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Maturity of BIM Implementation in the Jordanian AEC Industry

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Abstract

Purpose: The Architecture, Engineering and Construction (AEC) industry in Jordan is continually evolving and integrating new methods and technologies. However, the implementation of BIM workflows and digitised processes has been very slow. This research aims to provide an assessment of the current status of BIM implementation and use within the AEC industry in Jordan. Design / methodology / approach: AEC professionals in Jordan were surveyed using a questionnaire and perceptions of BIM was obtained by follow-up structured interviews with experienced AEC professionals. Findings: This research evaluates the maturity of BIM understanding and implementation in Jordan and identifies three critical areas for the improvement and optimisation of BIM implementation in Jordan. Originality / value: This research provides a current view of the status of BIM implementation within the AEC industry in Jordan, identifies progress to date towards raising awareness of the benefits of BIM adoption, makes the needed information available for policy makers and project stakeholders, and proposes potential initiatives to support the implementation of BIM across Jordan.

Keywords: Building Information Modelling, BIM, Jordan, Construction, AEC, Benefits, Barriers, Implementation.

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1. Introduction

The construction industry constitutes around 6% of the global Gross Domestic Product (GDP) (Turner & Townsend, 2017) and is valued at $4.5 trillion, based on 2016 global GDP of $75.9 trillion (World Bank, 2018). Within this marketplace, 30% of projects utilise BIM at some stage of the design and construction process, with growth projected at 13% per annum (McAuley et al., 2017). In 2016, in parts of the Gulf Cooperation Council (GCC) market (composed of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates), the value of construction activities was estimated at $76.5 billion (Foreman, 2018). Infrastructure reconstruction, following the conflict in Syria, was valued at up to $200 billion, whilst the redevelopment of Iraq remains an on-going opportunity.

Jordan is an evolving, developing country, with a lower-middle income economy (World Bank, 2017) and a GDP of JD27.4 billion in 2016, equivalent to $38.7 billion (Dept. of Statistics, 2016). Among the many active industries in Jordan, construction is a significant contributor to the economy, employing 6% of the national workforce and generating 4.4% of GDP (Dept. of Statistics, 2016). Growth of the construction industry in Jordan was 15% in 2015 and is forecast to continue to increase at a similar rate at least until 2022 (Economic Policy Council, 2017). A skilled workforce is readily available, with 9,080 university graduates in engineering subjects in 2017 alone (Dept. of Statistics, Jordan, 2017) and a pool of semi-skilled labour available from the 18.5% of the potential working population unemployed in 2017 (Dept. of Statistics, Jordan, 2018). In addition to growth, the capacity development and economic performance of the AEC industry in Jordan are important factors which must be taken into consideration and incorporated into the implementation model utilised for the national adoption of BIM (Olugboyega & Windapo, 2019).

To realise potential opportunities, the construction industry in Jordan must become more efficient and look outside the national marketplace. Improved application of BIM by the Architecture, Engineering, Construction (AEC) industry in Jordan could enable significant successes and provide opportunities currently dismissed as unfeasible. However, barriers to realising this objective exist and must be overcome (Materneh & Hamed, 2017a, 2017b).

In the rapidly evolving environment of the Jordanian AEC industry, absence of up-to-date quantitative data to support an assessment of progress and inform future development is a due consideration. According to the literature review, whilst 45% of practitioners had at least 2 years of experience in using BIM (Materneh & Hamed, 2017a, 2017b), it was only used on a minority (3%) of construction projects in Jordan, and principally at the design stage (Gerges, 2017). In addition, there is a dearth of studies from the developing world that focus on BIM maturity models and their indicators, including the assessment of people, policy, and organisational readiness (Yusof et al., 2018; Lepkova et al., 2019). The aim of this research is to measure the understanding Jordanian professionals and organisations have of BIM, the maturity of BIM implementation in the Jordanian AEC industry, and identify the potential barriers to implementation professionals and organisations may be facing. The paper provides recommendations to support the implementation of BIM-based digitised workflows in Jordan to encourage the adoption of BIM at a national level.

2. Literature Review

2.1. Definition of BIM

In recent years, BIM has been drawing the attention of the AEC industry (Liu et al., 2015), as it is changing the way that teams work within construction projects to increase productivity and enhance project outcomes, such as quality, safety, maintainability, time, and cost (Kiani et al., 2015).

BIM can be defined in many ways. The United States National Institute of Building Science reports that BIM stands for “new concepts and practices that are so greatly improved by innovative information technologies and business structure that they will dramatically reduce the multiple form of waste and inefficiency in the building industry” (NIBS, 2007).

ISO 19650 Series, which is the series concerned with information management for buildings and infrastructures, defines BIM as “use of shared digital representation of a build asset to facilitate design, construction and operation processes to form a reliable basis for decisions”. (ISO, 2018)

Although the definitions of BIM may slightly differ, it is almost universally accepted that the correct use of BIM as a workflow and a production process can play a powerful part in merging the different phases of an asset's lifecycle (Jung & Joo, 2011). A variety of advantages, both direct and indirect, may be realised from BIM implementation, whereby the design and construction processes become more robust and are simplified in several ways (Lee et al., 2012). In addition, BIM can play a vital role in promoting success factors in partnering projects, such as mutual trust, transparency, collaboration, well definition of work scope, and clear definition of responsibilities (Evans et al., 2020).

Collaboration is the heart of BIM process, as it is tightly associated with effective information management (Oraee et al., 2017) as well as to form a collaborative culture in construction projects (Kapogiannis, et al., 2018). ISO 19650 Series recommendations are based on a workflow in which all parties work collaboratively together (ISO, 2018). ISO 19650-1:2018 describes a sequence of maturity stages for BIM which are categorised into three stages based on the development of standards, adoption of technology and forms of information management. It is noteworthy that before the ISO 19650 Series, BIM maturity stages were referred to as "BIM Levels". The maturity stages measure levels of collaboration between project parties in BIM projects as they work together in a Common Data Environment to author all information defining an asset (Merschbrock & Munkvold, 2015).

2.2. BIM Use within Construction projects

The collaborative nature of BIM continues to leverage change in the AEC industry, offering the ability to make better design decisions, realise more efficient construction processes and optimise facility and asset management. BIM and the technologies supporting it are one of the most promising advances currently taking place in the construction industry. In a BIM workflow, people, systems, technologies, business structures and management structures are integrated in collaborative processes which harness the strengths and insights of all parties and technology elements within a construction project (Glick, 2009).

Collaborative workflows and advances in BIM authoring tools enable enhanced information exchange and interoperability. A 3D BIM model refers to the geometrical information in an information container, which is based on object-oriented parametric modelling and sits within a Common Data Environment (CDE). 3D BIM models have enhanced multi-disciplinary and inter-organisational collaboration, resulting in coordinated building designs, efficient spatial visualisation and utilisation, accurate quantity estimations, and realistic building behaviour simulations (Miettinen & Paavola, 2014) including proactive behaviour to project managers (Kapogiannis et al., 2022).

Although BIM workflows revolve around the existence of geometrical information, non-geometrical information plays a key role in realising the promised BIM benefits. Non-geometrical information could contain manufacture-specific information such as price and stock information, time, cost, energy performance, maintenance and operations requirements, and a range of other information which remains invisible within the geometrical information container. Linking extra dimensions of data to the 3D information model is often referred to as "BIM Dimensions". 4D BIM models, which are the result of adding time related data to the geometrical information, facilitate scheduling and simulation of construction processes in addition to assessing the impact of design changes on the overall project plan and duration (Tulke & Hanff, 2007; Eastman C., 2008; Urbina Velasco, 2013). Using 4D BIM models, clashes between construction activities can be detected through a workflow clash detection process.

The 5th dimension of BIM is linking cost-related data to the geometry. 5D BIM creates a "live" cost plan which helps the delivery team to design and build on budget, allowing the most significant factors of project management to be understood using geometrical and non-geometrical information; design, time, and cost. With 4D and 5D BIM, the impact of design changes on the construction schedule and cost estimation can be considered against the requirements for the project. (Gerges et al., 2016; Bryde et al., 2013).

The dimensions have been defined variously beyond the 5th dimension of BIM (Saxon, 2018). Major consultants in the UK define the 6th BIM dimension to be associated with sustainability, the 7th with facility management and whole-life performance, and the 8th dimension with health and safety.

The type of data associated with each BIM dimension suggests wide benefits from the extracted information. The BIM process can be integrated with and make use of various technologies, such as robotics, Internet of Things (IoT), Artificial Intelligence (AI) and other technologies which are still underused in the AEC industry. Such integration supports the BIM process by facilitating faster data capturing, smarter authoring and utilisation of building information, eventually resulting in higher returns and benefits for all project stakeholders. It is noteworthy that it has been argued that dimensionality can be a misleading semantic beyond 4D (Koutamanis, 2020).

There is a clear, wide range of benefits and application areas associated with BIM. The benefits BIM offers the construction industry range from technical benefits, interoperability, asset data capturing, building information authoring and use throughout its lifecycle, improved cost control, integrated procurement, reduced errors and omissions, reduced conflicts, and fewer legislations in construction projects. BIM facilitates the sharing of information over the entire lifecycle of the asset (Popov et al., 2010). During the delivery phase of the asset, BIM brings additional benefits as it improves communication between the various parties involved and provides a mechanism for more rapid decision making and risk mitigation (Cho et al., 2011). Completion of a construction project of higher quality due to improving the organisation of activities and project phases during the planning stages brings several benefits (Azhar, 2017), as illustrated in Figure 1.

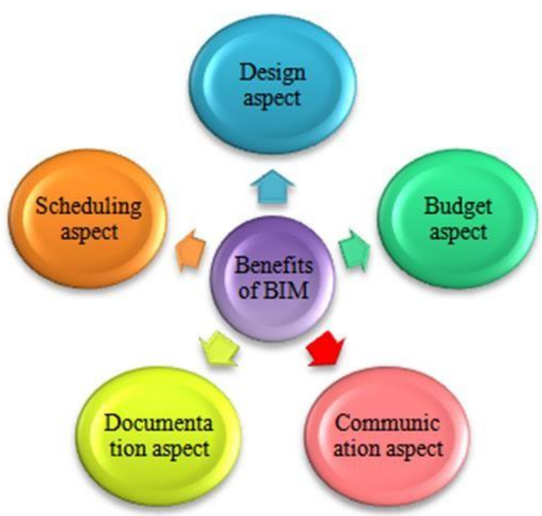

Figure 1: Benefits of Building Information Modelling, (Latiffi et al., 2018).

Nevertheless, potential and definitive benefits of BIM have not yet been fully realised by the AEC industry because of the lack of a widespread full adoption and uptake of BIM by the industry (Ghaffarianhoseini et al., 2016). BIM implementation levels of 7% and 71% for Jordan and North America respectively up to 2016 clearly show that the uptake of BIM workflows in any form by the construction industry has not progressed evenly on a global level (Matarneh & Hamed, 2017a). Similar variations occur globally in the level of awareness of BIM and the rate of growth of uptake of this process and methodology (Shaikh et al., 2016).

It can be argued that BIM needs to be adopted at a systemic level to realise it benefits (Murguia et al., 2021), especially that several frameworks, models and methodologies have been proposed in different countries for macro BIM adoption (Kassem & Succar 2017; Ahmed et al., 2018; Elhendawi, 2018; Lepkova et al., 2019; Elhendawi et al., 2019a and 2019b). Banawi et al. (2019) analysed a selection of framework methods, tools, and processes, identifying some key strategies and guidelines required to create a BIM framework that is customized to local requirements. In addition, several research papers and case studies have been published in recent years on the benefits and barriers of BIM implementation, with varied descriptions on the details of the process (Abdulfattah, et al., 2017; Hamma-adama et al., 2020). Despite the benefits of BIM in the design, delivery, and management of a constructed asset, there remain several challenges to the implementation of BIM processes (Criminale, 2017).

2.3. Challenges associated with BIM implementation

The belief that significant investment of time and human resources for implementation is required (Yan & Demian, 2008), insufficiency/inadequacy of computer hardware, and difficulties in software integration, are all identified as barriers to adoption (Liu et al., 2015). Once a BIM process has been adopted, the accuracy of the outputs is reliant on the data which is entered and used within the project workflow. This is particularly the case for processes involving 4D BIM and above. Inaccurate information such as the lead-time for procurement of materials and equipment, and time and cost for construction of the various components will inevitably lead to incorrect forecasts from the BIM process. The detail of the information included at the various stages of project development is also critical to successful implementation of BIM (Bolpagni & Ciribini, 2016).

BIM implementation is also often stifled by ‘resistance to change’. This resistance to change is perceived as a significant challenge to BIM adoption in Jordan and the Middle East (Batoush & Haron, 2017; Gerges et al., 2017; Matarneh & Hamed, 2017a; Elhendawi et al., 2019b). According to a study by Matarneh and Hamed (2017b), lack of support from policy makers and/or Government mandated requirements represent significant challenge to BIM implementation in Jordan. The capacity of AEC companies to successfully implement BIM has also been highlighted as a challenge on many occasions (Matarneh & Hamed, 2017a). The same study by Hamed & Matarneh (2017a, 2017b) found that 90% of respondents to the survey of AEC practitioners in Jordan were not fully aware of the benefits of BIM and “do not know where to start”. A lack of technical and operating knowledge was also a concern to the industry, with 46% of users in the Middle East being self-taught in 2010 (Building Smart, 2011), and 64% of BIM practitioners in Jordan being either self-taught or trained ‘in-house’ in 2016 (Matarneh & Hamed, 2017a).

Incorrect application of BIM is also a barrier to achieving success (Ahmed, 2018). Professionals in the Middle East look at BIM as just a tool that presents a 3D model of the building (Awwad, 2013). In 2015, a study of BIM implementation conducted by Jung across six continents found that the Middle East employed BIM for design authoring, 3D coordination, and clash detection (Jung, 2015). This also appears substantiated by a study of BIM utilisation in municipal projects in the UAE, where maintaining records, 3D modelling and clash-detection were identified as the uses of BIM in 65% of cases, whilst collaboration on special data was used in 10% of cases (Venkatachalam, 2017).

The lack of standards, along with incomplete information on related implementation costs and uncertain profitability, are the main challenges when investigating the use of BIM in the UAE, which also inhibits application of the more useful dimensions of BIM (Mehran, 2016). Likewise, in Syria, the lack of implementation strategies and frameworks has been reported as a significant barrier for BIM adoption (Ahmed et al., 2018).

Generally, lack of client demand, resistance to change, both within the construction industry institutions and as a part of human nature, together with a lack of regulatory or legal framework defining responsibilities within a BIM workflow, are cited as significant challenges which must be overcome (Ghavamimoghaddam & Hemmati, 2017). In their research on the obstacles and requirements for BIM implementation in Syria, Shaban and Elhendawi (2018) categorised the challenges of BIM implementation into management, technical, surrounding environment, financial, and legal and contractual challenges.

Challenge Category	Typical Example
Management Challenges	
	Lack of BIM experience (know-how)
	Lack of support from the organisation’s top management
	Resistance to change
	Inability to manage change in the project’s workflow, roles and responsibilities
Technical Challenges	
	Software interoperability
	BIM model management
	Lack of software knowledge and skill
Surrounding Environment Challenges	
	Lack of government mandates
	Lack of client demand
	Use of BIM among project stakeholders
Financial Challenges	
	Costs associated with implementation
Legal and contractual challenges	
	Intellectual property rights
	Procurement methods

Table 1: BIM challenge categories (Shaban and Elhendawi, 2018)

A summary of the main benefits and challenges of BIM implementation within the construction industry is presented in Table 2.

Benefits	References
Clash detection Dimensions of BIM Sustainability	Czmoch and Pękala, 2014
Easy collaboration during decision making Increased design clarity Strong link between design and cost Early virtual prototyping Improve visulaisation and simulation Reduce waste Decrease errors in documents Reduces time and cost	Suermann, 2009; Azhar, 2011; Bryde et al., 2013
Better quality information for estimation and bidding Early contractor involvement to contribute to constructability and effective scheduling	Suermann, 2009; Sebastian, 2010
Enhance quality of as built drawings Improved handing over information	Azhar, 2011; Arayici et al., 2012b
Better performance and quality of the project Improve productivity Faster project delivery New opportunities for revenue and business	Jung and Joo 2011
Enhance collaboration and communication Faster and more effective design method Improve quality	Matarneh and Hamed, 2017a
Challenges	**References**
High implementation cost Lack of legal regulations	Czmoch and Pękala, 2014
Lack of information sharing in BIM High initial cost of software	Bernstein & Pittman, 2004; Thomson & Miner, 2006; Björk & Laakso, 2010; Azhar,2011; Aibinu & Venkatesh, 2014; Alreshidi et al., 2014
High cost of training and education Process problems Learning curve Lack of senior support Ownership	Arayici et al., 2011; Won et al., 2013; Aibinu & Venkatesh, 2014; Demain & Walters, 2014
Responsibility for inaccuracies Licensing problems	Thomson & Miner, 2006; Chynoweth et al., 2007; Azhar, 2011; Udom,2012
Lack of understanding about BIM Changing the way firms do business	Azhar, 2011
No client demand Resistance to change Lack of BIM specialist Cost (software, hardware upgrade, training and time)	Matarneh and Hamed, 2017a

Table 2: Benefits and challenges of BIM use

2.4. BIM Use in the Middle East & Jordan

The use of BIM processes and growth of implementation in the Middle East varies significantly between different countries. A 2010 survey of AEC professionals on the adoption and implementation of BIM in the Middle East region showed an average of 25% of companies using BIM across Jordan and the Gulf Cooperation Council (GCC) (Building Smart, 2011). At that time, the comparative use level in Western Europe was 36%, and 49% in the USA (Building Smart, 2011). In 2012, the Middle East was reported to have the lowest average take up of BIM globally, primarily because the public sector was not taking any steps to implement it (Awwad, 2013). The status of BIM implementation in the Middle East in 2016 showed a large degree of variability, as represented in Figure 2 (Shaikh et al., 2016).

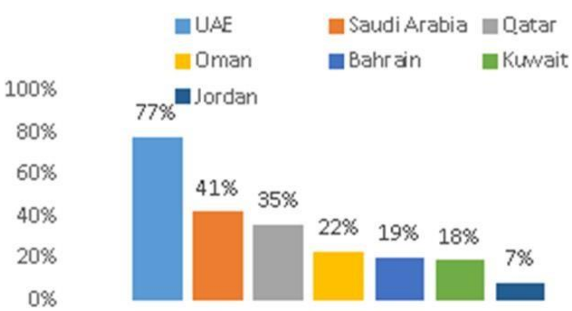

Figure 2: BIM Uptake in the Middle East (2016) (Shaikh et al., 2016).

The higher levels of BIM use are largely associated with the three countries with the largest levels of construction, being UAE, Saudi Arabia and Qatar, whilst the overall use of BIM in projects was approximately 31.2% in the region. However, in November 2013, Dubai Municipality in the UAE issued Circular No. 196, specifying the requirement for the use of BIM processes on larger and / or more complex projects from 2014 (Dubai Municipality, 2013). This was subsequently revised by Circular No. 207 in 2015 to include a broader scope of projects, including all government projects, which potentially highlights the importance of regulatory requirements for the development of BIM adoption (Beale & Company, 2017).

A concurrent study (Gerges et al., 2017) also reported the wide variations in BIM implementation across the region, together with the probable reasons behind them. That research made additional observations regarding the uses of BIM processes, allowing an assessment of the maturity stage of BIM to be made. One of the conclusions was that most professionals within this region still consider BIM merely as an advanced CAD tool that gives a 3D model of the built asset.

The conclusion concerning the lack of correct BIM understanding being among the challenges facing BIM adoption in Jordan aligns with a study by Btoush in 2017, which was done with the purpose of investigating the understanding of BIM by Jordanian contractors and collected information about their views on its implementation. The findings of the study showed a variation of the contractors' understanding of BIM; 13% perceived BIM as a 3D modelling tool, 33% defined BIM as using 3D, intelligent, computable data for project collaboration, 27% saw BIM as creating an intelligent, computable 3D data set, 13% saw BIM to be "multidimensional data concerning cost and value". The remaining 13% understood BIM to be a tool providing "5D modelling, creating an intelligent computable, 5D data set which includes time and cost" (Btoush & Haron, 2017). The variations mentioned above are included within the five BIM dimensions put forward by Khosrowshahi and Arayici (2012).

This perception of BIM in the Jordanian construction industry constitutes major challenges and barriers for adoption and implementation. It also indicates an embryonic maturity stage for the collaboration and BIM processes in use, and a consequential failure to realise the benefits to projects which BIM is intended to support. Lack of awareness, resistance to change and the costs associated with the shift from CAD to BIM, in addition to lack of Governmental support and the absence of specialists to deliver adequate BIM training and support remain among the barriers facing the adoption of BIM in Jordan. (Btoush & Btoosh, 2019)

As the country with the lowest reported level of BIM take-up in the region, Jordan has the potential to make the most rapid gains. A survey by Matarneh and Hamed between 2016-2017 showed that BIM was used by only 5% of AEC companies in Jordan, and that 43.5% of respondents used BIM processes for <20% of their time (Mataraneh & Hamed, 2017b), which also correlates with the study conducted by Gerges in 2017 which showed that only 3% of respondents in

Jordan were involved in construction projects using BIM. This reflects the very low levels of BIM implementation in the country (Gerges et al., 2017).

In comparison to the 2010 study findings (Building Smart, 2011), it appears that the use of BIM processes in Jordan has stagnated and may even be in decline. There appears to be an urgent requirement to develop an understanding of current practices and foreseen evolution of the use of BIM in the AEC industry in Jordan.

3. Research Methodology

The philosophy and methodology of this research are intended to fulfil the aim of the study, including the collation of relevant previous studies on BIM use worldwide, in the Middle East, and in Jordan in particular, supplemented by current information on BIM maturity and the perceived and realised advantages of its implementation in the AEC industry. The methodology applied is based on the refinement of broadly-based and global knowledge, to objective-specific and localised knowledge, as illustrated in Figure 3.

The first stage involves a review of available literature, whereby an understanding of the development of BIM processes, requirements for successful implementation, and the benefits of its use were collated. The rate of BIM uptake worldwide, in the Middle East, and in Jordan are also reviewed, together with factors which promote BIM use and those which present constraints to implementation in the AEC industry.

Based on the information collected during the literature review, a questionnaire is developed to identify: the current scope and scale of BIM use, such as the level of information need, BIM dimensions, technology integrated within BIM workflow; the benefits realised by BIM implementers; and the advantages/disadvantages perceived by those who have not yet done so. The questionnaire was distributed to professionals within the AEC industry in Jordan, who were asked to indicate their level of agreement or disagreement with statements regarding the use of BIM. The results of the questionnaire were then used to establish a scale for benchmarking BIM use, as well as the potential advantages and disadvantages this presents to the AEC industry in Jordan, and the main factors limiting BIM implementation.

In the development of the research process, a mixed-method approach is adopted since it was clear that quantitative or qualitative information alone would not resolve the requirements of the study's aims and objectives. The use of quantitative and qualitative information provides a better insight into the issues being studied and a better understanding of the research problem, more than that which would be gained from using either type alone (Matarneh & Hamed, 2017a).

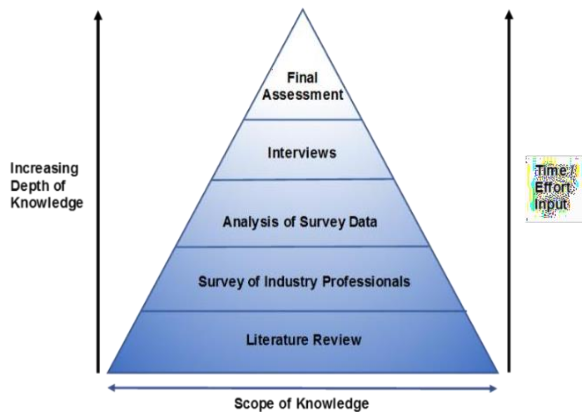

Figure 3: Refinement of Knowledge Process

3.1. Data Collection

The approach to data collection consisted of three distinct stages. The first stage was an extensive literature review to develop deep understanding of the technical aspects of BIM, and historical and current situation regarding implementation, within the scope of the planned research. The second stage consisted of a questionnaire to investigate AEC professionals' knowledge, experience, perceptions and plans in implementing and using BIM in Jordan. This questionnaire was refined using feedback gathered from individual interviews with seven AEC professionals with at least 10 years of experience in Jordan. This satisfies the minimum acceptable proportion of 5% of the targeted 100 responses for the questionnaire (Hertzog, 2008).

The final questionnaire was made available via the online platform "SoGoSurvey," which supported rapid completion of the questionnaire and collection of responses. Respondents were requested to provide 12 quantitative responses about their background in order to allow for anonymised profiling, and their level of agreement / disagreement with 22 statements/questions on BIM implementation within their experience in Jordan, using a five-point Likert scale. The use of a quantitative approach to test the aspects of BIM implementation is reported to be a reliable methodology in the literature (Naoum, 2012).

The population under study can be defined as "AEC professionals in the Jordanian region." Convenience sampling was used for the survey, since it is appropriate for the collection of both quantitative and qualitative aspects of the questionnaire, within a reasonable time and at minimal cost, and has been used in many similar research studies. This type of non-random sampling is suitable for the collection of quantitative and qualitative data where the information should generally represent the full population but the randomisation of the sample itself is not necessary (Etikan, 2016). Due to time and resource restrictions, the research targeted a limited, but justifiable number of respondents. It is also the case that the survey targeted AEC professionals based in Jordan, whilst it must be acknowledged that many international organisations operate in this regional sector. However, the primary concern of this research is the implementation and maturity of BIM within the Jordanian AEC industry, and thus no conflict in the validity of the research by these acknowledged limitations of the research is foreseen.

Requests for participation were sent to experienced professionals across the Jordanian AEC industry via social media and e-mail to known contacts, and directly to principal managers of large AEC organisations, with an invitation for them to also include other qualified persons within their networks. The study does not address investigations into the area of speciality or length of experience of the respondents but is intended to identify aspects of BIM implementation from their experience. Although the survey did not target the selection of a random sample from the population of AEC professionals in Jordan, the respondents' profiles were collected to provide an indication that reasonable coverage of the various industry sectors and career experiences was achieved in support of the validity of the study.

The third stage of data collection was individual interviews with 5 industry professionals, each with over 10 years of experience working within and managing AEC organisations in Jordan. Additional insight into the status of BIM process use in Jordan and the perceptions, opinions and experiences of the AEC industry was gained, providing a commercial and operational context against which the questionnaire results were considered. Additional insights applicable to understanding the challenges and opportunities of BIM implementation in Jordan based on practical experiences were also obtained. The perceptions and opinions expressed during these interviews were recorded to provide the context under which current BIM implementation and maturity in Jordan is assessed by this research.

3.2. Data Analysis

The responses to the questionnaire were collated by the service provider and supplied to the research team. The closed-question (quantitative) responses within the first section were used to prepare an overall profile of respondents' operating sectors within AEC industry and their experience in BIM use. Results from the level of agreement questions in the second part of the questionnaire, concerning perceptions of BIM implementation and use, were assessed using the Relative Importance Index Method (Gerges, 2017). A Likert scale value for each response (from 'Strongly Agree' = 5 to 'Strongly Disagree' = 1) was applied, whereby a numerical value was assigned to the overall response to each question using the formula:

Relative Importance Index =

$$\frac{5n5 + 4n4 + 3n3 + 2n2 + 1n1}{5N}$$

Where:

N = Total number of responses

n5 to n1 = Number of strong agreements to number of strong disagreement responses

This method provides an indication of the overall level of agreement, or disagreement, to each statement, and the ability to rank the statements by order of importance to the survey population.

3.3. Respondents Profile

A total of 107 individual respondents completed the online questionnaire over a period of 23 days. As shown in Figure 4, the principle sectors of Architecture, Engineering and Construction (AEC) service providers are robustly represented, together providing 93% of responses, indicating that the broad spectrum of respondents targeted was achieved.

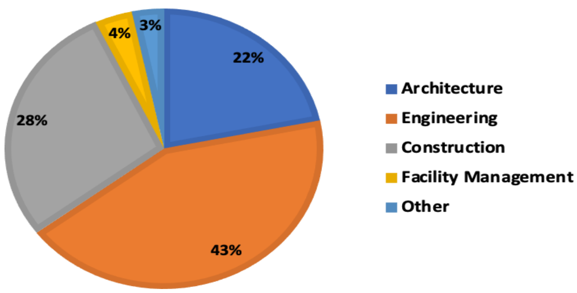

Figure 4: Operational Sectors of Respondent Companies

The 5% of responses from companies involved in facility management is lower than what would be preferred. However, it is known, and was confirmed during the supplementary interviews, that there is little demand for this service by clients in Jordan, who prefer to take responsibility for operation and maintenance of facilities within their own control.

The opinions of professionals from well-established AEC service providers were also targeted in order to utilise their knowledge of the Jordanian industry. As shown below, 64% of respondents to the questionnaire represented companies with 10 years or more of operating experience in the Jordanian AEC industry.

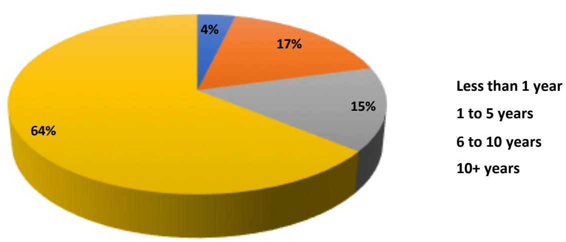

Figure 5: Experience of Responding AEC Companies

The client-base of respondent AEC companies was also studied (see Figure 6). As shown in the Figure, it is clear that both public and private sector clients are equally important to the Jordanian AEC industry.

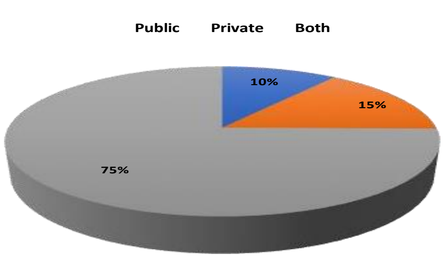

Figure 6: Client Type of Respondent AEC Companies

A balance of responses from experienced and forward-thinking professionals was also achieved, as shown in Figure 7. This provides a balance between inexperience and the previously identified challenge of 'resistance to change' of long-standing professionals potentially constraining BIM implementation in the AEC industry.

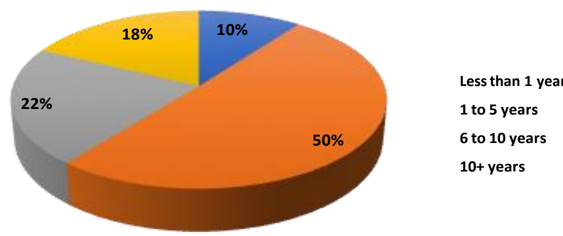

Figure 7: Professional Experience of Respondents

As shown in Figure 8, a reasonable balance between BIM users and non-users within responding professionals in the Jordanian AEC industry was also obtained. Around 54% of respondents reported that they are aware of and are currently using BIM, while 35% of respondents reported that they are aware of but not currently using BIM. The remaining 11% reported no awareness of BIM.

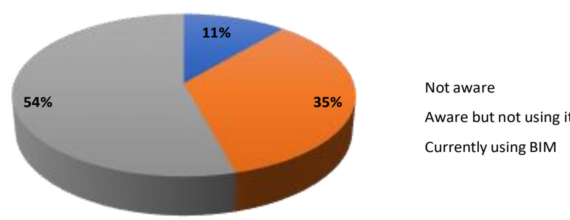

Figure 8: BIM Awareness

4. Results and Discussions:

4.1. Questionnaire

The results of the questionnaire provided quantitative information concerning the respondents' adoption of BIM, and details of how it is implemented and used within their organisation. In response to specific statements concerning the respondents' opinions of BIM and its implementation in Jordan, qualitative information was gathered. The data was then analysed to provide current information of the usage and level of development of BIM processes within the AEC industry in Jordan. Challenges and barriers to successful implementation of BIM processes were also assessed and compared to previous studies in the region including those by Matarneh & Hamed (2017b), Batoush & Haron (2017), Gerges (2016 and 2017), and Venkatachalam (2017). The response analysis also allowed for the identification of potential BIM benefits to the Jordanian AEC industry from its stakeholders' perspective.

4.1.1. BIM Adoption & Implementation

The reasons for implementing BIM in the Jordanian AEC industry are an important aspect of assessing the benefits which users have realised, and so is identifying potential future drivers for further increases in effective use of BIM processes, as shown in Figure 9.

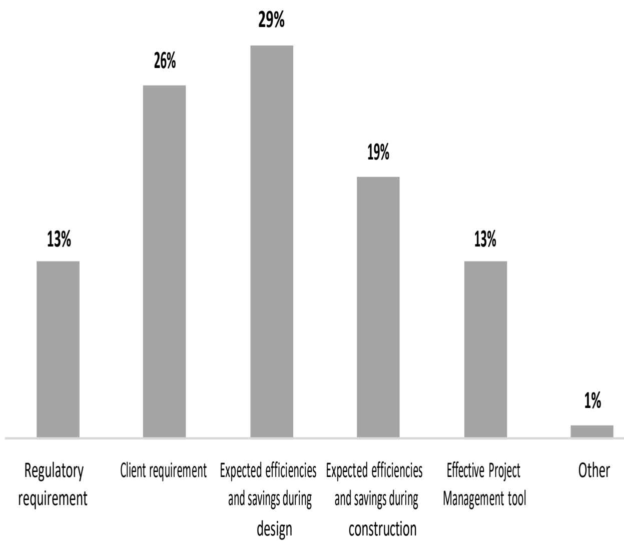

Figure 9: Reasons for Implementing BIM

According to the data collected, 48% of individual respondents are using BIM workflows or BIM authoring tools to gain efficiencies and savings during design and construction, suggesting a strong economic driver for implementation. Client requirement for BIM use came as one of the top reasons for implementation as reported by 26% of respondents, whilst 13% of respondents reported using BIM due to regulatory requirements. Since there is no regulatory requirement for BIM use in Jordan, this requirement most likely affects AEC companies which are based in Jordan, but also work on projects in different countries in the Middle East which require BIM, confirming the findings of Gerges in 2016 (Gerges, 2016). It may also be that the AEC companies using BIM tend to develop larger and more complex projects, where the Clients require that BIM processes are used in order to reduce their own risk. The potential impact of regulatory and client requirements for increasing BIM use in Jordan is clearly demonstrated.

Figure 10 illustrates the project areas where respondents stated BIM processes were applied, and shows that 62% of respondents confirmed the use of BIM processes during the design stages, whilst only 30% use them during Construction. This reflects the composition of the respondents by AEC industry area as shown in Figure 4, as does the 7% use of BIM for facility management purposes. Figure 11 shows the highest level of BIM dimensions used by the respondents' companies, which closely correlates with the observations of BIM use by project stage above, with 3D and some 4D BIM at design stage, 4D and 5D at construction stage and 6D+ for facilities management.

Responses may suggest that BIM implementation in Jordan is weighted towards the benefits of the particular company undertaking a specific task such as design or construction, rather than being used as an effective tool for the entire lifecycle of the asset, involving all engineering disciplines in the process of developing the project information containers within a BIM workflow.

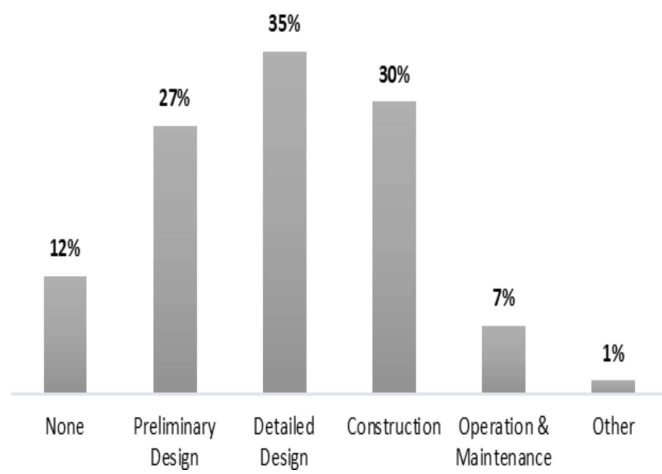

Figure 10: BIM use by Project Stage

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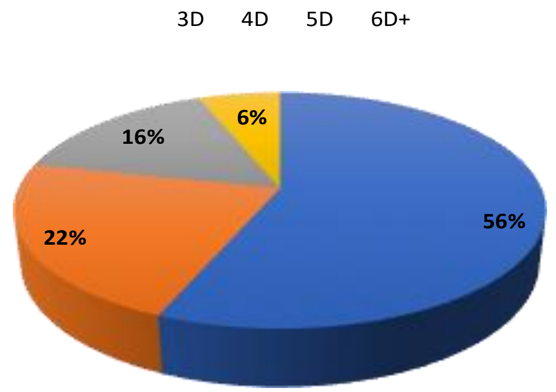

Figure 11: Highest Dimension of BIM Use

The Level of Detail (LOD) of BIM models is another indicator of the quality and maturity of BIM processes. Figure 12 shows the BIM LOD usually used by the respondents, which again parallels the results noted above according to the AEC operating area of the organisation, with 56% of users using LOD suited to various stages of design development, 22% with BIM suited to a construction model, and 7% of users developing BIM processes with LOD 6 as in as-built models.

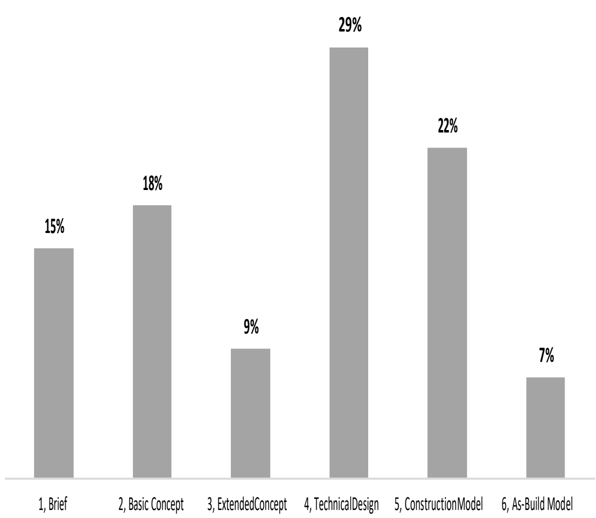

Figure 12: Usual LOD Employed by BIM Users

Jordanian AEC firms appear to recognise the need to develop and implement BIM processes on a wider scale. As shown in Figure 13, 47% of respondents plan to use BIM in over 40% of their future projects, whilst only 9% have no plans for implementation.

Figure 13: Planned Future Use of BIM

This development of BIM implementation is certainly influenced by the economic advantages discussed above, and other factors are also likely to contribute. Identifying and promoting these additional drivers would serve to further enhance the increase of BIM use if properly addressed.

A significant potential constraint to BIM implementation globally, and in the Middle East in particular, is the availability of suitably trained BIM users and system operators (Abdulfattah et al., 2017; Maratneh & Hamed, 2017a). A questionnaire was distributed by Matarneh & Hamed in 2017 within the Jordanian AEC industry, which showed that 65% of the respondents were self-taught and 12% in-house trained, whilst 3% learned BIM at a university (Matarneh & Hamed, 2017b). The training methods used by respondents to the current study are shown in Figure 14. Reliance on formal training provided by universities or BIM service providers remains a minority, with 26% of BIM users being self-taught and 45% educated through in-house company processes. This indicates that AEC firms in Jordan are trying to improve employee training for the purpose of organisational BIM implementation, whilst the static level of university-trained respondents may indicate either a lack of support from these institutions, or a delay of BIM training incorporation within study plans.

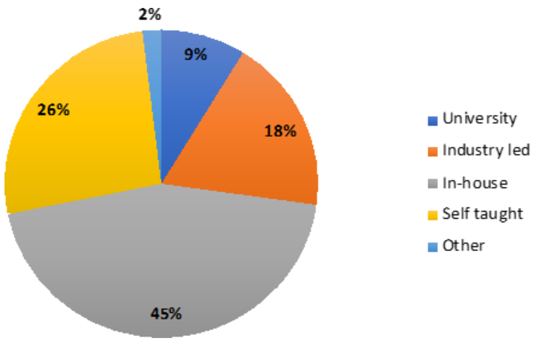

Figure 14: Training Methods for BIM Users

The accuracy and content of BIM knowledge gained through experience at work cannot be adequately judged, but potentially serves to restrict development of BIM processes and application of the latest techniques and workflows within these organisations. However, as illustrated in Figure 15, 66% of respondents report that BIM knowledge and skills are at least adequate for their company's current needs, with 34% satisfied that their planned future use of BIM is also supported by sufficiently trained and experienced staff.

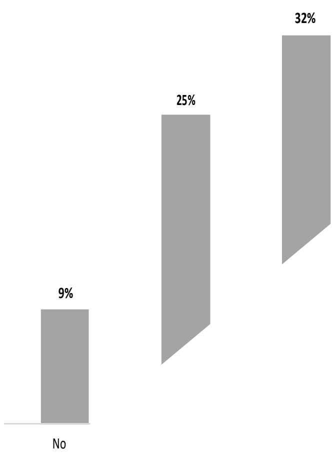

Figure 15: Level of BIM Knowledge and Skills

4.1.2. Benefits & Challenges of BIM in Jordan

The statements provided in the second part of the questionnaire were based on the understanding of challenges and opportunities for BIM implementation, concluded from the literature review from which the questionnaire was developed. The results of this part of the survey, with 63% of respondents indicating agreement or strong agreement, as shown in Figure 16, provide an indication that the perceptions of the research derived from the initial assessments are valid and worthy of further analysis.

Figure 16: Level of Agreement with Questionnaire Statements

The Relative Importance Index of respondents' opinions of statements based on the literature review of previously identified benefits and challenges for BIM implementation are shown in Table 3.

It is clear that overall approval of BIM processes exists from those who have implemented them, with an 84.2% index value for recommending BIM implementation to others. Financial and efficiency benefits are amongst those most strongly supported in the opinion of the respondents. Significantly, the benefits of BIM implementation and use and future plans to expand BIM use are all identified in the upper portion of the table, with index values of 73.5% and above, whilst the statements of expected challenges all rate at lower index values.

Responses also may suggest that individuals and companies are reluctant to implement BIM. However, responses indicated that companies' staff were more reluctant to use BIM than their companies. This may lead to conclude that resistance to change among AEC Jordanian professionals is an obstacle that must be overcome. Raising awareness towards the benefits of BIM for individuals and offering more trainings on how BIM can benefit professionals in their daily tasks may aid in reducing the reluctance of professionals to use BIM.

Although of less importance than the benefits, challenges of obtaining adequate staff training and changing the work culture need to be addressed further, which would most appropriately be achieved by the BIM service industry, potentially through appropriate professional bodies in Jordan.

Client requirements for the use of BIM also scored poorly, indicating that an increase in the requirement to use BIM, either by Client preference or regulation, could improve the level of BIM implementation within the Jordanian AEC industry.

The final observation from the analysis of the responses to this portion of the survey is that the lowest rating by the respondents is 57.7% when it is suggested that the risks of BIM implementation are too high, indicating a general recognition of the business case for implementing BIM within the AEC industry in Jordan.

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Relative Importance
I would recommend the use of BIM to others	3	1	12	44	45	84.2%
Reduces errors in design	3	1	13	45	44	83.8%
Reduces the time for decision making	2	3	16	54	31	80.6%
Improves communication between project partners	4	2	17	48	35	80.4%
Assists construction planning	2	2	19	53	30	80.2%
Reduces variations of works during construction	2	6	21	43	33	78.9%
Is a useful on-going record of the project for the owner	1	4	20	60	20	77.9%
Reduces design time & inputs	3	10	19	43	31	76.8%
Improves financial planning for the project	1	6	23	54	21	76.8%
Implementing BIM is worth the investment	5	4	20	51	24	76.3%
The company is looking to use BIM on more projects	5	4	25	50	20	74.6%
Helps improve sustainability of completed project	1	9	25	52	17	74.4%
Helps plan operation and maintenance of completed project	2	8	29	49	18	73.8%
The company is looking to increase the level of BIM used (e.g. from 3D to 4D, etc…)	5	9	22	47	21	73.5%
Hardware and software for BIM are very expensive	1	9	35	38	21	73.3%
Trained BIM users are in limited supply	2	7	37	39	18	72.4%
Training on BIM management and operation is not readily available	5	24	19	40	16	67.3%
Changes to working practices are prohibitive	5	13	44	38	4	64.4%
The company staff were reluctant to use BIM	4	20	36	36	7	64.3%
Clients often require BIM use on their projects	4	22	36	35	6	63.3%
The company was reluctant to implement BIM	5	19	41	32	7	63.3%
The overall risk of implementing BIM is too high	7	36	30	24	7	57.7%

Table 3: Relative Importance Index of survey responses

4.2. Interview Responses in the Context of Competition

An understanding of the competition environment within which the AEC industry in Jordan operates is essential, as it has an apparent direct influence on the current status of BIM implementation. The construction industry in Jordan is highly competitive, with a large number of AEC companies operating both locally and in the Middle East region. The largest Client in Jordan is typically government agencies in the public sector, mainly due to International Donor funded projects, which currently tend to emphasise constrained time schedules and minimal capital costs, since rapid maximum impact is required. The public sector in Jordan does not require BIM for their projects and there are no regulatory requirements for private sector projects to contain BIM components, although some Clients do mandate the use of BIM.

It should be noted that although ‘resistance to change’ has been previously reported as a barrier to BIM implementation in Jordan, the individual interviews indicated that the additional costs of implementing BIM and the risks of doing so within tight project delivery schedules are much more significant factors. It was also apparent that these experienced professionals are fully aware of the potential benefits of BIM. However, AEC companies are still reluctant to take voluntary independent actions to adopt BIM, which could only be resolved if regulatory or general Client requirements would make BIM implementation essential for the majority of projects.

4.3. Recommendations to enhance BIM use in Jordan

The scale of BIM implementation requires additional support, which should be equally applied to all organisations operating within the AEC industry. The most effective intervention would be the introduction of regulatory requirements, as can be seen by the effects of doing so in Dubai and in the UK. The BIM industry and academic institutions should work together to provide appropriate levels of high standard BIM training with qualifications which are recognised by the recognised bodies within the AEC industry.

The Jordanian industry should look into adopting BIM standards which provide recommendations for the workflows, processes, information management functions, organisational roles and responsibilities and technical specifications, which realise the benefits of BIM on organisational, client and industry levels. Standards such as ISO 19650 Series and the active parts of the British PAS 1192 Suite of Standards could support the Jordanian AEC industry to adopt BIM at a national level, by providing a set of lessons learned and a tested approach to implementation.

4.4. Recommendations for Further Research

This paper recommends further research into BIM implementation in Jordan, taking into consideration: a larger survey sample that targets facility management organisations, conducting interviews with a suitable number of contractors and academic professionals in order to provide a focused specialized perspective of BIM uses and awareness in Jordan, investigating BIM implementation according to size and complexity of projects, investigating the maturity of BIM implementation and the scale of cross-discipline collaboration, exploring the differences between BIM use in private and public sector projects, and studying the government perspective to identify future plans for improving BIM implementation in the Jordanian AEC industry.

5. Conclusions

The scope and scale of BIM implementation in Jordan's AEC industry have improved significantly since earlier studies of the issue were completed. The economic benefits of using BIM processes are now more clearly recognised, whilst the perceived challenges and risks are of lower concern. However, additional support to the development of both the scale and detail of BIM processes used is needed to fully realise the benefits of the workflow.

The research showed that many people are employing BIM in Jordan only for the use of a 3D model and the basic benefits realised from it, such as design coordination. However, responses may suggest that BIM is being practiced across the industry with low levels of collaboration between the different engineering disciplines involved in a project. Instead of working collaboratively to create federated models that include all disciplines, project parties are working in isolation and producing mono-discipline models. Such attitude to the implementation of BIM may suggest that the local understanding of BIM is as a modelling and coordination tool instead of a collaborative process which promotes communication and exchange of data and information across an asset's lifecycle. This indicates that BIM in the Jordanian AEC industry still has not reached an implementation maturity of stage 2, as defined in ISO 19650 Series.

The research also showed that the government of Jordan is not driving the implementation of BIM by not requiring or mandating BIM workflows to be adopted by companies and professionals in the Jordanian AEC industry, for public or private projects. This finding is in line with what has been reported in other countries in the region such as Syria and Kuwait (Ahmed et. al, 2018; Abdulfattah et al., 2017).

This research also attempted to reinvestigate the benefits and barriers of BIM for the Jordanian AEC industry. In particular, the challenges to future expansion of BIM use were analysed and compared to those in other countries. In addition, the research aimed to identify and classify the strengths, risks and opportunities for BIM in the Jordanian AEC industry, identify the potential impact and significance of BIM implementation, and recommend methods for risk mitigation and promotion of BIM process implementation.

The research method fulfilled the research objectives. The literature review created a historical baseline of relevant information for BIM use in Jordan and the Middle East region, which was then compared to the current situation in Jordan. Identified benefits and challenges of BIM implementation were assessed according to their relative importance to respondents, and the perceptions of AEC professionals in Jordan to previously reported factors were ranked accordingly.

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