSTAINABILITY**

In this section of the study, BIM is discussed from the sustainability aspect. The increasing attention to sustainability is pushing the construction industry towards rapid changes. Policies, laws and regulations around the world are asking the sector to adopt sustainable innovation in terms of products and processes to encourage more sustainable buildings [4], [5]. Additionally, the studies show that the demand for sustainable building facilities with minimal environmental impact is increasing and sustainable buildings are considered as economically viable [6], [7], [9]. Hence, the adoption of technological innovations for sustainable data has been discussed in the industry. It is, therefore, intended to examine the studies related to sustainability concept and find out the tendency and approach so as to determine the gap in this field. There are 9 studies concern sustainability related issues within the examined articles. The studies mostly focus on impacts of BIM on sustainable design and BIM enhancement for energy analysis. The starting point of the studies is lack of BIM technology for reliable energy efficiency, sustainable building design and sustainable construction practices. Except one statistical results, model building is the contribution of the sustainability related studies and software usage is the most common tool used. The two of the articles are carried out within sector-university collaboration, which aim to examine the current situation within the industry. The results of the studies show there is a need for integration of BIM and green building market. Even though the importance of using BIM technology for sustainability is discussed in the literature, there are some barriers to a fully integration such as lack of functional tools and complex structure of existing tools.

## V. CONCLUSION

In this study, the concept of BIM, which has a great impact and importance in the construction industry, is examined via meta-classification system. In this context, refereed journal articles including “BIM” and/or “Building Information Modeling” in their title and/or keywords are discussed in terms of different dimensions to evaluate the research tendency and gap in BIM literature. The results of the analysis show that impacts of BIM on various topics from education to scheduling, integration of BIM for improved outcomes, easy BIM adoption and implementation, enhancement of BIM, accurate data exchange and interoperability are the main areas for BIM related studies. The influence of the listed aspects is indisputable on the construction projects generated by several participants composed of different professional fields. Therefore, the named areas are discussed in most of the studies. The other areas can be listed as benefits and advantages of and barriers and limitations to BIM usage. With the comprehension and dissemination of BIM importance in recent years, the number of the studies in which BIM is discussed for advanced solutions has increased when compared to the previous study [8]. Since BIM provides an opportunity for superposing the multidisciplinary information within one model powerfully, the importance of sustainable data addition into the BIM model has been discussed recently due to the increased demand for green certification. However, the number and content of studies related to sustainability concept indicate that there is still a gap for integrated solutions, especially studies intended for whole certification process in order to encourage sustainable construction. In this sense, integrated design process with sustainable properties simplifies the certification process in terms of time and cost. A supporting method that facilitates the sustainable project decisions generated by BIM software can be proposed for an integrated BIM – Sustainable Data model. On the other hand, due to the lack of BIM research on bidding process and contractual issues, BIM studies related to preparation of bid documents and contract administration especially in terms of submittals can be considered as potential future studies.

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