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Building Information Modeling in Construction Industry: Meta-Analysis

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Abstract*— Building Information Modeling (BIM) is a process of generating and managing building data during the building's life cycle. Typically, BIM uses three-dimensional (3D), real-time and dynamic building modeling software to increase productivity in building design and construction. Due to its characteristics and benefits, BIM-related studies have gradually increased recently and researchers have investigated this new technology in many disciplines. This research contributes mainly to provide a map displaying important disciplines in the construction industry in which BIM has been used for, identifies and highlights the research gaps in the literature. It applies and extends a methodology for reviewing BIM-related publications through a four-dimensional meta-analysis system and its categories, which has been partially adapted previously. Furthermore, one of the main goals is to explore the adoption of BIM in civil engineering construction projects, in particular the construction of intermediate railway stations. A supporting method that increases the construction efficiency of intermediate railway stations by applying the BIM concept for the generation and management of station data can be considered as potential future research.

Index Terms— **Building Information Modeling, Construction Industry, Meta-Analysis, Intermediate Railway Station.**

I. INTRODUCTION

In recent years, both the concept and nomenclature which we now know as BIM— or Building Information Models and Building Information Modeling—have sufficiently engaged many professionals and industry awareness. The term 'BIM' have intentionally and consistently used to describe an activity (meaning building information modeling), rather than an object (building information model) [1]. This reflects the belief that BIM is not a thing or a type of software but a human activity that ultimately involves broad process changes in construction.

Building Information Modeling (BIM) is an emerging technological and procedural shift within the Architecture, Engineering and Construction (AEC) industry. Researchers have been investigating the components and effects of building product models for many years before the emergence of BIM as a new term [2]. Liu [3] described BIM in two ways: modeling and application. From the standpoint of modeling, BIM means Building Information Modeling, based on a three-dimensional digital technology that integrates the construction project and related information of graphical engineering models, and also contains the physical engineering properties and functional properties and its related project life cycle information. On the other hand, from the application perspective, BIM means a Building Information Model that is fully digital, supports various operations of a construction project, is dynamic, and can add all kinds of project information in a project life cycle freely, to meet any kind of demand [3]. It is important to note that BIM is not just software; it is a process and software. BIM means not only using three-dimensional intelligent models but also making significant changes in the workflow and project delivery processes [4]. BIM represents a new paradigm within AEC, one that encourages integration of the roles of all stakeholders on a project. It has the potential to promote greater efficiency and harmony among players who, in the past, saw themselves as adversaries [5]. BIM also supports the concept of integrated project delivery, which is a novel project delivery approach to integrate people, systems, and business structures and practices into a collaborative process to reduce waste and optimize efficiency through all phases of the project life cycle [6].

Building (Construction) Information Model (BIM) is defined by international standards as "shared digital representation of physical and functional characteristics of any built object […] which forms a reliable basis for decisions" [7]. BIMs originate from product models [8, 9] that are widely applied in the petrochemical, automotive or shipbuilding industry [10, 11]. BIM represents real buildings virtually over the whole life cycle as semantically enriched, consistent, digital building models [11-13]. BIM is realized with object-oriented software and consists of parametric objects representing building components [9, 14, 15]. Objects may have geometric or non-geometric attributes with functional, semantic or topologic information [10, 11]. According to the National Building Information Modeling Standard [16], a BIM is a digital representation of physical and functional characteristics of a facility and its related project/life-cycle information, and it is intended to be a repository of information for the facility owner/operator to use and maintain throughout the lifetime of the structure. A fundamental premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a project to insert, extract, update, or modify data in the BIM process to support and reflect the roles of that stakeholder. Thus, a BIM is a shared digital representation of a facility founded on open standards for practical interoperability, Fig.1 [17].

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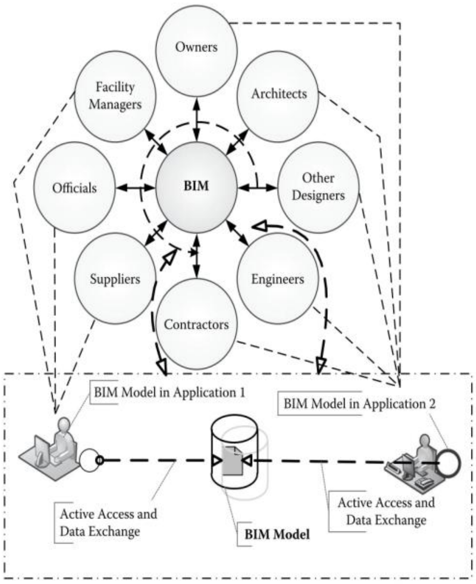

Fig. 1 BIM concept and process [17]

The Architecture, Engineering and Construction (AEC) industries have long sought techniques to decrease project cost, increase productivity and quality, and reduce project delivery time. Building Information Modeling (BIM) offers the potential to achieve these objectives. BIM represents the development and use of computer-generated n-dimensional (n-D) models to simulate the planning, design, construction and operation of a facility. It can be used by the owner to understand project needs, by the design team to analyze, design and develop the project, by the contractor to manage the construction of the project and by the facility manager during operation and decommissioning phases [18]. Looking to the future leads to speculation that BIM will eventually lead to a virtual project design and construction approach, with a project being completely simulated before being undertaken for real [19]. As such BIM will provide potential beneficial project outcomes by enabling the rapid analysis of different scenarios related to the performance of a building through its life cycle [20].

On the other hand, studies of publication patterns are useful indicators of scientific productivity, trends, emphasis of research in various disciplines and researchers' preferences for publication outputs [21]. A research conducted by T. Ilter et al. [22] showed that the studies of publication patterns related to a specific area, which are also known as meta-analysis studies, are beneficial in the decision-making processes of academic research from planning to management. Moreover, academic journals, which are one of the most important communication channels of knowledge sharing, provide a platform for communication of research findings and scholarly debate to take place. In the academic world, 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 [22]. According to Betts and Lansley [23], 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. While analysis 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, T. Ilter et al., and Betts and Lansley [22. 23] concluded that the analysis of a broader sample provides a map displaying important patterns in a discipline. The meta-analysis studies are concerned with 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 [22].

II. RESEARCH OBJECTIVES AND STRUCTURE

This paper presents a general overview of BIM-related studies.

1. The objective of this research is to identify the research topics and trends in the area of BIM through interdisciplinary endeavors as well as the gaps for potential directions, which could advance the state-of-the-art in BIM technology.
2. Furthermore, one of the main goals is to explore the adoption of BIM in civil engineering construction projects, in particular the construction of intermediate railway stations.
3. It examines the main points of the articles in BIM literature. Accordingly, articles published in refereed journals and databases are classified according to four dimensions: (1) the content, (2) style/input-output, (3) purpose/outcome relationship and (4) the author of the study, and their categories and sub-categories.

The paper continues with an explanation of the research approach and methodology. Subsequently, it presents the results and detailed discussions of using the four-dimensional meta-analysis system. Next, it investigates the application of BIM in transportation research areas and finally potential areas for future BIM studies are suggested in the conclusion.

III. RESEARCH APPROACH AND METHODOLOGY

This paper applies and extends a methodology for reviewing BIM-related publications through a meta-classification system which has been partially adapted in earlier studies.

A. Contribution of BIM to advanced research

Building Information Modelling is a set of interacting policies, processes and technologies [24] generating a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle" [25]. BIM concept is originated from Professor Charles Eastman at the Georgia Tech School of Architecture in late 1970s [26, 27]. In 1986 Graphisoft, a Hungarian software company introduced their first "Virtual Building Solution" known as ArchiCAD. Shortly after, other software companies, such as Autodesk and Bentley Systems created their own versions of the software. Each software company tried coining the BIM concept in different names until Jerry Laiserin helped to standardize the term as "Building

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Information Modelling". He knew that every stakeholder in a project must understand what BIM is and is not. Having different terminology created even more confusion amongst Architect, Engineer, and Construction (AEC) professionals [28].

Eastman [1] had reported that the earliest documented example which have found for the concept, known today as BIM, was a working prototype "Building Description System" published in the now-defunct AIA Journal by Charles M. Eastman at Carnegie-Mellon University in 1975 [1]. The first documented use of the term "Building Modeling" in English–in the sense that "Building Information Modeling" is used today–appeared in the title of a paper by [29]. Aish set out in his paper all the arguments for what we now know as BIM and the technology to implement it, including: 3D modeling; automatic drawing extraction; intelligent parametric components; relational databases; temporal phasing of construction processes; and so forth [29]. He illustrated these concepts with a case study applying the RUCAPS building modeling system to the phased refurbishment of Terminal 3 at Heathrow Airport, London. From "Building Model" it was but a short leap to "Building Information Model", for which the first documented use in English appeared in a paper by [30].

Thus, by first attempt to popularize the term [31] and craft a multi-vendor consensus around it [32], the core nomenclature of Building Information Modeling had been coined at least fourteen years earlier, and the concept or approach had been established more than a further sixteen years before that. This research has explored the BIM-related literature comprehensively and reviewed BIM-related publications, which have been accessed through different sources including journal articles and conference papers. Within the scope of this study, articles published exclusively in refereed journals and databases are manually analyzed to ensure a certain academic standard. In this regard, leading ten international refereed journal publishers and databases are selected. They are Engineering Village (EI), Web of Science (WS), Elsevier (ELS)–Science Direct (SD), American Society of Civil Engineers (ASCE), Springer (SPR), IEEE Xplore Digital Library (IEEE), Taylor & Francis (T&F), Wiley Online Library (WOL), Emerald Insight (EMD), and EBSCO-host (EBS). The articles were identified using three search phrases, "BIM", "Building Information Modeling" and "Building Information Models" in their titles and/or abstracts and/or keywords during the time period from 2002 – 2016. Instead of using "BIM" by itself, which also represents other research topics from disciplines such as genetics or economics, combined phrases like "BIM" AND "building" and "BIM" AND "information modeling" were used together to enlarge the corpus size. BIM-related textbooks, trade magazines, brochures and product/software related white papers were not considered, because the analysis focused on research publications. Since most research reports and theses result in academic articles, they were also not considered to prevent duplication in the corpus.

Betts and Lansley [23] showed that the selection of the classification method is of great importance for meta-analysis studies that examine a discipline, interrelate different areas of the study and identify emerging and neglected themes. 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 processes [22].

B. Meta-Analysis System

The meta-classification system consists of four main dimensions that are (1) content, (2) style/input-output, (3) purpose/outcome relationship and (4) author respectively. First and second dimensions have been adapted from [23], fourth dimension has been adapted from [22], whereas third dimension is added by the authors. Each dimension has its own categories. While area, subject, process and study level categories are addressed in the content dimension, the style dimension examines the articles in terms of input and output. In the purpose/outcome relationship, the used BIM tools are analyzed. Finally, the last dimension concerns the aspects of author's country and institution. Table 1 shows the meta-classification system used in this study with the number of publications for each sub-category and the percentage of reviewed publications.

The content dimension firstly concerns the professional area related to the construction industry. Area analysis designates a professional boundary. The second category of the content dimension examines the articles on which the subject is based. This 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. The process category of the content dimension analyses each stage of the building construction process. In the last 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 that had been used in the study and its contribution. The purpose/outcome relationship of the articles is analyzed in the next dimension which determine the used BIM tools for generating the study. Country and institution categories are examined in the last dimension – the author dimension – in order to reveal which countries contribute most to the BIM field. The country is considered to be the country affiliated with the author's institution, in other words, the country where the research is performed. On the other hand, the type of institution is identified in the institution category.

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Table 1. The meta-classification system

Dimension	Category	Sub-Category	Articles	Percentage
Content *	Area	AECO Industry	1997	72.17
		Building/Construction	174	6.30
		Civil Engineering	47	1.69
		Construction Management	261	9.44
		Education	127	4.60
		Facility Management	161	5.81
	Subject	Impacts of BIM	402	14.53
		Benefits of BIM	60	2.18
		BIM Adoption	154	5.57
		BIM Usage	295	0.65
		Implementation of BIM	402	14.53
		Communication	41	1.48
		Collaboration	94	3.39
		Coordination	33	1.21
		Data Exchange	167	6.05
		Enhancement of BIM	60	2.18
		Interoperability	74	2.66
		Integration	985	35.59
	Process	Planning	94	3.39
		Design	375	13.56
		Procurement	81	2.91
		Construction	590	21.31
		Operating	214	7.75
		Whole Life Cycle	1413	51.06
	Study Level	Sector	1447	52.29
		Firm	489	17.67
		Project	757	27.36
		Product	74	2.67
Style/Input – Output *	Methodology	Theoretical	549	19.84
		Practical	905	32.71
		Case Study	898	32.45
		Survey	321	11.60
		Interview	94	3.40
	Contribution	General Evaluation	777	28.08
		Model Building	1300	46.98
		Statistical Results	261	9.43
		System Development	429	15.50
Purpose / Outcome Relationship	BIM Tools	Module Addition	174	6.30
		Common File Usage	489	17.68
		Software Usage	1393	50.36
		Software Development	182	6.57
		N/A	529	19.13
Author **	Country	Top-ten countries by number of BIM-published articles are shown in Fig.10		
	Institution	University	2553	92
		Research Centre	121	5
		Private Sector	93	3

Note: * [23], ** [22]

IV. RESULTS AND DISCUSSIONS

As of July 31, 2016, the authors have gotten 2767 BIM-related articles distributed as 1205 journal papers and 1562 conference papers as shown in Fig.2.

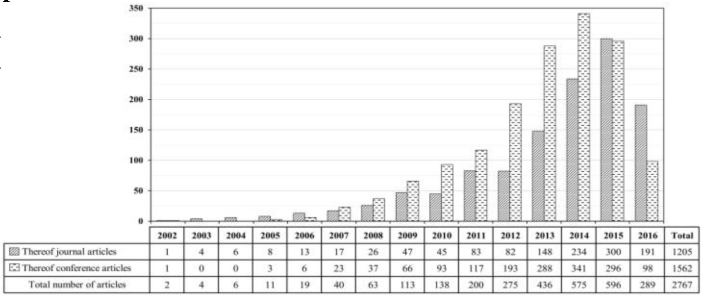

Fig.2 Number of articles per publication year

Because a large number of journals and conferences from different origins had focused on BIM, so it is difficult to encompass all the researches that is why authors have presented only the top-ten results. The resulted articles are published by many different refereed journals and conferences as shown in Table 2 and Table 3.

Table 2. Top-ten ranked journals by number of BIM-published articles

Journal Name	No. of articles
Automation in Construction	233
Advanced Engineering Informatics	65
Computing in Civil Engineering	57
Information Technology in Construction	44
Construction Engineering and Management	38
Construction Innovation	31
Engineering News-Record	31
Structural Engineers	22
Energy and Buildings	19
Architectural Design	18
Management in Engineering	17
Professional Issues in Engineering Education and Practice	17

Table 3. Top-ten ranked conferences by number of BIM-published articles

Conference Name	No. of articles
International Symposium on Automation and Robotics in Construction (ISARC)	108
European Conference on Product and Process Modelling (ECPPM)	83
Construction Research Congress (CRC)	77
International Conference on Computing in Civil and Building Engineering (ICCCBE)	71
ASCE International Workshop on Computing in Civil Engineering (IWCCE)	51
International Conference on Education and Research in Computer Aided Architectural Design in Europe (eCAADe)	48
International Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA)	46
International Conference on Construction and Real Estate Management (ICCREM)	38
International Conference on Civil Engineering, Architecture and Building Materials (CEABM)	32

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ASEE Annual Conference and Exposition (ACE)	31

information management tool, existing buildings, public work projects, infrastructure industry and transport industry. BIM usage, data exchange, BIM adoption, collaboration, interoperability, benefits of BIM and enhancement of BIM are the other prominent subjects.

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

A. Content

Area, subject, process and study level categories are discussed in the content dimension. In the area category, the professional areas are grouped as Architectural, Engineering, Construction and Operation (AECO) industry, building/construction, civil engineering, construction management, education and facility management. Fig.3 shows the distribution of the articles according to their area within the construction industry. While 1521 of the analyzed articles are intended for the AEC industry, 362 of them are related to architecture. Construction management in 261 of the articles is the next most frequent area. Results also show that BIM is covered in 127 studies for education in the construction industry. The area of civil engineering is the least frequent one with 47 articles only.

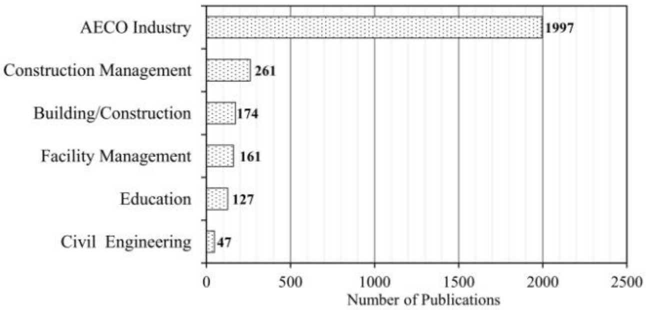

Fig.3 Articles by area

When BIM is analyzed from the perspective in the subject category, it concerns the aspects of BIM. Even though the theme of each article is specific, the subject 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.4. The mainstream of the articles (985 articles) examine the integration of BIM solutions for various suggested topics including but not limited to visualization, energy analysis, laser scanning, construction safety, 3D data collection, integrated project delivery, nD modeling, Geographic Information System (GIS), procurement process, information flow, simulation, augmented reality (AR), ontology, social networking systems (SNS) and radio frequency identification (RFID). Both of the subjects, impacts of BIM and implementation of BIM, is the next subject discussed in 402 articles for each of them. Impacts of BIM were examined 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, and 4D scheduling. Implementation of BIM includes the construction phase of the building life cycle, project management, construction firm, field operation,

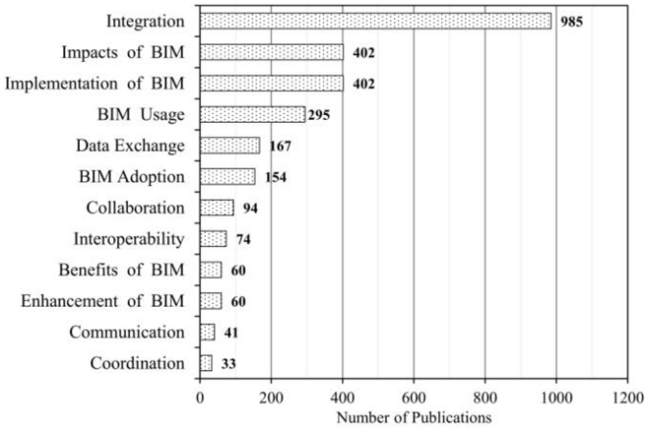

Fig.4 Articles by subject

In the third category of the content dimension, the process within the building production system is analyzed. Fig.5 presents the results of the studies by their intended process. While 1413 articles of the 2767 regard the whole life cycle of the facility, the construction stage is referred to in 590 articles. Then comes the design stage with 375 articles. The other sub-process stages, operating, planning, and procurement come last with 214, 94 and 81 articles respectively.

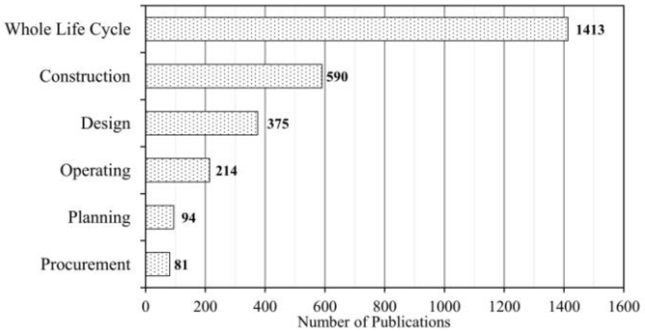

Fig.5 Articles by process

The study level of the articles is discussed in the last category of the content dimension. As shown in Fig.6, the vast majority of the studies are carried out at the sector level and project level with 1447 and 757 articles respectively, which means that 52.29% of the total studies are carried out at the sector level whereas 27.36% for project level. Even though the sector level and the project level are dominant, the firm level and the product level are the other levels that are discussed.

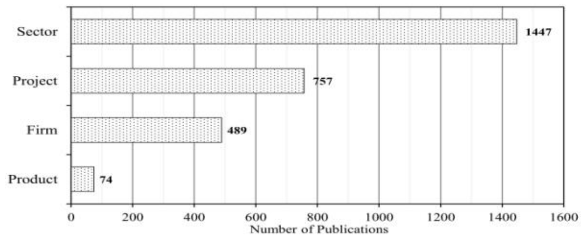

Fig.6 Number of articles by study level

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B. Style/Input-Output

In the second dimension of the meta-classification system, the articles are primarily evaluated by their methodology. In this context, articles are analyzed in terms of the methods including case study, practical, theoretical, survey and interview. The results are presented in Fig.7. Practical studies and case studies are the methodologies most used. They involved 905 and 898 articles respectively of the 2767 articles analyzed, whereas 549 articles are on theoretical studies. Studies based on survey and interview methodologies are generally conducted for measuring the impacts of BIM, understanding its benefits or identifying the factors preventing the use of BIM, and they were covered in 321 and 94 articles respectively.

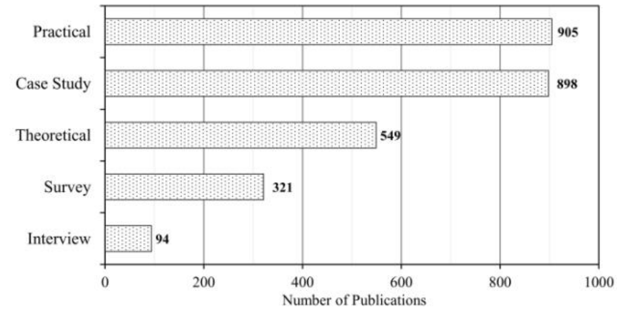

Fig.7 Number of articles by methodology

The contribution 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.8 indicates the analysis results of the examined 2767 articles. Model building comprises the majority with 1300 articles, 46.98% of the total articles. General evaluation, system development and statistical results follow with 777, 429 and 261 articles respectively.

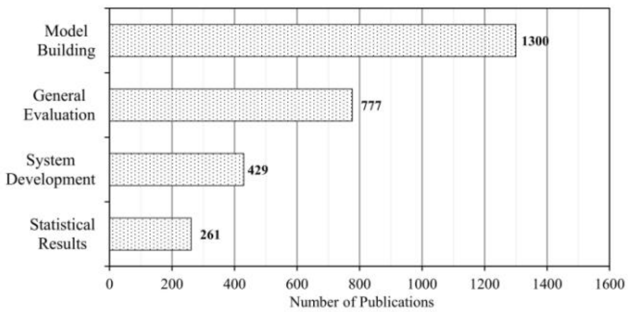

Fig.8 Number of articles by contribution

C. Purpose/Outcome Relationship

The third dimension of the meta-classification system has only one category, which is the BIM tools. 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 (N/A, 529 articles), software usage is the most common tool with 1393 articles, about 50.34% of the total studies, as indicated in Fig.9. Then common file usage, software development and module addition follow with 489, 182 and 174 articles respectively.

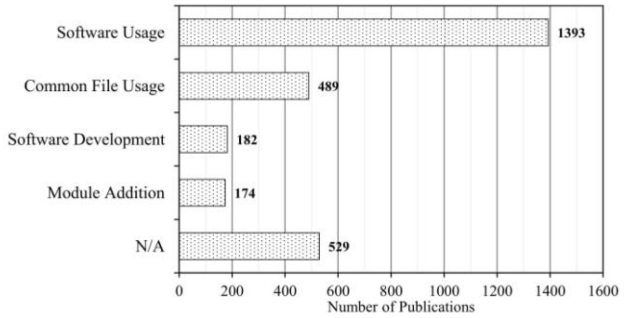

Fig.9 Number of articles by tools

D. Author

In the last dimension of the meta-classification system, the authors of the articles are examined in terms of their country and institution. The country 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 category, the studies are evaluated by the type of research. The examined articles in this study are carried out in many countries. The results show that studies related to BIM are discussed more in the United States than in other countries. Fig.10 presents the articles by country. There are 727 articles generated in the United States whereas 465 articles in China, as shown in Fig.10. UK, South Korea, Australia, Germany, Canada, Taiwan, Italy, and Finland are the countries that follow respectively.

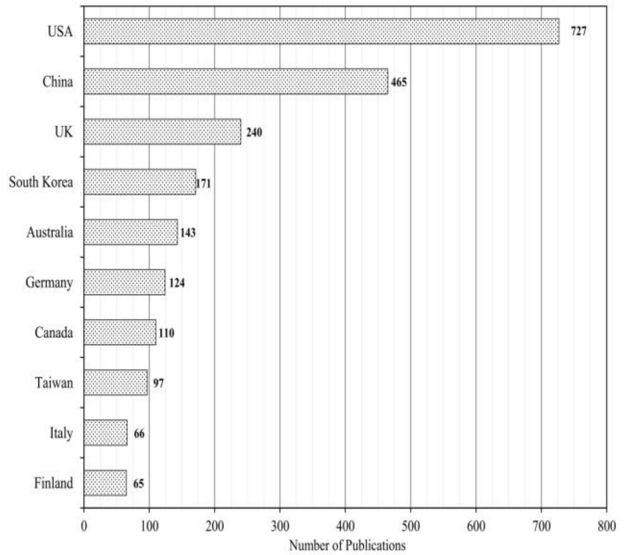

Fig.10 Articles by country

The collaboration of the authors is important in terms of gathering different perspectives and for contribution to the study field. Fig.11 shows the results of the institution category. As most of the public agencies, e.g. local and federal governments, request the universities to perform and prepare their projects studies on their behalf, so the "university" sub-category implies all related articles accordingly. The majority of articles were written at universities (2553 articles), which means that most of studies were performed in an academic environment. Few studies were done by research centers and in the private sector, with 121 and 93 articles respectively.

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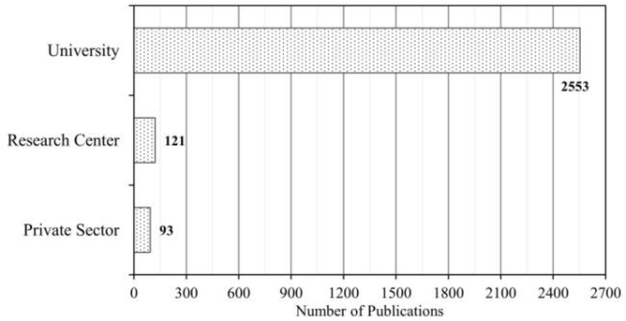

Fig.11 Articles by institution

V. APPLICATION OF BIM IN TRANSPORTATION RESEARCH AREAS

This section briefly explain some of the application of BIM in different transportation projects.

A. High-speed railways

Lee [33] have investigated a case study of the Taiwan High Speed Rail Corporation, which brings BIM technology into the Changhua Station construction project. During the construction stage, construction information is integrated by the model to enhance construction process flow throughout the different construction sectors. They found that the application of BIM coordination technology reduces the information gap, enhances construction quality and helps in meeting the schedule [33].

B. Tunnel construction

Tunnel construction involves significant uncertainties in ground conditions, often causing cost overruns and schedule delays. Ryu [34] developed a methodology to predict multiple sets of ground conditions by using simulated annealing, which is a geo-statistical method, and then evaluate excavation costs and durations of a tunneling schedule via BIM. It enables general contractors to formally evaluate risks in excavation costs and durations of tunnel construction with complete information about ground conditions acquired before construction [34].

C. Urban deep excavation projects

Wu [35] developed a BIM-based monitoring system to integrate and visualize monitoring data for risk assessments during urban deep excavation projects. This system assists construction project teams in identifying and understanding possible blind spots when attempting to achieve risk assessments during urban deep excavation projects, and further enables the adoption of measures to reduce risk levels [35].

D. Highway projects

Using BIM on a highway project has received a lot of attention recently. Sibert [36] explained how BIM can provide a structured approach to design data storage and sharing for design teams, contractors and operators. BIM has improved coordination and holistic design for multidisciplinary teams, and been helpful in communicating construction sequences and applications [36].

E. Metro transit systems

Metro transit systems have gained importance because of the large number of passengers depending on that vital mode of intercity transportation. Most metro transit systems contain subways that need to be efficiently ventilated in order to maintain the health and comfort of workers and passengers. Therefore, it is necessary to monitor the thermal comfort inside subways. Marzouk and Abdelaty [37] presented an application that utilizes wireless sensor network and BIM in order to monitor thermal conditions within a subway during construction and operation phases [37].

F. Bridges projects

Applying BIM technology on bridges is named Bridge Information Modeling (BrIM). Bridge Information Modeling (BrIM) is an intelligent representation of bridges since it contains all information needed about bridges throughout their whole lifecycle, from the pre-design stage to the post-construction stage. Marzouk and Hisham [38] presented a BIM-based cost estimation application that is capable of carrying out approximate cost estimation, and detailed cost estimation. This application integrates BIM with the earned value concept to determine the project status at a specific reporting date [38].

G. Track-alignment

BIM is mainly applied on the generation and management of building data. It utilizes the object-oriented concept to increase the efficiency of information management in the building life cycle. Huang [39] demonstrated that BIM can simplify the design and construction of track-alignment, increasing the abilities of computer-aided design and automation, which greatly shortens the design period and increases construction efficiency [39].

VI. CONCLUSIONS AND FUTURE DIRECTIONS

The conducted meta-analysis study of 2767 publications presented the state-of-the-art implementation and research of building information modeling (BIM) in construction industry with focus on the adoption of BIM in construction phase of intermediate railway stations. In this study, the concept of BIM which has a great impact and importance in the construction industry, is examined via a meta-classification system. In this context, refereed journal articles that include three search phrases, “BIM”, “Building Information Modeling” and “Building Information Models”, in their titles and/or abstracts and/or keywords are discussed in terms of different dimensions to evaluate the research trends and gaps in the BIM literature during the time period from 2002 – 2016.

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

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participants composed of different professional areas. Therefore, the named areas are discussed in most of the studies. The other areas can be listed as benefits and advantages of BIM and barriers and limitations to BIM usage.

This paper provides a map displaying important disciplines in the construction industry in which BIM has been used for. It shows the gaps in the literature of BIM technology as well as addresses the future directions that have to be fulfilled. Since BIM provides an opportunity for superposing the multidisciplinary information within one model powerfully, the importance of data addition of civil engineering projects into the BIM model has been discussed recently. However, the number and content of studies related to the construction phase in the area of civil engineering indicate that there is still a gap for integrated solutions, in particular, studies intended for the construction stage of intermediate railway stations.

As has been showed earlier, the majority of studies took place within an academic environment and very few studies were done by the research centers or the private sector, which means that there is still a lack of BIM implementation in the actual construction projects. A supporting method that increases the construction efficiency of intermediate railway stations by applying the BIM concept for the generation and management of station data can be considered as potential future research.

REFERENCES

[1] C. Eastman, P. Teicholz, R. Sacks, K. Liston. BIM handbook: a guide to Building Information Modeling for owners, managers, designers, engineers, and contractors, John Wiley & Sons, Inc., Hoboken, New Jersey, USA 2008.

[2] C. Eastman. Building Product Models: Computer Environments Supporting Design and Construction, CRC Press LLC, Florida, USA, 1999.

[3] Q. Liu, T. Gao, J. P. Wang. Research on Application of BIM Technology in Construction Project. International Conference on Computer Science and Service System, Xuzhou, China, June, 2011; IEEE, DOI:10.1109/CSSS.2011.5974366.

[4] B. Hardin. BIM and construction management, Wiley, Indianapolis, IN, USA, 2009.

[5] S. Azhar, M. Hein, B. Sketo. Building information modeling: Benefits, risks and challenges. Proceedings of the 44th Associated Schools of Construction National Conference, Auburn, Alabama, USA, 2008.

[6] S. Glick, A. Guggemos. IPD and BIM: Benefits and opportunities for regulatory agencies. Processing of the 45th Associated Schools of Construction Annual Conference, Gainesville, Florida, USA, 1-4 April, 2009.

[7] ISO Standard, ISO 29481-1:2010(E). Building Information Modeling — Information Delivery Manual — Part 1: Methodology and Format, 2010.

[8] A. Borrmann, E. Rank. Specification and implementation of directional operators in a 3D spatial query language for building information models. ADV ENG INFORMS **2009**, 23 (1): 32–44. DOI: 10.1016/j.aei.2008.06.005

[9] T. Cerovsek. A review and outlook for a "Building Information Model (BIM): a multi-standpoint framework for technological development. ADV ENG INFORMS **2011**, 25 (2): 224–244. DOI: 10.1016/j.aei.2010.06.003

[10] J. Wong, J. Yang. Research and Application of Building Information Modelling (BIM) in the Architecture, Engineering and Construction (AEC) industry: a review and direction for future research. Proceedings of the 6th International Conference on Innovation in Architecture, Engineering & Construction (AEC), Loughborough University, U.K., Pennsylvania State University, 2010.

[11] C. Eastman, P. Teicholz, R. Sacks, K. Liston. BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Architects, Engineers, Contractors and Fabricators, John Wiley and Sons, Hoboken NJ, USA, 2011.

[12] P. Tang, D. Huber, B. Akinci, R. Lipman, A. Lytle. Automatic reconstruction of as-built building information models from laser-scanned point clouds: a review of related techniques. AUTOMAT CONSTR **2010**, 19 (7): 829–843. DOI: 10.1016/j.autcon.2010.06.007

[13] A. Watson. Digital buildings — challenges and opportunities. ADV ENG INFORM **2011**, 25 (4): 573–581. DOI: 10.1016/j.aei.2011.07.003

[14] G. Lee, R. Sacks, C. Eastman. Specifying parametric building object behavior (BOB) for a building information modeling system. AUTOMAT CONSTR **2006**, 15 (6): 758–776. DOI: 10.1016/j.autcon.2005.09.009

[15] C. Nicolle, C. Cruz. Semantic Building Information Model and multimedia for facility management. Web Information Systems and Technologies, Lecture Notes in Budiness Information Processing, 2011.

[16] National Institute of Building Sciences. National Building Information Modeling Standard (NBIMS), Version 1, Part 1. Overview, Principles, and Methodologies, 2007. http://www.nationalcadstandard.org (Last Access: March 31, 2017).

[17] O. N. Nawari, M. Kuenstle. Building Information Modeling: Framework for Structural Design, CRC Press, Taylor & Francis Group, New York, USA, 2015.

[18] A. Grilo, R. Jardim-Goncalves. Value proposition on interoperability of BIM and collaborative working environment. AUTOMAT CONSTR **2010**, 19 (5): 522 – 530. DOI: 10.1016/j.autcon.2009.11.003

[19] M. Froese. The impact of emerging information technology on project management for construction. AUTOMAT CONSTR **2010**, 19 (5): 531 – 538. DOI: 10.1016/j.autcon.2009.11.004.

[20] J. Schade, T. Olofsson, M. Schreyer. Decision-making in a model-based design process. CONSTR MANAGE ECONO **2011**, 29 (4): 371 – 382. DOI: 10.1080/01446193.2011.552510

[21] D. Jacobs. A bibliometric study of the publication patterns of scientists in South Africa 1992-96, with particular reference to status and funding. INFORM RES **2001**, 6(3). Available at: http://www.informationr.net/ir/6-3/paper104.html (Last Access: March 31, 2017).

[22] T. Ilter, A. Dikbas, D. Ilter. An analysis of drivers and barriers of construction innovation. 5th International Conference on

Innovation in Architecture, Engineering and Construction (AEC), Antalya, Turkey, June, 2008.

[23] M. Betts, P. Lansley. Construction management and economics: A review of the first ten years. CONSTR MANAGE ECONO **1993**, 11, 221-245. DOI: 10.1080/01446199300000024

[24] B. Succar. Building information modelling framework: A research and delivery foundation for industry stakeholders. AUTOMAT CONSTR **2009**, 18(3): 357-375. DOI: 10.1016/j.autcon.2008.10.003

[25] H. Penttilä. Describing the Changes in Architectural Information Technology to Understand Design Complexity and Free-Form Architectural Expression. J INF TECHNOL CONSTR **2006**, 11(Special Issue the Effects of CAD on Building Form and Design Quality), 395-408. http://www.itcon.org/2006/29 (Last Access: March 31, 2017)

[26] K. P. Reddy. BIM for Building Owners and Developers: Making a Business Case for Using BIM on Projects, John Wiley and Sons, Inc., USA, 2012.

[27] A. Ahmad-Latiffi, S. Mohd, N. Kasim, M. S. Fathi. Building information Modeling (BIM) Application in Malaysia Construction Industry. CONSTR ENG MANAGE **2013**, 2(4A): 1-6. DOI:10.5923/s.ijcem.201309.01.

[28] American Institute of Architects. AIA Document E202, 2008.

[29] R. Aish. Building Modelling: The Key to Integrated Construction CAD. CIB 5th International Symposium on the Use of Computers for Environmental Engineering Related to Buildings, 7–9 July, 1986.

[30] G. A. Van Nederveen, F. Tolman. Modelling Multiple Views on Buildings. AUTOMAT CONSTR **1992**, 1(3): 215–224. DOI: 10.1016/0926-5805(92)90014-B

[31] J. Laiserin. Comparing Pommes and Naranjas, the LaiserinLetter™, Issue 15, December 16, 2002. http://www.laiserin.com/features/issue15/feature01.php (Last access: March 31, 2017).

[32] J. Laiserin. The BIM Page, the Laiser in Letter™, 2003. http://www.laiserin.com/features/bim/index.php (Last access: March 31, 2017).

[33] W. L. Lee, S. Kang, R. Moh, R.Wu, H. C. Hsieh, Z. H. Shu. Application of BIM coordination technology to HSR Changhua station. VIS ENG **2015**, 3(5). DOI: 10.1186/s40327-014-0008-9.

[34] D. W. Ryu, J. I. Kim, S. Suh, W. Suh. Evaluating risks using simulated annealing and Building Information Modeling. APPL MATH MODEL **2015**, 39, 5925-5935, DOI: 10.1016/j.apm.2015.04.024

[35] I. C. Wu, S. R. Lu, B. C. Hsiung. A BIM-based monitoring system for urban deep excavation projects. VIS ENG **2015**, 3(2). DOI: 10.1186/s40327-014-0015-x

[36] B. Sibert. Using building information modelling on a highway project. CIVIL ENG **2013**, 166(CE1), ICE publishing. DOI: 10.1680/cien.2013.166.1.9

[37] M. Marzouk, A. Abdelaty. Monitoring thermal comfort in subways using building information modeling. ENERG BUILDINGS **2014**, 84: 252–257. DOI: 10.1016/j.enbuild.2014.08.006

[38] M. Marzouk, M. Hisham. Implementing Earned Value Management using Bridge Information Modeling. JCIV ENG-KSCE **2014**, 18(5): 1302-1313. DOI: 10.1007/s12205-014-0455-9

[39] S. F. Huang, C. S. Chen, R. J. Dzeng. Design of Track Alignment Using Building Information Modeling. TRANSP ENG **2011**, DOI: 10.1061/(ASCE)TE.1943-5436.0000287.

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