Challenges of BIM Implementation in GCC Construction Industry

Abstract:

Purpose (mandatory):

In some regions including the Gulf Cooperation Council (GCC) region where construction is one of the main industries, the implementation of BIM is still at a slow rate. This article attempts to know the current situation of BIM and explore the challenges in the BIM implementation in the GCC construction industry.

Design/methodology/approach (mandatory):

A mixed research approach that includes a systematic literature review and a survey questionnaire was adopted to achieve the aim of this research. For the systematic review, four main databases were search considering a period of 2010 to 2019 to identify the main challenges in the BIM implementation. A total of 39 different challenges from 47 documents were classified into four main categories. A structured questionnaire developed on these challenges was sent to 206 selected from the top construction organizations from all over the GCC region.

Findings (mandatory):

A total of 39 different challenges from 47 documents were classified into four main categories. The respondents for the questionnaire were selected from the top construction organization from all over the GCC region. A large number of the respondents (69.79%) reported that their organizations are planning for BIM implementation in their future projects. The results show that top challenges fall under the main categories of “Organization”, “Technical”, Government and Legal”, and “Environment”.

Research limitations/implications (if applicable)

While the paper provides an overview of BIM in a global context, however, the dynamics and maturity of the construction industry in different regions are quite different from each other. Since the data collected in this research is from the GCC region, the results are more relevant to the GCC region.

Practical implications (if applicable)

The finding of this research identifies the main challenges which GCC construction is facing in the implementation of BIM. The finding will, therefore, be useful for the key stakeholders to develop strategies to overcome these challenges and pave the road to take the advantages of BIM implementation in construction.

Social implications (if applicable)
The BIM implementation in the GCC construction industry will not only improve the performance of the industry but will also open the doors for new opportunities and employment. The BIM implementation in construction will help the region to achieve Goal 9 (industrial innovation and improved infrastructure) of the United Nations Sustainable Development Goals.

Originality/value (mandatory):
The results of this study help to understand the overall situation including the challenges in the BIM implementation in the GCC construction industry. This study will be helpful for all the stakeholders to develop strategies for the effective implementation of BIM in the GCC construction industry.

Unstructured Abstract:

In some regions including the Gulf Cooperation Council (GCC) region where construction is one of the main industries, the implementation of BIM is still at a slow rate. This article attempts to know the current situation of BIM and explore the challenges in the BIM implementation in the GCC construction industry. A mixed research approach that includes a systematic literature review and a survey questionnaire was adopted to achieve the aim of this research. For the systematic review, four main databases were search considering a period of 2010 to 2019 to identify the main challenges in the BIM implementation. A total of 39 different challenges from 47 documents were classified into four main categories. A structured questionnaire developed on these challenges was sent to 206 selected from the top construction organizations from all over the GCC region. A large number of the respondents (69.79%) reported that their organizations are planning for BIM implementation in their future projects. The results show that top challenges fall under the main categories of “Organization”, “Technical”, Government and Legal”, and “Environment”. The finding of this research will be useful for key stakeholders to develop strategies to overcome these challenges. The BIM implementation in the GCC construction industry will not only improve the performance of the industry but will also open the doors for new opportunities and employment. The BIM implementation in construction will also help the region to achieve Goal 9 (industrial innovation and improved infrastructure) of the United Nations Sustainable Development Goals.

Keywords: Building Information Modelling, International Construction, Organization, Knowledge Management, Project Management, International Practice.

Article Type: Research Paper

1. Introduction:

Building information modelling (BIM) is one of the most promising recent developments in the architecture, engineering, and construction (AEC) industry which allows developing a digital and an accurate model of a building. Earlier to BIM technology, the AEC industry was required to use the traditional methods to reduce project cost, increase productivity and quality, and decrease project delivery time (Azhar, 2011). Some researchers concluded the in the absence of BIM not only the AEC industry (AECO) industry but also the operation part faces challenges in relation to construction projects that are fragmented and, in many cases, not particularly well integrated. The consequences are negative regarding energy efficiency, cost, sustainability, resource depletion, the wellbeing of end-users, and the efficiency of installers (Peng, 2016; Shy, 2017; Motamedi and Hammad, 2009). It is now more than 40 years since its origins that the BIM technology has been progressively implemented worldwide in the AEC sectors (Sacks et al., 2018). The BIM technology provides a framework to set up collaborative work in the construction industry and therefore gives the way to improve the overall quality of the whole value chain. BIM is a faster and more efficient method for construction management; it enhances design and construction qualities and reduces rework during construction (Masood et al., 2014). BIM technology allows the creation of an accurate virtual model of a building that is first digitally constructed. This technology can be used throughout the entire value chain from design to demolition, allowing all the stakeholders to work collaboratively rather than in a fragmented manner (Charef et al., 2018). There are, however, several challenges on the way to effectively implement BIM in construction and other industrial sectors.

Although the BIM implementation in many sectors is clearly a main concern of the world, some studies still considered that developing countries may not be interested in this new technology (Gu and London, 2010; Arayici et al., 2011-a; Tse et al., 2005). Most of these, however, appear to be a little older as there are plenty of new studies exploring the BIM implementation in some specific developing countries. For instance, a recent study conducted by Khodeir and Nessim (2018) has explored the BIM implementation in architectural firms working in Egypt. Similarly, a study conducted by Hanafi et al., (2018) examined the organizational readiness of BIM adoption through architectural practices. The example of Arunkumar et al., (2018) study on the implementation of BIM from the architects' and engineers' perspective in India is among these similar studies. The study conducted by Li et al., (2017) provided a greater insight into the barriers to BIM implementation in China.

The first and main challenge which the construction and other industries are facing is the requirement of technical experts. The BIM implementation requires significant technical expertise at first instance to pave the way for adopting BIM in a concerned organization or project. Definitely, the BIM implementations increase the organization's operational costs in short terms as such implementations require training the staff who not familiar with BIM. Construction organizations are considered to be reluctant to spend money on such issues particularly when they don't realize the return of such investment in the short or long-term (Kouider, Paterson, and Thomson 2007; Arayici et al., 2011-b; Umar et al., 2018). Apparently, Investment or training requirements are not the only reasons which hindered the progress of BIM implementation in construction, there could be multiple factors that are associated with management, technology, environment, and the costs (Umar and Egbu, 2018; Yeh and Chen, 2018). There are several studies which have established that BIM advantages are far greater than the disadvantages which have forced the governments in many countries to drive the BIM adaptation in their industrial sectors (Terreno et al., 2015; Barlish and Sullivan, 2012; Love et al., 2016; Azhar, 2011; Succar and Kassem, 2015; Kassem and Succar, 2016). Overall, there are challenges which are faced by many industries in different regions in the implementation of BIM. Know these challenges are important for the effective implementation of BIM in construction so that a strategy could be developed to overcome these challenges (Gamil and Rahman, 2019). Since the aim of this paper is to explore the challenges of BIM implementation in the Gulf Cooperation Council (GCC) construction industry; the next section, therefore, provides an overview of the regional construction industry.

1.1. GCC Construction Industry:

The GCC consist of five main oil-producing countries that include Saudi Arabia, United Arab Emirates, Oman, Qatar, Bahrain, and Kuwait (Umar et al., 2019-a). There have been social and economic developments in the whole region since 1970 when the region was actually able to earn sufficient money from the oil and gas reserve. Currently, the economy of the most GCC member countries is still highly dependent on oil and gas revenue while in some GCC countries it contributes up to 50% of the total gross domestic product and in others; it contributes up to 84% of the export earnings (Umar and Wamuziri, 2016-a; CBO, 2015; NCSI, 2015). Similarly, in Saudi Arabia, the construction industry is accounted for 10% of the total Gross Domestic Product (GDP) (Banawi, 2017).

The improved economic condition of the region has brought a boom in the construction and infrastructure projects as well. Although there was a dip in oil and gas prices in the international market recently, the construction industry is still at peak (Umar et al., 2019-b). The construction industry in this region, therefore, has been an employment sector for both overseas workers and international companies. Research conducted by Umar and Wamuziri, (2017) that there are more than 700,000 foreigner construction workers in Oman which constitute about 92% of the total workforce in the country. Similarly, the registered international organizations working in the construction sector with the Tender Board of Oman rose to 1092 in 2018. It needs to be noted that the Tender Board of Oman only deals with the government tenders valued at US$ 7.79 Million or more (TBO, 2018). It is expected that in Oman the number of construction workers and international construction will be increasing because the value of the construction industry in Oman is expected to grow to 2.64 US $ Billion, which was less than the US $ 1 Billion in 2016 (BMI, 2018). Similarly, the Middle East Economic Digest (MEED) report for the year 2019 indicates that the value of the planned project in the GCC countries stands at US $ 2,563,966 Million (MEED, 2019). As indicated in figure 1, Saudi Arabia projects alone are valued at the US $ 1,188,432 Million, the highest in the region. These projects (shown in figure 1) do not count those which have been awarded till July 2019 as shown in table 1 which is worth the US $ 3,459 Million.

Figure 1: The Values of Planned Projects in the GCC countries

Table 1: Contract Awarded in Different GCC Countries until July 2019

The increased number of construction projects in the region has created several issues related to sustainability, energy efficiency, waste and resources, safety and health, materials demand, delays in completion, and environmental issues. For instance, in Saudi Arabia, the average estimated delay amounted to 39% of the contractual time (Elawi et al., 2016). Similarly, Umar (2018-a) while investigating the causes of delay in construction projects noted that the causes of delay in construction projects are directly associated with the owner, consultant, and contractors. Thus, to avoid the delay in construction projects, it is important that all the stakeholders are closely connected with each other’s and have access to all relevant information particularly those which are crucial for the timely completion of the project. Similarly, Btoush and Harun (2017) noted that the main causes of delay in the construction projects are poor scheduling and planning, change orders, site conditions, weather, late deliveries, incompetent technical staff. They argued that the implementation of BIM is helpful in avoiding such causes. For instance, to address the poor scheduling and planning, the BIM experts can create the geometry in the BIM models, and work in groups to create different parts of the model. Similarly, they can embed information about the processes and resources required. Adding phases to the resources develops building phasing files that can be used for planning by the general contractors. Similarly, extracting information from the BIM model for space planning, asset management, and maintenance schedules, strategies development, typically, from medium to long-term based can also be done through BIM. The lack of communication among the construction project team also results in a delay in the project. The BIM can, however, resolve the issue of lack of communication between project parties. BIM specialists will act as a communication cycle between the project partners by modelling the project and make it available to all the parts, update using an integrated communication web site so any correction on the model will be available to all partners. The specialist’s duty is to identify communication errors, improve communication and information technology and facility communication protocol. The BIM expert can coordinate project teams and establishes connections for correspondence between various offices. All these actions help to avoid communication errors and thus help to eliminate the possible delay of the construction project. The poor design of the construction projects is also regarded by many researchers as one of the main causes of the delay (Sweis et al., 2008; Al-Momani, 2000, Emam et al., 2015; Alnuaimi and Mohsin, 2013; Al-Hazim et al., 2017; Al-Werikat, 2017). The BIM implementation, however, can improve the design by dividing the phases into intervals, developing 3D models, and making a virtual model which are helpful to identify the design errors. Thus, the design can be improved before the work start and thus avoid any interruption in the construction stage of the project.

A similar argument was able developed by Umar and Wamuziri (2016-b) in their research on “challenges and opportunities for construction safety” in which they noted that close collaboration among all the stakeholders including the client, designer, contractor, sub-contractor, and the government agencies is mandatory to convert the challenge’s associated with the construction safety into opportunities. The research conducted by Tahir et al. (2018) argued that BIM technology has the potential to control and solve the issue related to project cost and time as this technological platform improves the stakeholders' collaboration associated with a project.

The results of another study show that in the last two decades energy consumption in the GCC member countries has increased rapidly (Umar, 2018-b). Just to present a brief comparison, in 2013, the average electricity consumption in GCC countries was approximately 12370.91 kWh (kilowatt-hour) per year per capita while in China this value was 3762.07 (Umar, 2017; WB, 2016). Different studies indicate that worldwide a significant portion of the energy is consumed by the building sector. For instance, in the United States, 21% of the energy is consumed in the residential building (EIA, 2016). The world average of energy consumed in the building is, however, 14% of the total energy consumption (EIA, 212). Comparatively this percentage in the GCC countries is quite high. For instance, in Qatar, the percentage of the energy which is consumed in the building is 41% (Ayoub et al., 2014). Excessive energy consumption in buildings and other sectors can cause global warming issues as most of the energy produced worldwide is from fossil fuels resulting in a large quantity of emission (Umar, 2020-a). Such energy production and consumption can derail the progress of the several United Nations Sustainable Development Goals (UN SDGs) (Umar et al., 2020-a). Researchers are, however, agreed that an energy-efficient design of building considering several parameters such as orientation, passive cooling, and heating system, an envelope system and shape, and glazing and shading can help to reduce the energy consumption in building (Pacheco et al., 2012). The application of technological tools such as the integration of information technology is considered mandatory to deliver better decisions related to building design (Papamichael, 1999).

The statistics of the World Bank issue in 2012 reveal that globally the total quantity of solid waste is 1.3 billion tonnes per year which are expected to reach 2.2 billion per year in 2025. Interestingly the report indicates that the construction waste is half of the total solid waste. In other words, by 2025, the global quantity of waste coming from the construction section will reach 1.1 billion tonnes per year (Redling, 2018). Similarly, the average per capita waste generation in the GCC region is 1.8 kg which brings the region among the top 10% of per capita waste producers in the world (Zafar, 2018). The annual waste generation is around 120 million tons while construction and demolition stand for 55% of the total waste generated in the GCC countries (Ouda et al., 2017). Similarly, in Abu Dhabi (United Arab Emirates) during 2010, 75% of the total waste generated was coming from construction and demolition waste (Alzaydi, 2014). Currently, most construction waste goes to landfills or dumpsites which further create several environmental issues. The application of BIM can improve construction waste management and can play a role to reduce waste from the construction industry (Akinade et al., 2018). A case study conducted in South Korea on the application of BIM to reduce construction waste reveals that BIM has the potential to reduce construction waste up to 15% (Won et al., 2016). Such reduction construction waste can help countries to achieve the goal 11 of UN SDGs that is related to sensible consumption and production. The GCC region has comparatively low progress towards UN SDGs and many studies reveal the region is not on the track to achieve the UN goals by 2030 (UN SDGs, 2015).

The next section provides an overview of the application of BIM in construction with a specific reference to the GCC construction industry.

1.2. Applications and Challenges of BIM in Construction Sector:

There have been many studies which establish that most of the issues related to the building and construction can be better managed with the BIM technology (Won et al., 2016; Azhar, 2011; Wong and Fan, 2013; Migilinskas et al., 2017; Zhang et al., 2015; Martinez-Aires et al., 2018). The research conducted by Malsane and Sheth (2015) divided the key applications of the BIM technology into five different categories including modeling, simulation, coordination, documentation, and visualization. Similarly, Mesároš and Mandičák (2017) while exploring the benefits of the BIM for construction projects Slovak reported the top 10 benefits. These advantages include i) cost reduction, ii) quality document, (iii) financial control, iv) reduced time for documentation, v) timely access to project information, vi) reduce error in the construction process vii) time reduction in the project lifecycle, viii) improve decision making, ix) increase revue, and x) improve workers productivity. Despite all these benefits of BIM, Mesároš and Mandičák (2017) further revealed that almost 80% of the construction companies in Slovak are not using BIM. One of the top benefits of the applications BIM in construction reported by Hall (2018) is that it improves communication and collaboration. The BIM enables the entire team member to share project plans, coordinate in the planning stage, and thus ensuring that all the project stakeholders have insight into the project.

Similarly, an effective supply of materials and equipment, management of spaces for storage, and other dynamic construction processes at the workplace are important for the smooth running of construction projects (Akinci et al., 1998). Therefore, the logistics management in construction projects that include, transportation, receiving, storage, and distribution of resources such as materials, machines, and manpower, and management of construction areas become very important in the successful and timely completion of the project (Sullivan et al., 2011). BIM can also be integrated to better manage the logistics in construction projects. The study conducted by Whitlock et al. (2018) established some components associated with logistics that can be integrated into BIM to improve construction logistics management. The key applications of BIM that can improve the construction logistics management include i) Developing 3D site plans, ii) 4D coordination of temporary site installation. Similarly, the applications of BIM in construction logistics management can result in a number of advantages that improve the overall project performance. For instance, the 3D layout plan developed, and integrated trough BIM helps the individuals to understand the site layout information easily even if they don't have a solid background in logistics or construction projects (Bortolini et al., 2015). The 3D logistics plans are also very useful to minimize the safety and health risk at the construction site as the 3D plans provide more clarity in the proposed logistics approaches that are normally difficult to display on a 2D plan. Other benefits arising from the integration of BIM in construction logistics include improved and effective site planning, and improved efficiency of construction logistics (Zhang et al., 2001).

It is estimated that BIM technology will be able to give a saving of 10 to 20% of the construction project's values (Banawi, 2017). A survey conducted in the United States indicates that 72% of the construction organizations believe that they use BIM can reduce the cost of their project significantly (Woetzel et al., 2017). Considering such financial benefits some advanced countries have made good progress towards BIM implementation in construction projects (Singh, 2017). For instance, it was in 2010 when Wisconsin a state in the United States, which had made it mandatory to incorporate BIM technology in all public projects with a budget of US $ 5.0 million and above (Yoders, 2009). Similarly, in the United Kingdom, as part of their construction strategy to reduce the procumbent cost by 20%, it was made mandatory in 2016 for all central construction projects to have BIM implementation at least at level 2 (RIBA, 2016). Some countries in the GCC such as United Arab Emirates (Dubai Municipality) has made it mandatory to use the BIM for the government building projects when the number of the floor is 40 or has an area of more than 27,800 sq.m (Mehran, 2016). In Oman, there are however no such regulations that support BIM implementation in construction. It is obvious when construction organizations will not be forced to adopt a technology, the process of adaptation and implementation will be slow. Apart from regulations for BIM implementation that are normally enforced by the government organizations or the client, there are, however, some other challenges that provide obstacles in BIM implementation. For instance, the NBS National BIM survey conducted in 2014 reported that five main challenges are being faced by organizations that were struggling to implement BIM in their projects (NBS, 2014). These challenges include the demand for BIM from the client. In other words, these organizations reported that there is no demand from their client to adopt BIM in their projects. Similarly, while there are clear benefits of the BIM implementation, the initial implementation involves some investment in terms of software, training, and time. Interestingly some small construction organizations reported that their work is not of a complex nature and thus they do not need such a tool. Of course, one of the main challenges in BIM implementation is the required skilled staff. The results of the above-quoted survey indicated that 62% of the participants quoted this challenge. Similarly, the challenges in BIM implementation reported in the study conducted by Criminale and Langar (2017) include staff training, local standards and regulations, and interoperability of BIM software. The white paper released by the MagiCAD on the BIM adaptation in Europe reveals that currently convincing the owners is the main challenge in BIM implementation across Europe (MagiCAD, 2020).

Clearly, the challenges of BIM implementation could be carried from region to region, however, knowing these challenges are important as it can provide a road map to develop strategies to overcome such challenges. As noted in the introduction section that construction is a major industry in the GCC region as there are currently many construction and infrastructure projects going one (figure 1), however, the industry suffers from a number of issues that affect industry performance. These issues include poor productivity, delays, and safety performance. BIM can be a possible solution for most of the issues that the industry is facing. It is therefore important to determine the challenges that are involved in the implementation of the BIM technology in the GCC construction sector. A mixed research method was adopted to achieve the aims and objectives of this research. The research methodology used in this research is explained in the next section.

2. Research Methodology:

Broadly, the research methods can be classified into two main categories namely qualitative and quantitative research methods (Bryman, 2016). Both of the approaches are quite different from each however many researchers prefer to use the mixed method by incorporating the qualitative and quantitative methods (Maxwell, 2019; Guetterman et al., 2019). Considering the nature of this research, a mixed methodology was deemed to be the best suit to achieve the aim of the research. The research approach adopted is suitable to investigate the challenges of BIM implementation in the GCC construction industry as the topic is seldom considered by the local or international researchers in the regional context. It was, therefore, considered appropriate to first find the key challenges faced by other regions in BIM implementation in construction. There has been much research carried out on this topic worldwide. It was, therefore, assumed that the challenges faced by other countries or regions in the BIM implementation in construction could be faced by the construction industry in the GCC region. Knowing BIM implementation challenges faced by construction industry around the world was therefore considered important in the research. The perception of the local professionals working in the construction industry was another factor that was important to know the BIM implementation challenges in the GCC construction industry. Similarly, the literature review around the research methodologies in different areas of construction also reveals that a mixed research approach was adopted by many researchers (Charef et al., 2018; Gamil and Rahman, 2019; Tan et al., 2019; Yi and Chan, 2016; Yi and Chan, 2017). Considering all the factors associated with the aims and objectives of the research, it was finally decided that a mixed research approach using a systematic review method and a questionnaire survey will serve the purpose.

In the first stage, a systematic approach was adopted to identify the main barriers or challenges being faced by the construction industry in the implementation of BIM technology. Four main scientific databases mentioned in Appendix I were considered for this review using specific keywords including, Building Information Modelling, BIM Implementation, Barriers, Challenges in BIM. These keywords were considered suitable based on the aims and objectives of the research. Since the research is related to BIM, therefore, the first keyword which is used is the "Building Information Modelling. Similarly, since the research is related to the BIM implementation, therefore "BIM implementation" was used as a second keyword. Likewise, and more specifically, the research investigating the barriers and challenges of BIM implementation in the construction, therefore, BIM challenges" and "BIM barriers" were used as subsequent keywords. A similar approach that includes the systematic review method was also adopted by Umar (2020) in a recent study on the factors that influence 3D printing implementation in the construction industry. Furthermore, the search was kept limited to the past 10 years from 2010 to 2019. This period was considered as most of the studies related to the challenges in BIM implantation were carried out during this period

(Tan et al., 2019). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were for this review (Liberati et al., 2009). The PRISMA compliance in the literature review was considered important in many studies (Welch et al., 2016; Wang et al., 2019). For instance, Randolph (2009) suggested that a defective literature review is one of the many reasons which can derail the thesis, paper, or dissertation. A faulty literature review may result in a flawed thesis, dissertation, or paper due to the fact that comprehensive research cannot be performed without a full understanding of the existing literature in the relevant area (Boote and Beile, 2005). The literature review of the paper or thesis also gets due considerations by the reviewer or examiner as well. A research conducted by the Mullins and Kiley (2002) concluded that most of the reviewers and examiners get a perception of the whole paper or thesis from the literature review. If the literature review is found poor, the examiners assume that the rest of the thesis would also have problems. Fellows and Liu (2015) argued that the literature should not merely be found and reviewed; the body of relevant literature from previous research must be reviewed critically. Thus, literature must not be accepted ‘at face value’ but different sources should be reviewed for different perspectives. There is a possibility that the same authors will change their views over time (Alexander, 1983). It was ensured that the review involves comparing a set of literature against an established set of criteria. The existing research was not aggregated or synthesized with respect to each other but was judged against this standard and found to be more or less acceptable (Grant and Booth, 2009; Paré et al. 2015; Xiao and Watson, 2019).

For the systematic review approach adopted in this research, only papers published in the journals were considered. Papers published in the conference proceedings are although provide good pieces of work however were not considered due to the fact conference papers usually are of lower quality and less mature than journal articles (Levy and Ellis, 2006). All the challenges associated with the BIM identified through the literature review were coded so that to make it easier to merge similar nature of challenges in one category. The main categories of the challenges were managed in a way so that it can fall into four main categories.

Two criteria were adopted for the ranking of the challenges associated with the BIM extracted from the papers included in the qualitative synthesis. 50% of the weightage was given to the journals impact factor in which the papers were published from where the factor was extracted, and 25% weightage was given to citations of the papers from which the factors were extracted. The journal impact factor is considered important when it comes to research quality. A recent study reveals that the journal impact factor is used in 40% of the research-intensive universities in the United States and Canada for the review and promotion of the faculty (McKiernan et al., 2019). This study further reported that 63% of the institutions believe that the journal impact factor is related to the quality, impact, importance, or significance. In this research, a 50% weightage was, therefore, given to the journal impact factor. Similarly, the citations of a specific paper provide a quantitative way to measure the quality of published works, to detect emerging research topics, and to follow evolving ones (Valenzuela and Etzioni, 2015). Considering the importance of the citations of the research paper, a 25% weightage was deemed suitable for the ranking of the papers in this research.

The remaining 25% weightage was given to the importance of the challenge that was given in the paper. For instance, if the challenge was given the top importance in the paper, it was given a score of 10. If the paper summarizes a specific challenge of BIM implementation in construction as the first or top leading challenge, that means the author consider that challenge as the most important challenge of BIM implementation in the construction and therefore deserve full weightage. The score reduces if the importance of the challenge reduces in the paper. For instance, the challenges fall under the “Technical” category as mention in table 3 is ranked on the top as this challenge achieved on the highest score based on the criteria adopted using equation 1. The score and the ranking of all the main challenges determined based on the above-mentioned criteria are listed in table 4.

Ranking of Factor = R_f = $Sum\ of\ Impact\ Factors\ (SIF) x\ 50\% +$

$Sum\ of\ Citaitons (SoC) x\ 25\% +$

$Sum\ of\ Impportance\ Factor (SoIF)\ x\ 25\%$ ………………Equation 1.

In the next stage, a structured questionnaire was developed based on the results from the systematic review carried out in the first stage. The questionnaire was administrated among the construction professionals working in the GCC region. The questionnaire was first tested on a small group to observe the acceptability and time required for the completion. The link to the questionnaire was then sent to the respondents through email. The email addresses of the respondents were collected from their organization website. The construction companies were identified through the contactor association in each GCC country. The top 40 construction companies from each country were selected making the total number of organizations equal to 200. The potential participant's email addresses were either taken from the selected organization's websites if available, otherwise, an email was sent to the organization's general email for the participant in the study. The link of the questionnaire was however only sent to the individual email only. The purpose of the study, the confidentiality policy, ethical statement, and consent to participate were indicated on the first page of the questionnaire as well as in the email sent to the participants. The respondents were given one month's time to complete the survey, during this period two reminders were sent to them.

The structure of the questionnaire was based on the data collected in the first stage. The first section of the questionnaire has two main parts. In the first part of this section the purpose of the study, confidentiality policy, consent to participate in the study, and guidance for the additional information related to the study were provided. In this part, it was made clear to the participants that the participation in this study is on a volunteer basis, but they were ensured that data collected will be treated anonymously and will not be shared with any agency or government institution or their employer. In the second part of the questionnaire, personal information related to employment category organization type, organization activity, academic qualification, specialization, experience, and year of birth were asked. In the second part of the questionnaire, three simple questions related to the respondents' organization's current BIM employment, benefits of using BIM, and future plan to implement the BIM were asked. In the third part of the questionnaire was consisting of four main challenges/barriers (Technical, Organization, Environment, and Government/Legal) identified in the systematic review. Each challenge was supported by a number of statements as mentioned in appendix I. Respondents were asked to rate them on a Likert scale of 1 to 5 (1 = strongly disagree, 5 = strongly agree). The last part of the questionnaire was an open-end question in which participants were given an opportunity to provide any comments which they may feel important in relation to this study. Graneheim and Lundman (2004) guidelines were used for content analysis. Based on this method the meaning units which have the same central meaning, from the comments section were organized from most common to least common. Using this approach, all the completed questionnaires will first check for the comments. The questionnaires with the comments were separated from those which had no comments in the comments box. The questionnaires which had the comments were thoroughly checked and reviewed. The comments which trigger the same meaning were classified into one group. Similarly, all the comments were reviewed and where possible they were classified in groups using a content analysis approach.

The statistical analyses were carried out using SPSS software. Questionnaire in which more than 50% of the questions were not answered, were rejected, and were not considered in the data analysis. The normality of the data was checked through the ratio between skewness and its standard error, and the ratio between kurtosis and its standard error. The data was considered normal if the ratio was between –1.96 to +1.96. Briefly, Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the centre point. Similarly, Kurtosis is a measure of whether the data are heavy-tailed or light-tailed relative to a normal distribution. That is, data sets with high kurtosis tend to have heavy tails or outliers. Data sets with low kurtosis tend to have light tails or a lack of outliers. Cronbach's Alpha (α) value was calculated to know the internal reliability of the Likert scale items. An independent sample T-test (two-tailed) was conducted to see if there is any notable variation among two independent groups. A probability value (p-value) less than 0.05 from a two-tailed T-test was treated statistically powerful for all tests.

The results and analysis are presented in the next section.

3. Results and Analysis:

The results and Analysis section is divided into two parts. In part one, the results and analysis of the systematic review are presented, while in the second part, the results and analysis of the structured questionnaire are presented.

3.1 Results and Analysis of Systematic Review:

During the systematic review search, a total of 616 items were identified using the specific keywords in the selected databases. After the duplicate's items were removed, the items were reduced to 503. After applying further screening, 172 items were found to be eligible for further screening. At the final screening stage, a total of 125 were excluded and thus the final items considered for the qualitative synthesis stood at 47 as mentioned in Appendix I. The web of Science was one of the main databases which accounted for 34.04% of the final items selected for the qualitative synthesis. This was followed by Scopus (25.53%), Pro-Quest (21.27%), and Science Direct (19.14%). Although the search period was kept from 2010 to 2019, the final selected studies included in the qualitative synthesis indicate that the studies published in 2017 were on the top accounting for more than 17% of the total studies. This was followed by the year 2018 (15%), 2019 (15%) and then 2010 (11%) and 2015 (11%).

Based on the information gathered from these 47 items, the BIM implementation challenges were divided into four main categories that include Technical, Organization, Environment, and Government/Legal. Each category was consisting of a number of sub-items as mentioned in appendix I. For instance, if the challenges discussed in a reported paper was related to difficulty in adapting BIM technology and process, lack of domestic-oriented BIM tools, increased workload for model development, cost of technology, BIM training, and its cost, complexity of BIM technologies (software), and requirement of high-spec computers, such items were classified under the main category of "Technical" challenge. A similar approach was also adopted for other main categories of challenges as reported in appendix I. The literature review suggests that developing a main category from sub-items is a common practice in the research of the same nature (Umar, 2020-b; Yeh and Chen, 2018). While using equation 1, the main challenge categories as "Technical" achieved the maximum score (47.31) and was thus raked as first. The technical challenges associated with the BIM implementation also took the first position in the study carried out by Gerrish et al., (2017) on the BIM application to the building energy performance. The "Technical" challenge was followed by “Organization” with a total score of 41.98, “Environment” with a total score of 37.78, and finally “Government/Legal” with a total score of 35.27. The Organization and the management system in the organization have been recognized as key to the successful implementation of BIM in many studies. For instance, a study on the organizational change perspective on people management Liao and Ai Lin Teo (2018) noted that there are twenty-four hindrances to and 13 drivers for BIM implementation in people management in organizations. The organizational awareness of the importance of BIM implementation is also a critical factor for BIM maturity level which refers to the quality, repeatability, and degree of excellence within BIM capability (Keskin et al., 2019; Khosrowshahi and Arayici, 2012; Succar et al., 2012).

Environmental challenges that could influence the BIM implementation in construction can be categorized into competitive pressure, expectations from market trends, trading partners, and government support. The research conducted by Jeyaraj et al., (2006) concluded that competitive pressure generally refers to the factor that positively influences the technology adoption. Many other researchers are in the view that such influence delivers even stronger power when the implementation contributes directly to market competition (Wang et al., 2010; Yee-Loong Chong et al., 2009; Zhu et al., 2006).

The last category of the challenge mentioned in table 3 is a combination of the challenges associated with the government or the legal issue related to the law and regulation countries that restrict the implementation of BIM in a specific country. Since making supportive law and regulation are the responsibility of the government of such countries, it was therefore considered appropriate to merge these two challenges under one category. A recent study on the challenges associated with implementing BIM conducted by Vass and Gustavsson (2017) also considered factors such as governmental regulations, government initiatives, and country-specific factors under one main challenge. The country-specific factors as described by Melville et al., (2004) include the education system and residents’ maturity of information technology.

Table 2: Year Wise/ Database Wise Details of the Selected Items

Table 3: Ranking of the Main Challenges from the Literature Review

The next section provides the results and analysis of the data collected through the survey questionnaire.

3.1 Results and Analysis of the Structured Questionnaire:

The websites of the selected organizations in the GCC countries were used to find the email addresses of the potential respondents. This, however, only resulted in 27 potential participants from 11 different organizations across the region. In the next step, emails were sent to the email of the general email available on each organization's website. In this email, the organizations were requested to provide contact details of the employees who can participate in this study. All the required information related to the study was mentioned in the email. Two reminders were sent after every ten days during a month period to the organizations who have not responded to the email. As mentioned in table 4, only 53 (26.5%) organizations responded to the email, however, the number of organizations who provided the required information was only 47 (23.5%). Most of these organizations that have provided the accurate required data were from the United Arab Emirates (31.91%), followed by Qatar (21.27%), Bahrain (17.02%), Saudi Arabia (12.76%), Oman (10.63%), and Kuwait (6.38%). Similarly, United Arab Emirates was on the top of the list not only in terms of the number of participant’s information provided by organizations but also in terms of the number of participants participated in the study as mentioned in table 4. To increase the participant of the respondents, they were given one month's time to complete the questionnaire, and during this period; two reminders were sent to the respondents if they have not completed the survey. After the period of one month, the link to the survey was set to be expired. The questionnaire was sent to a total of 206 participants. The number of respondents who participated in the study stand at 104 representing a response rate of 50.48%. A total of eight questionnaires were rejected due to the lack of information, bringing the total valid questionnaires to 96 which were used in further analysis. The criterion set for the rejection of a questionnaire was answering less than half of the questions in the questionnaire.

To justify the response rate and valid sample size used in the analysis of this study some relevant studies were reviewed and it has been found that a response rate of 50.48% with valid questionnaires of 96 is acceptable in such studies. For instance, a study carried out by Shih and Xitao (2008) analysed a total of 39 different papers published from 1998 to 2006 which have used the data collection tool administrated through web and paper based. The results show that the average response rate of the web survey was 33.87% while the paper-based response rate was 44.56%. Since the questionnaire used in this research was a web base and was distributed through email, thus the response rate received (= 43.5%) is considered satisfactory. There have been some studies that used a qualitative approach and interviewed only six respondents (Umar and Egbu, 2018; Umar et al., 2017). A recent study in the area of renewable energy conducted by Filho et al., (2019) was based on a sample size of only 50. Similarly, Umar et al. (2018) in their study which aimed to assess the construction worker's productivity and safety performance used a quantitative approach selecting a total of 30 respondents only. The total population (construction workers) in their study was, however, stood at 700,000. Some researchers, however, recommend that the sample size or the response rate needs to be calculated based on the population size (Kotrlik and Higgins, 2001). In some cases, the sample size calculated based on the population size could not be helpful or even not adoptable. For instance, if the population is the ‘population of China’; then the sample size calculated through this principle will be very large and thus could not be achieved. A recent study on the challenges associated with renewable energy in the Arabian Gulf region also used a sample size of 87 respondents from five different countries (Umar et al., 2020-b). Similarly, Dawson in his research investigated the perspective of university teachers on climate change considering a sample of 39 participants (Dawson, 2012). Overall, the existing review of different research reveals that a response rate of 50.48% with a valid questionnaire of 96 is good to draw a conclusion on BIM challenges in the GCC region.

Table 4: Composition of the Participants from Different GCC Countries

The ratio between skewness and its standards error for age was 0.59. The age of the respondents was calculated using the year of birth mentioned by the respondents in the questionnaire. Similarly, the ratio between kurtosis and its standard error for age was 1.24. Both the ratios were found to be less than +1.96 and reflect the normality of data. The correlation between age and qualification of the respondents was found to be significant at the 0.05 level (2 tailed). The internal reliability of all the Likert items along with qualification, position, and country of respondents was checked by calculating Cronbach's Alpha (α) using SPSS and was found to be 0.638. The correlation between age and qualification of the respondents was found to be significant at the 0.05 level (two-tailed).

The majority of the respondents who participated in the survey were male (91.66%). The results reflect that the construction industry is heavily populated by male workers. Such indicators were also published in many other studies and reports. For instance, a report published by the Oman Society of Contractors shows that the number of Omani in the construction industry as of 2016, stood at 54,753 (7.41%), consisting of 45,454 (6.56%) male and 9,299 (1.25%) female workers. Similarly, the total number of expatriate workers in the Omani construction industry was 683,840 (92.58%), dominated by male workers that stood at 682,485 (92.40%). There were only 1355 (0.18%) expatriate women working in the construction industry in Oman (OSC, 2016). Thus, the total number of female workers in the Omani construction industry is only 1.43% of the total workers. The situation over the female workers in the construction industry in other GCC countries is more or less than the same as in Oman.

A total of nine categories of employment including Company Director, Project Manager, Construction Manager, Architect, Civil Engineer, Design Engineer, Site Engineer/Site Supervisor, Quantity Surveyor, and Other were shown on the questionnaire. The “other” category was provided in case the participants don’t fit any of the categories mentioned in the questionnaire. The category of “Civil Engineer” was leading the respondents’ population by making 21.87% of the total participants followed by the “Design Engineer” category which was accounted for 17.70% of the total population as shown in figure 2. Respondents were asked to select their organization types from the three given options.

Sixty-six respondents (68.75%) classified their organizations as “International Contractor” while 21 participants (21.87%) classified their companies as “Local Contractor”. Two participants (2.08%) selected the “Other” option which means that their companies do not fall under the definition of international or local contractors and their company may be registered in a specific region or with a specific ministry/organization in any GCC country. The options of companies’ classification as an international or local contractor are also used by many government organizations in the GCC region for the classification of contractors. For instance, the Tender Board of Oman classifies the companies into three categories which include International contractors, local contractors, and Small and Medium organizations (TBO, 2018). Similarly, the majority of the respondent's organizations (53.13%) were classified as “General Contractor” followed by the Building Contractor category which makes 13.54% of the total. As far as the qualifications of the respondents are concerned, 48.96% of the participants reported their qualifications as a “Bachelor's Degree”. Similarly, 23 participants (23.96%) noted their qualifications as “Diploma”. In terms of respondents’ specialization, the majority of the participants’ specialization was civil engineering (38.54%) or architecture (23.96%). Similarly, the majority of the participants (36.46%) experience was in the range of 6 to 10 years. The full description of the respondent's Organization Type, Organization Activities, Qualification, Specialization, and Experience of given in table 5.

Figure 2: Respondents Classification Based on the Employment Categories

Table 5: Respondents’ Demographic Information

As part of the questionnaire, respondents also have to provide their view on the implementation, awareness of benefits, and future plans of the BIM in their respective organizations. A total of three questions were required to be answered by the respondents by selecting one of the three options provided with each question. The results as displayed in figure 3 show that 68.75% of the respondents considered that their organizations do not implement the BIM technology in their construction projects. Only 29.16% of the respondents reported that their organizations employ BIM technology in the different stages of construction projects. Two respondents (2.08%) noted that they do not know that either their respondents use BIM in their construction projects or not. This was quite strange, but it may be due to the reason that these participants have just joined the concerned organizations and they may still don’t have a clear picture of the situation over the BIM. Similarly, a large number of respondents (71 ~ 73.95%) noted that their organizations don’t know the benefits of BIM employment in their projects. Only 22.91% of respondents reported that their organizations are aware of the BIM implementation benefits. As far as the planning for BIM implementation is concerned, the majority of the respondents (67 ~69.79%) answered positively that their organizations are planning to employ BIM in their future projects. A small, but a considerable portion of the respondents noted that their organizations do not have such a plan which aims to implement BIM to the future projects of the organizations. Two respondents (2.08%) stated that do not know that either their organizations have a plan for BIM implementation or not.

Figure 3: Awareness of BIM in the GCC Construction Industry

As discussed in the methodology section, there were four main challenges identified in the literature review. Each main challenge was further divided into sub-challenge. Thus, to rank each main and sub challenge, the mean score and standard deviation of the main and sub-challenges were calculated using SPSS software. Based on the results, the “Organization” challenge was ranked with a mean score of 4.15 and a standard deviation of ±0.96. This challenge was followed by “Technical” (4.03±0.91), “Government/Legal” (4.01±1.03), and “Environment” (3.941±0.92) respectively. In the sub-challenges fall under the technical category, “difficulty in Adapting BIM Technology and Process” with a mean score 4.51±1.08 was ranked as the top sub challenge. The top-ranked sub-challenges in the organization category was the “resistance to change” with a mean score of 4.95±1.03. Similarly, unwillingness to try the BIM process and technology (4.71±0.86) was ranked as the first sub challenge in the environment category. The lack of a national agenda under the “government/legal” category was ranked as the top challenge with a mean score of 4.52±0.94. based on the overall mean score of all the sub-challenges irrespective their category, “resistance to change” (4.95±1.03), “unwillingness to try BIM process” (4.71±0.86), and “lack of support from top management” (4.68±0.88) were classified the top three challenges of the BIM implementation in the GCC construction industry. The ranking of all the challenges based on the mean score is further summarized in table 6.

Table 6: Challenges Associated with BIM Implementation in GCC Construction Industry

The next section provides a discussion on the results and analysis presented in this section.

4. Discussion and Conclusion:

As discussed in sections 1 and 1.1, the construction industry in the GCC region is at the peak, however, there are a number of issues associated with this industry. The application of advanced technological tools such as BIM can be helpful to address these issues; however, the implementation of BIM is a challenge itself in the GCC construction industry. An understanding of these challenges is therefore important so that strategies can be developed to overcome these challenges. Considering the wide range of advantages, the BIM has been adopted in many parts of the world (Jung and Lee, 2015). In the construction industry, it has been used for many tasks and stages including cost estimation, property management, equipment management, building, and structural design (Doumbouya and Guan, 2016). Another study carried out in Korea reported that 74% of the architects use BIM in their design work (Coates et al., 2010). Apart from the compulsory use of BIM from the regulatory authorities, these architectural firms know the benefits of BIM in their construction projects. such benefits are quite helpful convince the organizations to move towards new technology such as BIM (Hsiao et al., 2009; Brooks et al., 2014). Similarly, in some countries, it is mandatory to implement BIM is specific types of construction projects. For instance, in the United States, the General Services Administration requires the use of BIM on all major projects (Lee et al., 2012). A study from the UK conducted by Eadie et al. (2013) reported that BIM is used in the construction industry in different stages including the design phase (55%), the detail design and tender stage (52%), construction stage (35%), feasibility stage (27%), and operation and maintenance stage (9%). The literature review, however, clearly reveals that the BIM implementation and adaptation in the GCC construction industry is quite slow due to some factors. This article, therefore, attempted to explore the current status of the BIM implementation and the challenges associated with its adaptation in the GCC construction industry. A mixed research methodology was adopted to achieve the aim of this research. the results from the systematic literature review that incorporated some of the main databases from 2010 to 2019 show that the broadly divided categories of the main challenges are Technical, Organization, Environment, and Government and Legal. These results from the literature review were then subjected to a group of respondents from the top construction organizations working in the GCC region. A total of 104 respondents participated in the study, however, eight questionnaires were rejected as they were not fulfilling the set criteria, this the valid questionnaire used in the results and analysis was 96. The results and analysis provided quite useful information to understand the overall situation of BIM over the GCC region. For instance, 68.75% of the respondents noted that currently, their organizations do not implement BIM in their current projects. Similarly, 73.95% of the participants reported that their organizations do not know the BIM implementation benefits. The current BIM implementation is therefore justified as if an organization does not know the benefits of technology, they would not adopt it. It clearly, trigger out that there is a need to increase the awareness associated with the BIM benefits so that it can attract the construction organizations in the GCC region. The positive aspect of the respondents was that the majority (69.79%) of them reported that their organizations are planning to implement BIM in their future projects. the respondents considered the challenges fall under the main category of “Organization” (4.15±0.96) as the top-rated challenge in the way of the BIM implementation in the GCC construction industry. This category was followed by “Technical” (4.03±0.91), Government and Legal (4.01±1.03), and then “Environment” (3.94±0.92) category. The sub-categories of the challenges in these main items were also ranked as mentioned in table 6. The sub-categories of the challenges were also ranked irrespective of their main categories and thus the top five rated challenges reported in this study were “Resistance to change” (4.95±1.03), “Unwillingness to try BIM process” (4.71±0.86), “Lack of support from top management” (4.68±0.88), “Improper interoperability between traditional methods and BIM” (4.64±0.91), and “negative attitude towards working collaboratively” (4.63±0.86). The results of this study help to understand the overall situation including the challenges in the BIM implementation in the GCC construction industry. The implementation of new technological tools such as BIM is in the great interest of all stakeholders including the government, designer, client, and contractors. Thus, this study will be helpful for these organizations to develop strategies for the effective implementation of BIM in the GCC construction industry. Further research is recommended to explore how each challenge in the BIM implementation can be overcome in the GCC region considering different solutions.

5. Appendix I:

Keywords	Period	Inclusion Criteria	Exclusion Criteria	Database	Total Downloaded Articles/ Reports	Total Articles/ Reports/ Tools After Criteria	Derived Challenges in BIM Implementation
Building Information Modelling, BIM Implementation, Barriers, Challenges in BIM	January, 2010 to September, 2019	Publications and Reports on BIM implementation, barriers and challenges in architecture, engineering, and construction (AEC)	Publications and Reports where the keywords are not in the title, abstract or in the keywords Articles and Reports in a non-English language	Web of Science Pro Quest Scopus Science Direct	172	47	**1. Technical:** I) Difficulty in adapting BIM Technology and Process ii) Lack of domestic-oriented BIM Tools iii) Increased workload for model development iv) Cost of technology v) BIM training and its cost vii) The complexity of BIM technologies (software) viii) The requirement of high-specification computers

							2. Organization: i) Resistance to change ii) Negative attitude towards data sharing iii) Misunderstanding of BIM iv) Negative Attitude towards working collaboratively v) Lack of a well-established BIM-based workflow vi) Immature dispute resolution mechanisms for BIM implementation vii) Lack of BIM knowledge viii) Lack of awareness of BIM benefits ix) Lack of BIM expertise x) Reluctance to hire BIM experts

							xi) Fear of the outcomes xii) Reluctance to change to BIM xiii) Lack of collaboration among parties xiv) Immigration of skilled experts xv) Lack of support from top management **3. Environment:** i) Lack of professional Interactivity ii) Insufficient external motivation iii) Lack of research on BIM implementation GCC iv) Improper introduction of BIM concepts v) Unwillingness to try BIM process vi) Lack of experience

							vii) Improper interoperability between traditional methods and BIM viii) Lack of BIM demand ix) Lack of time to implement x) Immigration of skilled experts **4. Government/Legal:** i) Lack of protection for intellectual property rights ii) Lack of BIM standards iii) Lack of a standard form of contract for BIM implementation iv) Lack of insurance applicable to BIM implementation v) No-governmental enforcements vi) Lack of national

							agenda vii) Lack of support and motivation

6. References:

Akinade, O.O., Oyedele, L.O., Ajayi, S.O., Bilal, M., Alaka, H.A., Owolabi, H.A. and Arawomo, O.O., 2018. Designing out construction waste using BIM technology: Stakeholders' expectations for industry deployment. Journal of Cleaner Production, 180, pp.375-385.

Akinci, B., Fischer, M., and Zabelle, T. (1998). Proactive approach for reducing non-value adding activities due to time-space conflicts. Proc. 6th Annual Conf. of the Int'l. Group for Lean Constr., (IGLC 6), Guaruja, Brazil.

Alexander, J.C. (1983) Theoretical Logic in Sociology, Vol. 1–4, University of California Press, Berkeley, California, United States.

Al-Hazim, N., Salem, Z.A. and Ahmad, H., 2017. Delay and cost overrun in infrastructure projects in Jordan. Procedia Engineering, 182, pp.18-24.

Al-Momani, A.H., 2000. Construction delay: a quantitative analysis. International journal of project management, 18(1), pp.51-59.

Alnuaimi A S and Mohsin M A Al 2013. Causes of Delay in Completion of Construction Projects in Oman Int. Conf. on Innovations in Engineering and Technology (Bangkok, Thailand) (Bangkok: International Institute of Engineers) pp 267–270.

Al-Werikat, G., 2017. Analysing the role of clients in the Jordanian construction supply chain delays. Int. J. Eng. Res. Sci. Technol, 6, pp.22-29.

Alzaydi, A. 2014. Recycling Potential of Construction and Demolition Waste in GCC Countries. Scientific Forum in the Recycling of Municipal Solid Waste. The Centre of excellence in Environmental Studies (CEES), King Abdulaziz University, Jeddah.

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K.J.S.S., 2011-b. BIM adoption and implementation for architectural practices. Structural survey, 29(1), pp.7-25. https://doi.org/10.1108/02630801111118377.

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'reilly, K., 2011-a. Technology adoption in the BIM implementation for lean architectural practice. Automation in construction, 20(2), pp.189-195. https://doi.org/10.1016/j.autcon.2010.09.016.

Arunkumar, S., Suveetha, V. and Ramesh, A., 2018. A feasibility study on the implementation of building information modeling (BIM): from the architects'& engineers' perspective. Asian Journal of Civil Engineering, 19(2), pp.239-247. https://doi.org/10.1007/s42107-018-0020-9.

Ayoub, N., Musharavati, F., Pokharel, S. and Gabbar, H.A., 2014. Energy consumption and conservation practices in Qatar—A case study of a hotel building. Energy and Buildings, 84, pp.55-69. https://doi.org/10.1016/j.enbuild.2014.07.050.

Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. Leadership and Management in Engineering, 11(3), 241–252. https://doi.org/10.1061/(asce)lm.1943-5630.0000127.

Banawi, A. (2017). Barriers to Implement Building Information Modeling (BIM) in Public Projects in Saudi Arabia. Advances in Intelligent Systems and Computing, 119–125. https://doi.org/10.1007/978-3-319-60450-3_12.

Barlish, K. and Sullivan, K., 2012. How to measure the benefits of BIM—A case study approach. Automation in construction, 24, pp.149-159. https://doi.org/10.1016/j.autcon.2012.02.008.

BMI, 2018. (Business Monitor International Ltd). Oman Infrastructure Report. BMI, Rsearch, 2018. London, UK. See: https://store.bmiresearch.com/oman-infrastructure-report.html (accessed 04/02/2018).

Boote, D.N. and Beile, P., 2005. Scholars before researchers: On the centrality of the dissertation literature review in research preparation. Educational researcher, 34(6), pp.3-15. http://dx.doi.org/10.3102/0013189x034006003.

Bortolini, R., Shigaki, J. S., and Formoso, C. T. (2015). Site Logistic planning and control using 4D Modelling: A Study in a Lean Car Factory Building Site, Proceedings. 23rd Annual Conference of the International Group for Lean Construction, 28-31 July, Perth, Australia, 361-370.

Brooks, G., Kinsley, K. and Owens, T., 2014. 3D printing as a consumer technology business model. International Journal of Management & Information Systems (Online), 18(4), p.271. https://doi.org/10.19030/ijmis.v18i4.8819.

Bryman, A., 2016. Social research methods. Oxford university press. Oxford, UK.

CBO (Central Bank of Oman), 2015. Annual Report 2014. Central Bank of Oman, Muscat, Oman. See: https://cbo.gov.om/sites/assets/Documents/English/Publications/AnnualReports/AnnualReport2014.pdf (accessed 05/09/2019).

Charef, R., Alaka, H. and Emmitt, S., 2018. Beyond the third dimension of BIM: A systematic review of literature and assessment of professional views. Journal of Building Engineering, 19, pp.242-257. https://doi.org/10.1016/J.JOBE.2018.04.028.

Coates, P., Arayici, Y., Koskela, Lauri, Kagioglou, Mike, Usher, C. and O'Reilly, K. (2010) The Limitations of BIM in the Architectural Process. In: ICSU 2010: First International Conference on Sustainable Urbanization, 15-17th December 2010, Harbour Grand Kowloon, Hung Hom, Kowloon, Hong Kong.

Criminale, A. and Langar, S., 2017. Challenges with BIM implementation: a review of literature. In Proceedings of 53rd Associated School of Construction International Conference, Seattle, WA, April (pp. 5-8).

Dawson, V., 2012. Science teachers' perspectives about climate change. Teaching Science: The Journal of the Australian Science Teachers Association, Vol. 58 Issue 3, p8-13.

Doumbouya, L., Gao, G. and Guan, C., 2016. Adoption of the Building Information Modeling (BIM) for construction project effectiveness: The review of BIM benefits. American Journal of Civil Engineering and Architecture, 4(3), pp.74-79. https://doi.org/10.12691/ajcea-4-3-1.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C. and McNiff, S., 2013. BIM implementation throughout the UK construction project lifecycle: An analysis. Automation in construction, 36, pp.145-151. https://doi.org/10.1016/j.autcon.2013.09.001.

EIA (Energy Information Administration), 2016. Share of the Total Energy Consumed by End Use Sector in the United States in 2016. Energy Information Administration, Washington, United States.

EIA Energy Information Administration), 2012. World Energy Consumption by Sector. Energy Information Administration, Washington, United States.

Elawi, G.S.A., Algahtany, M. and Kashiwagi, D., 2016. Owners' perspective of factors contributing to project delay: case studies of road and bridge projects in Saudi Arabia. Procedia Engineering, 145, pp.1402-1409. https://doi.org/10.1016/j.proeng.2016.04.176.

Emam H, Farrell P and Abdelaal M 2015. Causes of delay on infrastructure projects in Qatar Procs 31st Annual ARCOM Conf. (Lincoln, UK) (Lincoln, UK: Association of Researchers in Construction Management) pp 773–782.

Fellows, R.F. and Liu, A.M., 2015. Research methods for construction. John Wiley & Sons, Oxford, United Kingdom.

Filho, W. L., Salvia, A. L., Paço, A. do, Anholon, R., Gonçalves Quelhas, O. L., Rampasso, I. S., … Brandli, L. L. (2019). A comparative study of approaches towards energy efficiency and renewable energy use at Higher Education Institutions. Journal of Cleaner Production, 117728. https://doi.org/10.1016/j.jclepro.2019.117728.

Gamil, Y. and Rahman, I.A.R., 2019. Awareness and challenges of building information modelling (BIM) implementation in the Yemen construction industry. Journal of Engineering, Design and Technology. https://doi.org/10.1108/JEDT-03-2019-0063.

Gerrish, T., Ruikar, K., Cook, M., Johnson, M., Phillip, M., & Lowry, C. (2017). BIM application to building energy performance visualisation and management: Challenges and potential. Energy and Buildings, 144, 218–228. https://doi.org/10.1016/j.enbuild.2017.03.032.

Graneheim UH and Lundman B (2004) ''Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness''. Nurse Education Today Feb 2004; 24(2): 105-12. https://doi.org/10.1016/j.nedt.2003.10.001.

Grant, M. J., and A. Booth. 2009. "A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies." Health Information and Libraries Journal 26 (2): 91–108. http://dx.doi.org/10.1111/j.1471-1842.2009.00848.x.

Gu, N. and London, K., 2010. Understanding and facilitating BIM adoption in the AEC industry. Automation in construction, 19(8), pp.988-999. https://doi.org/10.1016/j.autcon.2010.09.002.

Guetterman, T.C., Babchuk, W.A., Howell Smith, M.C. and Stevens, J., 2019. Contemporary approaches to mixed Methods–Grounded theory research: A Field-Based analysis. Journal of Mixed Methods Research, 13(2), pp.179-195. https://doi.org/10.1177/1558689817710877.

Hall, J., 2018. Top 10 Benefits of BIM in Construction. Connect and Construction, AutoDesk BIM 360. See: https://connect.bim360.autodesk.com/benefits-of-bim-in-construction (accessed 30/04/2020).

Hsiao, S.J., Li, Y.C., Chen, Y.L. and Ko, H.C., 2009. Critical factors for the adoption of mobile nursing information systems in Taiwan: the nursing department administrators' perspective. Journal of medical systems, 33(5), p.369. https://doi.org/10.1007/s10916-008-9199-8.

Jeyaraj, A., Rottman, J.W. and Lacity, M.C., 2006. A review of the predictors, linkages, and biases in IT innovation adoption research. Journal of information technology, 21(1), pp.1-23. https://doi.org/10.1057%2Fpalgrave.jit.2000056.

Jung, W. and Lee, G., 2015. The status of BIM adoption on six continents. International journal of civil, environmental, structural, construction and architectural engineering, 9(5), pp.444-448.

Kassem, M. and Succar, B., 2017. Macro BIM adoption: Comparative market analysis. Automation in Construction, 81, pp.286-299. https://doi.org/10.1016/j.autcon.2017.04.005.

Keskin, B., Ozorhon, B. and Koseoglu, O., 2019. BIM Implementation in Mega Projects: Challenges and Enablers in the Istanbul Grand Airport (IGA) Project. In Mutis, I., & Hartmann, T. (Eds.) Advances in Informatics and Computing in Civil and Construction Engineering (pp. 881-888). Springer, Cham.

Khodeir, L.M. and Nessim, A.A., 2017. BIM2BEM integrated approach: Examining status of the adoption of building information modelling and building energy models in Egyptian architectural firms. Ain Shams Engineering Journal. https://doi.org/10.1016/j.asej.2017.01.004.

Khosrowshahi, F. and Arayici, Y., 2012. Roadmap for implementation of BIM in the UK construction industry. Engineering, Construction and Architectural Management, 19(6), pp.610-635. https://doi.org/10.1108/09699981211277531.

Kock, N., 2015. One-tailed or two-tailed P values in PLS-SEM? International Journal of e-Collaboration (IJeC), 11(2), pp.1-7. https://doi.org/10.4018/ijec.2015040101.

Kotrlik, J.W.K.J.W. and Higgins, C.C.H.C.C., 2001. Organizational research: Determining appropriate sample size in survey research appropriate sample size in survey research. Information technology, learning, and performance journal, 19(1), pp.43-50.

Kouider, T., G. Paterson, and C. Thomson. 2007. “Bim as a Viable Collaborative Working Tool: A Case Study.” In Yu Gang; Zhou Qi, and Dong Wei (Editors). Proceedings of the 12th International Conference on Computer Aided Architectural Design Research in Asia. 19-21 April 2007, Beijing, China. Pp. 57–68http://papers.cumincad.org/data/works/att/caadria2007_057.content.pdf.

Lee, G., Lee, J. and Jones, S.A., 2012. The business value of BIM in South Korea. SmartMarket Report. See: https://www.icn-solutions.nl/pdf/bim_construction.pdf (accessed 09/11/2019).

Levy, Y. and Ellis, T.J., 2006. A system approach to conduct an effective literature review in support of information systems research. Informing Science, 9 (2006). pp 181 – 212. http://www.scs.ryerson.ca/aferworn/courses/CP8101/CLASSES/ConductingLiteratureReview.pdf.

Li, H., Ng, S.T., Skitmore, M., Zhang, X. and Jin, Z., 2017. Barriers to building information modelling in the Chinese construction industry. In Proceedings of the Institution of Civil Engineers-Municipal Engineer (Vol. 170, No. 2, pp. 105-115). ICE Publishing. https://doi.org/10.1680/jmuen.16.00059.

Liao, L., & Ai Lin Teo, E. (2018). Organizational Change Perspective on People Management in BIM Implementation in Building Projects. Journal of Management in Engineering, 34(3), 04018008. https://doi.org/10.1061/(asce)me.1943-5479.0000604.

Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gøtzsche, P.C., Ioannidis, J.P., Clarke, M., Devereaux, P.J., Kleijnen, J. and Moher, D., 2009. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. PLoS medicine, 6(7), p.e1000100. https://doi.org/10.1136/bmj.b2700.

Love, P.E., Zhou, J., Matthews, J. and Luo, H., 2016. Systems information modelling: Enabling digital asset management. Advances in Engineering Software, 102, pp.155-165. https://doi.org/10.1016/j.advengsoft.2016.10.007.

MagiCAD, 2020. BIM Adoption in Europe: Current State, Challenges and A Vision of Tomorrow. MagiCAD, Finland.

Malsane, S.M. and Sheth, A.Z., 2015. Simulate construction schedules using BIM 4D application to track progress. TheIIER International Conference, London, United Kingdom, 20th April 2015, pp.10-15.

Martinez-Aires, M.D., Lopez-Alonso, M. and Martinez-Rojas, M., 2018. Building information modeling and safety management: A systematic review. Safety science, 101, pp.11-18. https://doi.org/10.1016/j.ssci.2017.08.015.

Masood, R., Kharal, M.K.N. and Nasir, A.R., 2014. Is BIM adoption advantageous for construction industry of Pakistan? Procedia Engineering, 77, pp.229-238. https://doi.org/10.1016/j.proeng.2014.07.021.

Maxwell, J.A., 2019. Distinguishing between quantitative and qualitative research: A response to Morgan. Journal of Mixed Methods Research, 13(2), pp.132-137. https://doi.org/10.1177/1558689819828255.

McKiernan, E.C., Schimanski, L.A., Nieves, C.M., Matthias, L., Niles, M.T. and Alperin, J.P., 2019. Meta-research: use of the journal impact factor in academic review, promotion, and tenure evaluations. ELife, 8, p.e47338.

MEED (Middle East Economic Digest), 2019. GCC projects market slumps in 2018. Middle East Economic Digest (MEED), Dubai, United Arab Emirates. See: https://www.meed.com/gcc-projects-market-slumps-2018/ (accessed 10/08/2019).

Mehran, D., 2016. Exploring the Adoption of BIM in the UAE Construction Industry for AEC Firms. Procedia Engineering, 145, pp.1110-1118. http://creativecommons.org/licenses/by-nc-nd/4.0/.

Melville, N., Kraemer, K., and Gurbaxani, V., 2004. Review: information technology and organizational performance: an integrative model of IT business value. MIS quarterly, 28 (2), 283–322.

Mesároš, P. and Mandičák, T., 2017. Exploitation and benefits of BIM in construction project management. In IOP Conference Series: Materials Science and Engineering (Vol. 245, No. 6, p. 062056). IOP Publishing.: https://doi.org/10.1088/1757-899X/245/6/062056.

Migilinskas, D., Pavlovskis, M., Urba, I. and Zigmund, V., 2017. Analysis of problems, consequences and solutions for BIM application in reconstruction projects. Journal of Civil Engineering and Management, 23(8), pp.1082-1090. https://doi.org/10.3846/13923730.2017.1374304.

Motamedi, A. and Hammad, A., 2009. Lifecycle management of facilities components using radio frequency identification and building information model. Journal of Information Technology in Construction (ITCON), 14(18), pp.238-262. http://www.itcon.org/2009/18.

Mullins, G., & Kiley, M. (2002). “It’s a PhD, not a Nobel Prize”: How experienced examiners assess research theses. Studies in Higher Education, 27(4), 369-386. http://dx.doi.org/10.1080/0307507022000011507.

NBS, 2014. The top five barriers to BIM implementation. NBS, United Kingdom. https://www.thenbs.com/knowledge/the-top-five-barriers-to-bim-implementation (accessed 02/05/2020).

NCSI (National Centre for Statistic and Information), 2015. Statistical Yearbook. National Centre for Statistic and Information, Muscat, Oman. See: https://www.ncsi.gov.om/Elibrary/LibraryContentDoc/bar_Statistical_Year_Book_2015_ce39a978-0e80-4b04-b240-1ffe6ada445c.pdf (accessed 05/09/2019).

OSC (Oman Society of Contractors). 2016. Annual General Meeting: Distribution of Expatriate in Construction Organizations of Oman. OSC, Muscat, Oman.

Ouda, O. K. M., Peterson, H. P., Rehan, M., Sadef, Y., Alghazo, J. M., & Nizami, A. S. (2017). A Case Study of Sustainable Construction Waste Management in Saudi Arabia. Waste and Biomass Valorization. https://doi.org/10.1007/s12649-017-0174-9.

Pacheco, R., Ordóñez, J. and Martínez, G., 2012. Energy efficient design of building: A review. Renewable and Sustainable Energy Reviews, 16(6), pp.3559-3573. https://doi.org/10.1016/j.rser.2012.03.045.

Papamichael, K., 1999. Application of information technologies in building design decisions. Building Research & Information, 27(1), pp.20-34. https://doi.org/10.1080/096132199369624.

Paré, Guy, Marie-Claude Trudel, Mirou Jaana, and Spyros Kitsiou. 2015. “Synthesizing Information Systems Knowledge: A Typology of Literature Reviews.” Information & Management 52:183–99. http://dx.doi.org/10.1016/j.im.2014.08.008.

Peng, C., 2016. Calculation of a building's life cycle carbon emissions based on Ecotect and building information modeling. Journal of Cleaner Production, 112, pp.453-465. https://doi.org/10.1016/j.jclepro.2015.08.078.

Randolph, J.J., 2009. A guide to writing the dissertation literature review. Practical Assessment, Research & Evaluation, 14(13), pp.1-13. https://scholarworks.umass.edu/pare/vol14/iss1/13.

Redling, A., 2018. Construction debris volume to surge in coming years. Construction & Demolition Recycling. Construction & Demolition Recycling Magazine, Ohio, United States. See: https://www.cdrecycler.com/article/global-volume-construction-demolition-waste/ (accessed30/04/2020).

RIBA (Royal Institute of British Architects), 2016. National BIM Report 2016. Royal Institute of British Architects, UK. See: https://www.thenbs.com/knowledge/national-bim-report-2016 (accessed 02/05/2020).

Sacks, R., Eastman, C., Lee, G. and Teicholz, P., 2018. BIM handbook: a guide to building information modeling for owners, designers, engineers, contractors, and facility managers. John Wiley & Sons. New Jersey, United States.

Shi, Y., 2017. 118. Life Cycle Cost of Green Building Based on BIM Technology. Revista de la Facultad de Ingeniería, 32(11).

Shih, T.-H., & Xitao Fan. (2008). Comparing Response Rates from Web and Mail Surveys: A Meta-Analysis. Field Methods, 20(3), 249–271. https://doi.org/10.1177/1525822x08317085.

Singh, I., 2017. BIM adoption and implementation around the world: Initiatives by major nations. Geospatial World, 4. See: https://www.geospatialworld.net/blogs/bim-adoption-around-the-world/ (accessed 02/05/2020).

Succar, B. and Kassem, M., 2015. Macro-BIM adoption: Conceptual structures. Automation in construction, 57, pp.64-79. https://doi.org/10.1016/j.autcon.2015.04.018.

Succar, B., Sher, W. and Williams, A., 2012. Measuring BIM performance: Five metrics. Architectural Engineering and Design Management, 8(2), pp.120-142. https://doi.org/10.1080/17452007.2012.659506.

Sullivan, G., Barthorpe, S., and Robbins, S. (2011). Managing Construction Logistics, Wiley-Blackwell.

Sweis, G., Sweis, R., Hammad, A.A. and Shboul, A., 2008. Delays in construction projects: The case of Jordan. International Journal of project management, 26(6), pp.665-674.

Tahir, M.M., Haron, N.A., Alias, A.H., Harun, A.N., Muhammad, I.B. and Baba, D.L., 2018. Improving Cost and Time Control in Construction Using Building Information Model (BIM): A Review. Pertanika Journal of Science & Technology, 26(1), 21 - 36.

Tan, T., Chen, K., Xue, F. and Lu, W., 2019. Barriers to Building Information Modeling (BIM) implementation in China's prefabricated construction: An interpretive structural modeling (ISM) approach. Journal of Cleaner Production, 219, pp.949-959. https://doi.org/10.1016/j.jclepro.2019.02.141.

TBO (Tender Board of Oman) (2018) International Registered Companies. TBO, Muscat, Oman. See: https://etendering.tenderboard.gov.om/product/ReportAction?eventFlag=SearchVendPublic (accessed 04/02/2018).

TBO, 2018. (Tender Board of Oman). International Registered Companies. 2018. Tender Board of Oman. See: https://etendering.tenderboard.gov.om/product/ReportAction?eventFlag=SearchVendPublic (accessed 04/02/2018).

Terreno, S., Anumba, C.J., Gannon, E. and Dubler, C., 2015. The benefits of BIM integration with facilities management: A preliminary case study. In Computing in Civil Engineering 2015 (pp. 675-683). https://doi.org/10.1061/9780784479247.084.

Tse, T.C.K., Wong, K.D.A. and Wong, K.W.F., 2005. The utilisation of building information models in nD modelling: a study of data interfacing and adoption barriers. Journal of information technology in construction (ITcon), 10(8), pp.85-110. http://www.itcon.org/2005/08/.

Umar T and Wamuziri S (2016-b). A review of construction safety, challenges and opportunities – Oman perspective. In Proceedings of 5th World Construction Symposium, Colombo, Sri Lanka (Sandanayake YG, Karunasena GI and Ramachandra T (eds)). University of Moratuwa, Colombo, Sri Lanka, pp. 14–22.

Umar T, Wamuziri S and Egbu C (2017). Factors that influence safety climate in construction in Oman. In Proceedings of Joint CIB W099 and TG59 International Safety, Health, and People in Construction Conference, Cape Town, South Africa (Emuze F and Behm M (eds)). pp. 99–113, ISBN: 978-1-920508-78-4.

Umar, T. and Egbu, C., 2018. Perceptions on safety climate: a case study in the Omani construction industry. Proceedings of the ICE-Management, Procurement and Law, 171(6), pp.251-263. https://doi.org/10.1680/jmapl.18.00001.

Umar, T. and Wamuziri, S., 2017. Using 'safety climate factors' to improve construction safety. Proceedings of the Institution of Civil Engineers-Municipal Engineer (Vol. 170, No. 2, pp. 65-67). Thomas Telford Ltd. https://doi.org/10.1680/jmuen.16.00020.

Umar, T., & Wamuziri, S. (2016-a). Conventional, wind and solar energy resources in Oman. Proceedings of the Institution of Civil Engineers - Energy, 169(4), 143–147. https://doi.org/10.1680/jener.16.00011.

Umar, T., 2017, July. Towards a sustainable energy: the potential of biomass for electricity generation in Oman. Proceedings of the Institution of Civil Engineers-Engineering Sustainability (Vol. 171, No. 7, pp. 329-333). Thomas Telford Ltd. https://doi.org/10.1680/jensu.17.00001.

Umar, T., 2018-a. Causes of delay in construction projects in Oman. Middle East Journal of Management, 5(2), pp.121-136. https://doi.org/10.1504/mejm.2018.091132.

Umar, T., 2018-b. Geothermal energy resources in Oman. Proceedings of the Institution of Civil Engineers-Energy, 171(1), pp.37-43. https://doi.org/10.1680/jener.17.00001.

Umar, T., 2020-a. An Integrated Sustainability Management Approach for Universities. Proceedings of the Institution of Civil Engineers-Engineering Sustainability (pp. 1-12). Thomas Telford Ltd. https://doi.org/10.1680/jensu.19.00014.

Umar, T., 2020-b. Key Factors Influencing the Implementation of Three-Dimensional Printing in Construction. Proceedings of the Institution of Civil Engineers-Management, Procurement and Law, pp.1-12. https://doi.org/10.1680/jmapl.19.00029.

Umar, T., Egbu, C., Honnurvali, M.S., Saidani, M. and Al-Bayati, A.J., 2019-a. Status of occupational safety and health in GCC construction. Proceedings of the Institution of Civil Engineers-Management, Procurement and Law. 172 (4), pp. 137-141. https://doi.org/10.1680/jmapl.18.00053.

Umar, T., Egbu, C., Honnurvali, M.S., Saidani, M. and Al-Mutairi, M., 2018. An assessment of health profile and body pain among construction workers. Proceedings of the Institution of Civil Engineers-Municipal Engineer (pp. 1-12). Thomas Telford Ltd. https://doi.org/10.1680/jmuen.18.00019.

Umar, T., Egbu, C., Ofori, G., Honnurvali, M.S., Saidani, M. and Opoku, A., 2020-b. Challenges towards renewable energy: an exploratory study from the Arabian Gulf region. Proceedings of the Institution of Civil Engineers-Energy, 173(2), pp.68-80. https://doi.org/10.1680/jener.19.00034.

Umar, T., Egbu, C., Ofori, G., Honnurvali, M.S., Saidani, M., and Opoku., A., 2019-b. Exploring Safety Climate in Construction. International Journal of Applied Management Science, Inderscience Publisher. https://doi.org/10.1504/IJAMS.2019. 253274.

Umar, T., Egbu, C., Ofori, G., Honnurvali, M.S., Saidani, M., Shibani, A., Opoku, A., Gupta, N. and Goh, K., 2020-a. UAE's commitment towards UN Sustainable Development Goals. Proceedings of the Institution of Civil Engineers-Engineering Sustainability (pp. 1-19). Thomas Telford Ltd. https://doi.org/10.1680/jensu.19.00036.

Umar, T., Egbu, C., Wamuziri, S. and Honnurvali, M.S., 2018. Occupational safety and health regulations in Oman. Proceedings of the Institution of Civil Engineers-Management, Procurement and Law, 171(3), pp.93-99. https://doi.org/10.1680/jmapl.18.00007.

UN SDGs (United Nations Sustainable Development Goals), 2015. Transforming our world: the 2030 Agenda for Sustainable Development. United Nation, New York, USA. See: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E (accessed 24/09/2017).

Valenzuela, M., Ha, V. and Etzioni, O., 2015, January. Identifying Meaningful Citations. In AAAI workshop: Scholarly big data. See: http://ai2-website.s3.amazonaws.com/publications/ValenzuelaHaMeaningfulCitations.pdf (accessed 19/08/2020).

Vass, S., & Gustavsson, T. K. (2017). Challenges when implementing BIM for industry change. Construction Management and Economics, 35(10), 597–610. https://doi.org/10.1080/01446193.2017.1314519.

Wang, X., Chen, Y., Liu, Y., Yao, L., Estill, J., Bian, Z., Wu, T., Shang, H., Lee, M.S., Wei, D. and Tian, J., 2019. Reporting items for systematic reviews and meta-analyses of acupuncture: the PRISMA for acupuncture checklist. BMC complementary and alternative medicine, 19(1), p.208. https://doi.org/10.1186/s12906-019-2624-3.

Wang, Y.M., Wang, Y.S. and Yang, Y.F., 2010. Understanding the determinants of RFID adoption in the manufacturing industry. Technological forecasting and social change, 77(5), pp.803-815. https://doi.org/10.1016/j.techfore.2010.03.006.

Welch, V., Petticrew, M., Petkovic, J., Moher, D., Waters, E., White, H., Tugwell, P. and PRISMA-Equity Bellagio group, 2016. Extending the PRISMA statement to equity-focused systematic reviews (PRISMA-E 2012): explanation and elaboration. Journal of Development Effectiveness, 8(2), pp.287-324. https://doi.org/10.1001/jama.2015.3656.

Whitlock, K., Abanda, F.H., Manjia, M.B., Pettang, C. and Nkeng, G.E., 2018. BIM for construction site logistics management. Journal of Engineering, Project, and Production Management, 8(1), p.47-51.

Woetzel, J., Sridhar, M., and Mischke, J., 2017. The construction industry has a productivity problem — and here's how to solve it. Market Watch. See: https://www.marketwatch.com/story/the-construction-industry-has-a-productivity-problem-and-heres-how-to-solve-it-2017-03-04 (accessed 02/05/2020).

Won, J., Cheng, J.C. and Lee, G., 2016. Quantification of construction waste prevented by BIM-based design validation: Case studies in South Korea. Waste Management, 49, pp.170-180. https://doi.org/10.1016/j.wasman.2015.12.026.

Won, J., Cheng, J.C. and Lee, G., 2016. Quantification of construction waste prevented by BIM-based design validation: Case studies in South Korea. Waste Management, 49, pp.170-180. https://doi.org/10.1016/j.wasman.2015.12.026.

Wong, K.D. and Fan, Q., 2013. Building information modelling (BIM) for sustainable building design. Facilities, 31(3/4), pp.138-157. Wong, K., & Fan, Q. (2013). Building information modelling (BIM) for sustainable building design. Facilities, 31(3/4), 138–157. https://doi.org/10.1108/02632771311299412.

Xiao, Y. and Watson, M., 2019. Guidance on conducting a systematic literature review. Journal of Planning Education and Research, 39(1), pp.93-112. http://dx.doi.org/10.1177/0739456x17723971.

Yee-Loong Chong, A., Ooi, K.B., Lin, B. and Yi Tang, S., 2009. Influence of interorganizational relationships on SMEs'e-business adoption. Internet Research, 19(3), pp.313-331. https://doi.org/10.1108/10662240910965379.

Yeh, C.C. and Chen, Y.F., 2018. Critical success factors for adoption of 3D printing. Technological Forecasting and Social Change, 132, pp.209-216. https://doi.org/10.1016/j.techfore.2018.02.003.

Yi, W. and Chan, A., 2016. Health Profile of Construction Workers in Hong Kong. International journal of environmental research and public health, 13(12), p.1232.

Yi, W., and Chan, Albert, P.C. (2017). Effects of Heat Stress on Construction Labor Productivity in Hong Kong: A Case Study of Rebar Workers. International Journal of Environmental Research and Public Health. DOI: 10.3390/ijerph14091055.

Yoders, J., 2009. Wisconsin becomes the first state to require BIM on large, public projects. Building Design & Construction. See: https://www.bdcnetwork.com/wisconsin-becomes-first-state-require-bim-public-projects (accessed 02/05/2020)

Zafar, S., 2018. Waste Management Outlook for the Middle East. In the Palgrave Handbook of Sustainability (pp. 159-181). Palgrave Macmillan, Cham, Basingstoke, United Kingdom.

Zhang, J. P., Ma, Z. Y., and Cheng, Pu, (2001). 4D Visualisation of Construction Site Management, Proceedings 5th International Conference on Information Visualisation, 382-387.

Zhang, S., Sulankivi, K., Kiviniemi, M., Romo, I., Eastman, C.M. and Teizer, J., 2015. BIM-based fall hazard identification and prevention in construction safety planning. Safety science, 72, pp.31-45. https://doi.org/10.1016/j.ssci.2014.08.001.

Zhu, K., Kraemer, K.L. and Xu, S., 2006. The process of innovation assimilation by firms in different countries: a technology diffusion perspective on e-business. Management science, 52(10), pp.1557-1576. https://doi.org/10.1287/mnsc.1050.0487.