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Comparative Analysis of Building Information Modeling (BIM) Patterns and Trends in the United Arab Emirates (UAE) with Developed Countries

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Abstract: This research seeks to gain a deeper understanding of the current ecosystem of BIM technology and its utilization in the UAE. Since the UAE has been an early adopter of BIM, its utilization of BIM is now likely to reach that of developed nations. By adopting the BIM case study analysis framework, two sets of projects of similar categories in terms of functionality and typology were selected and mapped. One set represents projects within the UAE, and the second represents projects from developed nations utilizing BIM during the projects' lifecycle (LC). Incorporating expert interviews to triangulate the results collected from the case study analysis will further contribute to developing a more in-depth comprehension of BIM use in the UAE. The three significant inferences can be drawn from the findings. Firstly, in the UAE, stakeholders utilize BIM fragmentarily in different stages. Secondly, the full extent of BIM utilization over the project's LC is not pursued. Thirdly, no effective BIM standards or protocols exist. Even though international firms are the main drivers of UAE BIM adoption and utilization, UAE BIM is still in its infancy, necessitating a more collaborative effort to realize the holistic benefits of the BIM process. The findings could be utilized to identify industry standards and guiding principles for BIM implementation in the UAE and help identify areas for improvement. It also provides valuable insights into how BIM can be used more effectively in the country and how its use can be promoted. Additionally, it could be used as a guide for owners/asset managers and AEC professionals in the UAE looking to implement BIM in their projects.

Keywords: BIM benefits; BIM cases; BIM utilization; BIM for FM; construction projects; comparison; Dubai BIM mandate

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1. Introduction

BIM is a technology-enabled process that provides architects, engineers, construction professionals, and facility managers with a tool to plan, design, construct, and manage facilities [1]. The adoption of BIM has led to significant changes in the AEC industry. It allows for greater collaboration and coordination between project participants, better management of data and information, and improved decision making throughout the construction process [2,3]. BIM provides the ability to create and store a digital model/twin of the building before the physical building even starts to exist. It helps all parties identify and solve potential issues during the design and construction stages [2,4]. Additionally, it assists in the lifecycle management and operation of the facility. Furthermore, BIM makes it possible to monitor and evaluate multiple design scenarios during the design phase, narrowing down the options to the most advantageous in terms of costs, materials, and energy use [1].

BIM has been widely adopted in developed economies such as the USA, UK, and Australia and has been attributed to improving construction projects' efficiency, accuracy,

and quality [5]. Many developed economies have also adopted other technologies and concepts, such as BIM add-ins and BIM-enabled software, to improve the construction process further. These tools allow for more efficient and accurate data management, and enhanced collaboration and communication among project stakeholders over the projects' whole lifecycle [6]. While BIM is expected to be used throughout the entire life cycle of a project to improve collaboration and communication between stakeholders, in practice, this utilization remains a challenging and under-researched area.

The UAE has been making significant investments in the construction and infrastructure sectors [7], which has led to a growing interest in BIM to improve the efficiency and sustainability of these projects [8]. The UAE has been a leader in adopting and implementing BIM in the Middle East [9]. Dubai Municipality (DM) is the first authority to mandate the use of BIM in the Middle East [8], three years ahead of the UK BIM mandate in 2016 [10,11], on all new building projects above a specific size, followed by an update in 2015 added further requirements to the BIM mandate. Even though Dubai is the only Emirate among the seven UAE Emirates to have a BIM mandate, BIM projects are also found in other Emirates, including Abu Dhabi and Sharjah [9,11], which are included in our study.

The country has also launched several initiatives and programs to support the growth and application of BIM. The DM has gone one step further with the Dubai mandate by creating a new "Online Permitting System" that mandates all building projects submitted for approval be in BIM format [12]. Additionally, the UAE has introduced the National Guide for Smart Construction [13], which outlines the fundamental components of smart construction and uses benchmarking to assess the skills of contractors and foster cooperation among all parties involved in order to enhance the construction process as a whole [14]. These initiatives and requirements are likely to increase the use of BIM in the UAE. Indeed, as an early BIM adopter, the UAE is expected to have advanced BIM adoption and utilization levels comparable to those of developed countries with long histories of BIM implementation and culture, such as the United Kingdom, the United States, and Scandinavia.

The research aims to compare BIM patterns and trends in the UAE with those in developed nations by using case studies and qualitative descriptive analysis. Fifteen BIM cases of built projects from the UAE of varied typologies illustrate high-profile projects significant to this study. To facilitate the comparison, fifteen projects from developed countries with similar complexity of functions and typologies were studied (Table 1).

Such a comparison would require a detailed analysis of factors, including parties' involvement, the degree of BIM adoption and implementation, the available tools and software utilized during the process, and benefits [15].

The study may identify any unique challenges or opportunities for BIM adoption and utilization in the UAE and provide recommendations for addressing these challenges and capitalizing on these opportunities. The study's outcome will aid the construction industry, professionals, organizations, and government bodies in the UAE to grasp the current state of BIM adoption and utilization and enhance its future. It can also ensure more effective and efficient BIM utilization, resulting in improved building performance, cost savings, and other benefits for all stakeholders.

There is a lack of research that compares how BIM is being utilized in different regions through specific case studies of actual projects. However, some studies have examined BIM comparisons, such as a recent study by [16], which assessed BIM maturity levels between Qatar and the UK at a macro-scale based on expert evaluation and interviews. Nevertheless, this study was limited to BIM maturity factors and did not delve into specific case studies or actual projects. Another study by [17] compared BIM acceptance between Korea and the USA by investigating and comparing BIM acceptance mechanisms using key factors. A third study by [18] compared government roles in implementing BIM between Hong Kong and the USA, utilizing a literature review and focused interviews, but not including any case studies or specific projects.

The first section introduces the study's subject matter and defines the equivalent objective and research gap. The following section presents the literature review. The research methodology is outlined in the third section, the fourth section presents the results, and the fifth section discusses the comparison along with experts' viewpoints. Finally, the conclusion summarizes the findings, future research direction, and limitations.

Table 1. BIM Projects: Cases from UAE and Developed Countries.

	UAE BIM Cases				DC (Developed Countries) BIM Cases			
Typology	**P ID**	**Project**	**Location**	**Year**	**P ID**	**Project**	**Country**	**Year**
Opera House	UA 1	Dubai Opera House [19,20]	Dubai	2013–2016	DC 1	Sydney Opera house [21]	Australia	2007
Airport	UA 2	Midfield Terminal, Airport [20,21]	Abu Dhabi	2012–2023	DC 2	Istanbul Grand Airport [21,22]	Turkey	2018
	UA 3	Damac Towers [2,23]	Dubai	2012–2017	DC 3	Shanghai Tower [19,21]	China	2008–2014
High-rise Tower	UA 4	Burj Khalifa [24,25]	Dubai	2004–2010	DC 4	Alto Tower [19,21]	France	2011–2015
	UA 5	Capital Gate [19]	Abu Dhabi	2007–2011	DC 5	One Nine Elms [20,26]	UK	2015–2023
Stadium	UA 6	Hazza Bin Zayed Stadium [27]	Abu Dhabi	2012–2014	DC 6	CSKA Moscow Stadium [21]	Russia	2016
Hospital	UA 7	New Al Ain hospital [28]	Abu Dhabi	2007–2011	DC 7	Queen Elizabeth Univ. Hospital [20]	UK	2015
	UA 8	Mediclinic Parkview Hospital [23]	Dubai	2015–2018	DC 8	Perth's Children Hospital [20,21]	Australia	2018
Hotel	UA 9	The Address JBR [19]	Dubai	2015–2018	DC 9	Hilton Garden Inn Atlanta [29]	USA	2006–2008
Shopping Mall	UA 10	Al Zahia city center mall [19,21]	Sharjah	2017–2021	DC 10	Easton Commercial Centre [21]	Finland	2017
	UA 11	The Dubai Mall [19,27]	Dubai	2015–2018	DC 11	Mall of Tripla [27]	Finland	2015–2019
Museum	UA 12	Museum of the Future [19,21,30]	Dubai	2015–2021	DC 12	V&A Dundee Museum [21]	UK	2015–2018
	UA 13	Louvre Museum [21,30]	Abu Dhabi	2009–2017	DC 13	House of the Future [20]	Germany	2017
Headquarter	UA 14	Sharjah Bee'ah Headquarter [31]	Sharjah	2016–2021	DC 14	NATO headquarters [21]	Belgium	2010–2016
	UA 15	Aldar headquarters [19]	Abu Dhabi	2007–2010	DC 15	Siemens Headquarters [21,32]	Switzerland	2016–2018

1.1. BIM Adoption Status in the UAE

The UAE dominates BIM maturity in the region [8,9]. While some government organizations, such as Dubai Electricity and Water Authority (DEWA), have limited adoption of BIM in some of their construction projects, the Road and Transport Authority (RTA) in Dubai is among the most committed to fully incorporating BIM into all of their projects, as reported by [9].

The country's capital Emirate, Abu Dhabi, has still not mandated the use of BIM, even though some organizations have initiated its implementation in significant projects such as Abu Dhabi International Airport, Midfield Terminal; New Al Ain hospital; and Capital Gate, which are included in this study. Consequently, despite the immense potential, the AEC industry's BIM adoption in the UAE remains limited [9].

As explained by [4,33], the UAE construction sector continues to face several issues, such as inadequate collaboration and communication, as well as financial and schedule overruns. Ref. [5] brought attention to the issues that contribute to budget overruns in infrastructure projects in the UAE. The findings indicated that poor oversight and timely instruction from the contractor is the most significant difficulties management faces in UAE infrastructure projects. As evidenced in several case studies and addressed in the existing literature, BIM adoption can evidently overcome such frequently encountered obstacles. However, according to [34], only around 10% of the UAE's construction sector is aware of BIM's full extent. Ref. [34] suggested that the primary concern in deploying BIM in the UAE is the lack of "published and accepted BIM standards and protocols". The ambiguity and lack of knowledge surrounding the applicability and significance of BIM repel clients and project stakeholders who otherwise would benefit from the transition. To assess BIM specialists' opinions on the subject, [11] used three variables to describe the key difficulties connected with BIM adoption in the UAE: "technical dimension," "organizational dimension," and "attitude factor." The findings of the study suggested that 45% of participants identified the absence of standards and protocols as the primary reason for not adopting BIM in the UAE with "resistance to change from current construction methodology" and "lack of BIM awareness" as the second and third main reasons. The

results also revealed an agreement with [33,35] previously mentioned statements, as 53% of participants identified "improve collaboration and communication" as the main advantage of BIM implementation followed by "reduce rework". Similarly, [36] conducted a study in which AEC industry professionals from 362 organizations in the UAE were surveyed. Their result revealed that the lack of commitment from management and resistance to change, and the tendency to stick to traditional methods are major barriers to adopting BIM in the UAE.

1.2. BIM Protocol and Global Mandates

Many governments are actively promoting the use of BIM in the building sector, with many developed countries (DC) having already done so. This is due to the recognized benefits and needs for an advanced process to manage dynamic and complex construction projects. DC has gone a step further in promoting the use of BIM by issuing legislation and regulations, often referred to as BIM mandates [37].

According to [38], several countries have been leading in developing BIM policies and regulations, with the government playing a crucial role in promoting and supporting BIM adoption. Singapore, Finland, Korea, the United States, the United Kingdom, and Australia are examples of countries at the forefront of BIM policy development globally. These countries have implemented BIM mandates, established BIM standards and guidelines, and provided funding and training to support the adoption of BIM in the construction industry.

However, these countries have pursued different approaches regarding BIM mandates, contracts, and maturity levels. In the United States, for example, the General Services Administration (GSA) initiated a policy in 2007 requiring BIM for final concept approval on all major public-sector projects. Furthermore, the GSA released a suite of BIM guidelines, including "3D-4D-BIM overview, spatial program validation, 3D laser scanning, 4D phasing, energy" [10].

From 2015 forward, the European Commission has also prioritized the implementation of BIM. Overall ranking further demonstrates a top priority for 2014 and several other projects to make the EU a global leader in information and communication technology [39]. Thus, The EUBIM Task Group was granted funding to develop its aim to promote the widespread use of BIM, often known as 'digital construction', in government projects with the shared objective of increasing value for government funds, public estate quality, and industry's sustainability performance [40]. The Task Group's goal is to create a European network that connects various national initiatives to unify European approaches to the digital building sector [39,40].

A global pioneer in Europe's BIM application is the UK. The Centre for Digital Built Britain [41] declares the UK's BIS BIM strategy initiative as the world's most extensive and strategically driven. In 2011, the United Kingdom legislated to implement BIM as a 3D modeling component. The primary government projects were required to adopt new building principles outlined in the "Building Strategy" report to reduce costs and time while simultaneously delivering a higher-quality project [42]. This strategy also mandated BIM maturity Level 2 by 2016 for all publicly funded projects, in which data and models are shared between the involved parties through a complete collaborative 3D BIM [16,38]. Following that, as part of the Digital Built Britain program, the implementation of BIM Level 3 was launched [16,41]. In Finland, public authorities and the state-owned Senate Properties (a property service agency) have mandated using digital building models (BIM) for public projects since 2007.

Additionally, Senate Properties, alongside buildingSMART, issued a set of standards in 2012 known as "Common BIM requirements 2012" [38]. In 2014, buildingSMART Spain produced the UBIM guidelines, the first BIM guidelines in Spanish. Later in 2018, BIM was required in the design and construction phases of public infrastructure projects worth more than EUR 2 million, and an infrastructure and transportation innovation strategy (2018–2020) was also created for 2020 [43].

In Asia, by 2016, the South Korean Public Procurement Service (PPS) made BIM obligatory for all public-sector projects and over USD 50 million [44]. Singapore has also set a notable benchmark. Singapore's Building and Construction Authority (BCA) first introduced BIM adoption in July 2013. Initially, the use of BIM was mandatory for architectural plans in all new building projects with a gross floor area (GFA) larger than 20,000 m^2. Later, structural and MEP plans were also required to be in BIM format. By July 2015, the requirement was extended to all new building projects with a GFA of 5000 m^2, which had to follow the BIM submission guidelines [45].

2. Methodology

This study employs a mixed methods approach and, more particularly, the triangulation methodology, which entails gathering data from multiple perspectives and sources [46,47]. A qualitative method was adopted because it can be a powerful tool for gaining a rich and nuanced understanding of complex phenomena and can provide valuable insights for researchers and practitioners in the field [48,49]. One advantage of qualitative analysis is that it allows for a greater depth of understanding and insight into the data, as it seeks to capture the subjective experiences and perspectives of the participants. It also requires the researcher to be highly skilled in data analysis and interpretation, as often a great deal of subjectivity is involved [49,50]. Moreover, the authors bring their experiences of two decades in the field of BIM, construction, construction management, and architecture.

Initially, 35 BIM projects were identified in the UAE through thorough research and review of the relevant literature from various sources such as builders, consultants, and official BIM organization websites. The next step involved filtering and categorizing these projects based on their building typologies and functionality. A total of 15 projects and 9 different building typologies were selected to represent the infrastructure development in the UAE. To facilitate the comparison, 15 actual BIM projects from developed countries with similar functions and building typologies ensured that the projects were comparable in terms of goals and objectives. The aim is to acquire a detailed comprehension of how BIM is being utilized and its level of maturity in both regions.

Subsequently, an explanatory case study analysis was carried out by evaluating the identified projects from both regions using the case study analysis framework established by Chuck Eastman's BIM Handbook [15].

The UAE BIM cases are actual built projects categorized in various building typologies to ensure that large-scale, complex functions of buildings that could benefit from BIM technologies are included in the comparison (Table 1). These include iconic projects such as "Burj Khalifa," the world's tallest structure by Skidmore, Owings & Merrill (SOM); "The Dubai Mall," the world's largest retail mall by DP Architects; the "Museum of the Future," one of Dubai's most recognizable landmarks; Louvre Abu Dhabi by Jean Nouvel; Midfield Terminal, Abu Dhabi Airport by Kohn Pederson Fox Associates; and Sharjah Bee'ah New Headquarter by Zaha Hadid Architects.

The two countries listed in Table 1, China and Turkey, have lower per capita GDP than the conventional benchmark for developed countries [51,52]. However, China and Turkey are currently undergoing a construction boom and widespread use of BIM technology. Additionally, both countries are undergoing significant economic growth and development, and it is therefore expected to reach the developed nations' benchmark by 2023 [53].

Secondly, in order to make a valid comparison, the study undertakes a detailed evaluation of factors as outlined in Chuck Eastman's BIM Handbook, case study analysis [15] (see Mapping of Criteria to BIM Cases, Table 2).

These four main categories are:

(1) Extent of Participant (parties and teams) involvement (Figure 1);
(2) Level of BIM Adoption and Implementation at Each LC Stage (Figure 2);
(3) Availability of BIM-Related Technology and Software Utilized during the BIM Process
(4) Benefits Gained through the Utilization of BIM.

Thirdly, experts practicing BIM within the UAE market, representing different disciplines and industries (Table 3), are then interviewed to enhance the validity and reliability of the study's findings (ranking Table 4). This triangulation approach can provide a richer and more holistic understanding of BIM status in the UAE compared to developed countries. It also allows for cross-checking and validation of findings, which can enhance the reliability of the results [46,47].

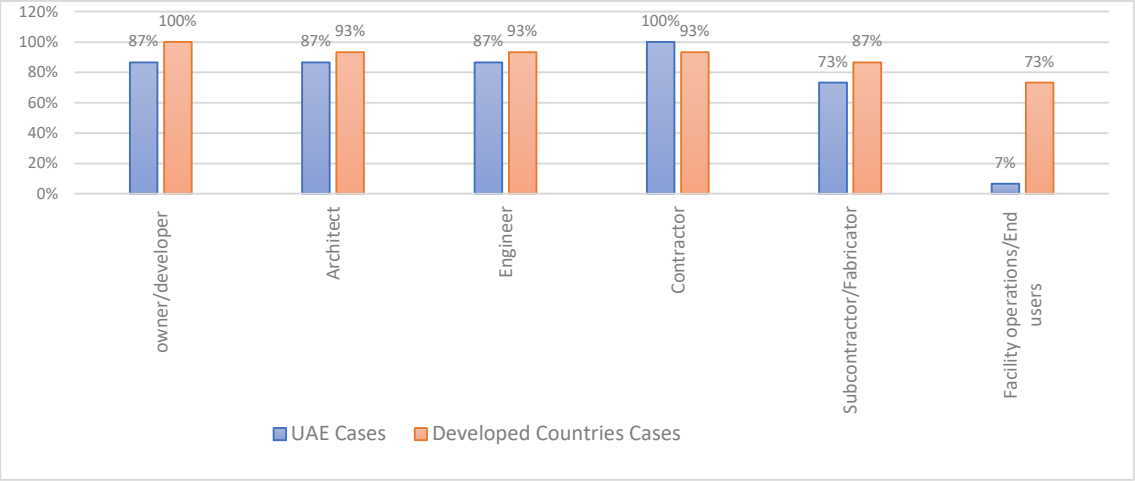


Figure 1. Extent Participant (Parties and Teams) Involvement.

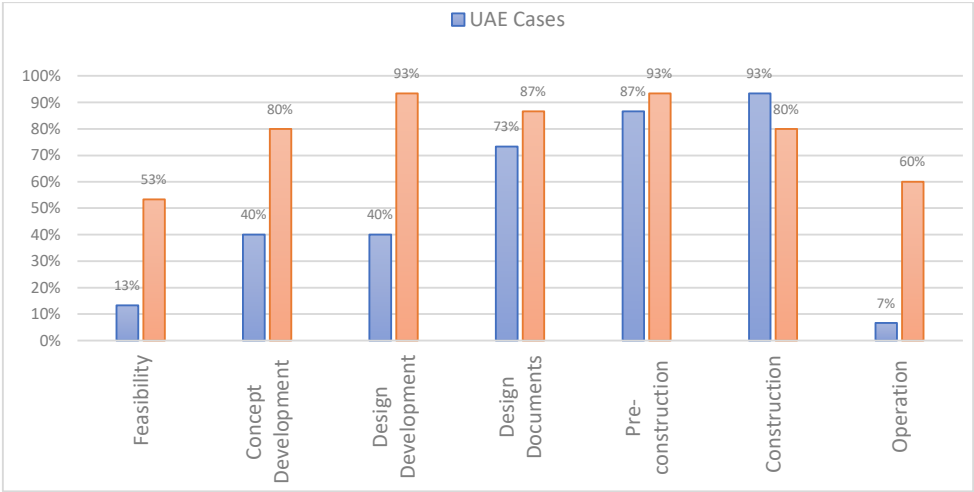


Figure 2. BIM Utilization Project Phases LC.

Table 2. Mapping of Criteria to BIM Cases.

		UAE BIM Cases															Developed Countries BIM Cases													
		UA1	UA2	UA3	UA4	UA5	UA6	UA7	UA8	UA9	UA10	UA11	UA12	UA13	UA14	UA15	DC1	DC2	DC3	DC4	DC5	DC6	DC7	DC8	DC9	DC10	DC11	DC12	DC13	DC14	DC15
Project Scope	Feasibility	•									•						•		•			•	•	•	•		•	•			
	Concept Development	•			•	•					•	•				•	•		•	•		•	•	•	•		•	•	•	•	•
	Design Development	•			•	•					•	•				•	•	•	•	•		•	•	•	•	•	•	•	•	•	•
	Design Documents	•	•	•	•	•		•	•		•	•	•			•	•	•	•	•		•	•	•	•		•	•	•	•	•
	Pre-construction	•	•	•		•	•	•		•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•
	Construction	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•		•
	Operation										•						•		•	•	•	•			•		•	•			•
Participants	owner/developer	•		•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Architect	•		•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•
	Engineer	•	•		•	•	•	•	•	•		•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•
	Contractor	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•
	Subcontractor/Fabricator	•	•		•	•				•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•	•
	Facility operations/End users										•						•		•	•	•	•	•		•	•		•		•	•

Table 2. *Cont.*

		UAE BIM Cases															Developed Countries BIM Cases													
		UA 1	UA 2	UA 3	UA 4	UA 5	UA 6	UA 7	UA 8	UA 9	UA 10	UA 11	UA 12	UA 13	UA 14	UA 15	DC 1	DC 2	DC 3	DC 4	DC 5	DC 6	DC 7	DC 8	DC 9	DC 10	DC 11	DC 12	DC 13	DC 14	DC 15
BIM Benefits	**Feasibility study:** Support for project scoping, cost estimation	•		•		•		•	•			•	•		•		•		•	•	•	•		•	•		•	•	•	•	•
	Concept design: 1. Scenario planning	•			•	•						•							•					•	•		•	•	•	•	•
	2. Early and accurate visualizations	•		•	•	•				•		•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•
	3 Optimize energy efficiency and sustainability	•		•	•	•				•		•	•				•	•			•			•	•				•		
	Integrated design/cons.: 1. Automatic maintenance of consistency in design.			•						•		•	•			•	•	•	•		•			•	•	•					•
	2. Enhanced building performance and quality.	•	•	•	•	•						•	•				•		•			•			•	•					
	3. Checks against design intent.		•	•		•				•							•	•	•	•				•	•	•	•	•			•
	4. Accurate and consistent drawing sets		•	•	•	•				•					•		•	•	•	•	•			•	•	•	•	•		•	•
	Construction execution/coordination: 1. Earlier collaboration of multiple design disciplines	•	•	•		•		•			•	•			•		•	•	•	•		•		•	•	•	•	•	•	•	•
	2. Synchronize design and construction planning.		•	•	•	•				•			•		•		•	•		•				•	•		•		•	•	
	3. Produce sufficient drawings for contractor bidding.							•	•									•							•						
	4. Discover errors before construction (clash detection).	•	•		•	•		•	•	•	•	•	•	•	•	•	•	•	•	•		•	•		•	•	•	•	•	•	•
	5. Drive fabrication and greater use of prefabricated components.	•	•		•	•			•	•				•	•	•	•	•	•						•	•					
	6. Support lean construction techniques.		•		•	•				•			•	•			•	•	•	•				•		•	•				
	7. Coordinate/synchronize procurement.		•		•			•	•		•		•			•	•		•			•			•						•
	Facility operation: 1. Lifecycle benefits regarding operating costs.																•			•		•			•			•	•		
	2. Lifecycle benefits regarding operating maintenance	•				•											•	•	•						•	•	•	•			

The BIM experts (Table 3) were contacted to provide their views and opinions on the four topics mentioned above. By incorporating expert interviews, the researchers can further triangulate the data collected from the explanatory case study analysis. The expert interviews would provide additional insights and perspectives on the BIM implementation process and help to validate the findings from the explanatory case study analysis. This can provide a more comprehensive view of the current state of BIM adoption and utilization in the UAE.

Table 3. Expert Profile.

Expert	*Affiliation*	*Field/Role*	*Experience/Years in AEC*	*Organization Type*	*No. of Employees*
E1	Turner Construction—International LLC: Digital Construction Lead	BIM speaker, BIM conferences/events contributor and organizer. Government consulting and partnering	18	Construction/contractor	171
E2	Centre of Excellence in Smart Construction	Director- Consultant/BIM consultant	12	Consultancy/Research	200
E3	EVERSENDAI ENGINEERING (L.L.C.)	Detailing Manager/Innovation in construction and composite structures. BIM structural modeling	15	Steel Contractor	99
E4	ASGC: a leading construction conglomerate	Digital Innovation Manager/BIM specialist	11	construction conglomerate	11,584
E5	Engineering group	Engineer manager/BIM specialist	14	Engineering contracting	525
E6	KFM Consultant	Design and Technical	7	Consultancy	1323
E7	Redington Gulf FZE	Technical Consultant AEC	18	Autodesk Software Solution Distributor	45

Table 4. Experts Ranking BIM Benefits (Based on Experience in UAE).

	Feasibility Study		*Concept Design*			*Integrated Design*				*Construction Execution/Coordination*					*Facility Operation*	
	support for project scoping, cost estimation	Scenario planning	Early and accurate visualizations	Optimize energy efficiency and sustainability	Automatic maintenance of consistency in design	Enhanced building performance and quality	Checks against design intent	Accurate and consistent drawing sets	Earlier collaboration of multiple design disciplines	Synchronize design and construction planning	Produce sufficient drawings for contractor bidding	Discover errors before construction (clash detection)	Drive fabrication and greater use of prefabricated components	Support lean construction techniques	Coordinate / synchronize procurement	Lifecycle benefits regarding operating costs	Lifecycle benefits regarding operating maintenance
E 1			5						3	4		1			2		
E 2		1	2			4	3	5	6	7	8	9					
E 3	3		2	4		5			1								
E 4		5			6	4				1		2	7		3		
E 5	2		1			6	3	4				5					
E 6		1	3		2				5	4							
E 7	5	1	3	2			4		5	6		7				9	8
												Ranking Scale: 1: Top-ranked; 9: lowest ranked					

3. Results

This section will examine the results of the explanatory case study analysis in the following four sections, providing a comprehensive understanding of their meaning and implications. The following four figures are extracted from the mapping of criteria to BIM cases (Table 2).

(1) Extent of Participant (parties and teams) Involvement

BIM participants from the UAE and developed countries' projects are shown side by side in Figure 1. In both regions, all stakeholders are involved in the BIM process throughout a project's entire LC, except for asset/facility managers (FM), who are hardly involved in the UAE BIM process. This is clearly indicated by the very low presence of FM/end-users in the UAE (UAE 7% and DC 73%). This is corroborated by experts (E1, E2, E5); despite the apparent benefits of BIM at the FM stage, facility managers, building owners, and end-users are not typically included at the beginning of the process.

(2) BIM Utilization by Phases of Projects' Lifecycle

The analysis of the BIM project phases reveals that BIM was used least frequently during the FM stage in UAE projects, which is consistent with the previous chart (Figure 2, Operations UAE 7% and DC 60%). It shows that BIM activities in the UAE primarily focus on the construction phases (Design Documents, Pre-construction and Construction) rather than the early design or facility management phases. Figure 2 indicates a large discrepancy in BIM utilization at the stages of early design (Feasibility, UAE 13% and DC 43%, Concept Development UAE 40% and DC 80%, Design Development UAE 40% and DC 93%).

(3) Tools utilized during BIM process

The study has revealed somewhat parallels in using certain BIM tools across both DC and UAE projects, specifically, the use of Autodesk (Figure 3, AutoCAD UAE 27%

and DC 47%, Revit UAE 33% and DC 47%, Revit structure UAE 27% and DC 53% and Navisworks UAE 27% and DC 27%) and Bentley software for architectural design and review (UAE 27% and DC 34%). The most widely utilized tools for structure analysis are Tekla Structure software (UAE 40% and DC 33%) and Revit Structure (UAE 27% and DC 53%). Other structure tools are utilized at lower margins such as Robot Millennium (Autodesk BIM structural analysis software for engineers) and ETABS (structure and earthquake engineering software).

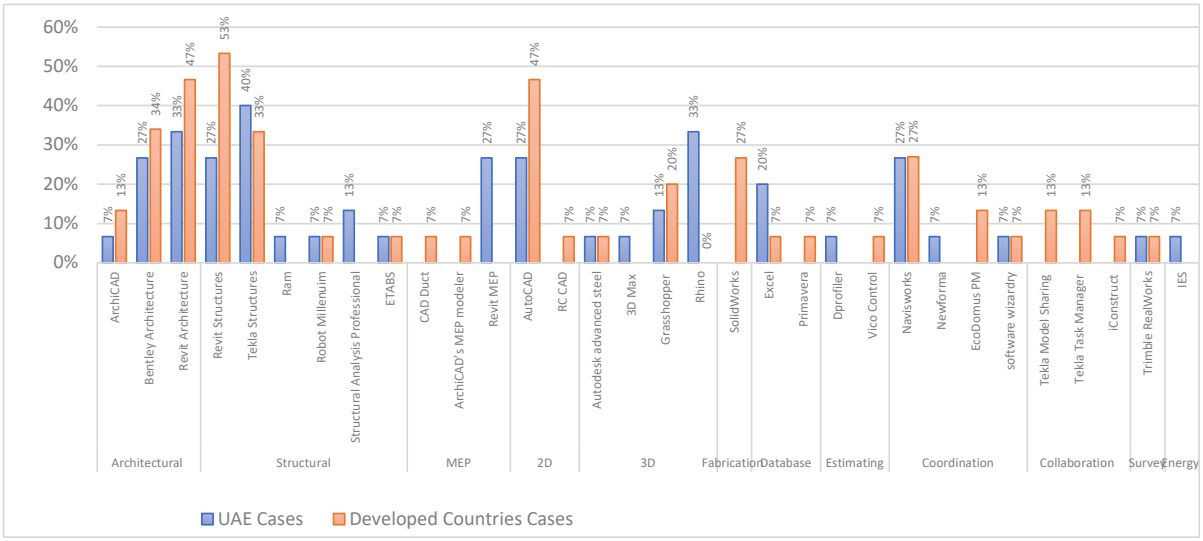


Figure 3. BIM Tools/Software Utilized during BIM Process. Source: [1,15].

(4) BIM benefits

The benefits of BIM utilization were classified into five categories, as illustrated in Figure 4. However, the magnitude of these benefits can vary between projects in different regions, with some projects or phases producing more benefits than others. This study has shown that the benefits of BIM utilization in the UAE are more pronounced in certain phases, such as design (support for project scope 53%, early accurate visualization 67%) and construction (clash detection 87%, drive fabrication 60%). However, the benefits of BIM at the Facility management and operation stage have been reported to be less significant in the UAE (LC benefits operation costs 13%, LC benefits operation maintenance 7%), which is consistent with findings in the above section.

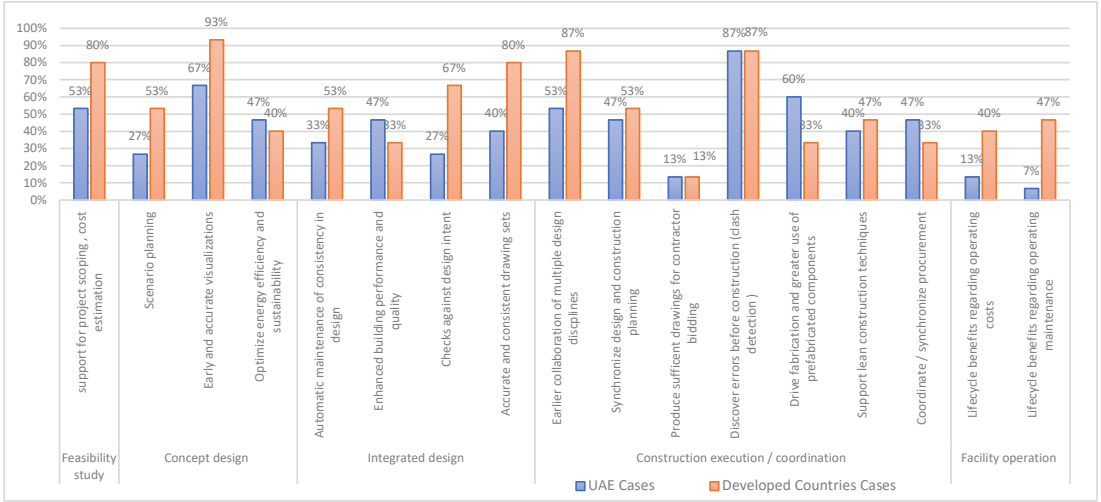


Figure 4. BIM benefits gained during the whole LC (BIM process).

4. Discussion and Implications

This section synthesizes and discusses the results from the previous section. The aim is to provide a comprehensive understanding of the results and their significance, drawing upon the knowledge and expertise of professionals in their relevant fields. Additionally, it delves deeper into the potential implications of these findings, examining the possible consequences or outcomes that may arise as a result of the data presented in the figures.

4.1. Extent of Participant (Parties and Teams) Involvement

Even though in Figure 1, there appears to be a consistency in stakeholders' presence in building lifecycle stages with the exception of the FM stage, the experts illuminate the complexity of the process. Experts made clear that as crucial participants during the BIM process, owners/developers who recently became aware of BIM but still need a specific understanding of BIM (E1, E3, E6). E2 and E4 emphasize that the majority of large clients and developers want to include BIM in projects' scope. However, they were not committed wholeheartedly in the absence of BIM standards and guidelines. Furthermore, the owners or developers were not knowledgeable about the advantages of facility management (FM). E1, E3, E4, E5, and E7 further advocate for early integration of all stakeholders to enhance communication and collaboration, which will lead to more effective and efficient building design, construction, and subsequent management.

4.2. BIM Utilization by Phases of Projects' Lifecycle

Figure 2 shows that in the UAE, BIM is primarily utilized for construction coordination and planning, rather than for the entire lifecycle of a building. This is in contrast to developed countries, where the majority of the cases studied indicate a clear intention to use BIM for the entire lifecycle. Several quotes from selected cases emphasize the significance of utilizing BIM at various stages of the FM process. In the case of Istanbul Grand Airport, LC goals were set at the outset:

> "Once the airport is done, it will be operated for 25 years, including the operation stage, where BIM will play a major role. "This methodology will allow us to reach the necessary information and solve future operation problems related to the airport systems along the pre-commissioning and maintenance stages. In addition, BIM will be used for all dimensions. The 6th dimension includes both facility management and lifecycle management stage" [22].

The Easton Commercial Centre case (DC14), was quoted:

> "The client set this as a key requirement in order for the model to be used in the future for maintenance and development purposes" [54].

From the NATO headquarter case:

> "Now, NATO has a quality 3D BIM model that can be used to operate their new headquarters" [21].

Hilton Atlantic BIM case similarly indicates:

> "Finally, the documentation of the building and its correspondence to an accurate digital model provided a valuable database for building maintenance" [30].

Furthermore, according to [15] study of BIM projects from DC, just 10% of those projects had reached the FM level, while later in 2018 [1], 45% of the projects reported that they had advanced to the FM level [1]. This highlights the importance of involving owners/decision makers and end-users early in the BIM process to ensure that BIM is utilized effectively throughout the project's life cycle. This can be achieved through education and awareness, as well as through the implementation of government regulations and standards that mandate the participation of owners and end-users in the BIM process.

Expertise attributed it to the lack of (1) clients/owners' knowledge about BIM potential (E1, E3, E4, E6), (2) local regulations (E2, E4, E5, E7), which still require boxes of information

when handing over assets from the construction phase to the operation phase, (3) a proper handing over process of "Assets Information Model AIM" form the contractor to facility managers/client (E2, E3, E5).

E3 on its discontinuity in FM,

> "However, most of these (expert's firm) projects are still under construction phase. So, we did not reach actually to that phase (FM) where we are really running the system efficiently".

According to experts (E1, E2, E3, E4, E6), UAE BIM is utilized the most during the design development stage, design documentation" phase, and construction phase but least at the FM stage. This is likely due to the benefits it provides to consultants and contractors, such as faster and more efficient production of shop drawings in a 3D environment, improved quality of outcomes, and better coordination. Because of these benefits, many consultants and contractors utilize BIM even when it is not part of the project's scope (E1, E5, E6, E7).

4.3. Tools Utilized during BIM Process

It was found in Figure 3 that there is a broader and more diverse use of tools across DC projects, particularly in MEP, Database, Scheduling, and Collaboration tools. This suggests that while some BIM tools are popular among professionals in both DC and the UAE, there is a greater variety and diversity of tools used in DC projects, possibly reflecting a more comprehensive range of project types, workflows, and requirements. This suggests the collaborative nature of DC and whole life cycle BIM utilization compared to the fragmented nature and lack of FM in UAE BIM utilization. Further, it is depicted that tools utilized in UAE BIM projects are primarily design and construction dependent but less on collaboration tools.

As corroborated by experts (E1, E2, and E5), no single BIM solution can be used in all contexts. Instead, there are a variety of BIM tools and applications on the market, each with a specific use or area of expertise. Some software may be more dominant or commonly used in particular fields or for specific tasks. This highlights the diverse BIM tools and software available, which offer a range of capabilities, features, and functionalities; thus, selecting the appropriate tool that meets the project's requirements is essential.

4.4. BIM Benefits

The benefits indicated in Figure 4 can be attributed to several factors, including the region's need for BIM awareness and expertise and a lack of BIM standards and regulations. Additionally, there may be a need for more importance given to the long-term benefits of BIM in the UAE, with more emphasis on a project's design and construction stages. Therefore, it is essential to raise BIM awareness and education, establish BIM standards and regulations, and focus more on the long-term benefits of BIM in the region in order to increase the adoption and utilization of BIM in facility management and operation stage in the UAE.

Figure 4 further suggests that UAE BIM is utilized primarily in the design and construction stages of the project lifecycle but less so in the FM stage. In addition, experts (E1, E5, E6) have asserted that BIM utilization in the UAE is often fragmentarily, with stakeholders utilizing BIM in different ways and for unique purposes.

For example, E2 stated

> "at the moment, we see something called the design intent model, and then we can see the contractor coming in and developing something from scratch, which is called a construction intent model. For many reasons, one of them is liability and risk; another is the modeling methodology; the other is the fact there is no trust between the contractor and the designer. The contractor would rather build something from scratch by themselves".

Similarly, E4 states,

> " . . . contractors would never want to take (risk) their life ability to use someone else's models".
>
> Furthermore, E5 emphasized
>
> "99% of the time, the contractor would want to develop their own, and they would call that construction intent model. Because when the design is conceived, all the way to the detailed design or even tender stage of the design, the designer/consultant uses a different methodology; they use a different way of modeling and designing that are contractor cannot/do not easily utilize".
>
> E1, based on past experiences, states
>
> "In the UK, it is totally different; the designer provides fully detailed drawings, so as a subcontractor, you need only to add hangers and support and continue to use the same model ".

This fragmented approach to BIM can lead to a lack of integration and collaboration among the different stakeholders, reducing the overall benefits that can be gained from BIM. In order to maximize the benefits of BIM, all stakeholders need to work collectively and use the same/share model throughout the entire building lifecycle (E3 and E4). This will ensure that all stakeholders have access to the same information and can work together more efficiently, ultimately leading to more successful projects. The authorities and industry leaders in the UAE should work on creating a more integrated approach to BIM utilization and encouraging collaboration among different stakeholders.

4.5. Ranking BIM's Benefits by Experts

Experts' ranking of BIM's benefits (Table 4) can provide valuable insight into the most impactful ways in which BIM can be used to improve project outcomes. In addition to findings from explanatory case studies analysis, experts who observed the use of BIM on real-world projects could identify the most significant benefits in their projects. They provide a comprehensive view of BIM benefits by ranking them according to their relative importance, impact, and how BIM can be utilized to address specific project challenges. It is noteworthy that Expert 7 who ranked FM, though low, is coming from the software industry, where tools are supposed to be used across all BIM phases. Additionally, others did not make FM any priority at all, by not ranking it. Experts E2, E3, E5, E6, and E7 noted that the early stages of a project are where the most benefits can be gained from BIM, and these benefits can ultimately filter down throughout the entire project. This is attributed to the need for more standardization and protocols in the BIM process. They also emphasized the importance of integrated design, which includes subsets of checks against design intent and early collaboration among multiple design disciplines. However, Experts E1 and E4 prioritize the benefits of BIM during the construction coordination stage, due to their background in the construction industry. Overall, FM benefits were not highlighted since they are still not a typical expectation in the UAE industry.

Overall ranking further demonstrates the disparity in benefit rankings, which is in part determined by the experts' areas of specialization (Table 4). For instance, the most widely used feature of BIM in the AEC industry is "find error before construction, clash detection," [55], which is scored highly and lowly by experts depending on their profession. This illustrates the fragmented and inconsistent nature of BIM implementation in the UAE, as well as the lack of standardization, guidance, and BIM protocols.

4.6. Experts on Unrealized UAE BIM Potential in FM

The study probed further into the unrealized utilization of BIM in FM, as indicated in Figures 1 and 2, by seeking the experts' perspectives.

The UAE's current regulations require the submission of detailed "as-built" information in the form of paper (boxes of information) when assets are handed over (E3, E5).

E1 states,

> "the municipality is asking to do a model, and that is it. That model could be empty or just like the simple exterior model and nothing inside. There was no auditing or reviewing, and eventually, the engineers were reviewing the information in 2D drawings".

E3 states that it is standard practice in the UAE to submit the BIM model to the owner at the end of the construction phase for further utilization during the FM stage. However, in many cases, the model is only archived for emergency use rather than regularly utilized for maintenance and operation. This is because facility management and owners often continue to use traditional methods and are not yet prepared to fully utilize the 3D BIM model. Additionally, as previously mentioned, owners and end-users are not typically involved in the process early enough to set FM goals from the outset. This lack of early involvement and preparedness to utilize BIM in the FM stage can limit the potential benefits of using BIM throughout the entire building LC (E2, E4, E6, E7).

E4 moreover mentioned,

> "in the UAE, the potential of utilizing BIM in FM stage is very high. Though our clients are well aware of what BIM can bring for them at FM stage, they do not know where to start"

E1 adds,

> "Facility operation is the new trend actually, and we are encouraging the clients to do it and so on, but, I think, except few attempts, there is no real yet full and efficient deployment. So, for some people trying to prove a concept, but it is not actually".

Accordingly, E2 notes on FM benefits:

> "The asset information model can be handed over to the facility management team and operation or even the asset owners. And this has a lot more potential than receiving drawings and specs and information about the building in printouts and boxes".

5. Conclusions

Combining explanatory case studies analysis with the experiences of experts practicing in the field is a unique approach that provides a comprehensive understanding of the BIM environment in the UAE. This approach can give a detailed and in-depth view of the real-world implementation and usage of BIM by experts/practitioners. This study can better understand the challenges and successes encountered and how these experiences can inform future implementation and research. Additionally, it can help to identify best practices for BIM implementation and use among practitioners.

The study has identified three significant implications for BIM utilization in the UAE. First, BIM for facility management (FM) is utilized less effectively in the UAE than in developed nations (Figures 1 and 2; Table 2). It thus indicates a lack of understanding and knowledge regarding the potential benefits of BIM in FM and how it may be utilized to benefit the operation and maintenance of buildings. The shortcoming is consistent with the findings of [4] study, which indicated that the use of BIM in the UAE is restricted to technological applications, hence failing to realize the full potential of the BIM process. The experts validate this deficiency further. Second, the outcomes of this study reveal that BIM is utilized fragmentarily by various stakeholders in the UAE. The expert interviews reveal that architects, engineers, and contractors may use BIM independently for different purposes and at different stages of the building's life cycle. This can lead to inefficiencies and inconsistencies in the utilization of BIM, impeding the full realization of its potential benefits. Third, the study indicates, through expert feedback, an absence of standardization and guidelines for BIM implementation in the UAE (see results and discussion sub-section, BIM benefits, and Ranking Table 4). This eventually leads to confusion and uncertainty

among stakeholders on how to properly utilize BIM and can also impede the ability to effectively share and exchange information.

Overall, the study findings highlight the need for increased awareness and education on the benefits and proper use of BIM in FM and the need for more collaboration and communication among stakeholders to promote more consistent and efficient use of BIM in the UAE. Additionally, it is essential to establish industry-wide standards and guidelines for BIM implementation to ensure that all stakeholders are working with the same information. Government support and incentives can encourage broader adoption and use of BIM in the UAE.

In terms of adoption compared to developed nations, Dubai is relatively advanced in the usage and implementation of BIM, particularly in the Middle East Region, but might be less advanced than some developed countries with a long history of BIM implementation and culture, like the UK, USA, and Scandinavian countries for instance.

It is worth noting that even though UAE is considered a leader in the region in terms of BIM implementation, there is still much room for growth and development. There are still many challenges to be addressed, including a lack of BIM education and training programs, a lack of standardization and integration with other technologies, and a lack of data-sharing and collaboration among stakeholders.

The results of this analysis could be used to identify best practices for BIM implementation in the UAE and areas for improvement. The analysis reveals that developed countries' projects had a more structured BIM implementation process, a higher level of software integration, and a better data management and sharing system. This could provide valuable insights for future UAE BIM adoption strategies beyond Dubai's borders.

Research like this, which focuses on actual BIM users' experiences, can provide insight into the technology's practical implementation and point out potential improvement areas or new research directions. This research can also provide practical guidance for BIM practitioners and organizations looking to implement or improve their use of BIM.

Additionally, the study highlights the benefits of BIM adoption in the UAE and could help promote the use of BIM in the country by showing the potential return on investment. However, the limitation of the study relates to the kind of case study used which is very context-dependent, and the outcome could vary depending on the number of projects, selection of projects, typologies, and the participants. Moreover, qualitative analysis relies on interpretation, and it can be subject to researcher bias and subjectivity. Therefore, it is important to take steps to ensure that the analysis is rigorous and transparent. This may involve using multiple researchers to review the data, keeping detailed notes on the analysis process, and documenting decisions made during the analysis.

Overall, the research can help to ensure that the BIM implementation in the UAE will be more effective and efficient, resulting in improved building performance, cost savings, and benefits for all stakeholders.

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