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Key drivers for adopting Building information modelling (BIM) and stakeholder management on construction megaprojects

Impulsores clave para la adopción del modelado de información de construcción (BIM) y la gestión de partes interesadas en megaproyectos de construcción

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Abstract

The construction industry has recently developed by adopting smart, innovative tools such as building information modelling (BIM). Furthermore, the construction industry faces massive challenges due to the huge construction development and stakeholder management practices. Therefore, there is a need for effective stakeholder management that traditional methods cannot achieve. This paper seeks to investigate, identify, and assess Key drivers for implementing BIM and stakeholder management on construction megaprojects. The quantitative methodology is adopted in this research to collect and know the views and conceptions of construction specialists in Qatar about stakeholder management in construction megaprojects. A questionnaire survey is carried out among large construction firms in Qatar, with a 60% response rate. The data were analysed by using the Statistical Package for Social Science (SPSS) software. This paper identifies the key drivers for implementing BIM and stakeholder management practices that contribute to improving stakeholder management performance in construction megaprojects; none of these is common, but they come together more integrative here, providing a smooth novel methodology to guide the stakeholder management process. Results will contribute to and Enhance/strengthen the present body of knowledge in stakeholder management study domains by considering and assessing the Key drivers that affect the (BIM & stakeholder management) implementation in construction megaprojects. This is the first research study on "BIM– stakeholder management synergy" that supports a theory with real-world data. It makes this research a starting point for other researchers. This study extends valuable insights into the essential drivers that can reinforce BIM and stakeholder management practices in construction megaprojects. Moreover, (BIM-stakeholder management) synergy will help expedite smart stakeholder management practices in the construction industry.

Keywords: Key drivers; stakeholder management; BIM; construction megaprojects.

Resumen

Recientemente, la industria de la construcción ha adoptado el uso de herramientas inteligentes e innovadoras como el modelado de información de construcción (BIM). Esta industria enfrenta además enormes desafíos debido al gran desarrollo de la construcción y las prácticas de gestión de stakeholders. Por este motivo, requiere de una gestión eficaz de stakeholders que los métodos tradicionales no pueden lograr. Este trabajo busca investigar, identificar y evalúar los factores clave para implementar BIM y la gestión de stakeholders en megaproyectos de construcción. Así, utilizando una metodología cuantitativa, se recopilan e identifican las opiniones y concepciones de los especialistas de la construcción en Qatar relativas a la gestión de stakeholders en megaproyectos de construcción. Con este fin, se encuestaron grandes empresas constructoras de Qatar, con una tasa de respuesta del 60%. Los datos se analizaron utilizando el software Statistical Package for Social Science (SPSS). Este artículo identifica los key drivers para la implementación de BIM y prácticas de gestión de stakeholders que contribuyen a un mejor desempeño de la gestión de stakeholders en megaproyectos de construcción; Ninguna de estas variables es común, pero aquí se combinan de forma integradora, proporcionando una metodología novedosa y fluida para guiar la gestión de stakeholders. Los resultados contribuyen a fortalecer el conocimiento relativo a la gestión de stakeholders al evaluar los factores clave que afectan su implementación (BIM y gestión de stakeholders) en megaproyectos de construcción. Este es un estudio pionero sobre "Sinergia BIM-gestión de stakeholders" respaldado con datos reales que proporciona un punto de partida para otros investigadores. De esta forma, se amplía el conocimiento sobre variables esenciales que pueden reforzar BIM y las prácticas de gestión de stakeholders en megaproyectos de construcción. Se espera que la sinergia (BIM-gestión de stakehoders) aceleré las prácticas inteligentes de gestión de stakeholders en la industria de la construcción.

Keywords: Key drivers; gestión de stakeholders; BIM; megaproyectos de construcción.

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Vol. 40
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1. Introduction

Recently, the construction industry (CI) tried to adopt smart tools such as BIM, among other things, to facilitate construction processes and integrate construction domain knowledge (Ahankoob et al., 2018). Furthermore, governments, industry professionals, and academics also show great interest in BIM (Giel and Issa, 2016). The two key BIM implementation characteristics are: (1) The technology, i.e., software that facilitates the modelling, and (2) visualization practices that let engineers examine and analyze models, besides recovering crucial information and data like clash detection, project schedule, costs, etc. (Sacks et al., 2018).

The CI has faced many obstacles and risks, particularly during the COVID-19 pandemic (Lee, 2021). That increases the demand for stakeholder management (SM) as a key strategic function (Mashali et al., 2022); (Mashali et al., 2023). Especially in light of classic stakeholder management models, which offer different perspectives on stakeholder management. Common stakeholder management models such as, although not limited to:

- The Power/Interest Grid (Mashali et al., 2022)
- Salience Model (Mashali et al., 2022)
- Stakeholder Influence vs. Impact Matrix (Maqbool et al., 2022)
- Stakeholder Engagement Matrix (Erkul et al., 2016); (Mashali et al., 2020b)
- RACI Matrix (Responsible, Accountable, Consulted, Informed) (Ma'arif et al., 2023); (Ahmed, 2019)

The adoption of smart technologies such as BIM in SM practices is intended to help assess the level of project completion. Also, BIM effectively treats a range of risks, from poor and insufficient communication to conflicts deriving from change. Its early engagement in the planning and design stages permits all stakeholders to contribute, shaping the project and minimizing the probability of future conflicts. BIM 3D models additionally improve this by determining design conflicts early in the process, significantly minimizing the risk of expensive on-site conflicts and stakeholder disputes. In addition, BIM 4D helps make unrealistic scheduling expectations less likely. BIM 5D assists in unifying financial expectations and reduces the probability of budget disagreements and a greater chance of project success (Mashali et al., 2022).

In the literature, many attempts and efforts have been made to handle subjects connected to BIM and SM applied in the construction industry, but separately (Mashali et al., 2022); (Mashali et al.,2023). Therefore, it is critical to consider and think about both concepts –BIM and SM; one approach to address this need is to consider the primary forces that impact BIM and SM adoption in construction megaprojects (CMPs) (Mashali et al., 2022); (Mashali et al.,2023). The research seeks to determine and appraise Key drivers (KDs) for implementing the synergy of BIM and SM in CI. This knowledge gap is bridged and handled in this paper.

The following research objectives are identified to achieve the main aim of the study as follows:
▪ 01: To create a comprehensive backdrop concerning BIM, as well as SM and synergy between BIM and SM, in CMPs.
▪ 02: To identify and evaluate the KDs for implementing BIM and SM practices in CMPs.
▪ 03: To specify the significance of BIM&SM drivers, the relative weight, and significance of factor clusters FCs correlating with BIM and SM integration in CMPs.

This article is organized as follows: Section 1 introduces the topic. Section 2 is a literature review. Section 3 describes the research methodology. Section 4 provides analysis of results and discussions. Section 5 presents the conclusions, Research Limitations and recommendations.

2. Literature review

2.1 Stakeholder management and construction projects success

All project stakeholders' effective and ongoing involvement has been associated with project success (Mashali et al., 2022); (Mashali et al., 2020). Additionally, stakeholder satisfaction has been added to the traditional criteria for project success: cost, quality, and timeline (Mashali et al., 2022). Previous studies (Olander and Landin, 2008) have linked project failures to either a lack of or ineffective stakeholder management during the project. Therefore, it is crucial to include stakeholders effectively to complete the project successfully and under the current perception of project success in CI (Mashali et al., 2022). Involvement and incorporating stakeholders early on and considering their interests are critical to

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

prevent adverse reactions to the project. Therefore, stakeholder management and involvement should continue the project's duration (Mashali et al., 2022).

2.2 BIM & Stakeholder Management in CMPs

In contrast, BIM appears as an efficient tool to assist in centralizing and managing information during the project life cycle (PLC) (Xu et al., 2014). According to the European Federation of Engineering Consultancy Associations EFCA (2019), BIM is a digital process and an information management approach that can reinforce project quality and enhance productivity in the CI. Furthermore, BIM adoption is a significant response to the challenges faced in the project phases as markets seek cost reduction and efficient evolution (Sacks et al., 2018). BIM systems can include significant amounts of data for storage, document management, stakeholder communication, visualization, analysis of outcomes, and so on (Husain et al., 2018); (Olawumi et al., 2017); (Mashali et al., 2022).

Hence, The incorporation of smart tools such as BIM in SM practice is aimed at assisting as a decision-making tool to evaluate the level of project achievement. Also, when BIM is utilised throughout different phases, it is a preconized collaboration (Georgiadou, 2019); (Mashali et al., 2022). Moreover, project teams' participation in the early phases of construction projects could promote the use of BIM (Van Tam et al., 2023). Additionally, the absence of BIM standards in the industry is one of the barriers to adopting BIM in some countries. (Rogers et al. (2015).

CMPs are complex and include numerous interrelated processes and stakeholders. Besides, it has a large scale & quantity and complex undertakes, commonly costing one billion USD or more. (Mashali et al., 2022); (Mashali et al., 2023); (Evans et al., 2020b).

Ayodele et al. (2021) examined the challenges to data sharing among construction stakeholders in the South African construction industry and also assessed stakeholders' perceptions of the benefits of data sharing. Toriola-Coker et al., (2021) investigated two public-private partnership road projects in Nigeria to explore factors that can motivate end-user stakeholders to contribute towards sustaining projects in the long term and identified an eight-factor structure indicating critical success factors for ensuring end-user stakeholder support on PPP projects on a long-term basis in their host communities. Kwofie et al., (2021) examined clusters of key barriers to life cycle assessment adoption in the South African construction industry from SM perspectives. Tai et al., (2021) investigated factors affecting BIM usage in China and its societal impact on project stakeholders.

In addition, by identifying a common set of key drivers for BIM-SM implementation, practitioners could better understand the key areas worth paying attention to for predicting the probability of successful BIM implementation and take necessary steps to avoid BIM-based SM failure (Mashali et al., 2022); (Mashali et al., 2023). Therefore, it is significant to consider both BIM and SM concepts; one way to do this is by exploring the (KDs) that can encourage using smart SM in CI.

Given the previous, (Table 1) summarizes the 20 KDs found through a review of the existing literature to improve the implementation of smart SM practices, while (Table 5) illustrates the FCs. As far as the researchers know, The drivers of adopting BIM and SM practices in CMPs have yet to be investigated, as this study has done. This study's scope includes CMPs, as a subset of the CI, BIM as a smart tool, and SM practices as they apply through the project life cycle. Furthermore, this also served as the foundation for this study's literature search about KDs. This research seeks to define and assess KDs that aid in implementing BIM and SM practices in the CI. This knowledge gap is bridged and handled in this research.

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

Table 1. Summary of KDs for the implementation of BIM and SM practices extracted from the literature.

Code	Key drivers (KDs)	Reference
KD1	Availability of funding resources for BIM software, licenses, associated applications, and its standard upgrades	8,26 and 28
KD2	Competent technical support team within organisations i.e. (technical competence of staff, and adapting to new BIM technologies by experts)	37,25, and 26
KD3	Variable market preparedness via organisations and geographic zones.	11,34, and 19
KD4	Greater awareness and experience level, knowledge, and skills of BIM and SM within the organisation	31, 26, and 33
KD5	The willingness of staff to learn new technologies	35 and 15
KD6	Awareness and collaboration amongst project stakeholders	5, and 19
KD7	Effective project participant coordination and collaboration	6, 22, and 28
KD8	Additional cross-field BIM and BIM-SM training initiatives are needed	27, and 33
KD9	Societal opposition toward changing the conventional values or long-held culture	12,32, and 34
KD10	Resistance to changing from traditional established working procedures	25, 9, and 30
KD11	Creating an appropriate legal framework for BIM utilization and deployment in projects	3, 28, 29, 1, 32, 11,7
KD12	Establishment of government commencement support for the construction companies to launch BIM initiatives	1, 14, 26, 32, and 34
KD13	Sharing risks, liability, benefits, and rewards between the project's stakeholders	11, 21, 4,32,7 1, 4,31, 26
KD14	Organisational challenges, policies, and project strategies	10, 11,6 and 38
KD15	Credit for innovative performance, BIM standards, codes, rules, regulations, proper legislation, and government enforcement	1, 21, 26, 5
KD16	Software developer adoption to standardisation of BIM software	4, 37, 32, 16
KD17	Client requirements and ownership	2, and 13
KD18	Technical support from software vendors	12, 25, 27
KD19	Early involvement of project teams	17, 29
KD20	Supportive organisational culture and effective leadership	6, 10, 25

Notes: 1= Abanda et al. (2015); 2= Ahn et al. (2016); 3= Aibinu and Venkatesh (2014); 4= Akinade et al. (2018); 5= Anton and Dıaz (2014); 6= Antwi-Afari (2018);7= Bradley et al. (2016);8= Bui et al. (2016); 9= Cao et al. (2015); 10= Carvajal-Arango et al. (2019);11= Chan (2014); 12= Chan et al. (2019); 13= Chan et al. (2019a); 14= Chen et al. (2015); 15= Ekemode (2023);16= Ding et al. (2015);17= Ghaffarianhoseini et al. (2017); 18= Darwish et al. (2020); 19= Chan et al. (2022); 20= Phang et al.(2020); 21= Jin et al. (2017); 22= Li et al. (2022);23= Olatunji et al. (2017a); 24= Saka and Chan (2022); 25= Olawumi et al. (2017); 26= Van Tam et al. (2021); 27= Ahuja et al. (2020); 28= Abbasnejad et al. (2019a); 29= Ozorhon and Karahan (2017); 30= Rogers et al. (2015); 31= Sacks et al. (2018); 32= Faisal et al. (2020); 33= Saieg et al. (2018); 34= Saka et al. (2019); 35= Tsai et al. (2014a); 36= Olanrewaju et al.(2021); 37= Zhang et al. (2018); 38=Wojewnik-Filipkowska et al. (2021).

3. Research methodology

The research strategy can be defined as how the research aims could be investigated, and it is divided into two sorts, namely, quantitative, and qualitative (Naoum, 2012). The important part of any research is to select appropriate methods and strategies carefully (Naoum, 2012). The quantitative approach is utilised to gather real information concerning the research subject from the concerned specialists/experts and analyse the obtained data by statistical methods, to define if the hypothesis or method is correct or not (Naoum, 2012). It is utilised to measure and quantify data around conclusions and findings in theory and literature (Fellows and Liu 2015). The quantitative methodology involves both studying the overall trends in data and adding appropriate statistical criteria (Field, 2018).

Questionnaire surveys are considered the best way to access sizeable numbers of participants at a sensibly low cost (Fellows and Liu, 2015). This paper utilized a quantitative approach employing an empirical realistic survey to determine the perceptions of 204 construction professionals and get the study's required data. These KDs aid key stakeholders in executing BIM and SM practices in the CI, especially in CMPs. Although respondents' opinions may be subjective depending on their experience, locations, and other factors, Numerous statistical techniques are employed to reduce these biases. The research methodology stages are demonstrated in (Figure 1).

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

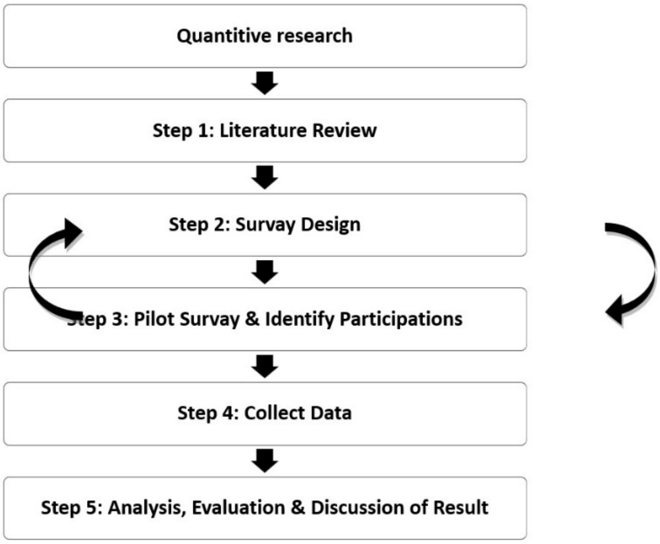

Figure 1. Research approach/methodology.

3.1 Survey design

The survey comprised dual sections. The first division collects primary professional information/details concerning participants (as specialization, profession, experience years in CI, organization classification, and awareness of BIM and SM concepts). The second section reflected the identified KDs to integrate BIM and SM in CMPs. The 20 identified KDs were regulated into six FCs (Farrell, 2016); (Fellows and Liu, 2015). Participants were invited to rank the KDs factors on a seven-point Likert scale: 1 = "very strongly disagree", 2 = "strongly disagree", 3 = "disagree", 4 = "do not know or not sure", 5 = "agree", 6 = "strongly agree", and 7 = "very strongly agree" (Farrell, 2016). Participants were engineers at various levels and with a variety of experiences. Participants were allowed to include any factor or observations in the questionnaire ending (Farrell, 2016). The gathered data has been analysed utilizing several statistical methods, as illustrated in the next subsection and the findings discussed in subsequent study sections.

3.2 Sample size

The gathered data was analysed by using the SPSS software (22) (Cronk, 2016). Participants are engineers at various levels and with a variety of experiences.

The relevant target population comprised all stakeholders who had an interest in SM on Qatari construction projects. As such, the developed questionnaire targeted Governmental, Semi-Governmental and municipal, Clients/Owners/Engineers, Consultants (supervision and design), and Contractors/Subcontractors who are recognised and familiar with the Qatar construction industry. Consultants (supervision & design) and contractors are picked based on their experience in the construction area in the public projects of Qatar and who had a valid registration in the Qatari Ministry of Municipality and Environment in international and local companies. The owners and clients are chosen from government agencies, semi-government agencies, ministries, and municipalities.

It involved engineers at various levels and experience varieties (Director/Senior Management, Project Managers & Construction Managers, Resident Engineers/Client Consultant, Senior Engineer Level, and Site Engineer). Furthermore, specialists and experts who had valid licenses and participated in MCPs in Qatar have participated.

The sample size has been randomly selected from diverse stakeholders: government, municipalities, clients/owners/engineers, consultants (supervision & design), and (contractors & sub-contractors). According to the Ministry of Municipality and Environment, Qatar (MME), the targeted population is engineers licensed and working in Qatar, numbered 14,000 approx. The sample size was determined using Slovin's formula (Slovin, E.,1960) as follows (Equation 1):

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

$$n = \frac{N}{1+N\,(c^2)} \quad (1)$$

Where,
c = "margin of error, taken as 10% = 0.10".
N= "Total population, taken as 14,000".
n = "Sample size".

Then, after applying the equation:

$$n = \frac{14{,}000}{1+14{,}000\,(0.10^{\,2})} = 99.29 \approx 100$$

The survey was conducted via various communication methods; principally, it was developed on Survey Monkey and conducted via LinkedIn and emails to run directly on 'SurveyMonkey' forms.

The questionnaire was forwarded to 332 individuals working in diverse organizations, with 204 (61%) responses received, an adequate response number (Heravi, 2014); (Babbie, 2015). After the questionnaire was created, a pre-testing and a pilot study proceeded to refine and assess it. Five construction experts were consulted during the pre-testing process to get their opinions and ensure the questionnaire's structure, phrasing, and clarity were appropriate (Farrell, 2016).

When questions are posed on a Likert scale (1–7), Cronbach's Coefficient Alpha (α) is the most popular indicator of internal consistency (reliability) (Cronbach,1951). According to George and Mallery, (2020), the values range from (0.0 to +1.0), with higher values implying greater internal consistency. A value of 0.7 or above, according to Pallant, (2005), indicates that the data is reliable for analysis. In this study, (α) equals 0.96, indicating outstanding reliability of entire questionnaire responses to meet the study's goals.

4. Analysis of Results and Discussions

4.1 Respondents' demographics

This division illustrates and analyses the survey results concerning the individual participants' demographics. Various segments of 204 survey respondents from various backgrounds from the Qatari construction market participated in this study (Table 2).

The results revealed that project consultants and the main contractors represented the study's majority respondent population. Public sector clients and academics followed closely.

Table 2. Participant.

Participant's demographics	Responses	
Client / Owner	16.67%	34
Consultant	42.16	86
Contractor/Sub-Contractor	32.84%	67
Academics	8.33%	17
Participant's Answers		204

Moreover, participants have been sorted according to their profession in descending order levels as follows: senior level (Engineering), manager level, mid-level (Engineering), junior level (Engineering), and Director/ Senior Management. It is illustrated in (Table 3).

Table 3. Profession levels.

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

Profession levels / Current career	Responses	
Director/ Senior Management	4.90%	10
Project Manager/ Construction Manager	25.98%	53
Senior engineer Level	45.10%	92
Mid-level (Engineering)	15.69%	32
Junior level (Engineering)	8.33%	17
Participant's Answers		204

Additionally, the survey respondents have a wealth of professional experience in the CI, as illustrated in (Table 4). As a result, diverse viewpoints from various perspectives can be captured due to the diversity of the respondents' groupings. Additionally, majority of respondents (48.04%), nearly half of the respondents reported working in construction for more than 15 years on average. This finding explains that responders have theoretical and practical knowledge of CI procedures and put such knowledge into implementation and practice.

Table 4. Professional experience in CI.

Professional experience	Responses	
More than 20 years	25.98%	53
16 – 20 years	22.06%	45
11 – 15 years	25.98%	53
5 - 10 years	20.10%	41
Less than 5 years	5.88%	12
Participant's Answers		204

Additionally, respondents were categorized based on the size of their largest ongoing projects in descending order as follows: megaproject(s) (over US$1 billion), large-scale (>500.00 million to 1 billion), medium-scale (>100.00 million to 500.00 million), small-scale (>50.00 million to 100.00 million), and research or project(s) under 50 million, refer to (Table 5).

Table 5. Ranking.

1.4 - Professional experience in CI	Responses	
megaproject(s) (over US$1 billion)	82.84%	169
large-scale (>500.00 million to 1 billion)	8.82%	18
medium scale (>100.00 million to 500.00 million)	4.41%	9
small-scale (>50.00 million to 100.00 million)	1.96%	4
research or project(s) under 50 million	1.96%	4
Participant's Answers		204

Furthermore, and according to the kind of the largest ongoing project, respondents were divided into four groups: infrastructure, metro/light rail transit, building, industrial, and other sorts of projects, refer to (Table 6).

Table 6. Ranking.

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

1.5 - According to the kind of the largest ongoing project	Responses	
Infrastructure	43.63%	89
Metro/light rail transit	44.12%	90
Building	8.33%	17
Industrial	1.47%	3
Other sorts of projects	2.45%	5
Participant's Answers		204

On their largest ongoing project(s), respondents were divided into categories based on the kind of contract or procurement they have used: design and build procurement, lump-sum type, measurement type, cost reimbursed type, besides other types of contracts as illustrated in (Table 7).

Table 7. Ranking.

1.6 - Categories based on the kind of contract or procurement	Responses	
Design and build procurement	87.25%	178
Lump-sum type	6,86%	14
Measurement type	1.96%	4
Cost reimbursed type	1.47%	3
Other types of contracts	2.45%	5
Participant's Answers		204

These indicate that the participants have adequate knowledge and awareness of (BIM & SM) by 54% and 40%, respectively. Also, BIM and SM were understood on average level by 36% and 33% of respondents, respectively. These findings demonstrated that BIM awareness is greater than SM knowledge in CI. In addition, and more specifically, participants were questioned about their familiarity with BIM concepts and procedures (Figure 2). The results showed that participants had the following level of BIM knowledge: experts (16.67%); very knowledgeable (19.12%); good knowledge (18.14%); some knowledge (23.53%); little knowledge (12.75%); and no knowledge (9.80%). The following information was disclosed from the findings regarding the participants' knowledge level of SM practices: Figure 3 shows the percentages of experts (23.53%), very knowledgeable (8.82%), good knowledgeable (8.33%), some knowledgeable (11.27%), little knowledgeable (22.06%), and no knowledgeable (25.98%).

According to these findings, BIM awareness is greater than SM knowledge in the CI. In addition, participants were also asked to what extent (BIM & SM) are enforced and integrated with their massive ongoing project(s) (Figure 3). Outcomes illustrated that BIM-SM adoption is slightly integrated and is still taking its first steps on respondents' current project(s). In addition, the demographic statistics of the participants showed that the professionals who provided the information needed for the study's findings had a combination of hands-on expertise and theoretical knowledge of the field. As a result, this further supports and gives more acceptance to the gathered data, later analysis, and investigation.

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

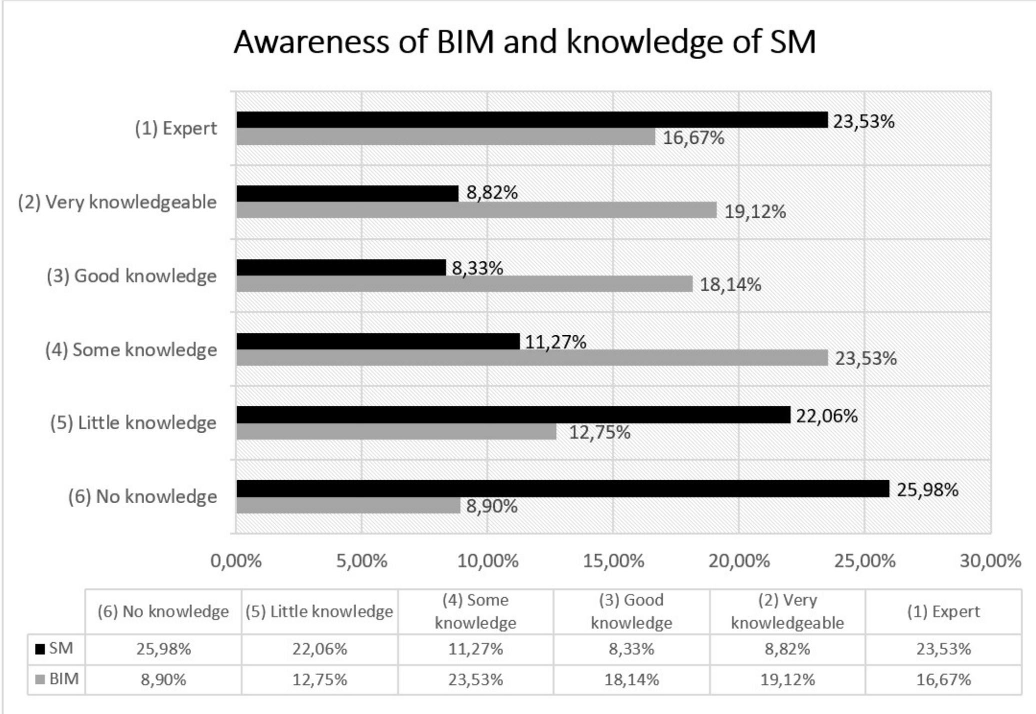

Figure 2. Awareness of BIM and knowledge of SM.

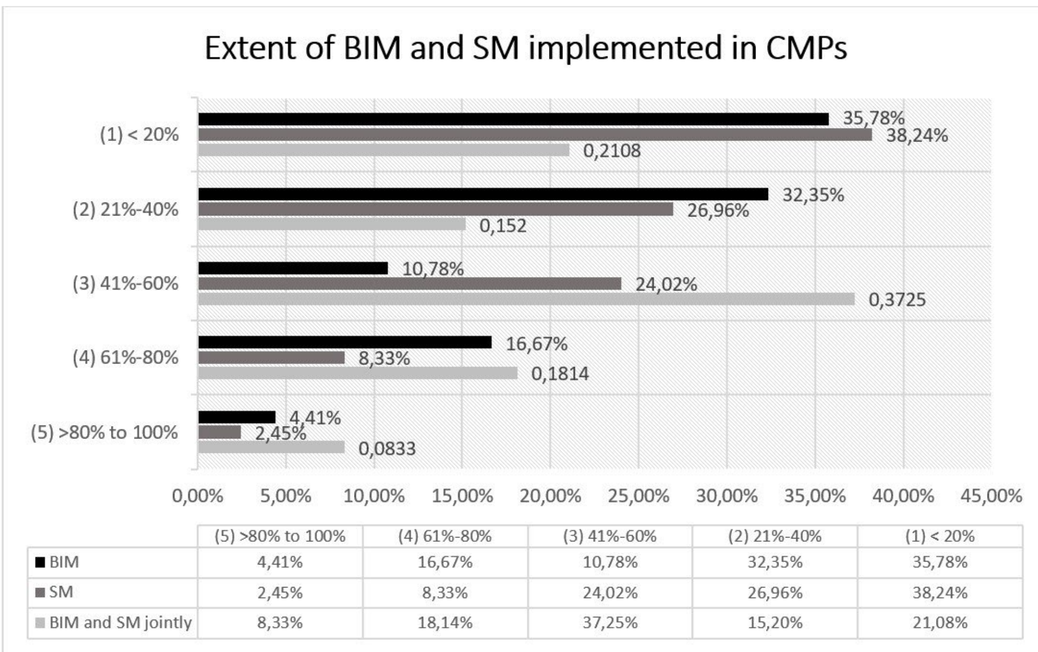

Figure 3. Extent of BIM and SM implemented in CMPs.

4.2 Statistical analysis findings

This division explains the findings from survey forms, analysed by applying several statistical procedures, besides discussing survey outcomes.

4.2.1 Descriptive statistical tests

Based on the information gathered from the survey participants, the mean score (m) and standard deviation (SD) were used to rank the KDs. The ranking considers the SD values of KDs when two or more have the same mean value. For the 20 identified KDs indicated below (Table 2) illustrates

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

the mean scores range from (m 4.65 & SD 1.224) for "KD3 - Variable market preparedness via organisations and geographic zones " to (m 6.07 & SD 0.67) for ‘KD2 - competent technical support team within organisations i.e. (technical competence of staff and adapting to new BIM technologies by experts).’ (Table 3) illustrates the significance of KDs ranked in descending order.

By adopting this approach, the study determines the most significant KDs indicated in below (Table 3), which are significant as follows:

- KD2 – ‘competent technical support team within organisations i.e. (technical competence of staff, and adapting to new BIM technologies by experts)’ (m 6.07, SD 0.67),
- KD8 – ‘Additional cross-field BIM and BIM-SM training initiatives are needed’ (m 6.03, SD 0.697),
- KD1 – ‘Availability of funding aid resources to BIM software, licenses, and associated applications, besides its standard upgrades.’ (m 6.0, SD 0.769),
- KD6 – ‘awareness and collaboration among project stakeholders’ (m 5.9, SD .842),
- KD9 – ‘Societal opposition toward changing the conventional values or long-held culture’ (m 5.87, SD 0.873).

The findings in (Table 8) and (Table 9) reinforce that the fulfilment of smart SM in CI relies on staff technical competence, adapting to new BIM technologies, and having available financial resources for BIM software, licenses, and associated applications, besides proper awareness, and collaboration amongst project stakeholders. Therefore, policymakers, local authorities, and key stakeholders must precedence all the above issues in their drive to adopt BIM technologies toward the execution of SM. Furthermore, stakeholders' success in CI would be facilitated by their extensive knowledge and skill set in smart SM practices. The outcomes show how the early engagement of key stakeholders in the project beginning could affect the fulfilment of smart SM practices. This is because consultants of projects are included in projects from their start.

Table 8. Independent samples test.

Organisation	Consultants		Main contractor		Clients		Academics		Overall				
Code	M	R	M	R	M	R	M	R	M	SD	R	F	Sig. ‘*p*’
KD1	6.03	2	6.07	1	5.85	3	5.82	4	6.00	0.769	3	0.120	0.730
KD2	6.08	1	6.03	3	6.09	2	6.12	2	6.07	0.670	1	1.601	0.208
KD3	4.52	20	5.00	20	4.41	20	4.41	20	4.65	1.224	20	6.346	0.050
KD4	5.38	11	5.76	10	5.44	11	5.71	8	5.54	1.033	11	12.145	**0.001**
KD5	4.84	15	5.28	17	4.65	16	5.12	16	4.98	1.094	16	0.014	0.907
KD6	5.90	4	6.01	5	5.76	5	5.76	7	5.90	0.842	4	3.090	0.081
KD7	5.78	8	5.90	9	5.74	7	5.53	11	5.79	0.941	8	3.827	0.052
KD8	6.00	3	6.03	3	6.09	2	6.12	2	6.03	0.697	2	1.284	0.259
KD9	5.83	5	6.01	5	5.76	5	5.76	7	5.87	0.873	5	6.403	**0.012**
KD10	4.62	19	5.00	20	4.41	20	4.41	20	4.69	1.231	19	4.377	0.052
KD11	5.07	12	5.51	12	5.24	12	5.41	13	5.27	1.106	12	7.917	**0.006**
KD12	5.58	9	5.93	7	5.68	9	5.82	4	5.73	0.968	9	12.248	**0.001**
KD13	4.72	18	5.28	17	4.50	18	5.00	18	4.89	1.118	18	1.345	0.248
KD14	4.84	15	5.30	15	4.71	15	5.29	15	5.00	1.090	15	0.524	0.470
KD15	4.79	17	5.28	17	4.50	18	5.00	18	4.92	1.129	17	0.164	0.686
KD16	5.81	6	5.90	9	5.74	7	5.53	11	5.80	0.932	7	2.915	0.090
KD17	5.51	10	5.73	11	5.47	10	5.59	9	5.58	1.006	10	6.866	**0.010**
KD18	5.79	7	5.93	7	5.68	9	5.82	4	5.82	0.927	6	2.393	0.124
KD19	4.92	13	5.36	13	5.00	13	5.41	13	5.12	1.126	13	1.170	0.281
KD20	4.83	16	5.33	14	4.85	14	5.41	13	5.04	1.098	14	0.200	0.656

Notes: - M = mean; S = standard deviation; R = rank; F = F test in analysis of variance (ANOVA)

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

Table 9. Significance of KDs ranked in descending order.

Code	Key drivers (KDs)	Rank
KD2	Competent technical support team within organisations i.e. (technical competence of staff, and adapting to new BIM technologies by experts)	1
KD8	Additional cross-field BIM and BIM-SM training initiatives are needed	2
KD1	Availability of funding aid resources to BIM software, licenses, and associated applications, besides its standard upgrades.	3
KD6	Awareness and collaboration amongst project stakeholders	4
KD9	Societal opposition toward changing the conventional values or long-held culture	5
KD18	Technical support from software vendors	6
KD16	Software developer adoption to standardisation of BIM software	7
KD7	Effective project participant coordination and collaboration;	8
KD12	Establishment of government commencement support for the construction companies to launch BIM initiatives	9
KD17	Client requirements and ownership	10
KD4	Greater awareness and experience level, knowledge, and skills of BIM and SM within the organisation	11
KD11	Creating an appropriate legal framework for BIM utilization and deployment in projects	12
KD19	Early involvement of project teams	13
KD20	Supportive organisational culture and effective leadership	14
KD14	Organisational challenges, policies, and project strategies	15
KD5	The willingness of staff to learn new technologies	16
KD15	Credit for innovative performance, BIM standards, codes, rules, regulations, proper legislation, and government enforcement.	17
KD13	Sharing risks, liability, benefits, and rewards between the project's stakeholders.	18
KD10	Resistance to changing from traditional established working procedures.	19
KD3	Variable market preparedness via organisations and geographic zones	20

4.2.2 Statistical tests

To identify any differences in perceptions of the survey respondents, parametric statistical procedures, such as the ANOVA test, were used.

ANOVA test is a statistical inferential tool that analyzes variance utilizing the mean of scores applied to define whether statistically significant differences occur between the means of two or more independent data sets. (Field, 2018); (Tsai et al., 2014a).

Before an ANOVA test is conducted, the homogeneity premise of the sample data (i.e., $p > 0.05$) declares that the sets' variances are equal. The KDs' significance level (p-value) was higher than $p > 0.05$, indicating that the sets' variances are equal. Hence, the ANOVA test will be helpful for additional data analysis.

4.2.2.1 Statistical tests based on organisational setups

ANOVA test was performed on the data (at a significance level of 5%). There was no evidence of divergence in the perceptions among the respondent sets according to the organization setups observed in this study. The respondents in this organizational setup are the consultants, main contractors, clients, and academics. The outcomes correspond to many participants who may have worked in more than one organizational setup in their professional careers. Furthermore, even academics often collaborate with industry colleagues, exchanging theoretical and practical experiences (Olatunji et al., 2017b).

4.2.2.2 Statistical tests based on professional disciplines

The ANOVA statistical method demonstrated some significant differences (sig. <5%) in the respondents' views on five KDs, as shown in (Table 2) above. These drivers comprise three factors with notable and significant differences 'KD4 - greater awareness and experience level, knowledge, and skills of BIM and SM within the organisation' ($F= 12.145$, $p=0.001$); and 'KD12- Establishment of government commencement support for the construction companies to launch BIM initiatives' ($F= 12.248$, $p=0.001$) and 'KD11- Creating an appropriate legal framework for BIM utilization and deployment in projects' ($F= 7.917$, $p=0.006$). The other two factors 'KD9 - Societal opposition toward changing the conventional values or

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

long-held culture' (F= 6.403, p=0.012); and 'KD17- Client requirement and ownership' (F= 6.866, p=0.010) have a moderately significant difference. When challenges connected to the execution of smart SM practices and other concepts are incorporated into construction projects, the stakeholders are implicated early in the construction process. Additionally, the key stakeholders collaborate to ensure the construction project conforms with pertinent regulatory and legal frameworks and standards, which must be committed during the project stages. This unique relationship makes their perception of this factor worthy of note. Concerned stakeholders must understand applicable legislation well, allowing them to create appropriate plans and strategies (Mashali et al., 2022a).

4.3 Discussion of survey findings

The outcomes will be covered in this section in two aspects: (1) a discussion of the FCs (Table 5) and (2) a discussion of the respondents' viewpoints on KDs.

4.3.1 Discussion of clustered KDs

To facilitate their explanation, the clustered factors that show the relationship between the main components are given an easily recognizable collective term and description. The labels were according to the researchers' conceptions, and perceptions and thus are subjective. The FCs were ranked according to their importance in descending order utilizing a factor scale rating. The ratio of the mean of individual factors inside a cluster divided by the number of factors in the cluster is known as the factor scale rating (FSR) (Thompson, 2004), (Hair et al., 2014), as mentioned in (Table 10). This section argues the clusters and provides recommendations for reinforcing smart and SM practices in CI.

Table 10. Ranking of factor clusters (FCs).

FC	Factor clusters (FCs)	(FSR)	Rank
FC5	Technical drivers	5.896	1
FC6	Information, and attitude-related drivers	5.783	2
FC1	Education, knowledge, and industry-related drivers	5.476	3
FC2	Financial, and market-related drivers	5.2675	4
FC4	Organisational and project-related drivers	5.060	5
FC3	Legal-related drivers	5.0266	6

4.3.1.1 Technical-related drivers

This cluster comprises three KDs (KD2, KD16, and KD18), with the highest (FSR) of M = 5.896. This cluster is connected to future investment planning, issues and challenges with organizational policies and strategies plans, the industry's fragmentation nature and difficulty with BIM and SM implementation in CI. The BIM concepts, and SM principles, are still all for integrating human strategies and efforts and strategies in CI.

Additionally, it is also necessary for the government and expert organizations/ bodies to back the purchasing cost associated with (BIM & SM) applying software to facilitate its embrace.

Overall, it must be confirmed how important it is for construction enterprises and other stakeholders to build solid and successful plans for adopting and implementing smart SM practices.

4.3.1.2 Information, and attitude-related drivers

This cluster comprises four KDs (KD6, KD9, and KD17); it is the second most significant factor cluster with an (FSR) of M = 5.783. These drivers relate to stakeholder attitudes toward BIM and SM practices adopting and integrating. The resistance to change impedes the implementation of innovative concepts, which has unfavourably affected project stakeholders' skills, knowledge, and experience regarding the implementation of BIM and SM in CI. Thus, to fully implement these concepts in CMPs, a substantial adjustment in stakeholders' attitudes and perceptions is necessary to raise (BIM&SM) application.

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

It is noteworthy that obstacles to change, such as a lack of support from senior management and clients, continue to be a major obstacle to integrating BIM and SM projects. Accordingly, this study advises key construction industry stakeholders to lessen their resistance to change and adopt dynamic, upbeat attitudes in the CI. To increase (BIM-SM) synergy, key stakeholders are encouraged to adopt (BIM & SM) strategies proactively.

4.3.1.3 Education, knowledge, and industry-related drivers

This FC is ranked third and consists of five KDs (KD4, KD5, KD7, KD8, and KD20), with an (FSR) of M = 5.476. This cluster concerns education, staff knowledge of construction organizations, understanding of BIM, SM, and the deficiency of smart SM practices professionals.

Training construction specialists to increase their knowledge, comprehension, skills, and abilities for utilizing new technologies has yet to receive much attention (Darwish et al., 2020). Consequently, professional societies, bodies, and organizations, besides construction enterprises must work together to enhance their members' and employees' capacities and skill sets in smart SM practices. Thus, there is a need for corporates, organizations, and professionals to boost the BIM and SM industry's aptitude, competence, and quality to ease the application of smart SM in CI.

The FCs on matters including, but not limited to, the firm's awareness and experience level, the technical proficiency of the personnel, a training program for experts in smart SM practices, and the effectiveness of project stakeholder coordination. To ease the application of smart SM in CI, the employees of construction organizations and government agencies needed the necessary training on both technical and non-technical BIM characteristics and aspects (Darwish et al., 2020); (Ma et al., 2018).

Accordingly, in light of the constantly evolving duties and responsibilities brought on by adopting BIM and implementing SM practices in the CI, they further stated that such training should be ongoing. In contrast, Antón and Díaz, (2014) and Olawumi and Chan, (2018b) highlighted the importance of creating and making an internal database accessible to maintain track of the information and manage the data and organization of past and present initiatives.

4.3.1.4 Financial, and market-related drivers

This FC is ranked fourth and comprises four KDs (KD1, KD3, KD10, and KD12) with an (FSR) of M=5.267. This factor concerns how simple it is to get finance for BIM software purchases, its concurrent licenses, and government financial support for construction enterprises, as the initial cost of purchasing BIM software is high. Therefore, the involved stakeholders must exert keen, concerted effort and commitment to make the required financial resources available to support and strengthen the implementation of smart SM practices in the CI. Moreover, senior management in construction enterprises should avert being reluctant to make planned long-term investments and commit to fulfilling BIM and SM in their organisation's projects to have an impact over the long term. Additionally, governments should seek to provide financial backing and incentives for small and medium-sized construction enterprises to implement smart SM practices internally and in their projects.

4.3.1.5 Organisational and project-related drivers

This FC is ranked fifth and comprises two key KDs (KD14 and KD19) with an (FSR) of M= 5.060. The factor considers customer satisfaction, early stakeholder involvement, interoperability, and data compatibility, besides the accessibility of cost-effective cloud-based technology.

It also considers the project's structure and system complexity. Therefore, additional endeavours are essential to be made by primary stakeholders to ensure interoperability and data compatibility to improve and enhance the undertaking of smart SM and emphasise the significance of thoroughly understanding and assessing smart criteria in construction projects.

Therefore, additional endeavors are necessary to be made by primary project stakeholders to ensure interoperability and data compatibility to improve and enhance the implementation of smart SM practices in the built environment and emphasise the significance of thoroughly understanding and assessing smart criteria in construction projects.

Integration of BIM and SM assessment techniques is essential. Therefore, to improve the implementation of smart SM practices in CI, it is advised to encourage key stakeholders, firms, professional societies and bodies, and governments to collaborate to improve project and organization-related/linked drivers.

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

4.3.1.6 Legal-related drivers

This FC is ranked last and consists of three key underlying KDs (KD11, KD13, and KD15) with an (FSR) of M=3.985. This factor is affiliated with government support in developing a proper legal frame to direct its distribution in the projects to guarantee intellectual possession rights. Thus, concerned stakeholders must demonstrate initiative, dedication, and commitment to facilitate the successful smooth adoption of smart SM practices in CI.

Overall, this section investigated BIM and SM practices by existing literature for identifying KDs for executing smart SM practices in CMPs, as displayed in (Table 11).

Table 11. Summary of FCs.

Rank	Code	Factor clusters (FCs) / KDs	Mean	Overall mean
	FC1	**Education, knowledge, and industry-related drivers**		5.476
11	KD4	Greater awareness and experience level, knowledge, and skills of BIM and SM within the organisation	5.54	
16	KD5	The willingness of staff to learn new technologies	4.98	
8	KD7	Effective project participant coordination and collaboration	5.79	
2	KD8	Additional cross-field BIM and BIM-SM training initiatives are needed	6.03	
14	KD20	Supportive organisational culture and effective leadership	5.04	
	FC1	**Financial, and market-related drivers**		5.267
3	KD1	Availability of funding aid resources to BIM software, licenses, and associated applications, besides its standard upgrades	6	
20	KD3	Variable market preparedness via organisations and geographic zones	4.65	
19	KD10	Resistance to changing from traditional established working procedures	4.69	
9	KD12	Establishment of government commencement support for the construction companies to launch BIM initiatives	5.73	
	FC1	**Legal-related drivers**		5.026
12	KD11	Creating an appropriate legal framework for BIM utilization and deployment in projects	5.27	
18	KD13	Sharing risks, liability, benefits, and rewards between the project's stakeholders	4.89	
17	KD15	Credit for innovative performance, BIM standards, codes, rules, regulations, proper legislation, and government enforcement	4.92	
	FC4	**Organisational and project-related drivers**		5.060
15	KD14	Organisational challenges, policies, and project strategies	5	
13	KD19	Early involvement of project teams	5.12	
	FC5	**Technical-related drivers**		5.896
1	KD2	Competent technical support team within organisations i.e. (technical competence of staff, and adapting to new BIM technologies by experts)	6.07	
7	KD16	Software developer adoption to standardisation of BIM software	5.8	
6	KD18	Technical support from software vendors	5.82	
	FC6	**Information, and attitude-related drivers**		5.783
4	KD6	Awareness and collaboration amongst project stakeholders	5.9	
5	KD9	Societal opposition toward changing the conventional values or long-held culture	5.87	
10	KD17	Client requirements and ownership	5.58	

5. Research Contributions

Previous research tackled BIM and SM separately, while those addressing both do not exist. Therefore, this study is foreseen to have multiple implications and provide a starting point for practitioners and academics by identifying the 20 KDs. This paper has contributed to the existing body of knowledge in BIM & SM areas, and its findings will create a solid motivation to carry out SM initiatives fully and support the (BIM-SM) synergy initiative in CMPs. Accordingly, Our academic contribution lies in it may help identify exciting research questions and encourage the use

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

of novel approaches. Moreover, Our study has implications for practitioners. The findings are foreseen to aid project managers in adjusting their strategies via a broad picture and understanding of BIM & SM and their relationships in CMPs.

6. Conclusion

Even though stakeholder management has long been recognized as a means to increase the likelihood of successful construction projects' completion, the full potential of stakeholder management has yet to be realized. According to earlier studies, a lack of thorough stakeholder management and BIM processes is evident throughout the project life cycle. Since traditional approaches cannot successfully manage stakeholders, that increases the demand for smart SM as a key strategic organisation's target. Meanwhile, BIM-based Stakeholder management has yet to be adopted as a promising strategy for managing construction projects. This paper seeks to explore the synergy of BIM and stakeholder management to establish a novel approach for SM in CI by implementing BIM to direct the process.

Furthermore, 20 KDs for adopting BIM and SM practices in CMPs were identified via a literature review and factors drawn in a survey ranked by 204 respondents with broad and direct experience in CI. The survey participants have various professional disciplines and organisational backdrops, thus giving creditability to the information gathered. KDs of BIM and SM in CI mentioned by the respondents involved: specifying training programs and cross-field specialists' workshops. However, the key drivers include the technical competence of the firm's workforce and the earlier engagement and integration of key project individuals. Besides, KDs' analysis generated six FCs.

A barrier to the systematic adaptation of smart stakeholder management may be that it usually takes more time and resources. The stakeholders will need some time to realize that employing BIM in stakeholder management practices is beneficial and outweighs the additional resources, effort, and input needed because of the fragmented nature of the construction sector. A company's or a client's incapacity to set aside funds to assist the smart stakeholder management process can be considered the major challenge and obstacle to adopting the process. As a result, it is advised that the client and the project core team set up some financial provisions for the process.

Therefore, there is a need for policy-driven support for stakeholder management to be implemented in construction projects, where the government and pertinent regulatory bodies should ensure this is done as stakeholders. Thus, a project's success may be realized if smart stakeholder management is effectively and comprehensively addressed in building projects. This study supported the viability and applicability of BIM in stakeholder management. However, more study is required to validate it in practice and further enhance it. However, this study provides a uniquely practical approach, considering smart tools like BIM deeper when managing stakeholders. Thus, it results in a clear understanding of the stakeholders and their contributions, reducing waste and boosting project value creation.

6.1 Research Limitations

Findings are limited to the Qatari construction projects context with an emphasis on (CMPs). Nevertheless, this research is still robust and suitable for evaluating SM in CMPs.

6.2 Recommendations

Based on the study outcomes, the recommendations comprise the following:

- There is an urgent necessity for crucial stakeholders to prioritize staff development to enhance current smart innovation practices.
- Government authorities and professional bodies should work together to deliver financial incentives encouraging construction companies to support the implementation of smart SM.
- Government authorities and professional bodies ought to work together to develop pertinent policies and standards within a local context.
- Organisations' senior management should prioritize evolving and installing reliable working strategies to realize smart SM practices.
- Cloud-based technology solutions must be developed, hastened, and advanced to minimize the cost of desktop-based software.
- Additional investigations could be conducted to create a BIM-based stakeholder management framework for construction megaprojects, encouraging stakeholder management adoption in the construction industry.

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00141.21

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Vol. 40
Nº1 2025
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