

CASE STUDY

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Reviewing the effects of deploying building information modelling (BIM) on the adoption of sustainable design in Gulf countries: a case study in Saudi Arabia

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Abstract

Sustainable construction is a challenging prospect in Gulf countries such as Saudi Arabia and the use of Building Information Modelling (BIM) is often suggested as a solution. However, achieving improvement is associated with considerable challenges, particularly regarding energy efficiency improvements. Furthermore, the extreme environmental conditions in Saudi Arabia increase the demand for energy. As energy consumption in buildings is one of the main problems related to the built environment in both dry and hot climates, although in hot climates especially the issue is exacerbated by the particularly great need for cooling systems in buildings. On the other hand, one of the most important factors that affect Saudi Arabia's building design is gender and function, demonstrating how the culture of Saudi Arabia, significantly influenced by the Islamic religion, affects design. This paper aims to present a literature review of the area of sustainable building design and the impact of cultural issues, focusing on the case of Saudi Arabia. This paper has analysed related literature in the area of sustainable building design and the influence of cultural issues, focusing on the case of Saudi Arabia. This review has identified the lack of using technology to support designs in Saudi Arabia, lack of achieving sustainability in Saudi Arabia, culture issues effect on designing in Saudi Arabia, and lack of using Building Information Modelling (BIM) in Saudi Arabia for both public and private project. These issues have led to a series of recommendations that have the potential to improve the adoption of sustainable design in Saudi Arabia by using (BIM). Some of these recommendations are developing and understanding the influence of cultural issues on achieving sustainable design. Secondly, analysing the different viewpoints on sustainability between the experts and members of the public. Furthermore, developing a framework of measures of sustainable design for buildings with consideration of specific factors. Additionally, showing the current level of using BIM technologies. Finally, developing a methodology, supported by BIM, for both government and private projects.

Keywords: Sustainable design, Building information modelling (BIM), Cultural factor, Energy consumption

Introduction

Sustainable construction refers to the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life cycle, from siting to design, construction,

operation, maintenance, renovation, and deconstruction (Kibert 2016).

The sustainable construction change is now global in scope, with nearly 70 national green building councils introducing ambitious performance targets for the built environment in their countries. To develop green building, countries improve and conduct building assessment systems that produce ratings for buildings based on an evaluation of their performance against a wide range of

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environmental, economic, and social requirements (Kibert 2016).

Existing buildings around the world account for almost one third of global energy requirements and the availability of fossil fuels declining, there is an urgent need to guarantee that this energy need can be efficiently met and controlled using renewable energy (Kaewunruen et al. 2018). Many past research papers have mentioned the need to decrease the energy demands of existing buildings and to find alternative energy sources to fossil fuels. An European union report stated that 40% of total energy consumption happened from buildings approximately equal to the energy use in the United States (Union 2010), where buildings account for 41% of total energy consumption (Administration, E. I. and Department, E 2015).

The new United Nations Sustainable Development Goals (SDG) that seek to end poverty, protect the planet, and ensure prosperity for all, require transformative and solution-oriented research to offer the knowledge required to support changes towards sustainable development (Leal Filho et al. 2018). In this regard, Future Earth has been designed as a global research platform, seeking to provide the knowledge needed to help transformation geared towards sustainability and to contribute to reaching goals on global sustainable development (Leal Filho et al. 2018).

In addition, the global extraction of non-metallic minerals such as stone, sand, clay, and limestone, reached about 35 billion tonnes in 2010. Sand and stone included the main share of global extraction of non-metallic minerals in 2010 (40.8% stone and 31.1% sand) (Ghaffar et al. 2020). Infrastructure developments and construction projects are the main of this consumption. The change towards a better circular economy where output flows could be reintegrated as secondary help give a good solution for the construction industry. Materials in buildings that should support their value were buildings should work as banks of valuable materials and products (Ghaffar et al. 2020). This procedure can be done using smart design and circular construction, which is critical for a sector to facilitate both waste and the number of resources used. Consequently, new business models replace the 'end-of-life' perception with decreasing, recycling, reusing, and recovering materials in production and consumption methods (Ghaffar et al. 2020).

Many studies are supporting adopting a tough goal of net-zero CO₂ emissions by the year 2050 to supercharge a powerful new step to avoid pervasive climate damage (Deutch 2020). The path to net zero in the U.S. needs a change to an essentially all-electric economy. Such a change begins with deep decarbonization of the electricity system by leveraging the massive penetration of

renewable electricity generation notably wind and solar (Deutch 2020).

One of the keys enabling technologies in this area is Building Information Modelling (BIM), a technology that supports architects in digitally constructing buildings. "Building Information Modelling (BIM) is the process that uses technology to store and analyse various information about the building aiding in the design, construction, and life cycle management (renovation and or demolition) of the building" (Sackey 2014). This enables clients, architects, and engineers alike to specify and understand the building before it is built (Autodesk 2005). Moreover, this modelling enables different design choices for sustainability to be studied and tracked (Autodesk 2005), as BIM provides for multi-disciplinary information to be integrated into one model, it creates an opportunity for sustainability measures to be included during the design phase of a building's lifecycle (Autodesk 2008). More specifically, the three main fields of sustainable design with a direct relationship to BIM are: (a) material site selection and management; (b) selection and use; (c) systems analysis (Hardin 2009).

Even though Building Information Modelling (BIM) is often suggested as a solution. However, achieving improvement is associated with considerable challenges, particularly regarding energy efficiency, currently, the use of BIM along is often insufficient to overcome these issues (Tawfiq Abu- Gazzeh 1995). This is especially true in Gulf Countries, where their adoption of BIM has done little to tackle a lack of sustainable design (Tawfiq Abu- Gazzeh 1995).

This is an important issue in Gulf Countries as there has been a boom in the construction industry, due to large commercial development projects and heavy governmental investments in housing and infrastructure (Ali et al. 2013). However, in comparison to other countries, the issue of energy efficiency is not typically given serious consideration with respect to building designs (Hanan and Sharples 2010). This means, that, with energy consumption increasing in Gulf countries, a study showed that engineers should devising innovative designs for the development of energy-efficient and environmentally sustainable buildings (Abanomi and Jones 2005). Energy consumption is, thus, one of the main problems related to the built environment and is exacerbated in Gulf climates, by the need for cooling systems in buildings (Abanomi and Jones 2005).

One of the posited reasons for the lack of engagement with sustainable design in gulf countries is, despite the increasing availability of BIM technology, the lack of integration between this technology and the culture of the region. Culture is the common beliefs, social forms, and material traits of a racial, religious, or social group; also:

the characteristic features of daily existence shared by people in a place or time.

However, the culture of Gulf countries is different from many other countries. For instance, the use of spatial boundaries is the most important design factor for residents, as these are the primary means by which privacy is achieved (Tawfiq Abu- Gazzeh 1995). More specifically, architects in the Gulf countries design physical boundaries using walls, curtains, and other forms of barrier (Tawfiq Abu- Gazzeh 1995). Moreover, the Islamic culture has influenced two main design factors: (a) function; and (b) gender, this means architects face a challenge in managing boundaries and design to achieve buildings with lower energy consumption (Tawfiq Abu- Gazzeh 1995). The most important cultural factors that affect building design in Gulf countries are gender and function, demonstrating how the culture of these countries, significantly influenced by the Islamic religion, affects design (Tawfiq Abu- Gazzeh 1995). Specifically, separation of male and female areas is commonplace and is required to adhere to the Islamic way of life (Nordin 2018). Moreover, in gulf countries, spatial boundaries are of prime importance in planning the use of space; Saudis create physical boundaries using walls, curtains, and other partitions (Tawfiq Abu- Gazzeh 1995).

For this paper, Saudi Arabia specifically has been chosen as a case study. Saudi Arabia has been chosen as a case study due to, its status as one of the driest countries in the world and the fact that it is facing serious difficulties related to a rapid increase in water demand (Hanan and Sharples 2010). This, coupled with the fact that the Saudi Arabia has some of the fastest developing urban centres in the world, with associated high levels of building development, presents significant challenges, notably regarding the energy efficiency of buildings (Abanomi and Jones 2005).

This requires building developers in Saudi Arabia to negotiate both the cultural and technological realities to construct and renovate buildings that adopt sustainable design principles, and to design buildings that have slight impact on the physical environment and a lower demand for energy resources (Pushkar 2005), while also meeting cultural expectations of the occupants. This process has become termed as 'sustainable construction'. This means "creating a healthy built environment using resource-efficient, ecologically-based principles" (Hill and Bowen 1997).

Many sustainable buildings in hot climates make efficient use of energy, freeing residents from the significant costs associated with cooling systems (Zanni et al. 2017). However, difficulties appear as architects attempt to apply the design and technical standards linked with designing sustainable buildings; among the factors that

contribute to this problem is information paucity and cultural issues (Zanni et al. 2017). Saudi Arabia is conservative country that follows the rules transcribed in the Holy Quran (Åström et al. 2011). The culture of Saudi Arabia citizens is family-oriented, where families are close, and the elderly are respected, and their opinion is considered by all members of the family (North and Tripp 2009). It is not unusual to find extended families of three or four generations living in the same house (North and Tripp 2009). The Saudi culture has been described as the most preservationist culture in the world (Nordin 2018), this factor has significantly affected the structure of the Saudi house.

In Saudi Arabia, with energy usage increasing, building designers are devising innovative plans to drive an increase in energy-efficient and environmentally sustainable buildings (Abanomi and Jones 2005). Thus, sustainability is particularly challenging in Saudi Arabia, where the focus on sustainable design is increasing at a rapid pace. BIM has the potential to support this challenging activity by implementing digital versions of the proposed building, enabling designers to begin address the sustainability of the proposed building (Smith and Tardif 2009). However, even aided by BIM, building developers in Saudi Arabia must determine the technical requirements for constructing sustainable buildings, which must have less impact on the physical environment and a lower energy demand (Pushkar 2005). However, these buildings must also meet with local cultural expectations.

In this context, architects and designers must adopt standards for designing, estimating, grading, and certifying the energy performance of buildings in Saudi Arabia. This is a compliance measure that has been successfully used to achieve sustainable improvement in countries such as the UK, where the Building Research Establishment Environmental Assessment Method (BREEAM) rating scale is a popular tool. BREEAM in the UK, and different certification systems in other countries, are of high importance at the global level and play a key role in the entire construction of sustainability (Zeinal Hamedani and Huber, 2012).

This will present a literature review in the area of sustainable building design and the impact of cultural issues upon it. Based on this review, gaps will be identified and recommendations made to improve the adoption of culturally aligned sustainable design, both globally and in our Saudi Arabia case study.

Methodology and summary of the literature review

This paper aims to present a literature review of the impact of cultural issues on the implementation of sustainable design around the world, and the technological efforts which represents the current approach to solve

this issue. Based on this review, this study will outline a series of recommendations for future research in this area in Saudi Arabia. This is because the current generation of Saudi buildings are massively dependent on the air conditioning which wastes massive amounts of energy. This problem has originated due to the poorly designed buildings in many Gulf countries, which include Saudi Arabia. In these buildings approximately 80% of the building's electricity is used for air conditioning and cooling purposes (Hanan and Sharples 2010). Based on the findings of this paper, a pathway of research recommendations will be proposed to guide the Saudi construction sector to achieve more sustainable design with less impact on the environment and less use of fossil fuels. This is achieved by firstly analysing the fundamentals, general process, and main challenges of sustainable design through a literature review. This literature review will use several keywords to identify relevant studies. The main keywords are: Building Information Modelling (BIM), Cultural factors, religious factors, Sustainability, Sustainable building design, and Sustainable construction. The keywords of this study have been chosen since it has been comely used in studies that focused on the designing field, Sustainability, and the effect of the culture factor on the design process. These keywords will be used to drive searches in relevant academic online databases, including, google scholar, web of science, and Scopus. Additionally, within each keyword papers relevant specifically to Saudi Arabia will be identified.

This process has led to a corpus of many papers that were identified as relevant to this study, ranging in date from 1995 to 2019. These keywords and the number of papers, as shown in Table 1, below were analysed critically and classified in this study into three areas: (1) Sustainable design, (2) BIM, and (3) Cultural around the world and focusing on Saudi Arabia. These keywords were selected since it was commonly used in the available research in this area. In this study, each area will be reviewed conclusions, gaps identified, and then this will be used to present a list of recommendations and how could these recommendations be implemented in Saudi Arabia to fill the gap. Saudi Arabia specifically has been

chosen as a case study in this project for many reasons such as, construction industry, and energy consumption in the country.

Paper summary

The remainder of this paper is structured as follows: **Sustainability** will address the current situation of sustainability and specifically in Saudi Arabia; **Building Information Modelling (BIM)** will discuss BIM and specifically in Saudi Arabia; **Cultural factors affecting sustainable design** will highlight the cultural factors affecting construction and building design in Saudi Arabia; **Current Deployment of Sustainable design and Future Recommendations** will discuss the deployment of sustainable design in Saudi Arabia, also, will discuss the current uses of BIM for sustainable design and present some recommendations; and **Conclusion** will present the conclusion.

Sustainability

This section provides an overview of the existing literature considering sustainability, sustainable design in Saudi Arabia.

Sustainable design was defined by the United Nations World Commission on Environment and Development (WCED) as “development which meets the needs of the present generations without compromising the ability of the future generations to meet their own needs” (Brundtland 1987). This definition implies the need to achieve a balance between, on the one hand, economic growth, and development, and on the other, natural resource conservation and social balance (Langston and Mackley 1998). Sustainability is consequently concerned with reducing negative influences while improving the environment to guarantee a better quality of living for future generations. This requires using renewable natural resources in a way which does not diminish nor destroy them and using non-renewable natural resources at a rate slow enough to guarantee a clear societal shift to new alternatives (Langston and Mackley 1998). Sustainability problems are often categorized into three main types environmental, economic, and social and the principles of sustainable construction have been generally applied in several countries across the world. The following sub-sections will discuss the state of art for sustainability around the world, sustainability assessment, and sustainability in Saudi Arabia.

Sustainable design state of the art

According to Cho, Chen and Woo, construction experts now need to pay attention to sustainability and the energy performance of new buildings (Cho et al. 2011). Notably, society is increasingly conscious of the environmental and energy implications of special building

Table 1 Keywords and number of studies

| No | Keyword | Number of studies |
|----|------------------------------------|-------------------|
| 1 | BIM | 15 |
| 2 | BIM in Saudi Arabia | 12 |
| 3 | Cultural factors | 1 |
| 4 | Cultural factor in Saudi Arabia | 9 |
| 5 | Sustainable design | 40 |
| 6 | Sustainable design in Saudi Arabia | 31 |

designs. Consequently, researchers must explore the assets that designer and architects can leverage, to design energy efficient buildings (Kensek 2014). In addition, architects need to engage in preliminary brainstorming sessions before approving a construction plan. It is regularly documented that nearly 40% of global energy usage is linked with the construction and maintenance of project (Berardi et al. 2014). Buildings are also responsible for 33% of greenhouse gas emission around the world. Following the high rate of energy and resource consumption of buildings, different sustainable strategies and environmentally responsible energy-efficient technologies have been recommended and implemented to obtain low-energy buildings. These include energy-efficient systems, advanced eco-technologies, and renewable energy sources (Berardi et al. 2014).

In recent years, consumption of fossil fuels has been steadily rising and the excessive use of fuel energy has the potential to create environment problems including global warming, loss of the ozone layer, acid rain, and air pollution which in some cases relating to the buildings (Sudhakar et al. 2019). Furthermore, the conversion of energy from primary energy to electricity is low and 60–70% of the energy is lost in terms of waste heat, so waste heat recovery is needed to increase the overall energy conversion efficiency (Sudhakar et al. 2019). The Organic Rankins Cycle (ORC) is a promising technology for recovering low-grade heat from loss (Sudhakar et al. 2019).

The construction industry plays a top role in improving the quality of the built environment, but its actions also affect the wider environment in several ways. As the rate of construction is set to grow, there is a critical need to decrease waste at all phases of construction by considering the long-term effects of design (Osmani et al. 2008). However, the construction industry's culture and resistance to change are important challenges. Moreover, the architect has a strong role to play in supporting to reduce waste in construction at all levels by concentrating on designing. In order to maximise their impact, architects need to understand the problems, constraints and opportunities linked to the practical means by which improvements can be achieved. By enhancing design practices, architects could realistically and successfully accelerate the rate of change (Osmani et al. 2008).

Sustainability assessment

Sustainability assessment can be easily explained as a process that directs decision-making towards sustainability (Bond and Pope 2012). It has been named the third generation of impact assessment, following strategic environmental assessment (SEA) and environmental impact assessment (EIA) (Sadler and Petts 1999). Additionally, it

is true that it has developed simultaneously from other areas such as natural resource management and planning (Kemp et al. 2005). Arguably, the point has not been reached yet at which there is a universal agreement as to what sustainability assessment is, either how it should be implemented. The international practice differs considerably depending on the legal and governance structures in place and the form of decision-making, also the conceptualization of sustainability that is included in the process (Bond and Pope 2012).

Environmental Impact Assessment (EIA) has expanded around the world and currently, it has been followed in at least 191 countries (Morgan 2012). Moreover, the US Environmental Protection Agency is regarding the adoption of sustainability assessment and management process. That would support the classic steps in the actual impact assessment method, for instance, scoping, screening, stakeholder involvement, analysis, and approval decision-making. However, there are three key features which are Comprehensive and systems-based, Intergenerational, and Stakeholder involvement and collaboration (National Research Council of the National Academies 2011). That could propose a new phase of assessment, designed especially to help to achieve sustainable improvement as explained in original documents and events which have taken place since the National Environmental Policy Act (NEPA) was set in 1970 (Bond and Pope 2012). Moreover, many factors can affect the criteria used in sustainability assessment tools, such as cultural issues, social, economic, and environmental factors. Therefore, standard international methods for estimating the sustainability of construction projects in all countries do not yet exist, considering the differences in some of these areas (Banani et al. 2013).

Sustainability in Saudi Arabia

The extreme environmental conditions in Saudi Arabia increase the demand for water and energy; as such, it is one of the countries spending the most money on water desalination globally, despite its limited non-saltwater assets (The Economic Times and News 2013). The Saudi government has reserved approximately \$53 billion for various water projects to be completed by 2022, and throughout the following decade, approximately \$79.9 billion was reserved for energy projects (The Economic Times and News 2013).

In addition, there is a basic need to receive manageability in numerous sectors in Saudi Arabia, including the development sector, which is a significant purchaser of non-renewable assets, moreover, it is responsible for a significant proportion of waste generation and CO₂ emissions (Bakhoum and Brown 2012). Globally, the construction sector in developed nations expends

approximately 30% of total used energy and is responsible for 40% of carbon emissions (IPCC 2007). For instance, in the USA, buildings are responsible for 40% of the national energy utilization, 72% of power utilization, 39% of carbon emissions, and 13% of water utilization (U.S. Green Building Council. 2012).

Compounding the growing housing crisis in the Saudi Arabia is the lack of government regulations concerning the use of sustainable methods. There are no enforceable building codes, neither are there any regulations that integrate the principles of sustainability in the KSA, especially for architects and engineers (Karam 2010). Many researchers have argued that one of the most important and cost-effective methods to promote the use of sustainable methods is to establish a clear set of standards and codes, particularly concerning decreasing buildings' energy and water consumption (Karam 2010).

In recent years, Saudi Arabia has experienced significant economic growth due to high oil prices and continuing improvements in the country (Al-Yami and Price 2006). This has been driven by significant government construction projects and the development of infrastructure and building projects, including accommodation, private construction, hospitals, and schools, as well as the rapidly growing tourism sector (Al-Yami and Price 2006). At the same time, the Saudi government has paid important attention to protecting the environment, preserving biodiversity, natural resources, and ensuring a better quality of life (Al-Yami and Price 2006). The government has contributed significantly to sustainable development through the initiation of several policies, regulations, and reports by relevant agencies, which are playing an important role in realizing principles of sustainability in the Kingdom (Al-Yami and Price 2006). Furthermore, Saudi Arabia entered the following international environmental organizations during the Seventh Five-Year Development Plan: The United Nations Framework Convention on Climate Change (UNFCCC); the supplement to the Kyoto Protocol, which was approved in 2005; the United Nations Desertification Control; and the United Nations Bio-Diversity Convention (Al-Yami and Price 2006).

These impacts are increasing the need to create maintainability estimates that will guarantee the construction of practical and green buildings to limit the negative environmental influence (Abdallah and El-Rayes, K., and Liu, L. 2013). More than 600 rating frameworks for appraising the sustainability of buildings are used around the world (Saunders 2008). These rating frameworks are used to assess the sustainability of buildings in accordance with green building criteria (Asif 2016). The differences in natural environments from one nation to another have led to various sustainability measures/criteria and diverse significance loads for these measures. It is necessary for

every nation to develop a sustainability rating framework that fits with its environmental conditions. Also, improving environmental benefits of buildings through construction of more efficient structures increases wellbeing and relieves stress, and discomfort (Asif 2016). Moreover, the general impacts of such ideas benefit the entire network, and society overall (Asif 2016).

However, emerging technologies and methodologies are transforming how people work and live. The Fourth Industrial Revolution, also known as Industry 4.0, is having an immediate impact on how people communicate and interact with each other (Bolpagni et al. 2022). This change affects all industries, including the built environment, which is transitioning to the "Construction 4.0" era. Climate change and global health emergencies have accelerated the digitization and automation of the construction sector, demonstrating the importance of having reliable real-time data to support decision-making processes. Construction 4.0 is creating new job opportunities and necessitates the addition of new knowledge and skills (Bolpagni et al. 2022).

BIM is an improvement and utilization of a PC programming model to mimic the development and activity of an office (AGC, A. 2006). The subsequent model, the building information model, is an information-rich, canny, and advanced parametric portrayal of the office, from which information relevant to different clients' needs can be distinguished and examined to guide decision-making and improve the process of office conveyance (Asif 2016).

In conclusion, sustainability encompasses a mix of economic, environmental, and social responsibilities (Hanan and Sharples 2010). Given new and emerging environmental and energy concerns, there has been significant interest in Saudi Arabia in recent years concerning the concept of sustainable design (Hanan and Sharples 2010). The main drivers behind supporting sustainable design are environmental and energy considerations, as well as additional factors such as the desire to improve residents' quality of life and address health-related concerns in the KSA. In principle, sustainable buildings are related to the idea of climate-responsive design (Hyde 2000). This indicates the need for natural energy sources and systems to deliver building comfort through interactions between the dynamic conditions of the building's environment (Hyde 2000). For example, the placing of a window in a sustainable building is of vital importance as it could provide useful natural light, comfortable ventilation, and cooling.

Building information modelling (BIM)

This section provides an overview of the existing literature considering BIM in Saudi Arabia.

BIM can be described as a process of data sharing, exchange, and information management, which delivers a building from the early stage of design to finish the project within reusable and interoperable means (Valande, 2008). This confirms that BIM is a process rather than being a tool (Eadie 2013). It is important to note that some observers believe the acronym BIM should be modified to Building Information Management, while others use the expression BIM(M) to point to Building Information Modelling and Management (Eadie 2013). BIM functions are possible in several applications, such as Ecotect, Tekla structure, Autodesk Revit, and Energy Plus. Available BIM functions can also be utilized using the Revit API (Application Programming Interface), which is a valuable tool for including external applications into Revit products, such as transferring data to other applications or linking with an external database (Wu 2010).

According to the Royal Institute of British Architects (RIBA), BIM is a “digital representation of physical and functional properties of a facility creating a shared data resource for information about it forming a strong basis for decisions during its life cycle, from earliest conception stages to demolition” (Plan and of Work 2012 Overview. [online] Available at, 2012).

In the present condition of globalized business, examining the construction sector likely remains the ideal method for investigating financial conditions in the economy in general (Alhumayn et al. 2017). Construction industry projects remain fundamental to the arrangement of the framework and to employment creation throughout the world (Zhou et al. 2015). In terms of business promotion, the construction industry is a driving force.

Abubakar and colleagues argue that the business that the construction industry creates benefits incompetent, lower gifted, and young professionals who generally have few elective chances (Abubakar et al. 2014). Numerous nations globally are highly dependent on construction employment, and this sector has consistently been the single largest source of employment in Saudi Arabia (Asif 2016). Regardless of the undeniable importance of the construction business to the national economy of most nations, the industry worldwide has faced numerous criticisms for its wastefulness and low efficiency (Abubakar et al. 2014). These criticisms have generally been based on the complex process of supply chain management in the construction sector. Also, that the construction business is commonly seen as poorly managed (Hassan 2012).

Building information modelling (BIM) in Saudi Arabia

Although BIM is utilized in Saudi Arabia, it remains in the early phases, and BIM usage in the Saudi Arabia construction industry remains generally moderate (Asif

2016). This is because some business owners began to recognize the various advantages related to BIM usage, such as enabling different structure choices, the capacity to carry out numerous tests on a model, and its capacity to accommodate early identification of planned errors to reduce expensive rebuilds. The usage of BIM in construction in Saudi Arabia is, for the most part, carried out by a small number of large organizations; the subcontracting sector is relatively underdeveloped (Sodangi et al. 2016). Considering that BIM usage in Saudi Arabia is limited to the few largest organizations, and the subcontracting sector comprises mainly small and medium-size construction companies it is yet to appropriate BIM, making it is necessary relevant to develop systems that would guarantee the adoption of BIM by the industry (Sun et al. 2017).

Developed nations in Asia, Europe, and North America are presently receiving the benefits of BIM in continuous resource the executives alongside development venture conveyance. In an investigation directed by Gerges and colleagues to determine the present status of BIM in the Middle East by investigating the degree of BIM execution among partners in the construction industry, it was found that BIM reception in the Middle East has been unfavourable (Gerges et al. 2017). The authors further identified that just 20% of construction companies that are using BIM or are engaged with the BIM adoption process in some way, while the remaining 80% are neither applying it nor associated with it in a limited capacity. Some studies show that the use of BIM in some construction projects in Saudi Arabia, which, there are no available sources to determine the genuine status of BIM usage in the whole Saudi region. Chief among the findings of this study was evidence of a low usage rate for BIM in construction projects in the Saudi construction sector and the absence of BIM awareness and reluctance of partners to accept changes to the current working practices (Alhumayn et al. 2017).

In a related study by Ahmed and colleagues, the aim was to assess the awareness and experience levels of 4D planning and BIM in the construction industry in Qatar, and to distinguish the potential barriers to the general usage of BIM (Ahmed et al. 2014). The assessment was based on an industry-wide overview limited to related professionals in Qatar. Again, in the Middle East, Hamada and colleagues carried out a similar investigation on the use of BIM innovation to identify the key benefits and barriers that point of confinement BIM appropriation in the Iraqi construction industry. The findings of the study suggested low BIM adoption among construction experts in Iraq (Hamada et al. 2016). Much prior investigation was attempted in the Middle East by buildingSMART. The objective of the study was to provide important information on the construction market in relation to

BIM and to identify the relevant skills, proficiencies, and barriers to BIM usage. The respondents to the study were generally ventured proprietors, temporary workers, venture designers, specialists, and providers (Sun et al. 2017). The findings of the study showed that over half of the respondents did not use BIM, and approximately 20% were inexperienced with BIM, which suggests a low awareness level. Furthermore, the review uncovered that 'accessibility of skilled staff', 'cost of programming', and 'cost of usage' were the highest-ranking barriers to BIM appropriation in the area. However, the study did not explicitly plot the nations surveyed and the nations the respondents originated from. From the findings of the literature review discussed previously, BIM usage status is associated with awareness level, difficulties in execution, and barriers in selected Saudi regions. Considering the significance of the Saudi Arabia economy, which is one of the largest in the Middle East, and the volume of construction projects being initiated in Saudi Arabia, a similar study needs to be conducted to provide further insight into this subject (Alhumayn et al. 2017). However, there is no evidence of any such examination carried out in the context of the Saudi Arabian construction industry (Alhumayn et al. 2017).

One of the principal contributions of BIM to sustainable improvement, which additionally is one of its general uses, its immediate role in financial management. Evaluating the costs of a project and the required resources can be broken down into phases to predict and calculate the costs of each stage (Banawi 2017). In addition, to reducing the cost of a project, and aside from the 3D models of BIM portrayals, project administrators can utilize 4D models to measure the risks of the project more accurately and efficiently (Alhumayn et al. 2017). Despite the fact that this procedure can help the project to be dynamic and practical, it would not be considered a sustainable methodology unless it incorporated environmental benefit and individual and societal needs (Alhumayn et al. 2017). In addition, the use of BIM in different parts of the project can contribute significantly to cost efficiency (Alhumayn et al. 2017). For example, predicting the future requires coordinated efforts and communication among colleagues reducing wastage, saving time, improving the structure of the board, and lowering project costs (Alhumayn et al. 2017).

BIM is a building industry improvement that reflects a shift from electronic planning to a model-based procedure (Alhumayn et al. 2017). BIM is used to make a model that is not just a geometrical portrayal, but also contains information and properties that can be utilized by project members at any time and place (Brundtland 1987). The BIM model can be made 4D by associating model components with time timetables,

as typically 5D models involve coordinating cost estimations with model components (Alhumayn et al. 2017). Furthermore, 6D is defined as the representation of the As-Built model, an extension of the BIM model for Facilities Management that incorporates specific data required for the Operation & Maintenance (O&M) stage using information embodied in the rich Project Information Model (PIM) (Charef et al. 2018). O&M manuals, plans, and technical support can all be embedded in the 6D BIM. This is an "As-Built" model that must be updated throughout the asset lifecycle. The 6D is also defined by the National Building Specification (NBS) as a dimension that includes information to support facility management and operation actions (Charef et al. 2018).

Within BIM, a significant proportion of the information required for supporting a task's execution can be captured readily through planning (Salgueiro and Ferries 2015). By utilizing a structured data model, designers can dissect how a structure will perform in the early stages of planning and based on this, can rapidly survey structure choices to decide on the best option to repeat on a greener structure (Salgueiro and Ferries 2015). The majority of BIM tools have different benefits for assessing energy and material utilization investigation and an electrical and mechanical component of the structure with the aim that it would quickly generate data for reducing the wastage of energy and resources (Salgueiro and Ferries 2015). Part of the BIM programming, for example, Autodesk Ecotect and Revit, give some normal devices that process data to clarify the environmental benefits of the project. This further empowers designers and planners to manage utilization of energy and material assets effectively (Bahar et al. 2013). Giving examination on the sun-oriented way, building direction, concealing plan and warming, and cooling assurance, such programming can incorporate information to accomplish a greener structure (Bahar et al. 2013).

The Western Australia Council of Social Services (WACOSS) characterizes the event of social sustainability as "when the formal and casual procedures, frameworks, structures, and connections effectively bolster the limit of present and future ages to make sound and decent networks" (Ghahramanpouri et al. 2013). Socially practical networks are fair, various, associated, and law-based and provide personal satisfaction (Ghahramanpouri et al. 2013). Usually, the advantages of sustainability from a social perspective are considered inside enhancement for different aspects of sustainability, which result in advancing human prosperity, happiness, and wellbeing (Alhumayn et al. 2017). In regard to sustainability, social responsibility tends to incorporate a wide range of ideas and definitions, which can be separated into two groups

relative to their association with BIM: reliant and free benefits (Alhumayn et al. 2017).

However, most of the definitions and ideas recommended as socially sustainable plans are independent from different factors, which are primarily subjective (Sassi 2006). There are various different ways in which a sustainable building structure can improve personal satisfaction for the general public, leading to a better-quality environment, neighbourhood reclamation, and reducing threats to wellbeing from toxins related to building energy use (Asif 2016).

One of the benefits that can be considered is the openings in vernacular design and their advantages in inactive energy (significance and size) (Alhumayn et al. 2017). This issue can reach out to the arranging components of the area to take account of Islamic and cultural factors. If a new region is to be built, moving away from the present predominately cement neighbourhoods, investigating the utilization of latent cooling and conventional ventilation procedures could be helpful (Alhumayn et al. 2017). One of the current issues is the materials used for roads and structures, which add significantly to the warmth island impact made in existing urban communities. Conventions are significant, but not the only necessity for structures. Strict adherence to customary criteria may be wasteful. If a conventional building method is 10% or less incapable in energy reserve funds contrasted with the most feasible technique, at that point, the customary path is to be preferred (Alhumayn et al. 2017).

The significance of sustainability is that it must be considered in the initial phases of the project, beginning from the plausibility arrange, and should execute a few elements. Earth, as a building material, is the most practical material for housing in Saudi Arabia, as well as in the vast majority of the world (Sun et al. 2017). For a long time, it was the main building material used in Saudi Arabia, until oil wealth changed how Saudis planned and built their homes (Alhumayn et al. 2017). All districts of Saudi Arabia used earth as the principle building material, regardless of whether it was mud fortified with straws (as in the central, northern, and eastern regions) or stones (as in the western and southern areas). The new building methods using earth can make houses look very contemporary; the issue is with the architects and acknowledgement from individuals, as there is a psychological boundary to returning to the use of earth as a truly sustainable and appropriate solution for current conditions (Sun et al. 2017).

BIM is important in this study because it allows for a better design interpretation; better evaluation of design options; and better analysis, early detection, and resolution of conflicts between building components. BIM makes Mechanical Electrical Plumbing (MEP) and Fire

Protection (FP) work better, which is not optional in any project.

Cultural factors affecting sustainable design

This section provides an overview of the existing literature considering cultural factors which effect the sustainable design in Saudi Arabia.

According to the Merriam-Webster Dictionary (2010), culture is “the customary beliefs, social forms, and material traits of a racial, religious, or social group; also: the characteristic features of everyday existence (as diversions or a way of life) shared by people in a place or time” (Dictionary 2010).

In academic literature, the home environment is conceptualized in many ways. Some designers consider a home in terms of the rich interdependent psychological meaning for the residents (Stafford 2011). Different designers advise that a home represents a typical social communication that describes an interpersonal creative expression and style, also, describes the social network and social class of its homeowner (Othman et al. 2015).

The 2030 Agenda for Sustainable Development, which adopted by all United Nations Member States in 2015, aims to coordinate efforts to improve sustainable growth. The 12th Sustainable Development Goal promotes sustainable consumption and production patterns; one of its goals encourages people to educate and interest in sustainable consumption and lifestyles. However, different results are observed across countries, these countries differences highlight the importance of the influence of the complex cultural and geographical contexts where studies were carried out (Othman et al. 2015). Individuals with a similar religious affiliation/belief in the same religion are thought to share a common cognitive system of beliefs, values, and aspirations and are expected to behave accordingly. However, this theory ignores the contextual influences that may explain why those sharing a religious affiliation behave differently in many countries. Moreover, cross-cultural studies have shown that religion cannot be studied in isolation from all contextual influences (Othman et al. 2015). In a study conducted in the United States and Canada, researchers discovered that not only religious affiliation and religiosity but also the nation and the relationships between the two significantly predicted sustainable behaviour (Othman et al. 2015). Another cross-country study in the United States and Germany discovered striking differences between people of the same religion in these two countries: among United State respondents, a positive greater correlation between religious attendance and ethical consumption was found, whereas, among Germans, the relationship was negative and not substantial (Othman et al. 2015). The religion factor is vital for this study senses it

represents the influence of the religion to achieve the sustainable design across the world.

According to a study by Heathcote (2012), the interior decoration or the design of the furniture in the home shows the lifestyle and goals, as well as the personal life journey of the homeowner (Heathcote 2012). Furthermore, the same study identified some architectural elements for example windows, doors, and bedrooms as features that are functional and useful but also exert much impact on human domestic behaviours and actions inside the house environment. Despite the size, the number of rooms, style, or real estate value, each house provides its residents or owners with objects that help both their social and personal needs (Heathcote 2012). Furthermore, the architectural styles and materials utilised in houses created in the Middle East change from houses in her predominantly Muslim countries, for instance, Malaysia, because of climate factors and the locally available materials in the country. Despite these factors, some houses in predominantly Muslim countries tend to share a “humility in design” approach, such that houses are built with more sustainable and economical materials that additionally give thermal comfort inside the building (Othman et al. 2015).

With the significant development of projects in the gulf countries and specifically in Saudi Arabia, culture is different which may effect on the design of houses, construction industry, and energy consumption in these countries.

Cultural factors affecting sustainable design in Saudi Arabia

For a significant period, the provision of housing to Saudi inhabitants has used a traditional methodology, since interest in housing in the Middle East developed because of fluctuations in population growth and income levels. The Saudi culture is characterized by the teachings of Islam, represented by the Hadith and the Qur’an. Islam is an extensive lifestyle where every human action—for example, education, business, social connections, and science is driven and administered by God (Moritz 2013). The Saudi culture has been described as the most preservationist culture in the world (Nordin 2018). The religion of Islam is followed by 100% of the Saudi population, also, Islam governs all aspects of Saudi life (Nordin 2018). The Qur’an and the Hadith of Prophet Mohammed (PBUH) are followed and applied in regular activities (Sulandari et al. 2017). Islam is reflected in the structure of a Saudi or Muslim house on account of the requirement for separation between male and female members of the family (Sulandari et al. 2017). Muslim women must not uncover herself in front of any man, except for her father, siblings, uncle, spouse, children, nephews (of blood connection),

and grandfather. This requirement has significantly affected the structure of the Muslim house, requiring separate sections: one for men and the other for women. Gender segregation in Saudi houses is commonplace and required to follow the Islamic way of life (Nordin 2018).

In addition, the social and strict foundations of Saudi society determine how far people live from a mosque, further influencing the structure of a Saudi house from various perspectives. Since a Muslim must pray five times a day, living near to a mosque is a necessity in the Saudi culture (Al Surf et al. 2012). Traditional neighbourhoods were based on a large focal Masjid (mosque), which was commonly surrounded by the town.

Traditionally, one large Masjid would serve the entire town, which had various implications of interest (Nordin 2018). One of the many disadvantages of having such a large number of Masjids in a single neighbourhood is that individuals do not collaborate as they used to previously (Al Surf et al. 2012).

Furthermore, a typical Saudi home is intended to be as far away from others’ view as possible. Privacy is central to the design of any Saudi house, and all individuals associated with development projects in Saudi Arabia—for example, urban originators, draftsmen, scene planners, and social researchers—should consider this critical aspect of the building (Tawfiq Abu- Gazzeh 1995). Furthermore, privacy is fundamental to the building of housing for tenants in accordance with Muslim culture (Mahmud 2009).

Privacy

In the last years, many Muslims have established new houses in many different locations around the world. Islam has strong religious traditions that are directly applicable to the construction and organization of life within the home and its environment (Othman et al. 2015). The design of traditional Muslim houses is subjected to guidelines from principles outlined in Islamic Sharia Law, which is obtained from the Quran as well as hadiths and sunnah (Othman et al. 2015). Following three main principles have developed from these guidelines: privacy, hospitality, and modesty. In order, these three principles form the primary considerations of those who aim to build a traditional Muslim house. However, the migration of Muslims around the world also exposes them to the traditions and cultures of their host nations (Othman et al. 2015). Privacy in the traditional Islamic house contains four central layers: (a) privacy between gender (male and female), (b) privacy between neighbours, (c) privacy between family members inside the house, and (d) personal privacy. Such privacy conditions are usually met by a very careful design by making sure that the safety of the family and separating the private life

from public associations (Memarian et al. 2011). Several studies have focused on how Muslims can achieve privacy and increase hospitality within their houses. However, about the importance of domestic spaces for performing religious ceremonies and the practice of humility in the context of house design (Othman et al. 2015).

Privacy violation in Saudi Arabia

Violation of privacy is the primary issue faced by inhabitants of Riyadh today (Ukuhor and Abdulwahab 2018). This is the result of the lack of appropriate building regulations preventing the development of elevated structures in proximity to low-level private homes (Cardenas 2016). This has meant that the inhabitants of homes have suffered violations of their privacy, something that is considered to a greater extent in the MENA district as a result of the requirements of the religion and culture of the region (Nordin 2018). There is now a potentially hazardous mix of single workers that would prefer to live in densely populated high rises, living in or close to separated single-family residential zones (Nordin 2018). This has prompted numerous privacy issues across the city of Riyadh, and throughout the KSA (Ukuhor and Abdulwahab 2018).

According to a study carried out by Hanan and Sharples which focused on typical Saudi residential buildings (i.e., apartment complex), such buildings must achieve energy and water efficiency, and certain design and operational changes could have a major influence on the sustainability performance of the building (Hanan and Sharples 2010). The energy-saving measures considered were increasing thermal insulation of the roofs and external walls, fitting external shading devices, efficient glazing, and fitting energy-efficient fluorescent lighting (Hanan and Sharples 2010).

In **conclusion**, The Saudi culture is characterized by the teachings of Islam, represented by the Hadith and the Qur'an. Islam is an extensive lifestyle where every human action—for example, education, business, social connections, and science is driven and administered by God. Furthermore, privacy is central to the design of any Saudi house, and all individuals associated with development projects in Saudi Arabia—for example, urban originators, draftsmen, scene planners, and social researchers—should consider this critical aspect of the building. Moreover, the interior decoration or the design of the furniture in the home shows the lifestyle and goals, as well as the personal life journey of the homeowner.

Current deployment of sustainable design and future recommendations

This section provides an overview of the sustainable design implementation and future recommendations.

Sustainable performance of buildings is currently a huge concern between Architecture, Construction, and Engineering experts due to measures such as building codes in addition to national and regional purposes (Zanni et al. 2017). The overall aim is to decrease the influence of buildings on the environment while improving human comfort and health. Many countries and international organisations such as the UK and the USA have started rating systems to assess sustainable construction. Currently, these assessment methods are utilised as frameworks for environmental design by building experts, although they do not guide the design process. Furthermore, the design of high-performance buildings is a complex, nonlinear, iterative, and interactive process that needs active collaboration between the multidisciplinary teams from the early stages to reach sustainability results (Zanni et al. 2017). In the UK, BIM adoption has risen in recent years, there is limited evidence that sustainability has been systematically considered as an essential part of the BIM collaborative process. Some BIM related frameworks are based on the international assessment rating systems such as BREEAM and LEED, while others have generated tools that are combined into BIM design software to automate performance-based decision making (Zanni et al. 2017). This is a compliance measure that has been successfully used to reach sustainable improvement in countries around the world such as the UK, where the BREEAM rating scale is a successful tool. BREEAM in the UK, and different certification systems in other countries, are of high importance at the global level and play a key role in the entire construction of sustainability (Zeinal Hamedani and Huber, 2012). Furthermore, more clients in the USA are requesting LEED or other third-party certification of their projects (Brahme et al. 2001). To maximize the actual sustainability advantages of LEED certification, designers are required to understand which combination of credits gives the optimal design variables to raise the building's sustainability while keeping within budgetary limitations (Brahme et al. 2001). Moreover, there are more sustainability standards around the world such as, Minergie from Switzerland, Passivhaus from Austria, and Deutsche Gesellschaft für Nachhaltiges Bauen (dgnb) from Germany.

The main drivers promoting sustainable design are environmental and energy considerations, as well as several other factors such as health-related concerns and the desire to improve citizens' quality of life (Hyde 2000). In principle, sustainable buildings relate to the notion of climate-responsive design, which highlights the importance of natural energy sources with the aim of achieving building comfort through interactions between the dynamic conditions of the building's

environment (Hyde 2000). For example, the position of a window in a sustainable building is of the greatest importance as it could provide natural light, a source of air cooling, and ventilation.

Specifically, in gulf countries (including the KSA), as a result of badly designed buildings, approximately 80% of electricity in the home is used for air conditioning and cooling purposes (Akbari et al. 1996). In addition, in Saudi Arabia, as a result of fast population growth and increased urbanization, the residential sector booming and accounts for more than half of the country's energy demand (Al-Shehri 2008). The design of new houses in Saudi Arabia is no longer based on the principles of vernacular architecture, which tends to involve the utilization of local building resources, as well as the use of passive and low-energy strategies that could begin to decrease the need for both air conditioning and lighting requirements (Al-Ismaily and Probert 1997). Furthermore, electricity generation in Saudi Arabia is entirely dependent on the unsustainable practice of using fossil fuels, which has major environmental impacts on the climate, air, land, and water (Alnatheer 2006).

Furthermore, in the KSA there are no regulations, or compulsory building codes, that include laws related to sustainable architecture (Chwieduk 2003). Many architects support the idea that establishing a clear set of such codes and rules is one of the most important and cost-effective methods to increase the adoption of sustainable practices, particularly those concerned with decreasing the consumption of energy and water in homes (Chwieduk 2003). Following the energy crises of the 1970s, building codes have been established in developed nations, and more recently in the developing countries of China, Argentina, and Taiwan; the sustainable building laws in some of the countries of the European Union are among the most stringent (Chwieduk 2003). The role that can be played by BIM in meeting sustainability requirements should thus be investigated. In addition, Saudi Arabia construction industry is not growing well in achieving effective management and reaching great organisational performance. This was proved by the number of projects suffering delay, which increased from 700 projects in 2009 to 3000 projects in 2013 (Alhumayn et al. 2017). Also, the Saudi Arabia construction industry is characterized by inefficiency, due to a range of factors such as; rising demands from the clients and the use of traditional methods (Alhumayn et al. 2017). Furthermore, it has been stated that most of the construction companies in Saudi Arabia have a lack of knowledge, experience and management across the lifecycle of the project which makes it difficult for these companies to compete with more technologically advanced international companies. This inefficiency makes delays, time

overruns, and increases construction project costs (Alhumayn et al. 2017).

In general, technology helps to, achieve better safety, identifying problem, and analysing and simulate potential environmental influences (Alhumayn et al. 2017). In Saudi Arabia, usually, the traditional building designed by 2D CAD drawings (plans, sections, elevations, etc.). In the world, technology increases this to 3D (width, depth, and height) and a 4D (the dimension of time) and 5D (cost). Furthermore, incomplete projects are common, the reasons for this is the large number of projects being put on hold, with project design errors, and ineffective project management. One key explanation can be attributed to the lack of design and planning, and this lack of planning is due to the limitation of participation of project team leader in the project processes (Alhumayn et al. 2017). Moreover, 6D is an extension of the BIM model for Facilities Management for the Operation & Maintenance (O&M) stage (Charef et al. 2018). On the other hand, It is common for a few generations of one family to live in a single house, where the elderly are cared for by the younger family members and held in high regard. Because of the multigenerational family units, Saudi houses must be larger in scale than those where a single-family life in Alrashed and Asif (2015).

Current uses of BIM for sustainable design

A number of studies have shown that Saudi Arabia is considering cultural issues and how these are having an effect on the design of houses, especially given the large area of the country and the differences of culture between regions (Hanan and Sharples 2010). Furthermore, there are no required building codes or regulations, that support the sustainable design in Saudi Arabia (Hanan and Sharples 2010). Additionally, it is unfortunate to note that the electricity in Saudi Arabia is totally dependent on the practice of burning fossil fuels, which has major environmental influences on air, climate, water, and land because it is an unsustainable practice.

The housing construction industry in Saudi Arabia has grown rapidly over the past two decades; this is despite many barriers in relation to government regulations and building codes, one of which is the application of sustainable systems to housing construction (Al Surf et al. 2014). The years 1990–2010 saw dramatic growth in the urbanization of Saudi Arabia as compared with the other developing countries of the Arabian Gulf. Moreover, the Saudi housing typology and citizen behaviours and preferences have greatly changed over the past three decades. In developing countries such as Saudi Arabia, the experience of a rapid rate and ratio of urbanization and infrastructure expansion, especially with respect to residential buildings, is large (Karam 2010). However, comparing

this significant growth with other countries is clear that the issue of energy efficiency is not given serious consideration in Saudi building designs (Karam 2010).

Consequently, a few studies have been conducted in the areas of development advancement and basic leadership, prompting the improvement of various enhancement models utilizing an assortment of methodologies. The establishment of a rating framework for green building is proposed to fit the unique natural conditions in Saudi Arabia. This rating framework is called the Saudi Arabia Green Building Rating System (SAGRS). The SAGRS would be coordinated as a system committed to selecting the most ideal appropriate building materials highlighting the potential benefits of BIM innovation (Ahmed et al. 2013). The system will consider the cultural issues and Life Cycle Cost (LCC) to complete its functionality. Saudi Arabia is one of the Middle East developing countries that consider cultural issues as a key criterion for green building assessments which restrict the architect during the design process (Ahmed et al. 2013). Also, with no Saudi building code to support sustainability, it is very complicated to manage and achieve sustainable designs especially in the domestic sector (Hanan and Sharples 2010). The using of BIM for sustainable design has many benefits as follows below.

Benefits of utilizing BIM for sustainable design

The Saudi locale is suffering, arguably more so than in many parts of the world, from difficulties with regard to sustainability in the housing sector (Asif 2016). Not only is the region well known for its harsh dry conditions, but it also additionally shows evidence of an exceptionally high use of energy and water per capita compared with other densely populated territories globally (Asif 2016). Thus, it is essential to provide some insight into the unique difficulties, which include financial, environmental, and socio-cultural issues, facing Saudi Arabia (Asif 2016). BIM can offer and set out multi-disciplinary information within one model. This enables sustainability to be measured through planning and conveying expectations (Alhumayn et al. 2017). BIM has become an essential piece of sustainability examination and recreation and assumes a significant role in reducing industry waste and environmental damage (Alhumayn et al. 2017). In this way, the interest in BIM-based investigations in the field of sustainability is increasing significantly (Alhumayn et al. 2017). BIM innovation, alongside its general uses, can add to sustainable development in different phases of a building project, from making significant decisions in the early stages to destruction, to increase the efficiency and execution of the project. Concerning practical development, the commitment of BIM to building procedure can be contrasted, and the three fundamental elements of

sustainability: environmental, financial, and social (Alhumayn et al. 2017).

Integration of a BIM model with a decision-making tool and sustainability metrics could address the challenges of making decisions earlier in the design process and allow for specific sustainability cost–benefit analyses to be conducted, based on the exact building state and characteristics (Bank et al. 2010). BIM is intended to improve the way information is used in a building throughout its life cycle, and to reduce the influence of design, operations, maintenance, and occupant behaviour modification decisions made to improve the building's contribution to sustainable infrastructure (Bank et al. 2010).

According to a study by Maria, Robby, and Kirti using BIM to achieve a sustainable building in the UK, BIM has an important impact on the sustainable outcome of buildings. The development of a structured process can help in sustainable design practice with building professionals (Soetanto et al. 2014). Learning from implemented projects, using BIM methods, facilitates the scope of this process creation and advises future projects to prevent crashes. Process mapping is necessary to streamline the process, support key project processes and assist the design team to manage their responsibilities (Soetanto et al. 2014).

Recommendations

This paper has discussed the current situation of the sustainable design in Saudi Arabia and how is there a lack of government regulations concerning the use of sustainable methods.

As part of this review, several studies have shown that Saudi Arabia is considering the cultural issues and how is that effect on the design of houses especially with the large area of the country and the differences of culture between the cities.

A key limiting factor is that there are no required building codes or regulations, that include the principles of sustainable design in Saudi Arabia that support engineers and architects to achieve sustainability in Saudi Arabia. Additionally, it is unfortunate to note that the electricity in Saudi Arabia is totally dependent on the practice of burning fossil fuels, which has major environmental influences on air, climate, water, and land because it is an unsustainable practice.

The explicit research recommendations are thus as follows:

1. To develop and understanding of the extent and impact of cultural issues on achieving sustainable design. In Saudi Arabia specifically this means Saudi is a country relating to Islam which needs a special understanding of the culture. (As discussed in

“Sustainability” and “Cultural factors affecting sustainable design”).

2. To analyse the different viewpoints on sustainability within and between the professionals involved in sustainable design and members of the public. In Saudi Arabia this means the designer should consider both the professionals and public opinion about the designing process. (As discussed in “Sustainability”).
3. To develop a framework of comprehensive measures for evaluating, rating, and certifying the sustainable design of buildings with consideration to locality-specific factors. In Saudi Arabia specifically this means Saudi Arabia needs to consider specific factors to achieve more sustainable design in the country. (As discussed in “Sustainability” and “Building Information Modelling (BIM)”).
4. To ascertain the current level of utilization of BIM technologies in general, and specifically for sustainability analysis. In Saudi Arabia the current level of BIM is still developing and need to be more incorporate in the construction sector (As discussed in “Building Information Modelling (BIM)” and “Conclusion”).
5. Developing a methodology, supported by BIM, for both government projects and private houses. Specifically Saudi Arabia, needs to enable BIM in the construction industry to improve its decision-making regarding sustainability for both refurbishment and new buildings (As discussed in “Building Information Modelling (BIM)” and “Conclusion”).

Conclusion

The lack of measures and not having extensive understanding of Building Information Modelling (BIM) adoption, and the related expenses and benefits, are among the fundamental difficulties facing BIM execution in the Saudi Arabia construction industry. This literature review has shown that BIM is now used in Dubai, but only for particular kinds of projects. Although BIM is beginning to be adopted in Saudi Arabia, there is a lack of authoritative sources about BIM (Alhumayn et al. 2017). There are a few programming organizations that provide some component of the BIM procedure, but they do not regard the procedure as one entirety. Thus, there is a need to institutionalize the BIM procedure strategically in the Saudi Arabia construction industry (Asif 2016). To advance BIM adoption, businesses and organizations must learn about its affordances (Alhumayn et al. 2017). Businesses should develop procedures and approaches to advance BIM adoption to mitigate current risks within the construction sector.

BIM came as a solution which can be used during the project life cycle, which can help the quality of the design from the early stage of design until the demolition of the building. BIM is at the forefront of moving the construction industry into the digital age and will help to achieve the sustainable design in Saudi Arabia. Although building associations are demonstrating enthusiasm for BIM, their interest is communicated as belief in things to come and not as a present-day reality.

This paper has analysed relevant literature in the area of sustainable building design and the impact of cultural issues, focusing on the case of Saudi Arabia. This review has identified the lack of using technology to support designs in Saudi Arabia, lack of achieving sustainability in Saudi Arabia, culture issues effect on designing in Saudi Arabia, and lack of using BIM in Saudi Arabia for both public and private project. These issues have led to a series of recommendations that have the potential to improve the adoption of sustainable design in Saudi Arabia by using Building Information Modelling (BIM). The explicit research recommendations are thus as follows:

1. To develop and understanding of the extent and impact of cultural issues on achieving sustainable design. In Saudi Arabia specifically this means Saudi is a country relating to Islam which needs a special understanding of the culture. (As discussed in “Sustainability” and “Cultural factors affecting sustainable design”).
2. To analyse the different viewpoints on sustainability within and between the professionals involved in sustainable design and members of the public. In Saudi Arabia this means the designer should consider both the professionals and public opinion about the designing process. (As discussed in “Sustainability”).
3. To develop a framework of comprehensive measures for evaluating, rating, and certifying the sustainable design of buildings with consideration to locality-specific factors. In Saudi Arabia specifically this means Saudi Arabia needs to consider specific factors to achieve more sustainable design in the country. (As discussed in “Sustainability” and “Building Information Modelling (BIM)”).
4. To ascertain the current level of utilization of BIM technologies in general, and specifically for sustainability analysis. In Saudi Arabia the current level of BIM is still developing and need to be more incorporate in the construction sector. Moreover, implement some software’s such as, Nevada software, ACCA software (As discussed in “Building Information Modelling (BIM)” and “Conclusion”).
5. Developing a methodology, supported by BIM, for both government projects and private houses. Specif-

ically Saudi Arabia, needs to enable BIM in the construction industry to improve its decision-making regarding sustainability for both refurbishment and new buildings (As discussed in “[Building Information Modelling \(BIM\)](#)” and “[Conclusion](#)”).

It is our view that Saudi Arabia needs to support Building Information Modelling (BIM) not as a digitally transform the construction sector but as a unique way to achieve sustainability in Saudi Arabia.

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Author contributions

Contributors MSA made a substantial contribution to the conception and design of the work; the acquisition and drafting of the work. TH and YR made a substantial contribution to the design of the work, and acquisition. All authors critically revised drafts of the work and approved the final version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors read and approved the final manuscript.

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This study did not use any type of data to address its aim and objectives.

Declarations

Competing interests

The authors declare that they have no competing interests.

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References

- Abanomi W, Jones P (2005) Passive cooling and energy conservation design strategies of school buildings in hot, arid region: Riyadh, Saudi Arabia. *Proceedings from international conference passive and low energy cooling for the built environment*. P 619–630
- Abdallah M, Rayes K, Liu L (2013) Operational performance of sustainable measures in public buildings. *J Constr Eng Managem, ASCE* 139(12):A4013008
- Abubakar M, Ibrahim YM, Kado D, Bala K (2014) Contractors' perception of the factors affecting building information modelling (BIM) adoption in the Nigerian construction industry. In *computing in civil and building engineering*. p 167–178
- Administration, E. I. and Department, E (2015) *Annual energy outlook 2015: With projections to 2040*. Government Printing Office
- AGC A (2006) *The contractors guide to BIM*. <http://iweb.agc.org/iweb/Purchase/ProductDetail.aspx>
- Ahmed M, Hasan MA, Mallick J (2013) World green building rating systems: a comparative study
- Ahmed SM, Emam HH, Farrell P (2014) Barriers to BIM/4D implementation in Qatar. *The 1st international conference of CIB middle east & north Africa conference*. p 533–547
- Akbari H, Morsy M M, Al-Baharna N (1996) *Electricity saving potentials in the residential sector of Bahrain, Vol 1* Lawrence Berkeley National Laboratory Publication, p 11–20
- Al Surf M, Susilawati C, Trigunaryah B (2012) Analyzing the literature for the link between the conservative Islamic culture of Saudi Arabia and the design of sustainable housing. In *proceedings of 2nd international conference socio-political and technological dimensions of climate change*. University Putra Malaysia Press, p 3–16
- Al Surf MS, Susilawati C, Trigunaryah B (2014) The role of the Saudi government and the Saudi Building Code in implementing sustainable housing construction in Saudi Arabia. <https://eprints.qut.edu.au/75970/>. Accessed 06 Aug 2019
- Alhumayn S, Chinyio E, Ndekugri I (2017) The barriers and strategies of implementing BIM in Saudi Arabia. *WIT Trans Built Environ* 169:55–67
- Ali HAEM, Al-Sulaihi IA, Al-Gahtani KS (2013) Indicators for measuring the performance of building construction companies in the kingdom of Saudi Arabia. *J K Saud Univ-Eng Sci* 25(2):125–134
- Al-Ismaily HA, Probert SD (1997) Energy overview of the Sultanate of Oman. *Appl Energy* 57(4):287–325
- Alnatheer O (2006) Environmental benefits of energy efficiency and renewable energy in Saudi Arabia's electric sector. *Energy Policy* 34(1):2–10
- Alrashed F, Asif M (2015) Analysis of critical climate-related factors for the application of zero-energy homes in Saudi Arabia. *Renew Sustain Energy Rev* 41:1395–1403
- Al-Shehri A (2008) Electricity industry in Saudi Arabia: an overview. In: *Saudi Water and Power Forum, Jeddah*
- AL-YAMI A, Price A (2006) An overview of sustainability in Saudi Arabia. In: *proceedings of 2006 joint international conference on construction culture, innovation, and management (CCIM 2006): sustainable development through culture and innovation, Dubai*, p 109–119
- Asif M (2016) Growth and sustainability trends in the buildings sector in the GCC region with particular reference to the KSA and UAE. *Renew Sustain Energy Rev* 55:1267–1273
- Åström DO, Bertil F, Joacim R (2011) Heat wave impact on morbidity and mortality in the elderly population: a review of recent studies. *Maturitas* 69(2):99–105
- Autodesk (2005) *Building information modeling for sustainable design*. <http://www.federalnewsradio.com/pdfs/BuildingInformationModelingforSustainableDesign-white%20paper.pdf>. Accessed 30 Jul 2019
- Autodesk (2008) *Improving building industry results through integrated project delivery and building information modeling*. http://images.autodesk.com/adsk/files/bim_and_ipd_whitepaper.pdf. Accessed 30 Jul 2019
- Bahar Y, Pere C, Landrieu J, Nicolle C (2013) A thermal simulation tool for building and its interoperability through the building information modelling (BIM) platform. *Buildings* 3(2):380–398
- Bakhoum E, Brown D (2012) Developed a sustainable scoring system for structural materials evaluation. *J Constr Eng Manag, ASCE* 138(1):110–119
- Banani R, Vahdati M, Elmualim A (2013) *Demonstrating the importance of criteria and sub-criteria in building assessment methods*. PhD dissertation, WIT Press. <https://www.witpress.com/Secure/elibrary/papers/SDP13/SDP13037FU1.pdf>. Accessed 06 Nov 2019
- Banawi A (2017) *Barriers to implement building information modelling (BIM) in public projects in Saudi Arabia*. In *international conference on applied human factors and ergonomics*. Springer, Cham, p 119–125
- Bank LC, McCarthy M, Thompson BP, Menassa CC (2010) Integrating BIM with system dynamics as a decision-making framework for sustainable building design and operation. In *proceedings of the first international conference on sustainable urbanization (ICSU)*, p 15–17
- Berardi U, GhaffarianHoseini A, GhaffarianHoseini A (2014) State-of-the-art analysis of the environmental benefits of green roofs. *Appl Energy* 115:411–428
- Bolpagni M, Gavina R, Ribeiro D, Arnal IP (2022) *Shaping the future of construction professionals*. In *industry 40 for the built environment*. Springer, Cham, 1–26
- Bond A, Pope J (2012) *The state of the art of impact assessment in 2012*. *Impact Assess Proj Apprais* 30(1):1–4

- Brahme R, Mahdavi A, Lam K P, Gupta S (2001) "Complex Building Performance Analysis in the Early Stages of Design." Seventh international IBPSA conference, Rio de Janeiro, Brazil, p 661–668
- Brundtland GH, (1987) Our common future. World commission on environment and development, Oxford Paperbacks
- Cardenas MG (2016) The diplomatic quarters in Riyadh. A western-shaped neighbourhood in an Islamic city. *Int Plan Hist Soc Proc* 17(1):393–404
- Charef R, Alaka H, Emmitt S (2018) Beyond the third dimension of BIM: a systematic review of literature and assessment of professional views. *J Build Eng* 19:242–257
- Cho C, Chen D, Woo S (2011) Building information modeling (BIM)-based design of energy efficient buildings. *Proceedings of the 28th ISARC*, p1079–1084
- Chwieduk D (2003) Towards sustainable-energy buildings. *Appl Energy* 76(1):211–217
- Deutch J (2020) Is net zero carbon 2050 possible? *Joule* 4(11):2237–2240
- Dictionary MW (2010) Tolerance. Dari <http://www.merriam-webster.com/dictionary/tolerance>. Diunduh, 1
- Eadie (2013) BIM implementation throughout the UK construction project lifecycle: an analysis. *Autom Constr* 36:145–151
- Gerges M, Austin S, Mayouf M, Ahiakwo O, Jaeger M, Saad A, El Gohary T (2017) An investigation into the implementation of building information modeling in the Middle East. *J Inf Technol Constr* 22:1–15
- Ghaffar SH, Burman M, Braimah N (2020) Pathways to circular construction: an integrated management of construction and demolition waste for resource recovery. *J Clean Prod* 244:118710
- Ghahramanpouri A, Lamit H, Sedaghatnia S (2013) Urban social sustainability trends in research literature. *Asian Soc Sci* 9(4):185
- Hamada HM, Haron AT, Zakaria Z, Humada AM (2016) Challenges and obstacles of adoption BIM technology in the construction industry in Iraq. In the national conference for postgraduate research
- Hanan MT, Sharples S (2010) Developing sustainable residential buildings in Saudi Arabia: a case study. <https://salamahconsulting.com/technical-paper/Saudi%20Arabia%20Applied%20Energy.pdf>. Accessed 04 Nov 2019
- Hardin B (2009) BIM and construction management. John Wiley & Sons, Indianapolis
- Hassan SA (2012) Health, safety and environmental practices in the construction sector of Pakistan
- Heathcote E (2012) The meaning of home, Illustrated. Frances Lincoln Limited, London
- Richard C Hill, Paul A Bowen (1997) Sustainable construction: principles and a framework for attainment. <https://www.tandfonline.com/doi/ref/https://doi.org/10.1080/014461997372971?scroll=top> p 223–239. Accessed 12 July 2019
- Hyde R (2000) Climate responsive design: a study of buildings in moderate and hot humid climates. E. & F. N. Spon, London
- IPCC (2007) Summary for policymakers, climate change, IPCC WG1 Fourth assessment report. Cambridge University Press: New York. (<http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf>)
- Sakdirat Kaewunruen, Panrawee Rungskunroch, Joshua Welsh (2018) A digital-twin evaluating of net zero energy building for existing buildings. <file:///C:/Users/c1929827/Downloads/sustainability-11-00159.pdf>. Accessed 13 Aug 2019.
- Karam S (2010) Special report: can Saudi Arabia fix its housing time bomb? Reuters
- Kemp R, Parto S, Gibson RB (2005) Governance for sustainable development: moving from theory to practice. *Int J Sustain Dev* 8(1–2):12–30
- Kensek K (2014) Building information modeling. Routledge, London
- Kibert CJ (2016) Sustainable construction: green building design and delivery. John Wiley & Sons
- Langston C, Mackley C (1998) The role of environmental economics in the cost management of projects, AACE international transactions
- Leal Filho W, Azeiteiro U, Alves F, Pace P, Mifsud M, Brandli L, Disterheft A (2018) Reinventing the sustainable development research agenda: the role of the sustainable development goals (SDG). *Int J Sust Dev World* 25(2):131–142
- Mahmud S (2009) Conservation of the old buildings by transformation and income generation: case of dammam in the eastern province. King Faisal University, Saudi Arabia
- Memarian GH, Toghr-oljerdi SMH, Ranjbar-Kermani AM (2011) Privacy of house in Islamic culture: a comparative study of pattern of privacy in houses in Kerman. *Int J Archit Eng Urb Plan* 21(2):69–77
- Morgan R (2012) Environmental impact assessment: the state of the art. *Impact Assess Proj Apprais*. <https://doi.org/10.1080/14615517.2012.661557>
- Moritz JM (2013) God's creation through evolution and the language of scripture. *Theol Sci* 11(1):1–7
- National Research Council of the National Academies (2011) Sustainability and the U.S. EPA. National Academies Press, Washington, DC, p 163
- Nordin MM (2018) Keeping communities healthy: the Islamic paradigm. *Int J Hum Health Sci (IJHHS)* 2(2):49–54
- North P, Tripp H (2009) Culture shock! A survival guide to customs and etiquette in Saudi Arabia. [https://books.google.co.uk/books?hl=en&lr=&id=XRWJAAAAQBAJ&oi=fnd&pg=PR4&dq=North,+P.+%26+Tripp,+H.+\(2009\).+Culture+shock!+A+survival+guide+to+customs+and+etiquette+in+Saudi+Arabia.&ots=MHh552aiON&sig=TZrOQN2B7JKOd3cVaQ64LPcy44U#v=onepage&q=North%2C%20P%20%26%20Tripp%2C%20H.%20\(2009\).%20Culture%20shock!%20A%20survival%20guide%20to%20customs%20and%20etiquette%20in%20Saudi%20Arabia.&f=false](https://books.google.co.uk/books?hl=en&lr=&id=XRWJAAAAQBAJ&oi=fnd&pg=PR4&dq=North,+P.+%26+Tripp,+H.+(2009).+Culture+shock!+A+survival+guide+to+customs+and+etiquette+in+Saudi+Arabia.&ots=MHh552aiON&sig=TZrOQN2B7JKOd3cVaQ64LPcy44U#v=onepage&q=North%2C%20P%20%26%20Tripp%2C%20H.%20(2009).%20Culture%20shock!%20A%20survival%20guide%20to%20customs%20and%20etiquette%20in%20Saudi%20Arabia.&f=false)
- Osmani M, Glass J, Price AD (2008) Architects' perspectives on construction waste reduction by design. *Waste Manage* 28(7):1147–1158
- Othman Z, Aird R, Buys L (2015) Privacy, modesty, hospitality, and the design of Muslim homes: a literature review. *Front Archit Res* 4(1):12–23
- Pushkar S (2005) A methodology for design of environmentally optimal buildings by variable grouping. *Build Environ* 40(8):1126
- Royal institute of British architects (2012) RIBA plan of work 2012 overview. <https://www.architecture.com/-/media/gathercontent/riba-plan-of-work/additional-documents/bimoverlaytotheribaoutlineplanofworkpdf.pdf>. Accessed 9 Jun 2018
- Sackey E (2014) A sociotechnical systems analysis of building information modelling (STSaBIM) implementation in construction organisations (Doctoral dissertation, ©Enoch Sackey).
- Sadler B (1999) A framework for environmental sustainability assessment and assurance. In: Petts J (ed) *Handbook of environmental impact assessment*. Blackwell, Oxford, pp 12–32
- Salgueiro IB, Ferries B (2015) An "environmental BIM" approach for the architectural schematic design stage. *Int J Archit Comput* 13(3–4):299–312
- Sassi P (2006) Strategies for sustainable architecture. Taylor & Francis
- Saunders T (2008) A discussion document comparing international environmental assessment methods for buildings. BRE Global, Watford
- Smith D, Tardif M (2009) Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers. Wiley
- Sodangi M, Salman AF, Shaawat ME (2016) Exploring the challenges in utilization of BIM in maintenance management of mosques. In *Proceedings of the first international conference on mosque architecture*. p 31–48
- Soetanto R, Zanni MA, Ruikar K (2014) Defining the sustainable building design process: methods for BIM execution planning in the UK. *Int J Energ Sect Manag*
- Stafford A (2011) The psychological significance of home (Doctor of psychology/thesis). The Wright Institute, Ann Arbor
- Sudhakar K, Winderl M, Priya SS (2019) Net-zero building designs in hot and humid climates: a state-of-art. *C Stud Therm Eng* 13:100400
- Sulandari S, Wijayanti M, Sari RD (2017) Religious activity: an alternative to achieve happiness in later life. *J Soc Sci Educ* 6:55–64
- Sun C, Jiang S, Skibniewski MJ, Man Q, Shen L (2017) A literature review of the factors limiting the application of BIM in the construction industry. *Technol Econ Dev Econ* 23(5):764–779
- Tawfiq Abu-Gazze (1995) Privacy as the basis of architectural planning in the Islamic culture of Saudi Arabia. p 93–109. Accessed 13 Sept 2019.
- The Economic Times News (2013) http://articles.economictimes.indiatimes.com/2013-04-11/news/38463111_1_energy-projects-alternative-energy-consumption.
- Ukuhor HO, Abdulwahab AA (2018) Prevalence and workplace correlates of tobacco smoking among male expatriate workers in Riyadh. *Saudi Arab East Mediterr Health J* 24(12):1155–1164
- Union E (2010) European GNSS (Galileo) open service: signal in space interface control document. Office for official publications of the European communities.

- US Green Building Council (2012) Green building design and construction. US Green Building Council, Washington, DC
- Valande. (2008) IFC and building lifecycle management. *Autom Constr* 18(1):70–78
- Wu W (2010) Integrating building information modelling and green building certification: the BIM-LEED application model development. University of Florida. <http://meyar.co/wp-content/uploads/2017/02/Wei-Wu-2010.pdf>. Accessed 06 Nov 2019
- Zanni M, Soetanto R, Ruikar K (2017) Towards a BIM-enabled sustainable building design process: roles, responsibilities and requirements. *Archit Eng Des Manag* 13(2):101–129
- Zeinal Hamedani, F. Huber, (2012) A comparative study of DGNB, LEED and BREEAM certificate systems in urban sustainability. <https://www.witpress.com/Secure/elibrary/papers/SC12/SC12011FU1.pdf> Accessed 09 Sep 2019.
- Zhou Z, Goh YM, Li Q (2015) Overview and analysis of safety management studies in the construction industry. *Saf Sci* 72:337–350

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