

ORGANISATIONAL CULTURE IN BUILDING INFORMATION MODELLING MATURITY RESEARCH: A BIBLIOMETRIC ANALYSIS

Sonali Alankarage¹, Nicholas Chileshe^{1,2}, Aparna Samaraweera¹, Raufdeen Rameezdeen¹ and David J Edwards^{2,3}

¹ UniSA STEM, Sustainable Infrastructure and Resource Management (SIRM), University of South Australia, Adelaide, Australia

² Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa

³ Department of the Built Environment, Birmingham City University, Birmingham, UK

Building Information Modelling (BIM) has gained a traction in the construction industry, driven by the plethora of benefits of its usage. Because of the differences in BIM maturity, not all organisations benefit equally from BIM. Organisational culture is vital in stimulating the growth of BIM maturity and is frequently considered a critical element in BIM maturity model. This study takes a bibliometric approach to reveal the focus and emerging trends of BIM maturity and culture research. VOSviewer software was used to map keyword co-occurrence and Scopus database was searched for keywords related to culture and BIM. The number of publications in the discipline ascended between 2012 and 2021, with the UK producing majority of the articles. Keyword cluster analysis highlights five research themes: research on BIM adoption, basic management, safety culture, waste management, and pure culture. According to the content analysis of the papers organisational culture is considered either as a variable or a root metaphor.

Keywords: bibliometric analysis; BIM; maturity; organisational culture; VOSviewer

INTRODUCTION

Building Information Modelling (BIM) is a collection of interconnected policies, processes, and technologies that produce a methodology for managing critical building project and design data in digital format throughout the building's life cycle (Succar, 2009). The potential of BIM extends beyond technological aspects and fosters new ways of thinking along with a shift in the way processes and activities are carried out across all phases of construction projects (Sebastian and Van Berlo, 2010). Given BIM in Construction is a fast-growing area, still, its full utilisation in construction organisations remains limited. Despite the benefits of cost reductions, improved productivity, and collaborations, the level of improvement in BIM deliverables and services varies from organisation to organisation, as does their BIM

¹ hewsy008@mymail.unisa.edu.au

maturity (BIMM) (Smits, *et al.*, 2017). In terms of BIMM, BIM implementation in organisations mature from a basic level of to a more advanced level in terms of policies, processes, and technologies (Alankarage *et al.*, 2022). While some organisations have higher levels of BIMM than others, others are struggling with lower levels of BIMM (Saka and Chan, 2019). Fragmented views of the BIM users have caused this differentiation as the extent of BIM use largely depends on the users' perceptions (Afifuddin *et al.*, 2018). Similarly, Davies *et al.*, (2017) emphasise that the defensive and adverse nature of the thinking of BIM users is a significant hurdle to achieving desired levels of BIM uptake in organisations. Changing these perspectives and thinking is changing the culture of an organisation.

The BIM survey conducted by the UK BIM Alliance in 2021 highlights that changing the deeply held beliefs of BIM users to facilitate needed culture change is the most significant barrier of all in BIM implementation. Organisational culture has been identified as an important factor in defining BIMM level, making it a component in recently developed BIMM models that assess BIMM in organisations (Siebelink *et al.*, 2018). However, earlier BIMM models were more process-oriented and neglected the people-oriented factors (Wu *et al.*, 2017). Recent growing attention on human-related softer aspects like culture justifies the need for maturity in cultural elements to achieve BIMM in organisations. Organisational culture is explained by Schein (2004) as a set of fundamental, deeply held beliefs of people which distinguishes one organisation's members from another. Beliefs are anchored in an organisation and determine the rational and irrational behaviour of people in the BIM environment. Even if an organisation's BIM technology is advanced but not its culture, its BIMM suffers from a lack (Siebelink *et al.*, 2018). Even though culture is becoming a popular topic in BIMM related research, co-themed research is still relatively new and has not been thoroughly investigated. This paper follows a bibliometric approach to find emerging trends and the role of culture in the BIMM domain.

METHOD

A bibliometric analysis allows identifying the depth of knowledge of a particular research topic through examining the research front and producing networking structures of the interested scientific community (El Baz and Iddik, 2021). Scholars have commonly accepted this method to understand BIM-related research work. For example, Santos *et al.*, (2017) highlighted emerging fields in BIM by conducting a bibliometric analysis using literature published from 2005 to 2015 and the bibliometric analysis by Oraee *et al.*, (2017) reviewed collaboration in BIM-based construction networks. This study adopts a bibliometric approach to ascertain major research areas and emerging organisational culture- BIMM research trends.

Scopus was chosen as the database due to its more comprehensive range of coverage in scientific publications compared to other literature databases and its use in literature reviews in the BIM research field (Alankarage *et al.*, 2021). Peer-reviewed journal and conference papers were chosen as the sources of knowledge due to their reliability and conciseness in information (Aghimien *et al.*, 2020). Publications in English were used, and no starting year was established for data retrieval, and 2021 was set as the end of the time span. A two-stage search was carried out in with separate search strings linked by Boolean connectors. The combinations were queried in the database using the function TITLE-ABS-KEY (title, abstract and keywords). First stage of search located 481 articles using the keywords ("BIM" OR "Building Information modelling" OR "Building information modelling") AND ("maturity" OR "maturity

model”). Next, using the terms ("Culture" OR "Cultur*") 103 articles were separated for further analysis. A similar strategy of two-stage searching was adopted by many previous studies, such as Guo and Feng, (2019). Later, results were analysed using the software called Visualisation of Similarities (VOS) viewer (van Eck and Waltman, 2010) - a software for reviewing literature that provides the fundamental functionality required for easily visualising bibliometric networks and avoids challenges in analysing papers manually (Aghimien *et al.*, 2020). The collected papers were descriptively analysed to identify research trends in publications from around the world over the years. Then, using a keyword co-occurrence analysis, clusters of studies covered in the filtered set of publications were identified. Leading articles in each cluster with the highest number of citations were identified to further analyse these clusters. To strengthen the bibliometric analysis, an analysis was carried out accounting the content.

FINDINGS

Research Trends-Descriptive Analysis

The findings on the number of publications by year, source of publication, and publications per country are presented in Table 1 as a summary of descriptive analysis. The trajectory of the total number of publications has been limited to the 10-year period between 2012-2021. The first paper linking culture to BIMM research was found in 2012. According to Moretti and Giana (2018), the research on the BIMM research has been rising since 2009. This disparity is because the first established BIMM models are more process-focused than human or culture focused (Wu, *et al.*, 2017). A relatively flat-lined series is present from 2012 until 2015. Although in last years the overall number of publications has not been extensive, the number of publications per year is notably surged from 2015 to 2021, from two publications in 2015 to 26 publications in 2021. This is going in line with the scientometric analysis conducted by Jin, *et al.*, (2019) on BIM-based research, which found a significant increase in research in the field after 2015.

Amidst the gradual increase in the total publications, there was a rise and fall in the number of publications between 2015 and 2021, with 2020 experiencing the highest number of 29 published articles. Overall, there is an increase in academic interest, reflecting the flourishing of culture research in the BIMM context. A total of 103 papers on culture in BIMM model research were extracted, 79 (76.7%) of which came from journals, while the remaining 24 (23.3%) were conference articles. Guo and Feng (2019) mention that leading outlets for publishing studies provides a more comprehensive perspective of the current state of a research area. Thus, publication sources were evaluated, and only the top five sources with at least four published articles on culture- BIMM research. Engineering Construction and Architectural Management journal (8 out of 103) and Journal of Construction Engineering and Management (8 out of 103) published most of the articles in the field. Many bibliometric analysis and systematic reviews conducted in the BIM arena recognise Automation in Construction as the dominant source (Jin, *et al.*, 2019). However, this study contradicts the above statement as Automation in Construction has only two publications in the culture- BIMM field. This might be due to the highly technology-oriented nature of the papers in this journal compared to other journals, focusing on management and professional issues (Guo and Feng, 2019).

The countries at least four publications are included in the analysis, and the United Kingdom tops the list with 27 articles (29%). This could imply that the United

Kingdom is a market leader in BIM implementation, owing to the government's policy-driven mandate for all public projects (Alankarage *et al.*, 2021). This was followed by China and Australia publishing 13 and 12 articles, respectively. It is surprising that being a developing country; China has a competitive interest compared to developed countries like the United Kingdom and Australia. The emerging interest of China in BIM and organisational culture related research was also emphasised by the recent systematic review done by Alankarage *et al.*, (2021). Rapid developing countries in the field like India, Malaysia and Iran show increased research attention in the culture-BIMM context. However, a surge of publications in other developed countries like Italy, the Netherlands and Spain could be justified by the active business operations, cultural background, and high concentration of academic institutions (Aghimien, *et al.*, 2020).

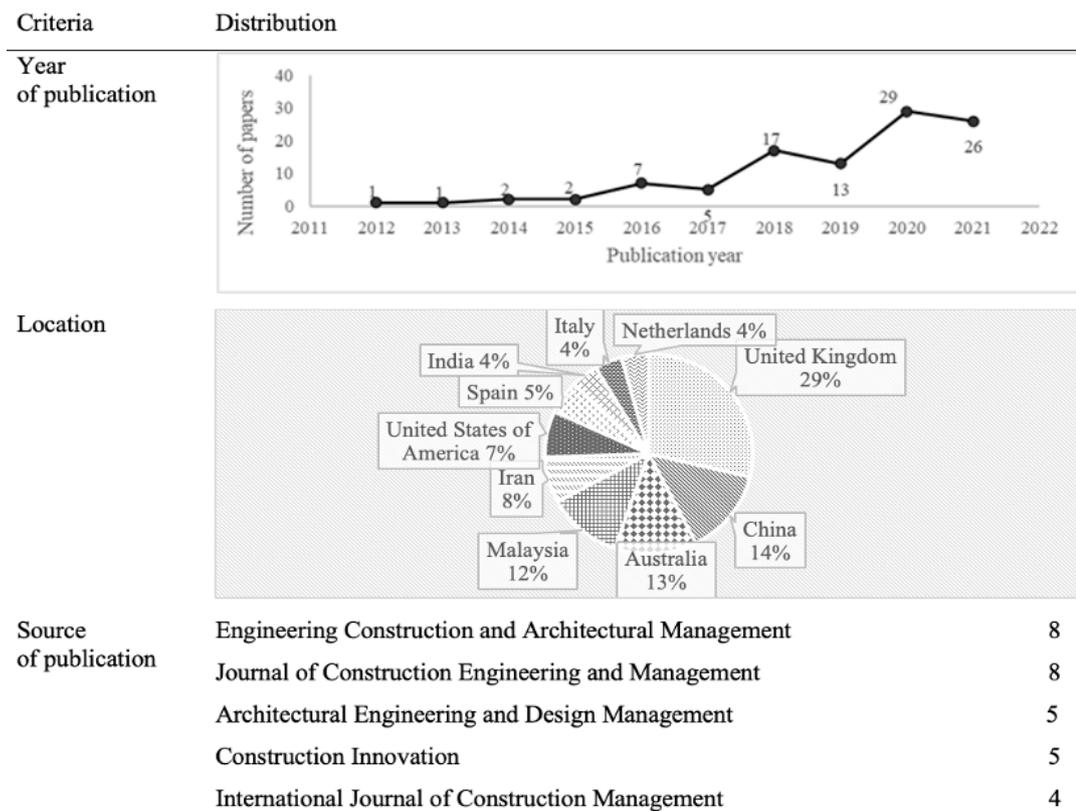


Figure 1: Summary of descriptive analysis

Research Trends-Co-Occurrence Analysis

The keywords used in a research study summarise the main findings of the study, and it is possible that they will have better relationships with one another (Guo and Feng, 2019). Therefore, a keyword co-occurrence analysis was conducted to demonstrate highlights of studies covered in the filtered set of publications. Developing a co-occurrence map using the bibliographic data gathered starts with setting the minimum number of co-occurrences for the keywords to be extracted. This is critical for effective keyword clustering into themes that can be used to explain the areas of concentration in previous studies (Aghimien, *et al.*, 2020). Even though the predefined minimum number in Vos viewer for co-occurring keywords is 5, many studies have used different numbers as the minimum threshold. For example, Saka and Chan (2019)- 2 co-occurrences, (Aghimien, *et al.* (2020) - 4 co-occurrences arguing that adopting the default minimum of 5 gives a very light output, whereas

using 2 or 4 results in a significant number of repeated keywords. Growing from this argument, this study adopted a minimum co-occurrence number of 2. This means that for a keyword to be extracted, it must appear at least two times in the author and source indexed keywords. The analysis of 103 extracted publications revealed 376 keywords in total. 46 keywords met the threshold of two co-occurrences out of the total keywords. To ensure the consistency of the analysis, a manual normalisation was used to avoid spelling errors and word repetition. Terms with general meaning such as Malaysia, and survey were excluded. Terms with different spelling, such as Building information modelling and Building information modelling were merged. Accordingly, the final number of keywords in the co-occurrence network is as in Figure 2.

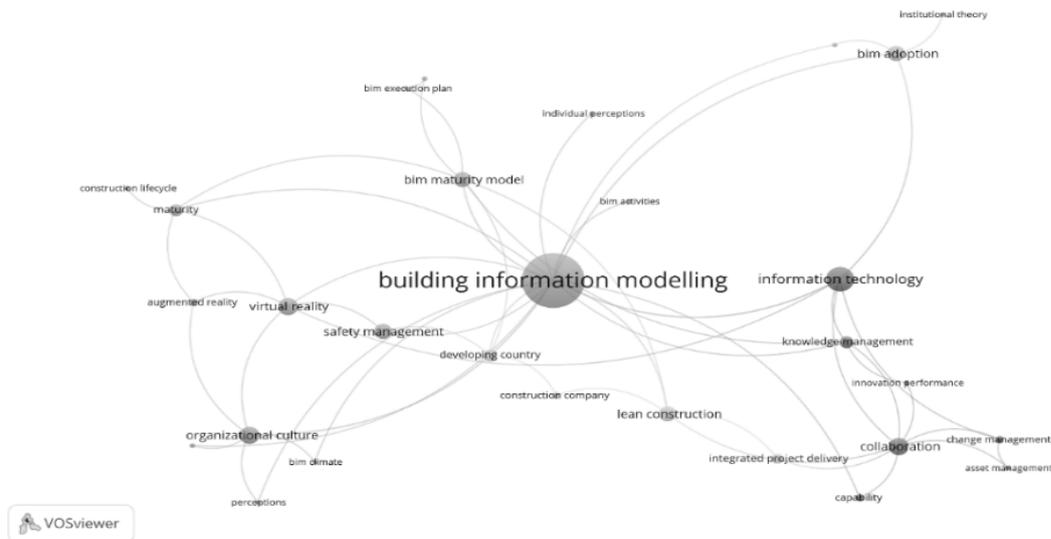


Figure 2: Keywords Co-occurrence network

The circle size reflects the frequency of the occurrence of keywords in the selected papers. The line lengths represent the closeness of the keywords, and it is vital to note that the higher the co-occurrence of keywords, the closer they are to each other (van Eck and Waltman, 2010). In this visual word co-occurrence network, the node sizes represent the frequency of occurrence of the respective keywords. The arcs represent keyword co-occurrence relationships. The line thickness represents the strength of each relationship (Wang, Pan, and Luo, 2019). The keywords listed in the same group appear to have close similarities in terms of research topics. From the keyword analysis, 5 clusters were found where different colours of circles in Figure 2 indicate different clusters. The keywords are grouped in 5 clusters: BIM adoption research, basic management research, safety culture research, waste management research, and pure culture research. Only the cluster 5 articles are directly tried to understand the BIMM in cultural perspective. Based on the keyword co-occurrence, the leading articles with these keywords; the first three articles with the highest citations in each cluster, are presented in Table 1.

Table 1: Leading articles in each cluster

| Cluster | Cluster 1- BIM adoption research | Cluster 2- Basic management research | Cluster 3- Safety culture research | Cluster 4- Waste management research | Cluster 5- Pure culture research |
|-----------|---|--|---|--|--|
| Reference | (Ahmed and Kassem, 2018) (Ahuja, <i>et al.</i> , 2018), (Enegbuma, <i>et al.</i> , 2016) | (Abbasnejad, <i>et al.</i> , 2020) (Matthews, <i>et al.</i> , 2018) | (Bhagwat, <i>et al.</i> , 2021) (Olugboyega and Windapo, 2019) | (Ahuja, <i>et al.</i> , 2018) (Fakhimi, <i>et al.</i> , 2016) | (Khan, <i>et al.</i> , 2018) (Lee, 2020) (Xu <i>et al.</i> , 2018) |

A content analysis of the leading articles in each cluster was conducted considering the cluster 5 as the core cultural studies in the domain. The analysis revealed that the role of ‘organisational culture’ in BIMM research has been developed on a dual way. Some consider organisational culture to be a variable- it is only a one element that the organisation has (Siebelink, *et al.*, 2021), while others consider it to be a root metaphor (Enegbuma *et al.*, 2016). They believe that organisation itself is the culture; in other words, organisation equals culture. Accordingly, Figure 3 presents a schematic representation of the relationship between organisation and organisational culture as depicted in this literature. The circle represents the organisation, and within it, the organisational elements are shown.

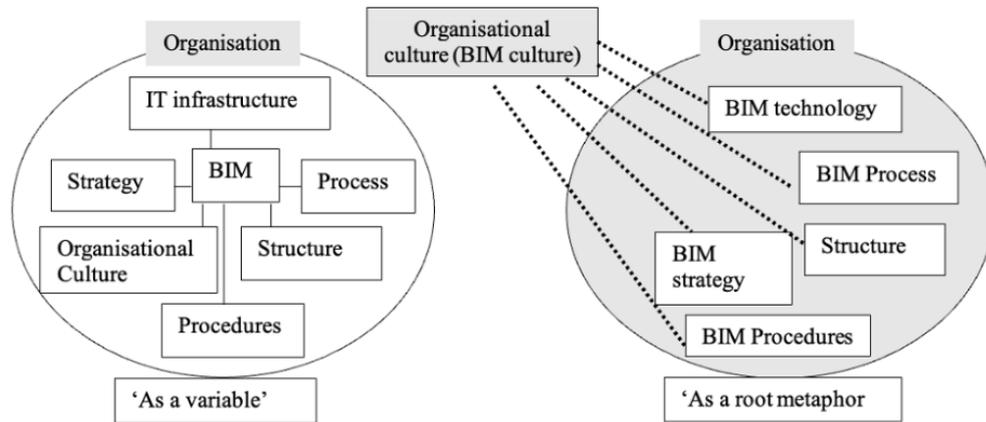


Figure 3: Schematic representation of the relationship between organisation and culture

Culture as a variable

The term culture is frequently mentioned in the literature as an impediment or an aid in coping with the changes that come with BIM use. Siebelink, *et al.* (2021) identify organisational culture as one of the critical barriers to BIMM in construction organisations. Culture is presented in these studies as a variable that the organisation can manage, control, or manipulate to achieve the desired level of BIMM. Culture is viewed as a variable "X" that influences variable "Y," which is BIMM. By viewing organisational culture as a variable allows for investigating how it varies and how these variations are related to organisational BIMM. The study by de Almeida *et al.*, (2017) analyses organisational culture in Brazilian construction companies and conclude that clan culture is the ideal setup for successful BIM deployment. Recently developed BIMM models identify organisational culture as a component affecting BIMM. Sebastian and Van Berlo (2010) include culture in their BIMM model, alongside organisation and management, information structure and information flow and tools and applications.

To Siebelink *et al.*, (2018), culture was one criterion of their BIMM model, among other criteria such as strategy, organisational structure, processes and procedures, IT infrastructure and data. These studies assume that culture is one element of a BIM using organisation and make predictions about BIMM. They attempt to characterise organisation culture with a goal to develop and understand causal relationships with other variables such as technology, structure, and strategy before trying to control or manipulate these variables to attain a desired BIMM level. This functionalist approach proved attractive to many researchers. Many of the authors who consider culture a variable that is frequently mentioned culture in their studies, but no explanation is provided to define it.

Culture as a root metaphor

This approach is not much popular in BIMM research. The root metaphoric representation of culture sheds light on the end results (BIM performance) and other processes (change). Xu, *et al.*, (2018) explain the culture in BIMM through concepts of BIM climate and BIM culture, and BIM climate and the BIM culture are defined by the individuals' perceptions on BIM implementation. To them, culture is more of a process than a variable. Siebelink *et al.*, (2018) define BIM culture as the organisational culture rooted in fundamentally shared issues, which groups must deal with when trying to achieve higher BIMM levels. They abandon the notion that culture is something an organisation has in favour of the notion that a culture is something an organisation is.

Hua and Liu (2017) emphasise that the way to achieve higher BIMM is the cultural fit between BIM and the organisational culture. Their inquiry focus was also on the members' beliefs or assumptions of the culture and how BIM users think and what patterns of reasoning that are shared among them. According to Enegbuma *et al.*, (2016), BIM systems and business processes should be integrated to reshape the organisational culture. Chen *et al.*, (2014) describe the differences between USA and non-USA members of the same organisations from different national cultures. To mature in BIM, USA experts focus on training, whereas non-USA experts focus on regulating the team structure, suggesting that to USA experts, BIM is a technology and to non-USA experts BIM is more like a process. Culture was centred on other concepts like BIM enabled Safety and BIM integrated lean construction. The term culture was used often conjunction with other words (Ex: Lean culture, Safety culture) and BIM was considered as a tool enabling the safety culture BIMM and lean culture maturity (Ahuja, *et al.*, 2018; Olugboye and Windapo, 2019). However, like Safety and lean culture maturity models, no BIM specific culture maturity models are developed. Therefore, as these studies emphasise an organisation needs to embrace the BIM culture within the organisation to attain the needed levels of maturity.

CONCLUSIONS

This paper investigates the role of organisational culture in BIMM model research and research trends in the domain. According to the collected bibliometric data, topic culture is an emerging research focus in the BIMM research, whereas the domain studies showed an increase from 2015. The highest number of publications were recorded from the UK, followed by China and Australia. Publications in a broad spectrum of journals show a higher interest in the research community in the culture-BIMM research. Despite the importance of understanding the culture to achieve higher BIMM, studies on pure culture-related research were limited. The research is spread through the areas of BIM adoption, Basic management, safety culture, and waste management. The deep conceptual structure of the field shows that the focus of culture research in BIMM takes more of a functionalist view and considers culture as a variable influencing and influenced by BIMM. However, with emerging research on BIM organisational culture, it is necessary to look at the culture from the interpretive perspective to understand the BIM culture maturity. Therefore, future research can consider a more in-depth analysis of an organisational culture in the BIM environment.

This paper presents an analysis to understand the evolution and the role of culture in BIMM research. However, the study possesses some limitations. The data collection is limited to the Scopus database, which might not include all the articles in the field.

Further, only articles published in English were considered. Therefore, future research can consider more databases, including the web of science and articles from multiple languages. This might give additional insights into the research area. This study will serve as a basis for future research in the culture- BIMM domain, being the first literature paper to explore BIMM research through a cultural lens.

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