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ABSTRACT

According to the European Directive 2014/24/EU, the European Member States may require in the coming years the use of Building information Modelling (BIM) for public tenders. More than 99% of the European construction market is composed by Small and Medium Enterprises (SMEs), and SMEs are late in the adoption of BIM. As consequence, the Small and Medium enterprises represent the keystone for the spreading of this digital methodology. The present work aims to provide the state of the art of the research on BIM adoption by SMEs through a systematic literature review. The analysis of more than 200 papers, coming from international referred journals and proceedings, identified 34 of them as relevant for the study through specific keywords and an in-depth investigation. The output is a framework of the academic literature about benefits, barriers and drivers to BIM adoption by SMEs. The research would be of interest for both industrial decision makers and policy makers. The former would take benefit from a study resuming the current issues on BIM implementation by SMEs, the latter would get a theoretical basis to develop more effective policies to support SMEs in the use of BIM.

Keywords: building information modelling, BIM, SMEs, construction sector, literature review

Introduction

Global competition, technological changes and advances in information technology are pushing organizations of different sectors to improve their processes to deliver high quality products in a short time. As consequence, also the construction industry has been facing several changes related to technology and innovation in order to improve the productivity, that is on a significantly lower level than other industries (Shehu et al., 2014). However, this digitalization process is not easy since it requires investments in digital technology, in new equipment, in staff training and especially needs a radical change in the information exchange among the project stakeholders. One of the digital methodologies that seems well suited for increasing the productivity is Building Information Modelling (BIM).

Several definitions of BIM exist. The organizations listed below deliver some of the descriptions of BIM currently in circulation.

- ISO – International Organization for Standardization
- NBIMS - National BIM Standard – United States
- NBS - National Building Specification- UK
- BuildingSMART
- Autodesk

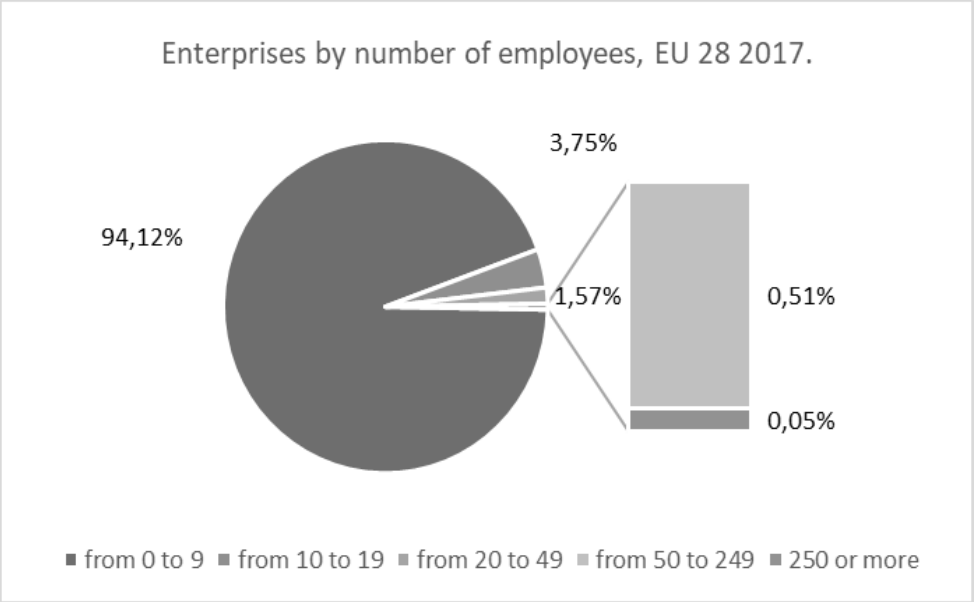
Reworking the definitions provided by the entities listed above the following description can be derived:

> "BIM is a digital object-oriented representation/model of the construction process, used as reliable basis for decisions, with the aim of sharing knowledge for information on physical and functional characteristics in a collaborative way between stakeholders of the project during the life cycle of the built assets".

According to the definition, BIM concerns the information management along the all construction process (from design to use and maintenance), as consequence also the European governments showed an interest in BIM methodology. Indeed, with the implementation of the European Directive 2014/24/EU, EU Member States may require in the coming years the use of specific electronic tools for public tenders. Consequently, the expected large-scale application of BIM will imply a strong change within the construction enterprises due to the EU Directive recommendations and to the rapid evolution of the market in this era of digital transformation. As consequence, this change will interest the entire European construction sector that currently consists almost entirely of small and medium enterprise: the 99% of the European construction market is composed by SMEs and it is to highlight that the micro companies (with less than 9 employees) represent more than 94% (

Figure **1**).

Figure 1. *Enterprises by Number of Employees*



Source: Author's elaboration on Eurostat data retrieved on 31.01.2020.

The SMEs are characterized by very small profit margins that represent a major obstacle to invest in digitalization. So, even though Building Information Modelling is a methodology that could be required more and more in the coming years, the SMEs could be not ready to this change and could be excluded in several participation to public tenders.

According to the issue previous introduced, this paper wants to answer the following research question.

> RQ: According to the academic literature what are the benefits, the barriers and the drivers for BIM implementation and spreading among the Small and Medium Enterprises (SMEs)?

The study is structured as follows: next presents the method used for the literature review investigation, the section right after provides the findings about barriers, benefits and drivers for BIM implementation in SMEs, then follows the discussion and finally the conclusions.

Methodology

BIM is not a new topic in the academic field, indeed the first use of the term "building information model" was proposed in 1992 by Van Nederveen and Tolman. Moreover, the academic research on BIM application in SMEs is more recent: the first academic publication is by Sebastian in 2010.

To focus the topic an initial search on Google Scholar was carried out. The Google Scholar search was based on the keywords "BIM" AND "SMEs". The retrieved publications were over 3600: the search resulted too inclusive and the

reading of the first 40 titles retrieved revealed that many papers were not related to the issue investigated. So, to limit the number of results to only that papers focused on the topic examined the databases chose were Web of Science (WoS) and Scopus, because they are more refined compared to Google Scholar.

The literature search was performed considering the following highlights:

- Adopting a complete search in title, abstract and keywords.
- Main keywords used were "BIM" AND "SMEs"; by way of example, some alternative keywords used are "Building Information Model*" and "Small and Medium Enterprises".
- English written documents were the only ones considered.

The literature search found out 207 documents (52 in WoS, 165 in Scopus). After applying the elimination by handsearching filtering according to title and abstract, and removing duplicates, the resulting list was composed of 70 works. Then, this list of 70 documents was further screened through full paper readings to investigate and analyses barriers, benefits and drivers to BIM adoption in SMEs. The final pool of publications is composed by 34 papers. No limitation was imposed about the year of publication, and the papers retrieved are from 2010 to 2020. The results are presented in the findings chapter.

Table 1 presents the journals and proceedings (mainly associated to Construction and Management scientific communities) from which the examined articles were retrieved.

Table 1. *Journals and Proceedings Containing the Publications Analysed*

Journals and proceedings
Advances in Civil Engineering
Advances in Information and Communication Technology
Architectural Engineering and Design Management
Conference Proceedings of the 5th International Congress of Architectural Technology, Aberdeen 2014
Building Information Modelling (BIM) in Design, Construction and Operations
Construction Innovation
Engineering, Construction and Architectural Management
International Journal of Project Management
International Journal of Sustainable Development and Planning
IOP Conference Series: Materials Science and Engineering
ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences
Journal of Civil Engineering and Management
Journal of Management in Engineering.
Procedia Engineering
Proceedings of the 31st Annual Association of Researchers in Construction Management Conference, ARCOM 2015.
Sustainability
WIT Transactions on the Built Environment

The papers retrieved were published by research institutions that are from 13 nations. **Table 2** presents the list of countries of the research centres and the corresponding number of publications.

Table 2. *Research Institutions Countries and Related Number of Studies*

Australia	5
Canada	4
China	3
Finland	1
France	3
Germany	1
Italy	2
Japan	1
Malaysia	1
Netherlands	2
South Korea	1
Thailand	1
Unite Kingdom	11

From Table 2 is derived that the research on the subject matter is mainly from the United Kingdom with the highest number of publications (11). UK is followed by Australia with 5 papers, and Canada with 4.

Results

As previously presented in the introduction chapter, the final pool of publications is composed by 34 papers. From the 34 papers information about benefit, barriers and BIM implementation were retrieved, as shown in the tables Table **3**

Table **4**

Table 5. The benefits, barriers and drivers are presented with the corresponding references.

The references for the tables are the following:

[1] (Lam et al., 2017); [2] (Kouch, 2018); [3] (Vidalakis et al., 2020); [4] (Hosseini et al., 2016); [5] (Dainty et al., 2017); [6] (Tranchant, Beladjine, & Beddiar, 2017); [7] (Ayinla & Adamu, 2018); [8] (Li et al., 2019); [9] (Poirier et al., 2015); [10] (Van Berlo et al., 2013); [11] (Hong et al., 2019); [12] (Sebastian, 2010); [13] (Malacarne et al., 2018); [14] (Whiskard et al., 2018); [15] (Banihashemi, et al., 2019); [16] (Hosseini et al., 2018); [17] (Polter & Scherer, 2017); [18] (Ganah & John, 2014); [19] (Adamu et al., 2015); [20] (Rodgers et al., 2015); [21] (Longwe et al., 2015); [22] (Abuelmaatti & Ahmed, 2014); [23] (Forsythe, 2014); [24] (Sinoh et al., 2018); [25] (Liu et al., 2019); [26] (Joblot et al., 2019); [27] (Hong et al., 2019); [28] (Lu et al., 2019); [29] (Muñoz & Arayici, 2015); [30] (Kouider & Paterson, 2014); [31] (Mellon & Kouider, 2014); [32] (Joseph Garcia et al., 2018); [33] Schimanski et al., (2019); [34] (Malaikrisanachalee & Vathananukij, 2011).

Table 3. *Major BIM Implementation Barriers in SMEs*

Major BIM implementation barriers in SMEs	**References**
Poor internal and external (stakeholders) collaboration	8, 10, 16, 17, 19, 22
No interest from subcontractors	4
BIM is not beneficial enough for the project	4, 20
Lack in competence and knowledge (qualified staff)	3, 5, 7,9, 11, 15, 18, 23, 24, 30
Rigid cultural approach and awareness to adopt new technologies and innovation	2, 3, 5, 7, 8, 12, 15, 20, 21, 27
Implementation cost (hardware, software and training)	3, 4, 5, 6, 7, 8, 9, 11, 13, 14, 15, 17, 18, 23, 25, 28, 29
Software interoperability problems	3, 7, 9, 10, 19, 26
Legal requirements and legal uncertainty (on intellectual property rights)	7, 8, 9, 18
Lack of demand from clients	1, 9
Time consuming /added cost	9, 13, 31
Risk management issues	23
Uncertain return on investment (ROI)	4, 18
Lack of solid evidence of financial benefits	16

Table 4. *Major BIM Implementation Benefits in SMEs*

Major BIM implementation benefits in SMEs	**References**
Increasing of productivity	1, 6, 9, 32
Visualisation and integration of 3D spatial plans	10, 13
BIM clarifies the progress of the construction	12
Accurate quantity take-off and automated shop drawings	13
Share of knowledge and expertise	15

Development of consistent design without incompatibilities	32
Reductions in errors and rework	25
Improving data accuracy	11
Project's time and cost saving	32, 11

Table 5. *Major BIM Implementation Drivers and Strategies*

Major BIM implementation drivers and strategies	**References**
Integrated project delivery (IPD)	1, 8, 12
Collaboration between firms	9, 31
Industry initiatives, guidance and leadership	3
Bid estimation and work preparation can be digitalized and automated	33
Pressure from competitors	28
ICT requirements from clients and partners	28
Use of free software/open-source solution	34, 29
Incentive and mandatory policies from the government	28
Developing native software and standards and cloud-based technology	8
Open protocol containing a collaborative working method	12
Coordinated actions with the local authorities and professional associations	12, 25
Automation of complex workflows	17
Optimization of data transfer between stakeholders	17
Developing local BIM standard and guideline	25
Technical and managerial training (also from governmental authorities)	3, 25

Discussion

The 34 papers investigated are based on both qualitative and quantitative research. The focus of most papers is on the barriers that record the large number of references, as opposed to benefits and drivers (as displayed in Tables 3-5).

The overall benefits retrieved from the analysed publications can be expressed in an improved efficiency (reducing cost and time) along the all construction stages, with automated shop drawings, improved accuracy, reductions in errors and rework, improved documentation and better information flow. Furthermore, the 3D visualisation enables and facilitates the integration of plans from different disciplines enabling the identification of errors and reducing the resulting rework. A recurring theme in the literature is that BIM is known to give improvements in productivity, but for SMEs seems that working with BIM is more time-consuming and with higher costs compared to traditional drawings. Indeed, it seems the implementation cost for small organisations is a big barrier to overcome. For the SMEs buying the hardware and the software is a significant cost, considering also that it is always accompanied by the human resource cost. Indeed, the small enterprises often do not have internally the skilled personnel, so they should train their employees, hire new employees, or pay external consultants. Furthermore, is found that interoperability problems, flanked by the poor collaboration among the stakeholders discourage the use of BIM. Also, many clients do not ask for the use of BIM and the subcontractors do not use it, so the contractors, when the BIM

methodology is applied, have to insert manually in the BIM model the data received from the suppliers. In addition, the barrier related to cost of BIM implementation relates to the lack of confirmatory data regarding improved efficiency and reduced project cost. Moreover, there is a diffused cultural resistance to replace the traditional way of working in favour of the use of new technologies, together with limited knowledge by the managers on the potentiality of the new digital methodology as BIM. As consequence the SMEs prefer to not invest in Building Information Modelling. Uncertainty exists also about BIM as legal tool for the validity of the contract among parties. In many cases the enterprises (according to the client's requirements) have to work on both the 2D drawings and the 3D models because the drawings are the only that have lawful validity. On the industry level, indeed, the lack of standardization, regulations and laws delay the adoption of the BIM method, especially in terms of no clear legal responsibility for the model.

According to the literature investigated, it is needed to invest on collaboration between companies along the construction supply chain as a driver for BIM implementation. The IPD contract seems to be ideal contract to encourage the spreading of BIM. The pressure from competitors is considered as another driver, but only when there is a proof of practical gains (mainly economical). The incentives from the local authorities are also important as well a straight collaboration between the governments and the professional associations. This collaboration should push on training about digital technology in order to prepare both low-level and top-level employees. The incentives for free or open source software could have a high impact because the SMEs are sensitive about the economic expenditure. The digital innovation could help in the automatization of the information transfer among the stakeholders and facilitate the participation in public tenders.

Conclusions

Even though the research on BIM in the last years is spreading in the entire world, the academic studies focused on the adoption of BIM methodology by SMEs are few. Only 34 articles were founded that dealing with BIM implementation in SMEs. It should be stressed that the constructions SMEs up to 250 employees correspond to the 99% of the European market and that the 94,2% of SMEs have up to 9 employees. Looking at the previous data, research is especially needed for SMEs in Europe, because the implementation of the European Directive 2014/24/EU. The SMEs are not ready for a digital transformation and could lose market share in favour of big companies that, thanks to the higher financial resources can easier face this digital disruption era.

According to the literature review, it may be concluded that BIM could be beneficial also for small and medium enterprises but is needed to understand more about the barriers and the corresponding drivers to overcome them. For this purpose, some subtopics must be more deeply investigated: e.g. previous studies did not quantify the economic advantages for SMEs that apply the BIM

methodology. Future works may start by investigating deeply the SMEs current practice by means of case studies and action research with the final goal to guide the enterprise in adopting the new methodology. A close collaboration among enterprises, local authorities and professional associations is required to put in place the necessary transitional phase: in the first instance, mixing 2D drawings and BIM model in the same project could be a successful strategy to encourage the shift to BIM methodology.

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