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Investigation toward the Adoption of Building Information Modelling in Algeria from Architects' Perspective

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Abstract: This study attempts to identify and assess the individual perceptions of building information modelling (BIM) benefits and implementation barriers in the construction industry in Algeria from architects' perspective. An investigation was carried out through survey questionnaires distributed to Algerian architects with different profiles. A total of 100 questionnaires were used for the study. A subgroup analysis was conducted to investigate the differences in the individual perception of the different groups of architects segmented according to the respondent's work type, organisation size, experience length and computer-aided design (CAD) and BIM knowledge. The findings of the study revealed that the most important barriers to BIM implementation were people and policy factors. The subgroup analysis revealed that the architects working for design firms were more aware and had more readiness for adopting BIM compared to those working for project owners and contractors. Moreover, there were differences in the BIM maturity level between the large and small organisations in Algeria. It was concluded that at the actual BIM maturity level, BIM implementation would not occur without the implication of local authorities and policymakers, as they have a significant impact on promoting and accelerating BIM adoption in the country.

Keywords: Algeria's construction industry, Architects' perspective, Building information modelling (BIM), Implementation barriers, BIM maturity level

INTRODUCTION

Nowadays, information and communication technology (ICT) is becoming inevitable due to its complexity and large construction projects (Roy and Firdaus, 2020). Furthermore, the construction sector has experienced a quantitative evolution in the data shared between its actors. Building information modelling (BIM) was developed as a solution to facilitate and increase collaboration between different actors in a construction project. Thus, a race towards the adoption of BIM has been noted all over the world.

Talking today about the implementation of BIM in the construction industry in Algeria has become essential. Shortly, the construction industry will most likely be required to implement BIM. As it is now unthinkable for a design firm to present construction documents where plans are represented with the traditional method

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of drawing lines, it will soon be unimaginable to design a project with the traditional process that we know today without the use of BIM.

In Algeria, the actors in the construction industry continue to work separately with traditional design and construction methods, whether design-bid-build (DBB) or design-build (DB). However, several problems are associated with these traditional methods of the construction industry as the lack of efficiency, a high number of errors due to lack of coordination, lack of interoperability and incompatibility, as well as poor investment in information technologies (Arayici, 2015). It is only recently that interest in BIM has arisen in Algeria.

Since 2015, several events and workshops have been organised in different cities of the country to debate the issue of BIM implementation and the readiness level of the Algerian architecture, engineering and construction (AEC) industry. Furthermore, several private training institutions have recently started to promote the implementation of BIM in Algeria with the support of certain organisations by establishing a BIM approach. However, except for a few initiatives to promote BIM, it seems that most actors in the construction industry are not yet interested in undertaking BIM as a design and construction process in Algeria. This research particularly tries to answer the following questions: "Do the profiles of architects impact the implementation of BIM in Algeria?" and "Are there differences in the perception of BIM practice between architects, or are there other more impactful factors?"

Thus, this research was conducted to identify and assess individual perceptions of BIM benefits and implementation barriers from the architects' perspective. Furthermore, this study extends Bouguerra et al.'s (2019) and Bouguerra, Yaik-Wah and Ali's (2020) research on the BIM implementation in Algeria by focusing only on the architects' viewpoint and investigating the differences in the perception of BIM practise according to different multi-influence factors, namely, work type (design firm, project owner, contractor), organisation size, experience length and computer-aided design (CAD) and BIM knowledge.

The findings of the study also contribute to improving and developing a consistent implementation framework for BIM in Algeria and other countries with similar contexts and construction environments. Furthermore, this study extends the existing knowledge on the perception of BIM and leads to further discussion of how architects from less mature BIM countries perceive BIM practice compared to their counterparts from more mature BIM countries.

LITERATURE REVIEW

BIM is defined by the National BIM Standard-United States® (2015) as "a digital representation of the physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward". Initiated in the 1970s by Charles M. Eastman (Wong, Wong and Nadeem, 2011), BIM is considered the next paradigm shift in the construction industry (Shelden, 2009). Due to the capability of BIM to improve productivity while reducing costs and construction delays, it is considered "the most promising recent development in the AEC industry" (Azhar, 2011). Countries that had implemented BIM observed a real improvement in terms of project planning, design, construction and maintenance phases (Azhar, 2011). However, it seems like BIM implementation varies from country to country depending on different factors (Gu and London, 2010). The identification of BIM implementation barriers has been considered preliminary for enhancing BIM implementation (Kassem, Brogden and Dawood, 2012). In response to this, several studies investigated BIM adoption and implementation in both developed and developing countries. According to Sahil (2016), the BIM adoption issues are the same in both developed and developing countries. However, this can be true only if the comparison has been made at the same BIM maturity level. Differences can be identified in BIM implementation barriers according to the BIM maturity level of each country. Succar (2010) described the BIM maturity level as "the quality, repeatability and degree of excellence within a BIM capability".

The following sections elaborate on the major barriers to the implementation of BIM identified in previous studies. This will allow identifying for the survey the barriers likely to the implementation of BIM in Algeria. Table 1 shows the map of BIM implementation barriers worldwide.

Table 1. Map of BIM implementation barriers

BIM Barriers	**References**
Cultural change and mindset issues	Denzer and Hedges (2008), Eadie et al. (2013), Chan, Olawumi and Ho (2019), Nanajkar (2014), Abubakar et al. (2014), Gerges et al. (2017), Ahmed (2018), Arunkumar, Suveetha and Ramesh (2018), Saka and Chan (2019) and Marzouk, Elsaay and Othman (2021)
Lack of experienced and qualified professionals in BIM	NBS (National Building Specifications) (2013), Kumar and Mukherjee (2009), Nanajkar (2014), Memon et al. (2014), Liu et al. (2015), Gerges et al. (2017), Arunkumar, Suveetha and Ramesh (2018), Jamal et al. (2019), Saka and Chan (2019) and Roy et al. (2020)
clients do not require the application of BIM in their projects	Birkeland (2009), Chan (2014), NBS (2014; 2018; 2019), Baba (2010), Nanajkar (2014), Monko and Roider (2014), Gerges et al. (2017), Saka and Chan (2019), Roy et al. (2020), Bouguerra et al. (2019) and Marzouk, Elsaay and Othman (2021)
High cost of BIM hardware and software	Denzer and Hedges (2008), Eadie et al. (2013), NBS (2013; 2014; 2018; 2019), Abubakar et al. (2014), Abanda et al. (2014), Liu et al. (2015), Hosseini et al. (2016), Gerges et al. (2017), Chiponde et al. (2017), Ahmed (2018), Arunkumar, Suveetha and Ramesh (2018), Jamal et al. (2019), Saka and Chan (2019), Andreas et al. (2020) and Bouguerra et al. (2019)
Issues of interoperability and data exchange (incompatibility between software)	Saka and Chan (2019) and Chan et al. (2019)
the lack of support and absence of incentives for promoting BIM by the policymakers	Zahrizan et al., (2013), Abubakar et al., (2014) and Hosseini et al. (2015; 2016)

(*Continued on next page*)

Table 1. *Continued*

BIM Barriers	References
No legal or contractual agreement on BIM	Smith and Tardif (2009), Mehran (2016), NBS (2013; 2018; 2019), Chan et al. (2019), Zahrizan et al., (2013), Liu et al. (2015), Hosseini et al. (2016), Andreas et al. (2020), Bouguerra et al. (2019) and Marzouk et al. (2021)
Lack of BIM data library and standards	Saka and Chan (2019) and Bouguerra, Yaik-Wah and Ali (2020)
Reluctance to change the working method by project stakeholders	Yan and Demian (2011), Chan (2014) and Gerges et al. (2017)

For the developed countries, it seems more appropriate for this research to select studies carried out at a low level of maturity that reflect the real barriers for the first initiatives aiming at BIM implementation. For Eadie et al. (2014), there were differences between barriers to BIM implementation from the perception of those already using BIM and those that have not implemented BIM. According to Kalfa (2018), in 2003, the USA set up a national 3D–4D BIM programme to support the implementation of BIM for the realisation of public projects, while Europe, Norway, Denmark and Finland have supported BIM implementation since 2007 (Granholm, 2011; McAuley, Hore and West, 2017). In 2011, the United Kingdom started a programme to use BIM Level 2 in the construction industry (McAuley, Hore and West, 2017). However, in Asia, Japan, Korea and Hong Kong, guides have been established to enhance BIM adoption in the construction industry since 2009 (Cheng and Lu, 2015).

BIM Implementation Worldwide

In the UK, Sebastian (2010), cited by Jin et al. (2017), tackled the insufficient evaluation of BIM value from the company level. However, for Eadie et al. (2013), it was the training and software cost and the lack of idea about the benefits constituted the most important barriers to BIM implementation. The NBS, the UK institution that monitors BIM implementation, established in 2013 a report about BIM implementation in the UK, Canada, Finland and New Zealand and concluded that the most important barriers to BIM implementation were the lack of expertise, lack of standardised tools, lack of collaboration protocol and the cost. However, the latest NBS (2018; 2019) focusing only on the UK has identified that the main BIM implementation barriers were no client demand, lack of training, cost, lack of in-house expertise and no time to get up to speed.

On the other side, several studies have been conducted on the implementation of BIM in developing countries. For example, in India, Kumar and Mukherjee (2009) found that the main BIM implementation barrier is the lack of technical experts. Moreover, Nanajkar (2014) added that the lack of clients' demand, the lack of qualified staff and the high cost of training. In 2018, Arunkumar, Suveetha and Ramesh (2018), identified 19 main barriers to implementing BIM. Among those barriers, the most significant factors were related to cultural resistance, the lack of supply chain buy-in, the lack of ideas about the benefits, the cost of software and hardware and the lack of professionals (Arunkumar, Suveetha and Ramesh, 2018).

In Malaysia, Zahrizan et al. (2013) conducted research on the BIM implementation barriers and concluded that the top barriers were a lack of knowledge and awareness, a lack of policymakers' support and a lack of standards. In 2019, Jamal et al. (2019) surveyed BIM implementation barriers and found that the top three BIM implementation barriers were related to the lack of BIM experts, the difficulty of learning and the high cost of software and hardware.

In Indonesia, Roy and Firdaus (2020) surveyed to investigate BIM practices and implementation barriers in the AEC industry. They found that the most critical barriers were the lack of BIM training, the lack of BIM capability, the lack of requirements from the client, the high cost of software and hardware and ICT issues.

In Nigeria, studies were conducted by Amuda-Yusuf et al. (2017) and Ogwueleka and Ikediashi (2017) on the BIM implementation barriers in Nigeria. The researchers found that the major barriers to BIM implementation were clients' awareness, funding issues, a lack of incentive and supply, a lack of transparency and legal uncertainty.

In Egypt, Marzouk, Elsaay and Othman (2021) conducted research by investigating BIM implementation and proposing strategic solutions for the Egyptian AEC industry. The researchers found that the challenges to BIM implementation in Egypt were the lack of BIM awareness, cultural resistance, the lack of standards and regulations and the lack of requirements from the client. In addition, the research highlighted the role of the government and educational institutions in providing incentives and spreading awareness to facilitate BIM adoption in Egypt.

Saka and Chan (2019) investigated the intellectual evolution of BIM in the African AEC industry. The study is based on a scientometric review and meta-synthesis of BIM development in African countries. The researchers selected for the meta-synthesis five countries that cover four regions of the African continent: Kenya, Ghana, Nigeria, Libya and South Africa. The findings revealed that the major barriers facing the implementation of BIM in these countries were people and process barriers, followed by economic and technological barriers. The critical barriers could be summarised as a lack of requirements from the client, legal uncertainty, lack of experts, lack of management support, resistance to change, lack of government support, lack of awareness, lack of training, high implementation costs, interoperability, lack of idea about BIM benefits, lack of BIM standards and lack of collaboration.

BIM Implementation in Algeria

In Algeria, it is only recently that interest in BIM has arisen. In 2015, the first BIM event was organised to discuss the need to promote the implementation of BIM in Algeria. Since then, several institutions have been created to promote the practice of BIM through the organisation of training for individuals and companies, such as IP-FIG, INTELLISOLUTIONS, CIVISOFT, MBIM, etc.

This belated interest in BIM implementation in the AEC industry in Algeria is due to the context and culture of this country. One of the factors marking this Algerian context concerns the delay recorded in the digitalisation of the construction industry as well as the timid adoption of ICT technologies. It is only recently that the Algerian government has made the digitisation of the entire Algerian administration a hobby horse of its political strategy. This technological issue forced the actors in the construction industry to work with traditional design and construction methods, except for major projects that were awarded to international firms. Another factor concerns the strong impact of local authorities and policymakers on the construction industry. As in the majority of developing countries, the Algerian government controls the construction market through the budget allocated for the construction of public utility equipment, various infrastructures and housing. As mentioned previously, the digitization of the Algerian administration is not yet operational, which currently prevents the government from requiring the implementation of BIM in its public projects.

Scholarly, during the 2018 ministerial reform of the architectural curriculum, BIM was introduced as a module "modelling and simulation BIM" for the third level of architectural training in the LMD (Licence-Master-Doctorate) system. This initiative is a very important step in the implementation of BIM in Algeria. First, it helps to overcome the barrier of lack of BIM training for architects. Secondly, it trains and initiates the next generation of architects to adopt BIM as a design and build process.

A research was carried out by Bouguerra et al. (2019) to investigate the best practices and the challenges of BIM implementation in the AEC industry in Algeria. The researchers conducted a questionnaire survey from practitioners' perspectives (architects, engineers and contractors) in Algeria. The challenges were classified into three groups: technology, process and policy. The researchers found that the most critical challenges were within policy and process factors followed by BIM technology factors. On one hand, the most critical challenges could be summarised as a lack of standards on how to collaborate, lack of contractual agreement, lack of the client's requirements and the BIM software high cost. On the other hand, regarding the best practices, the findings were consistent with challenges where more effort should be taken regarding policy and process factors compared to technology. In another research based on the same survey, Bouguerra, Yaik-Wah and Ali (2020) investigated the BIM awareness, capabilities and maturity of the Algerian construction industry. The study proposed a mixed approach to implementing BIM with both the government and the industry. The finding suggested a preliminary framework for the implementation of BIM based on previous theories and the questionnaire survey's findings:

> Starting with the technical aspect such as training and awareness, then policy aspects such as BIM drivers support and motivation, followed by process aspects such as change management and finally, changing the contractual environment and elaborating a national BIM policy and mandating BIM usage. (Bouguerra, Yaik-Wah and Ali, 2020)

This study tries to investigate if the profiles of actors in the construction industry impact the implementation of BIM in Algeria. Thus, this research will focus on the viewpoint of architects by studying the individual perceptions of BIM benefits and implementation barriers from the architects' perspective. Different multi-influence factors selected in the current study, namely work type (design firm, project owner, contractor), organisation size, experience length and CAD and BIM knowledge, extend the current knowledge on BIM individual perceptions and contribute to improving the implementation framework of BIM in Algeria and other countries with similar construction environment and context.

RESEARCH METHODOLOGY

This research adopted a questionnaire survey followed by statistical analysis in investigating the individual perceptions (architects) of BIM benefits and implementation barriers in Algeria.

Data Collection

The collection of data on the BIM implementation barriers in Algeria was performed through an empirical survey. The data collection process followed the procedures described by Cao et al. (2016) and Jin et al. (2017), with various ways to reach potential survey participants, including events, seminars and online surveys (online questionnaire using Google Forms). The data were collected twice, first in January 2020 and the second in November 2020 to extend the sample size. The questionnaire was delivered to potential participants with different architect profiles.

A non-probability sampling technique was used to select a representative population for this research. The sample size was calculated based on the following Equation 1 and 2 for the sample size n (Daniel and Cross, 2018; Naing, Winn and Rusli, 2006):

$$n(1) = N^*X \,/\, (X + N - 1) \qquad \text{Eq.1}$$

where,

$$X(2) = Z\alpha \,/\, 2^2 \, ^*p^*(1 - p) \,/\, d^2 \qquad \text{Eq. 2}$$

$Z\alpha/2$ is the critical value of the normal distribution at $\alpha/2$. With α 0.1 and a 90% confidence level, the critical value is 1.645. d is the margin of error MOE (8% used for this study), *p* is the sample proportion (0.25 is used for the sample size needed) and *N* is the population size.

The population size of this research was estimated at 10,000. This estimation included around 10,000 certified architects in Algeria (according to the national table of registered architects in Algeria, as retrieved from https://www.cnoa.dz/Table_Architecte.php). Then, from Equation 1 and Equation 2, $n = 78.5$.

In this study, a total of 100 respondents completed the survey. This suggested that the sample size was representative and enough for the current research. The questionnaire (in French) had three parts. The first part included the purpose of the study. It covered questions that focused on the background information of participants including their work type (e.g., design firm, project owner, contractor, etc.), their CAD and BIM knowledge, their organisation size and working experience on CAD and BIM projects. The second part of the questionnaire was adapted from a similar study conducted by Liu et al., (2019). This part examined the respondent's perceptions of BIM benefits. The third part detailed 13 possible barriers to BIM implementation in Algeria divided into four parts and classified by factors core components as indicated in Jamal et al. (2019) according to the NBS (2017). The barriers in our questionnaire were identified after a comprehensive review of the literature presented in the earlier section. From the results of the previous studies on BIM implementation presented above, several factors appeared several times in both developed and developing countries such as software and hardware cost, no client demand, resistance to change, lack of government support and lack of BIM standard (as shown in Table 1).

The respondents were asked to evaluate every single factor using a five-point Likert scale, where 1 meant that the factor was "Not important" while 5 meant that the factor was "Very important". The five-point scale is the common (universal) method of collecting data used in most studies, the format aligns with a vast library of comparative external benchmark data. To identify potential practical problems as well as problems with the survey design, a pilot study with 15 questionnaires preceded the main survey. The results of the pilot survey helped to improve the questionnaire.

Analytical Procedure

Reliability analysis (Cronbach's alpha)

Reliability analysis was adopted to examine the internal consistency of the factors using Cronbach's alpha (Kim et al., 2016; Chileshe et al., 2016).

Ranking analysis

The ranking of BIM benefits and implementation barriers in Algeria was performed as indicated in Chileshe et al. (2015) by examining the descriptive statistics (mean score values, standard deviation [SD]). The mean score values represented the relative importance of each factor while the SD represented the degree of compromise between participants (Kim et al., 2016). Where two or more factors had the same mean values, the ranking was performed by selecting the factor with the lowest SD (Doloi et al., 2012).

Subgroup analysis

The survey sample was segmented into subgroups according to the respondent's work type, organisation size, respondent experience length and CAD and BIM knowledge. Analysis of variance (ANOVA) was adopted to analyse the differences in the perception of benefits and critical barriers to BIM implementation in Algeria, as indicated by Liu et al. (2019). An F-value and a p-value were calculated for each factor by taking the level of significance of 5%. A p-value lower than 0.05 suggests that differences were found between the groups of respondents. To identify the source of differences, univariate ANOVA tests were conducted as indicated by Yuksel, Kanık and Baykara (2000).

ANALYSIS AND RESULTS

Profile of Respondents

A summary of the background information of the respondents is presented in Table 2. The respondents consist of architects with 60% working in a design firm, 25% working for a project owner and 15% working for a contractor. The age of respondents varies between 20 years old and 60 years old. More than 80% of respondents ranged from 20 years old to 39 years old. The organisation size of respondents varies from 1 employee (10%) to more than 10 employees (24%). 41%

of the respondents had their organisation size with less than 5 employees and 25% with 5 to 10 employees.

Table 2. Personal and contextual characteristics of the respondents

Characteristics	**Frequency (*N*)**	**%**
Age of Respondents		
from 20 years old to 29 years old	47	47
from 30 years old to 39 years old	40	40
from 40 years old to 49 years old	8	8
from 50 years old to 59 years old	5	5
Work Type		
Design firm	60	60
Project owner	25	25
Contractor	15	15
Respondent's Organisation Size		
1 employee	10	10
Less than 5 employees	41	41
5 to 10 employees	25	25
More than 10 employees	24	24
Respondent's Experience Length		
Less than 1 year	8	8
1 year to 5 years	44	44
6 years to 10 years	33	33
11 years to 20 years	11	11
21 years to 30 years	3	3
More than 30 years	1	1
CAD and BIM Knowledge		
No mastery of CAD software such as AutoCAD	1	1
Mastery of CAD software in 2D modelling only	23	23
Proficiency in CAD software in 2D/3D modelling	34	34
Use of BIM software like Revit, ArchiCAD, etc.	37	37
A BIM expert (mastery of a collaborative platform that has already provided BIM coordination in a construction project)	5	5

According to Table 2, the experience length of respondents (as architects) varies from less than 1 year to more than 30 years: 44% of respondents have experience length from 1 year to 5 years, 33% have experience length from 6 years to 10 years, 11% have an experience length from 11 years to 20 years, 8% have experience length of less than 1 year, 3 % have experience length from 21 years to 30 years and only 1% of respondents have experience length more than 30 years.

Regarding CAD and BIM software mastery use by the respondents, 37% use BIM software like Revit and ArchiCAD, 34% are experts in CAD software (2D/3D modelling), 23% only use 2D modelling with CAD software, 5% are BIM expert (mastery of a collaborative platform that has already provided BIM coordination in a construction project) and only 1% have no mastery of CAD software such as AutoCAD.

Reliability analysis

The five-point scale has been found reliable with Cronbach's alpha of 0.93 for BIM benefits and 0.88 for BIM implementation barriers (higher than 0.7), which reflects the high internal consistency of participants' perceptions.

BIM benefits

The respondents were asked to rank items related to BIM benefits using a five-point Likert scale. The ranking of the individual perception toward BIM benefits is based on their means value and SDs. Table 3 presents the ranking of these factors.

According to Table 3, the respondents ranked "Strengthen collaboration between the different actors of the project (client, project manager, construction company)" as the top BIM benefit with a mean value of 4.13. The other higher-ranked BIM benefits were "Offering new services" with a mean value of 4.04, "Better project quality" with a mean value of 4.03 and "Reduction of omissions and errors" with a mean value of 4.00.

Table 3. Ranking of the BIM benefits

ID	BIM Benefits (Cronbach's Alpha = 0.93)	Mean	SD	Rank
B10	Strengthen collaboration between the different actors of the project (client, project manager, construction company)	4.13	1.05	1
B3	Offering new services (e.g., assistance in cost estimation, Life cycle analysis in project management, etc.)	4.04	1.03	2
B2	Better project quality	4.03	1.10	3
B1	Reduction of omissions and errors	4.00	1.03	4
B5	Marketing and promotion of the company image	3.84	1.01	5
B6	Easier for newly hired staff to understand	3.83	1.09	6
B11	Fewer claims/litigations	3.72	1.08	7
B4	Allow access to international calls for tenders	3.67	1.08	8
B9	Reducing overall project duration	3.57	1.13	9
B8	Increasing profits	3.38	1.10	10
B7	Reducing construction cost	3.34	1.22	11

Subgroup analysis based on the work type, organisation size, experience length and CAD and BIM knowledge of respondents is summarised in Table 4. Table 4 shows that there were consistent perceptions of BIM benefits for all the subgroups of respondents. Therefore, the perception of the "BIM benefits" seems to be similar for all groups of respondents in our sample.

Table 4. ANOVA analysis of subgroup differences towards BIM-benefits-related items

Item	Overall Mean	SD	ANOVA According to Work Type		ANOVA According to Organisation Size		ANOVA According to Experience Length		ANOVA According to CAD and BIM Knowledge	
			F-value	*p*-value	*F*-value	*p*-value	*F*-value	*p*-value	*F*-value	*p*-value
B1	3.53	1.30	2.207	0.115	1.8512	0.143	0.774	0.571	0.682	0.606
B2	4.29	1.01	0.388	0.679	0.6820	0.565	0.547	0.740	1.046	0.388
B3	4.23	0.98	0.357	0.701	0.0236	0.995	1.549	0.182	0.188	0.944
B4	4.29	1.09	0.137	0.872	0.0729	0.974	1.229	0.302	0.263	0.901
B5	3.46	1.23	0.102	0.903	0.4024	0.752	1.169	0.330	1.196	0.318
B6	2.66	1.16	0.232	0.793	1.4779	0.225	1.193	0.319	1.133	0.346
B7	2.85	1.23	2.338	0.102	1.4870	0.223	1.317	0.264	0.601	0.663
B8	4.10	1.11	0.967	0.384	0.5665	0.638	1.291	0.274	0.376	0.825
B9	3.78	1.12	0.498	0.609	0.3097	0.818	0.929	0.466	0.217	0.928
B10	3.93	1.12	2.350	0.101	1.5463	0.208	0.607	0.694	0.496	0.739
B11	2.25	1.12	1.169	0.315	1.3547	0.143	1.442	0.217	0.915	0.458

Barriers to the BIM Implementation

The respondents were asked to rank items related to BIM implementation barriers using a five-point Likert scale. The ranking of the individual perception toward BIM implementation barriers is based on their means value and SDs. Table 5 presents the ranking of these factors.

Table 5. Ranking of the barriers to the BIM implementation

Factors	ID	Barriers (Cronbach's Alpha = 0.88)	Mean	SD	Rank
People	P1	Cultural change and mindset issues	3.53	1.30	7
	P2	Lack of experienced and qualified professionals in BIM	4.29	1.01	1
	P3	Clients do not require the application of BIM in their projects	4.23	0.98	3
	P4	Non-involvement of local authorities in the application of BIM	4.29	1.09	2

(*Continued on next page*)

Table 5. *Continued*

Factors	ID	Barriers (Cronbach's Alpha = 0.88)	Mean	SD	Rank
Technology	T1	High cost of BIM hardware and software	3.46	1.23	9
	T2	BIM lacks the functionality or flexibility to produce a 3D model	2.66	1.16	12
	T3	Problems related to sharing and exchanging files (incompatibility between software)	2.85	1.23	11
Policy	C1	Lack of support and absence of incentives for promoting BIM by the policymakers	4.10	1.11	4
	C2	No legal or contractual agreement on BIM	3.78	1.12	6
	C3	Lack of best BIM practices within the construction industry	3.93	1.12	5
Process	S1	BIM does not reduce the time spent on planning	2.25	1.12	13
	S2	Lack of BIM data library and standards	3.14	1.14	10
	S3	Reluctance to change the working method by project stakeholders	3.52	1.14	8

As inferred from Table 5, the three most important barriers to BIM implementation in Algeria were related to the people factor. The survey participants agreed that the first barrier was "Lack of experienced and qualified professionals in BIM" with a mean value of 4.29 and SD of 1.01 while the second was "Non-involvement of local authorities in the application of BIM" with a mean value of 4.29 but a higher SD of 1.09 and the third barrier was "Clients do not require the application of BIM in their projects" with a mean value of 4.23.

The policy area was ranked as the second most important factor with the fourth, fifth and sixth most important barriers. The survey participants agreed that there was a "Lack of best BIM practices within the construction industry" with a mean value of 4.10, a "Lack of support and absence of incentives for promoting BIM by the policymakers" with a mean value of 3.93 and "No legal or contractual agreement on BIM" with a mean value of 3.78.

Barriers ranked from 7 to 13 were mostly derived from process and technology factors. Regarding the process factors, survey participants agreed that there was reluctance to change working methods by project stakeholders with a mean value of 3.52. Respondents also agreed that the most important technology barrier was the high cost of BIM hardware and software with a mean value of 3.46. Subgroup analysis based on the work type, organisation size, experience length and CAD and BIM knowledge of respondents is summarised in Table 6.

Table 6. ANOVA analysis of subgroup differences towards BIM-barriers-related items

Item	Overall Mean	SD	ANOVA According to Work Type		ANOVA According to Organisation Size		ANOVA According to Experience Length		ANOVA According to CAD and BIM Knowledge	
			F-value	*p*-value	*F*-value	*p*-value	*F*-value	*p*-value	*F*-value	*F*-value
P1	3.53	1.30	0.889	0.415	3.132	0.029*	0.602	0.698	0.205	0.935
P2	4.29	1.01	1.133	0.326	1.304	0.278	0.443	0.817	0.159	0.958
P3	4.23	0.98	0.417	0.660	0.265	0.850	0.393	0.852	0.401	0.808
P4	4.29	1.09	0.489	0.615	1.086	0.359	0.355	0.878	0.105	0.980
T1	3.46	1.23	1.824	0.167	2.930	0.038*	1.290	0.274	1.020	0.401
T2	2.66	1.16	3.683	0.029*	4.030	0.010*	1.510	0.195	4.100	0.004*
T3	2.85	1.23	0.300	0.741	1.820	0.148	3.690	0.004*	2.250	0.070
C1	4.10	1.11	1.213	0.302	0.406	0.749	0.441	0.818	1.848	0.126
C2	3.78	1.12	0.131	0.878	0.452	0.716	0.589	0.709	0.779	0.542
C3	3.93	1.12	1.129	0.327	1.100	0.353	0.585	0.712	0.661	0.621
S1	2.25	1.12	4.131	0.019*	1.160	0.328	0.912	0.477	0.742	0.566
S2	3.14	1.14	0.748	0.476	1.870	0.140	1.158	0.336	1.482	0.214
S3	3.52	1.14	0.020	0.980	1.150	0.335	0.930	0.465	0.230	0.921

Note: **p*-value lower than 0.05 indicates the significant differences among subgroups towards BIM barriers.

According to Table 6, there were significant differences in the BIM implementation barriers perception of the different groups segmented according to work type variables in light of T2 related to the BIM lack of functionality or flexibility to produce a 3D model (*p* = 0.029) and S1 "BIM does not reduce the time spent on planning" (*p* = 0.019). Table 6 indicates the differences between subgroups according to work type by adopting univariate tests ANOVA. From Table 7, it is seen that the difference came from the contractors. The architects working as or for contractors held significantly more confirmatory views on T2 (BIM lacks functionality or flexibility to produce a 3D model) with an average score of 1.93, compared to the architects working for design firms (2.80) and project owners (2.76).

Similarly, respondents working for contractors also held more confirmatory views on S1 (BIM does not reduce the time spent on planning) with a scoring average of 1.53, compared to the architects working for design firms (2.32) and project owners (2.52).

Table 7. Characteristics of respondents' work type and relationships with BIM barriers

ID	BIM Barriers	Work Type	*N*	Mean	SD	Standard Error (SE)
T2	BIM lacks the functionality or flexibility to produce a 3D model	Design firm	60	1.93	1.28	0.330
		Project owner	25	2.76	1.20	0.240
		Contractor	15	2.80	1.05	0.136
S1	BIM does not reduce the time spent on planning	Design firm	60	1.53	0.74	0.192
		Project owner	25	2.52	1.12	0.224
		Contractor	15	2.32	1.14	0.147

The subgroup analysis based on the organisation size of respondents (as shown in Table 6) revealed that there were differences in the BIM implementation barriers perception in light of P1 related to the culture change and mindset issues ($p = 0.029$), T1 "High cost of BIM hardware and software" ($p = 0.038$) and T2 "BIM lacks functionality or flexibility to produce a 3D model" ($p = 0.010$). Table 8 shows that respondents from organisations with more than 10 employees held less confirmatory views on P1 compared to the other organisations with fewer employees. Respondents from organisations with more than 10 employees had the lowest average Likert-scale score of 2.92, indicating a neutral attitude. Moreover, Table 8 shows that respondents from organisations with 5 to 10 employees and more than 10 employees were more likely to consider T1 as an important BIM implementation barrier, with average scores of 4.04 and 3.90, respectively. Furthermore, respondents from organisations with 5 to 10 employees (3.24) and more than 10 employees (3.29) held less confirmatory views on T2 compared to the other organisations with fewer employees. The average scores on T2 for organisations with 1 employee and less than 5 employees were 3.50 and 3.15, respectively.

Table 8. Characteristics of respondents' organisation size and relationships with BIM barriers

ID	BIM Barriers	Organisation Size	*N*	Mean	SD	SE
P1	Cultural change and mindset issues	1 employee	10	3.70	1.16	0.367
		Less than 5 employees	41	3.56	1.18	0.185
		5 to 10 employees	25	4.00	1.22	0.245
		More than 10 employees	24	2.92	1.44	0.294
T1	High cost of BIM hardware and software	1 employee	10	3.50	1.43	0.453
		Less than 5 employees	41	3.15	1.20	0.187
		5 to 10 employees	25	4.04	1.17	0.234
		More than 10 employees	24	3.90	1.13	0.232

(*Continued on next page*)

Table 8. *Continued*

ID	BIM Barriers	Organisation Size	*N*	Mean	SD	SE
T2	BIM lacks the functionality or flexibility to produce a 3D model	1 employee	10	2.10	0.88	0.277
		Less than 5 employees	41	2.66	1.06	0.166
		5 to 10 employees	25	3.24	1.33	0.266
		More than 10 employees	24	3.29	0.99	0.204

The subgroup analysis based on the experience length of respondents (as shown in Table 6) revealed that there were differences in the BIM implementation barriers perception in light of T1 "Issues of interoperability and data exchange" (p = 0.004). Table 10 shows that respondents with an experience length of less than five years were more likely to reject T1 as a critical barrier to BIM implementation in Algeria than respondents with more experience length. The average scores on T1 for respondents with experience lengths less than 1 year, 1 year to 5 years, 6 years to 10 years, 11 years to 20 years, 21 years to 30 years and more than 30 years were 2.27, 2.70, 3.17, 3.11, 3.67 and 3.00, respectively.

Table 9. Characteristics of respondents' experience length and relationships with BIM barriers

ID	BIM Barriers	Experience Length	*N*	Mean	SD	SE
T3	Problems related to sharing and exchanging files (incompatibility between software)	Less than 1 year	8	2.27	0.647	0.195
		1 year to 5 years	44	2.70	1.233	0.174
		6 years to 10 years	33	3.17	1.181	0.184
		11 years to 20 years	11	3.11	1.023	0.241
		21 years to 30 years	3	3.67	1.211	0.494
		More than 30 years	1	3.00	1.732	1.000

Furthermore, the subgroup analysis based on the respondent's CAD and BIM knowledge (as shown in Table 6) revealed that there were significant differences in the BIM implementation barriers perception in light of T2 "BIM lacks functionality or flexibility to produce a 3D model" (p = 0.004).

With an average score of 1.29 (as shown in Table 10), the respondents who were BIM experts were more likely to reject T2 as a BIM critical implementation barrier compared to those with no mastery of CAD (3.33), mastery of CAD software in 2D (3.15), proficiency in CAD software in 2D/3D (2.78) and who use BIM software like Revit and ArchiCAD (2.15).

Table 10. Characteristics of respondents' CAD and BIM knowledge and relationships with BIM barriers

ID	BIM Barriers	CAD and BIM Knowledge	*N*	Mean	SD	SE
T2	BIM lacks the functionality or flexibility to produce a 3D model	No mastery of CAD software such as AutoCAD.	1	3.33	0.58	0.333
		Mastery of CAD software in 2D modelling only	23	3.15	0.95	0.183
		Proficiency in CAD software in 2D/3D modelling	34	2.78	1.34	0.176
		Use of BIM software like Revit, ArchiCAD, etc.	37	2.15	1.09	0.148
		A BIM expert (mastery of a collaborative platform that has already provided BIM coordination in a construction project)	5	1.29	0.49	0.184

DISCUSSION

Through the results of the ranking analysis related to BIM benefits, it has been found that strengthening collaboration between the different actors of the project, offering new services and reducing omissions and errors were considered the most important BIM benefits. These most important BIM benefits were generally consistent with the findings of Liu et al. (2019) and Jin et al. (2015), who conducted a survey of the same question to AEC practitioners in China. However, there were differences in the top-ranked BIM benefits ("Offering new services" by Liu et al. [2019] and "Reduction of omissions and errors" by Jin et al. [2015]). Therefore, this similarity of the BIM benefits perception between the Algerian architects and the AEC practitioners in China can suggest that the Algerian architects had the same BIM benefits knowledge that the Chinese AEC practitioners in 2015 and 2019.

Moreover, the ranking analysis of BIM implementation barriers revealed that the architect in Algeria considered people and policy factors as the most critical barriers to BIM implementation. This agrees with the study's results on BIM barrier implementation in Malaysia conducted by Jamal et al. (2019). Similarly, it was found that the People factor was the most critical to the BIM implementation. This suggests that the BIM maturity level of Algerian architects in terms of implementation barriers is practically the same as the one of Malaysian architects in 2019. However, some differences can be identified in the ranking of these people's barriers. Thus, the results of this study disagree with the findings of Jamal et al. (2019), which have indicated that the two first barriers to BIM implementation in Malaysia were related to a lack of qualified and experienced BIM workforce and learning difficulty for those unfamiliar with BIM.

The findings seem to be coherent with the study results of Bouguerra et al. (2019) related to the challenges facing the AEC industry for BIM implementation in Algeria. This later found that the policy factors were the most challenging ones. It should be noted that Bouguerra et al. (2019) grouped the challenges into three main factors only and the people factors were grouped with the policy ones. Other studies, conducted in developing countries such as Malaysia (Zahrizan et al., 2013), Nigeria (Abubakar et al.,2014; Amuda-Yusuf et al., 2017), Egypt (Marzouk et al., 2021) and Iran (Hosseini et al.,2015), the first barrier of BIM implementation was related to policy factor and the role of policymakers in supporting and encouraging to promote the BIM.

The policy area was ranked as the second most important factor. The respondents agreed that there was a lack of support and absence of incentives for promoting BIM by the policymakers and a lack of best BIM practices within the construction industry. As in other developing countries such as Malaysia and Iran, the Algerian state has a crucial role and impact on the economy and the business environment. As long as the business plans of construction companies in Algeria depend on the budget that the policymakers allocate to construction projects, these latter could be a force to encourage AEC companies to implement BIM in their projects. Another barrier indicated by the respondents was that there was no legal or contractual agreement on BIM. This is in agreement with the study results conducted in Malaysia by Zahrizan et al. (2013), Jamal et al. (2019) and in Iran by Hosseini et al. (2015) that indicated that the unavailability of documents and policies to regulate the adoption of BIM in construction activities and the lack of understanding the legal and contractual relationship are critical barriers to the BIM implementation on a construction project in developing countries. As affirmed by Hosseini et al. (2015), construction companies, in this context, do not take the risk of adopting novel methods with uncertainties such as BIM and maintain their traditional methods (Hosseini et al., 2015).

Barriers ranked from eight to thirteen were mostly derived from process and technology factors. This result echoes the findings of Abubakar et al. (2014) in Nigeria and Hosseini et al. (2015) in Iran. Regarding the process factors, survey participants agreed that there was reluctance to change working methods by project stakeholders. Such as in Iran, the AEC industry in Algeria is dominated by a traditional project delivery method. Consequently, a radical change in the working method of construction companies is necessary. However, this routine change is faced with a great level of resistance by project stakeholders in Algeria, which is understandable as the internet speed and the ICT required for BIM adoption is still a real issue with the delay of the Algerian state in implementing ICT solutions. Respondents also agreed that the most important technology barrier was the high cost of BIM hardware and software. As the adoption of BIM requires specific hardware and software, it affects the cost. It is important to point out that in other studies (Arunkumar, Suveetha and Ramesh, 2018) in India, Roy et al. (2020) in Indonesia and NBS (2019) in the UK, this barrier was ranked as the main factor. It seems that it has a relationship with the maturity of BIM in these countries (more mature BIM countries). From this discussion, we can note that globally, the BIM maturity level of Algerian architects is approaching the one of developing countries (less mature BIM countries) studied in different periods (Malaysia in 2015–2019, Nigeria in 2014–2015 and Iran in 2015).

The subgroup analyses were performed according to the architect's work type, organisation size, experience length and CAD and BIM knowledge. No differences were found in architects' perceptions of BIM benefits. However, several subgroup differences were found in architects' perceptions of BIM implementation barriers.

The subgroup analysis according to the architect's work type revealed differences in the perceptions of two barriers, one related to the BIM technology barriers while the second is related to the BIM process barriers. It appeared that the architects working for a design firm were more likely to reject the barrier related to the BIM's lack of functionality or flexibility to produce a 3D model compared to the architects working for a project owner or contractor. This can suggest that the architects working in design firms are more familiar with BIM software than the others. Similarly, the architects working for design firms held more confirmatory views on rejecting the barrier related to the BIM does not reduce the time spent on planning as a critical barrier, compared to the architects working for project owners or contractors. This result seems to be coherent with the precedent findings and confirms that the design firms have more capabilities and readiness for adopting BIM compared to the project owners and contractors.

The subgroup analysis according to the architect's organisation size revealed differences in the perceptions of some BIM implementation barriers between small-size and big-size organisations. It has been found that big-size organisations (more than 10 employees) were more likely to reject culture change and mindset issues as a critical BIM implementation barrier compared to small-size organisations. This suggests that big-size organisations have more capabilities and readiness for adapting new technologies and new working methods compared to small-size organisations. Furthermore, the big-size organisations were more likely to consider the high cost of BIM hardware and software as a critical BIM implementation barrier compared to the small-size organisations. This can suggest that there are differences in the BIM maturity level between the big-size and small-size organisations in Algeria. As mentioned above, the technology barriers were considered the most critical barriers in countries with high BIM maturity levels. The same goes for the technology barrier related to the BIM lack of functionality or flexibility to produce a 3D model, which the big-size organisations held less confirmatory views on rejecting this barrier as a critical one compared to the small-size organisations.

Moreover, the subgroup analysis, according to the architect's experience length, revealed differences in the perceptions of the BIM implementation barrier related to the issues of interoperability and data exchange (incompatibility between software). It appeared that architects with experience length of more than six years held less confirmatory views on rejecting this barrier as a critical one compared to less experienced architects. This result seems to be coherent with the precedent findings if the experienced architects seem to have a high BIM maturity level compared to the less experienced architects.

In addition, the subgroup analysis, according to the architect's CAD and BIM knowledge, revealed differences in the perceptions of the BIM implementation barrier related to the BIM's lack of functionality or flexibility to produce a 3D model. It was further indicated that architects who had already used BIM software and those experts on BIM were more likely to reject this barrier compared to the others. This agrees with the findings and can be explained by the fact that respondents who were more familiar with BIM software have enough knowledge of the BIM functionalities in 3D modelling than the other groups of respondents.

CONCLUSIONS

The study investigates the benefits and barriers of BIM implementation in Algeria from the architects' perspective. Several factors were identified as major benefits and barriers to BIM implementation by a group of survey constituted only of architects. Moreover, a subgroup analysis was undertaken by dividing the whole survey sample into several groups according to the architect's work type, organisation size, experience length and CAD and BIM knowledge.

This study extends Bouguerra et al.'s (2019) and Bouguerra, Yaik-Wah and Ali's (2020) research on BIM implementation in Algeria by conducting an empirical study on barriers to BIM implementation in Algeria from the architect's perception and by studying different multi-influence factors, namely work type (design firm, project owner, contractor), organisation size, experience length and CAD and BIM knowledge.

In this article, 13 barriers have been identified. These barriers were classified by factors core components, which were People, Policy, Technology and Process. According to the ranking analysis, the most important barriers to BIM implementation were people and policy factors. The top five barriers were: (1) Lack of experienced and qualified professionals in BIM, (2) Non-involvement of local authorities in the application of BIM, (3) Clients do not require the application of BIM in their projects, (4) Lack of support and absence of incentives for promoting BIM by the policymakers and (5) Lack of best BIM practices within the construction industry.

In addition, this study revealed the individual perception of BIM benefits from the architects' perspective. The main BIM benefits were strengthening collaboration between the different actors of the project, offering new services, better project quality and reduction of omissions and errors.

The subgroup analysis according to the groups of architects mentioned above revealed differences in the perceptions of some barriers. These findings answer the first part of the study questions and suggest that the profiles of architects impact the implementation of BIM in Algeria. The findings of the analysis revealed that the architects working for design firms were more aware and had more readiness for adopting BIM compared to those working for project owners and contractors. Moreover, there were differences in the BIM maturity level between the big-size and small-size organisations in Algeria. It was found that big-size organisations have more capabilities for adapting to new technologies and new working methods compared to small-size organisations.

The findings of the study brought to light that the Algerian AEC industry is lagging compared to that of other developing countries (more BIM-mature countries) in terms of BIM implementation on construction projects. The ranking of barriers confirms this shift, with people and policy factors as the most important barriers, while technology and process factors are considered secondary barriers, which reflect the BIM readiness and maturity level of Algeria compared to other developing countries. These findings answer the second part of the study questions and suggest that, in addition to the impact of the architects' profiles on the BIM implementation, there are other more impactful factors. The impact and great role of the local authorities and policymakers in promoting and accelerating BIM adoption in the country are very important to the actual maturity level. Therefore, first, Algerian authorities should impose the implementation of BIM for large public projects gradually through regulation. Secondly, the government should consider giving incentives to accelerate BIM training courses in private and public schools, which would encourage large construction companies to start including BIM learning as internal training for their employees and, consequently, implementing BIM in their projects.

Although this research investigated the perception of BIM benefits and critical implementation barriers from the architects' perspective, as part of future studies, it will be interesting to extend the sample size to study the perception of both the construction industry and the educational institutions in the country.

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