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Review Article

Building Information Modeling and Internet of Things Integration in the Construction Industry: A Scoping Study

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Building Information Modeling (BIM) has emerged as a prospective technology used to advance the practices of construction projects. Also, Internet of Things (IoT), as a technology that connects sensing devices to share information across platforms, has become essential in building and construction environment. The integration of BIM-IoT in the construction industry, a high-risk industry, might increase overall performance and reduce related hazards. However, there is a dearth of studies on the integration of BIM and IoT in the construction industry. Scoping review of literature was performed using various databases such as IEEE Xplore, Science Direct, ACM, Emerald Insight, and Taylors & Francis databases to explore the study demographics, research direction, category, adoption, and performance of the BIM-IoT integration for the construction industry. Out of 2270 articles identified, a total of 81 key and vital articles were found and collected in scoping review to formulate the research questions. The study results revealed that the literature related to BIM-IoT integration and adoption is moderately steady, with constant output in the last four years. Twelve of the contributions were identified, and five were identified to be proposed more and conducted by researchers: investigation, evaluation, model, framework, and system. Also, fifteen (18.51%) studies were identified from the selected works that were evaluated using performance measurement. The findings shed light on some of the most significant difficulties in research related to BIM-IoT integration in the construction industries as well as potential future initiatives.

1. Introduction

Of recent, Building Information Modeling (BIM) has emerged as a prospective technology used to advance the delivery practices of construction projects. A project that utilized BIM is generally accurate and sustainable [1, 2]. Conversely, the Internet of Things (IoT), as a technology that connects sensing devices to share information across platforms, has become essential in building and construction environment. BIM adoption in the construction industry has been rigorously studied in the last decade [3–7]. Also, the factors that affect its adoption are examined and critically studied. However, the incorporation of BIM and IoT devices is a relatively innovative development. Generally, BIM and IoT complement each other by providing a key view of a given project. Hence, the two technologies supplement each

other's limitations [8–10]. BIM provides a high depiction of the project at the component level, while IoT improves this information by offering a real-time feed of operations in construction and operation.

Therefore, real-time data integration and BIM-IoT adoption provide a strong archetype for applications to increase construction operation efficiencies. Hence, the connection of real-time data from the speedily growing set of IoT sensor networks to the highly reliable BIM models offers many benefits. In recent years, various reviews and survey papers were published on BIM adoption and its integration with various technologies [1, 11–23, 26]. Also, Baydaa et al. conducted a systematic mapping study on the integration of BIM and IoT technologies. The study gives the trends and current challenges in the field of study [27]. However, based on our knowledge, no scooping review on integrating and adopting BIM-IoT technologies in the construction industry was found. Hence, in this study, we aim to fill this research gap.

This paper utilized a scoping review methodology that is evidence-based to guarantee that significant investigations on BIM and IoT coordination and appropriation in the development business in the previous decade (2011–2021) are found and gathered. The approach has a thorough determination and assessment strategies with a repeatable studies selection cycle. Also, this work gives results with regards to the studies selected overall characteristics and demographics, and the research focus of the studies selected. Besides, the contributions of the papers selected, the construction industry attitude toward the integration and adoption of BIM and IoT technologies, and the performance measures used in the research area were also reported. The key contributions of this paper are outlined as follows:

(i) A broad systematic review on BIM- IoT integration and adoption.

(ii) The critical synthesis of the current literature in the exploration area.

(iii) The identification of current challenges in the research area with areas that require more attention from the researchers.

Several studies have reported the applications of BIM in various dimensions. Eadie et al. surveyed the alleged changes necessary for adopting and accepting BIM in the United Kingdom (UK). The current issues and implications were outlined by the authors [11]. Jacobsson and Merschbrock also reviewed the BIM coordinator's role, practices, and responsibilities in the construction industry. The authors highlight the primary responsibilities of coordinators concerning the studied publications [12]. A review was done in a study by Noor and Yi to map out BIM utilization in the construction industry. The authors further highlight the existing research gaps [13]. Moreover, Jin et al. review recent studies on the BIM acceptance and application in the construction industry. The authors also gave future research directions for further research [14]. A study by Al-Yami and Sanni-Anibire highlights the current state of BIM implementation in Saudi Arabia. Furthermore, the advantages and obstacles of BIM implementation were presented [15]. Another study by Ayam and Al-Ghamdi presented a review of BIM and green buildings. The shortcomings and issues of BIM in green buildings are discussed and articulated [16].

Dixit et al. also conducted a review on integrating BIM and facility management (FM) in the construction industry. The key issues and challenges in the research area were highlighted and discussed [17]. A survey in [18] examines the main advantages of BIM implementation and sustainability practices in the construction industry. The study identified the advantages of BIM adoption and sustainability practices. Moreover, Witt and Kohkonen conducted a systematic review of BIM-enabled education [19]. Issues and challenges were further outlined. Another study also conducted a review on BIM for construction education [20].

A review of the integration of BIM and IoT devices was conducted by Tang et al. [1]. The authors highlight the trends in the field of study. In another review by Wang et al., a review on integrating BIM and geographical information systems (GIS) in a sustainable built environment was conducted [21]. Furthermore, a bibliometric analysis was also given by the authors. Another paper also works on BIM integration with existing technologies [22]. The research in [23, 24] explores the recent works on BIM for off-site construction. The authors also identify some key research trends and gaps in the area of study. Also, Baydaa et al. conducted a systematic mapping study on the integration of BIM and IoT technologies. The study gives the trends and current challenges in the field of study [25]. Recent papers also conducted an extensive review on BIM in the construction industry [26-28]. However, no scoping review works on BIM and IoT devices integration and adoption in the construction industry based on the identified review studies. Hence, this study aims to close this research gap.

2. Research Method

To conduct a scoping review, the finding, assessment, interpretation, and reporting of the related research in a given field is required by a researcher [29]. This study was based on [30, 31] studies. This method was designed to allow the inclusion of quality studies and give a comprehensive overview of a study field. Thus, to lead a scoping review, a search plan must be used that is clear and impartial. Subsequently, the search plan needs to ensure the culmination of the search [32, 33]. Currently, to the best of our knowledge, no scoping review paper gives a critical review and analysis of existing research on the integration or adoption of BIM-IoT technologies in the construction industry. Hence, this work aim is to close the gap in research. The current scoping review process comprises many stages that have to be done in an organized and orderly manner. These stages shown in Figure 1 comprise the building of the paper protocol in terms of formulating the appropriate research questions, the conduction of the review, the analysis of the acquired results, results in visualization, results on reporting, and lastly, a discussion of the outcome.

2.1. Research Questions. This study aims to understand works on the integration or adoption of BIM-IoT technologies in the

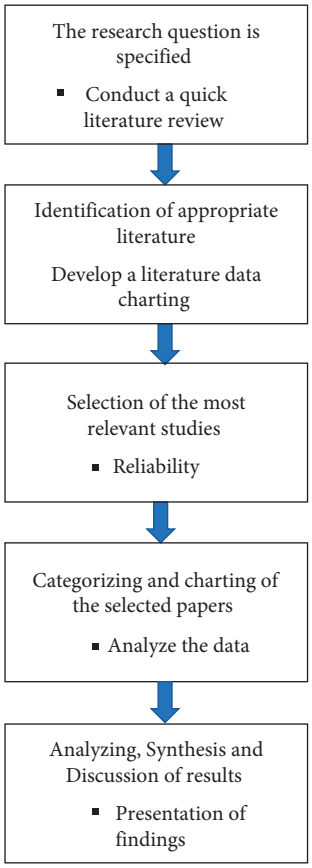

Figure 1: The schematic representation of the approach adopted in the scoping review.

construction industry. For a complete outlook of this research area, the study outlines, and answers five vital research questions (RQs). These RQs will help categorize further and understand the current works to find the limitations and future works proposed in the domain. The five defined RQs are given as follows:

(i) RQ1: what are the selected studies, demographics, and characteristics?

(ii) RQ2: what is the research focus of the selected studies?

(iii) RQ3: what are the contributions proposed by the selected studies, and how they can be categorized?

(iv) RQ4: what theories are used to study BIM adoption by the selected studies?

(v) RQ5: what are the different performance measures used in the research domain?

2.2. Data Sources. Normally, Table 1 features the five databases used for essential works retrieval. Thus, we believed these databases to be the prime hotspots for recovering any potentially related works in this examination.

2.3. Search Terms. To effectively locate the papers, key terms are essential for the search. Keele [29] reported that

Table 1: The data sources.

Database name	Link
IEEE Xplore	https://ieeexplore.ieee.org/
Science Direct	https://sciencedirect.com/
ACM	https://dl.acm.org/
Emerald Insight	https://emerald.com/insight/
Taylors & Francis	https://tandfonline.com/

population, intervention, comparison, and outcome (PICO) viewpoints were adopted by various SLRs and mapping works [34–36]. The following are the search terms for the viewpoints:

(i) Population: BIM and IoT

(ii) Intervention: integration and adoption

(iii) Outcome: construction and AEC

In this investigation, regarding the PICO structure's overall premise, we built a conventional Search string to continue searching on numerous databases. Therefore, to lead the programmed search, the blueprint nonexclusive Search string fills in as a guide.

Generic: ((Building information modeling OR BIM) OR (Internet of things OR IoT) AND (Integration OR adoption) AND (construction OR AEC))

Because each database has unique interfaces for advanced search, these particular search strings were utilized on the five selected databases to search for related articles. In Table 2, the search string for each database is presented.

2.4. Studies on Selection Procedure. In this stage (study choice cycle), the primary point is to distinguish successfully considers that are critical to our investigation's goals. In Figure 2, the examination choice technique (SSP) of this investigation is introduced. The examination choice cycle is in three stages; every one of these stages was refined through a top to bottom agreement meeting between the scientists to ensure high certainty with the least predisposition in the investigation SSP. Consequently, if a specific report is in different sources, we just bring one into considered concerning our hunt request. We at first discovered 2270 examination through our search. The examination's query items were coordinated for various searchers by the 1st author, the 2nd author, the 3rd author, and the 4th author. The authors also conduct an early screening of the 2270 studies retrieved regarding their titles, abstracts, and conclusion. Hence, for each screened, the study was examined by two researchers so as to agree if the study is to be added lastly. Hence, for a study that was critic contrarily, further deliberation was conducted by the two researchers who done the examination of studies they find concrete agreement. The purpose of this evaluation was to largely eliminate works that were obviously not significant, duplicate, or studies that did not tackle the issue of integration or adoption of BIM-IoT technologies in the construction industry.

2.5. Inclusion and Exclusion Criteria. In the mission to answer the characterized RQs in this study, we planned and

Table 2: Search strings.

Database name	Search string
IEEE Xplore	"Document Title": Building information modeling) OR "Document Title": BIM) OR "Document Title": internet of things) OR "Document Title": IoT AND "Abstract": integration) OR "Abstract": adoption) AND "All Metadata": construction) OR "All Metadata": AEC)
Science Direct	BIM, IoT, construction, AEC
ACM	[[Publication Title: building information modeling] OR [[Publication Title: bim] AND [Publication Title: internet of things]] OR [Publication Title: iot]] AND [[Abstract: integration] OR [Abstract: adoption]] AND [[Abstract: construction] OR [Abstract: aec]]
Emerald Insight	Title: "building information modeling" OR (title: "internet of things") AND (abstract: "integration") OR (abstract: "adoption") AND (abstract: "construction") OR (abstract: "AEC")
Taylors & Francis	[Publication Title: building information modeling] AND [All: construction] AND [[All: industry] OR [All: aec]]

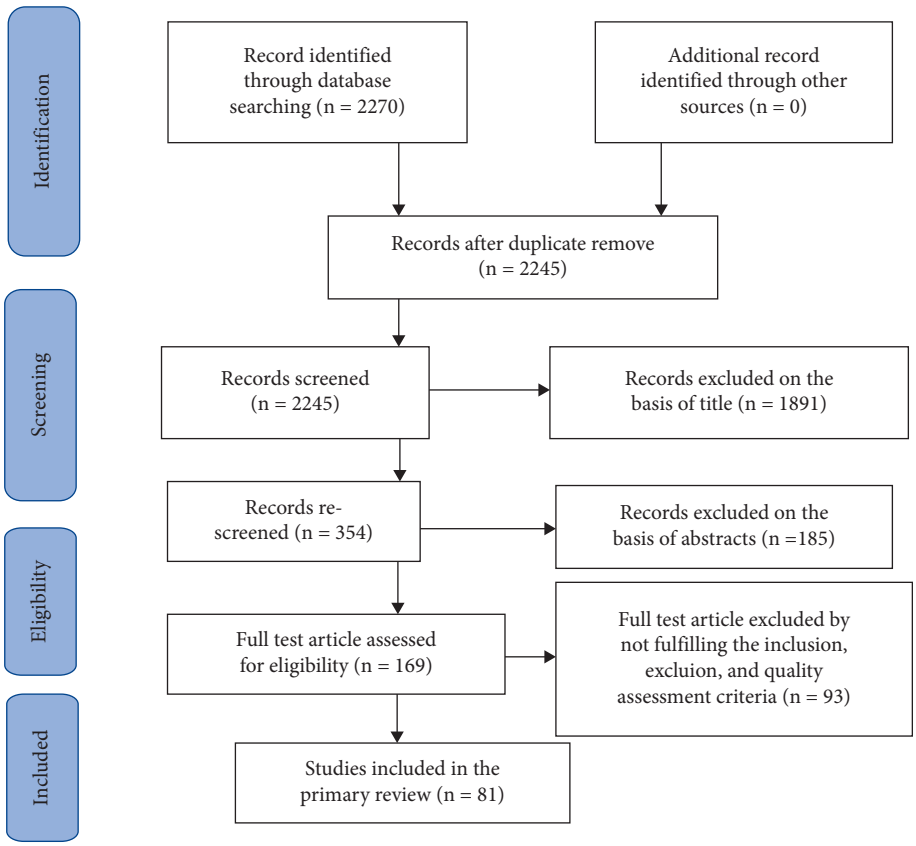

Figure 2: Studies of selection procedure.

utilized all around expressed consideration (IC) and avoidance (EC) measures to help in picking forthcoming investigations from the chose information bases. The rules were utilized on all the examinations gathered in the various degrees of the SSP. The period was set from 2011 to 2021 (11 years) for contemplates search, and this is to ensure that modern investigations were the just one's incorporated. We likewise incorporate early referred to contemplates, as long as the full examination content was accessible.

In Table 3, we delineated the IC and EC standards utilized in this SLR. These rules were used in the second and third SSP degrees (as portrayed in Figure 1). The IC and EC models were utilized on the subsequent level, dependent on the investigations' titles, modified works, and ends. In this manner, 169 out of 354 examinations were separated in the subsequent level. In the third level, to improve the certainty on examinations inclusion, we used a snowballing methodology on 169 full text considers inspected. On a similar note, a retrogressive and forward snowballing was directed. For in reverse snowballing, the analysts search through investigation reference rundown and eliminate considers that do not meet this examination's models. For forward snowballing, the specialists investigated the examinations dependent on the examinations' referring to the assessed investigation. With this, each examination referring to a specific report is assessed. Consequently, in this investigation, we consider incorporating and avoiding an examination dependent on the measures in Table 3 and the quality

Table 3: Inclusion/exclusion criteria.

	Inclusion criteria
IC1	Papers which are peer-reviewed
IC2	Papers that concentrate on BIM and IoT integration or adoption in the construction industry
IC3	Important papers published from 2011 to 2021
IC4	Papers that have the prospective to answer the formulated RQs
Exclusion criteria	
EC1	Papers that are written in other languages that are not English
EC2	Papers that are not related to the research questions
EC3	Gray studies: for illustration, articles with no data such as publication date/type, volume, and issue numbers were removed
EC4	Duplicate studies (addition of latest study when multiple studies have the same theme)
EC5	Papers with results and findings that are unclear

credits illustrated in Section 2.6. Henceforth, both criteria were utilized simultaneously to the full texts of all the 169 studies. Finally, 81 studies were lastly chosen for this work.

2.6. Quality Assessment Criteria (QA). QA is essential and exceptionally significant in each scoping review. QA of the investigations was directed in the third degree of the SSP. The IC and EC with the QA measures were utilized to recover examinations in the second SSP degree. One hundred nine (109) examinations were gathered by the specialists in the third level, where the scientists analyzed each investigation to eliminate inclination.

Therefore, to assess the nature of the chose articles, we planned a poll. The planning survey was propelled by a previous efficient investigation [35, 37].

(1) QA1: does the article contribute to the integration or adoption of BIM and IoT technologies? The potential answers are "Yes (+1)," "Partially (+0.5)," and "No (+0)."

(2) QA2: does the paper offer an adequate review of the literature in the domain of research? The potential answers are "Yes (+1)," "Partially (+0.5)," and "No (+0)."

(3) QA3: does the paper define the objectives and goals of the study? The potential answers are "Yes (+1)," "Partially (+0.5)," and "No (+0)."

(4) QA4: are the contributions and limitations of the article visibly outlined? The potential answers are "Yes (+1)" and "No (+0)."

(5) QA5: the paper has been published in a well-recognized and reliable publication source. To answer these quality criteria, for Conferences, Symposium, and Workshops, we deliberated the computer science conference ranking (CORE) (A, B, and C) [38]. For the journal articles, the Journal Citation Report (JCR) lists were used. Hence, the answers to these defined criteria can be as follows:

Journals:

(+2) if rated Q1,
(+1.5) if rated Q2,
(+1) if rated Q3 or Q4,
(+0) if it has no JCR ranking.

Conferences, Symposium, and Workshops:

(+1.5) if rated CORE A,
(+1) if rated CORE B,
(+0.5) if rated CORE C,
(+0) if not in CORE ranking.

Others; (+0).

The quality criterion score in (QA5) indicates that Journals have more weight than Proceedings (Conferences, Symposiums, and Workshops) because the chances of publishing a paper in Q1 or Q2 Journal can be hard in comparison with other published sources. Consequently, a scale of 1–6 will stay as the final quality score for a specific study.

2.7. Extraction of Data. After the second degree of the examination choice method, we chose the survey groups and then analyzed articles. In this way, each article's full content was investigated by, in any event, two specialists. Therefore, imperative data were additionally mined to a given information extraction structure. The structure was an assortment of the critical rundown of things as per the following:

(i) Title
(ii) The year of publication
(iii) The venue of publication
(iv) The type of contribution
(v) The research focuses
(vi) The utilized performance measures for evaluation
(vii) The citation counts of a study.

3. Results

This section presents the results for the RQs of this SLR paper.

3.1. RQ1: What Are the Selected Studies, Demographics, and Characteristics? Out of the 169 records analyzed and utilizing all the characterized models, 93 records were excluded, and only 81 articles were selected for this investigation. We firmly and fundamentally investigated the 81 articles selected to answer all the RQs introduced in Section 3.1. In Table 4, all the chose contemplates are delineated in detail.

Table 4: Overview of selected studies.

Identifier	Study reference	Publication year	Publication channel	Citation count
S1	[39]	2020	Journal	0
S2	[40]	2020	Journal	1
S3	[41]	2020	Journal	1
S4	[42]	2015	Journal	30
S5	[43]	2012	Journal	20
S6	[44]	2017	Journal	65
S7	[45]	2019	Conference	0
S8	[46]	2016	Journal	19
S9	[47]	2019	Conference	0
S10	[48]	2011	Conference	23
S11	[49]	2012	Conference	162
S12	[50]	2017	Conference	6
S13	[51]	2013	Symposium	2
S14	[52]	2014	Conference	11
S15	[53]	2018	Conference	1
S16	[54]	2013	Symposium	15
S17	[55]	2018	Journal	24
S18	[56]	2018	Journal	8
S19	[57]	2018	Journal	6
S20	[58]	2015	Journal	178
S21	[59]	2019	Journal	1
S22	[60]	2018	Journal	22
S23	[61]	2019	Journal	1
S24	[62]	2017	Conference	7
S25	[63]	2016	Journal	26
S26	[64]	2019	Journal	0
S27	[3]	2019	Journal	2
S28	[65]	2017	Journal	4
S29	[66]	2019	Journal	4
S30	[5]	2017	Journal	28
S31	[67]	2018	Journal	15
S32	[68]	2018	Journal	8
S33	[69]	2020	Journal	2
S34	[70]	2014	Journal	24
S35	[71]	2019	Journal	3
S36	[72]	2014	Journal	110
S37	[73]	2013	Journal	82
S38	[74]	2018	Journal	28
S39	[75]	2017	Journal	8
S40	[76]	2015	Journal	53
S41	[77]	2017	Conference	1
S42	[78]	2019	Conference	0
S43	[79]	2017	Journal	23
S44	[80]	2019	Journal	3
S45	[81]	2019	Journal	16
S46	[82]	2019	Journal	2
S47	[83]	2019	Journal	5
S48	[84]	2014	Journal	26
S49	[85]	2015	Journal	110
S50	[6]	2015	Journal	34
S51	[86]	2018	Journal	19
S52	[4]	2015	Journal	84
S53	[87]	2020	Journal	2
S54	[88]	2020	Journal	2
S55	[89]	2019	Journal	2
S56	[90]	2013	Journal	48
S57	[91]	2015	Journal	4
S58	[92]	2019	Journal	0
S59	[93]	2020	Journal	0
S60	[94]	2019	Journal	3

Table 4: Continued.

Identifier	Study reference	Publication year	Publication channel	Citation count
S61	[95]	2016	Journal	35
S62	[96]	2018	Workshop	2
S63	[97]	2013	Journal	83
S64	[98]	2012	Journal	42
S65	[99]	2016	Conference	1
S66	[100]	2020	Journal	5
S67	[101]	2018	Journal	32
S68	[102]	2013	Conference	7
S69	[103]	2013	Conference	35
S70	[104]	2018	Journal	17
S71	[105]	2019	Journal	3
S72	[106]	2018	Journal	7
S73	[107]	2019	Journal	0
S74	[108]	2018	Journal	12
S75	[7]	2019	Conference	1
S76	[109]	2019	Journal	3
S77	[110]	2021	Journal	2
S78	[111]	2021	Journal	8
S79	[112]	2021	Conference	12
S80	[113]	2021	Journal	1
S81	[114]	2021	Journal	12

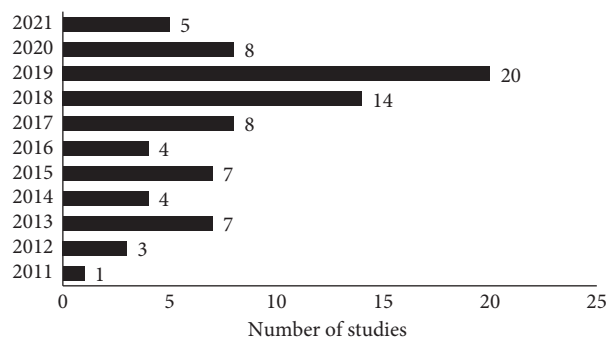

Figure 3: Articles published per year.

3.1.1. Publication Over Time. Figure 3 gives the all-out number of distributed works depending on the time of distribution (2011–2021). Over the most recent ten years, there is a significant measure of consideration given to scientists' research area at a reformist enthusiasm. We found that 2011 was the most undynamic year, with just one investigation distributed (S10). Subsequently, high positioning CORE procedures (Conferences, Symposium, and Workshops) and Journals have not distributed an investigation in the exploration area. Consequently, the investigation distributed in the year 2011 (S10) was distributed in the First International Technology Management Conference.

Notwithstanding, consistently, we have seen an expanded awareness from specialists, especially from 2017 to 2021. This can be clarifying by recognizing the development from 2011 to 2016, where a stable quantity of studies has been produced. In these years (2011–2016), key works have been produced, for example, S20, S25, S34, S40, S48, S49, S50, and S61that for both new and veteran researchers to

Table 5: Quality assessment of the studies selected.

Study	QA1	QA2	QA3	QA4	QC5	Total score
S1	1	1	1	1	2	6
S2	1	1	1	1	2	6
S3	1	0.5	1	1a	1.5	5
S4	1	0	1	0	1	3
S5	1	0.5	1	0	1.5	4
S6	1	1	1	1	2	6
S7	1	0	0.5	0	0	1.5
S8	1	1	1	1	2	6
S9	1	0	0.5	0	0	1.5
S10	1	0	0.5	0	0	1.5
S11	1	0.5	0.5	1	1	4
S12	1	0	0.5	0	0	1.5
S13	1	0.5	0	0	0	1.5
S14	1	0.5	0	0	0	1.5
S15	1	0	0.5	0	0	1.5
S16	1	0	0	0	0	1
S17	1	1	1	1	2	6
S18	1	1	1	1	1.5	5.5
S19	1	0.5	1	1	1.5	5
S20	1	0.5	1	1	1	4.5
S21	1	1	0.5	1	1	4.5
S22	1	0.5	0	1	0	2.5
S23	1	1	1	1	2	6
S24	1	1	1	1	1.5	5.5
S25	1	1	1	1	2	6
S26	1	1	1	1	2	6
S27	1	0	0.5	0	0	1.5
S28	1	1	1	1	2	6
S29	1	1	1	1	2	6
S30	1	1	1	1	2	6
S31	1	1	1	1	2	6
S32	1	0	0.5	0	0	1.5
S33	1	1	1	1	2	6
S34	1	1	1	1	2	6
S35	1	0.5	0.5	1	1.5	4.5
S36	1	1	1	1	2	6
S37	1	1	1	1	2	6
S38	1	0.5	1	1	2	5.5
S39	1	0.5	1	1	2	5.5
S40	1	1	1	1	2	6
S41	1	0	0.5	0	0	1.5
S42	1	0	0.5	0	0	1.5
S43	1	0.5	1	1	1.5	5
S44	1	1	1	1	2	6
S45	1	1	1	1	2	6
S46	1	0.5	1	1	2	5.5
S47	1	0.5	0.5	1	1	4
S48	1	1	1	1	2	6
S49	1	1	1	1	2	6
S50	1	0.5	1	1	2	5.5
S51	1	0.5	1	1	2	5.5
S52	1	1	1	1	2	6
S53	1	1	1	1	1.5	5.5
S54	1	1	1	1	2	6
S55	1	1	1	1	2	6
S56	1	1	1	1	2	6
S57	1	0	0.5	0	0	1.5
S58	1	1	1	1	1.5	5.5
S59	1	1	1	1	2	6
S60	1	0.5	0.5	0	0	2
S61	1	1	1	1	2	6
S62	1	0	0.5	0	0	1.5
S63	1	0.5	1	1	2	5.5
S64	1	1	1	1	1.5	5.5
S65	1	0.5	0.5	1	0	3
S66	1	1	1	1	2	6
S67	1	1	1	1	2	6
S68	1	1	0.5	1	1	4.5
S69	1	1	0.5	1	1	4.5
S70	1	1	1	1	2	6
S71	1	1	1	1	2	6
S72	1	0.5	1	1	2	5.5
S73	1	0.5	0.5	1	1	4
S74	1	0.5	1	1	2	5.5
S75	1	0	0.5	1	0.5	3
S76	1	1	1	1	2	6
S77	1	1	1	1	2	6
S78	1	1	1	1	2	6
S79	1	1	1	1	0	4
S80	1	1	1	1	0	4
S81	1	1	1	1	2	6

contribute to this new and interesting research area. The reader will likewise see that in the year 2019, there are numerous works published in contrast with the remaining years. We observed that there are high-level journals that contribute the most works in this domain, and these Journals are Journal of Engineering Construction and Architectural Management and Construction Innovation. All in all, regardless of a moderate beginning in the early years (2011 to 2016), the exploration movement in the field of study keeps on picking up force with consistent development, chiefly in the subsequent four years (2017 to 2020). It can be observed that there is growing interest in the awareness on BIM-IoT as indicated by S77–S81 in year 2021.

3.1.2. Publication Channel and Quality Scores. In Table 4, we recorded the distribution channels, distribution year, and reference means for each investigation. Four diverse distribution channels were distinguished and large: Journal, Conference, Workshop, and Symposium. We found that the dominant part of the examinations was distributed in Journals with 63 investigations (77.78%) of the examinations chose, 15 investigations (18.52%) distributed in Conference, two examinations (2.46%) were distributed in Symposium; lastly, one investigation (1.23%) was distributed in Workshop. With this, the general nature of the investigations selected is self-evident because 77.78% of the selected contemplates were distributed in Journals.

We likewise inspected the selected quality score readings for the characterized quality measures in Section 2.6. In Table 5, we introduced the quality score for each investigation. The consequences of the quality examination exhibit that all investigations have scored over 1, just one investigation score of 1, which is S16. Thirty-three investigations score 6 (S1, S2, S6, S8, S17, S23, S25, S26, S28, S29, S30, S31, S33, S34, S36, S37, S40, S44, S45, S48, S49, S52, S54, S55, S56,

S59, S61, S70, S71, S76, S77, S78, and S81), and thirteen examinations score 5.5 (S18, S24, S38, S39, S46, S50, S51, S53, S58, S63, S64, S72 and S74), while two investigations (S79) scored 4.

3.1.3. Publication Source. Table 6 summarizes the studies based on their publication sources. The publication sources will help to evaluate at a glance the distribution pattern of the various research themes and clusters in the years under study. Altogether, 43 publication sources from various publishers were identified. Publication sources such as Engineering Construction and Architectural Management, Construction Innovation, and Automation in Construction have more papers with 14, 8, and 6, respectively. It was also found that most of the examinations distributed in the top publication sources (for example, S1, S2, S17, S25, S26, S28, S29, S30, S31, S33, S34, S44, S45, S48, S49, S52, S55, S54, S59, S66, and S67) have a great score of 6.5 or more from the evaluation done in Table 5. In Table 6, we discovered five distributors who are Taylor & Francis, with 13 distribution sources, trailed by IEEE (13), Emerald Insight (10), ACM (4), and Elsevier (4). The least publication source was recorded by MDPI and Springer with 1 each.

3.2. RQ2: What Is the Research Focus of the Selected Studies? In this section, we present the research focus of the studies selected. Based on the analysis conducted of the studies selected in this paper, we categorized the selected studies into two research focus, which are BIM adoption and BIM integration. From Table 7, 50.62% of the selected studies focus on BIM adoption, and 49.38% of the selected studies focus on BIM and IoT devices integration. Hence, the following sections (Section 3.2.1 and Section 3.2.2) present and discussed the studies that focused on both research angles in the field of study.

3.2.1. BIM Adoption. There are 41 studies that work on BIM adoption in the construction industry from the selected studies. We observed that out of the 41 studies focused on BIM adoption, 13 studies (S47, S35, S26, S9, S75, S46, S29, S44, S45, S55, S21, S27, and S73) were published in 2019. This makes the year (2019) the most active year for the studies in BIM adoption. They were followed by 2018, 2017, and 2015 with 10, 4, and 4. Consequently, studies on BIM adoption will be presented. Shrivastava and Chini explore the use of BIM to examine the initial embodied energy of a building. The authors demonstrate BIM flexibility to modify the model [43]. In work by Davies and Harty, the authors define scales development used to assess the views about the significances of BIM and its use in the United Kingdom (UK) [73]. The result shows that BIM use is harmonious with current ways of working. Hence, their research is focused on understanding UK construction organizations concerning BIM adoption. Singh presents a behavioural perspective on system innovation adoption decisions in AEC [70]. The finding shows that the systematic innovation-related needs in the AEC network are interrelated. Enegbuma et al. investigate the factors affecting BIM adoption in Malaysia. Hence, the authors developed a model to do just that [84]. The findings serve as a guide for BIM adoption and effective and careful policymaking on BIM implementation in Malaysia.

Demian and Walters conducted a case study on the efficacy of BIM for transferring information within a building team [72], a study on existing concrete fabrication facilities, using four information management systems, such as e-mail, an Enterprise Resource Planning system, construction project extract tool, and a new BIM-based system. It was concluded that the use of a BIM-based system averted information flow via building models. With the growing attention given to BIM globally, Ding et al. conducted a study to know the apparatus for BIM adoption by architects in China [4]. In doing so, the authors formulate a questionnaire for architects in Shenzhen, China. The result shows that factors such as technical defects of BIM, motivation, and BIM ability affect the adoption of BIM techniques. Shafiq et al. evaluate carbon footprint in Malaysia's low-rise buildings by utilizing BIM technology [42]. The result is to help practitioners in selecting the best combination of structural materials. In another study by Rogers et al., to determine the obstacles and perceptions of BIM adoption, the authors explore BIM adoption from Malaysian construction organizations' perspective. The result shows that even though the organizations have a good concept of BIM, they lack well-trained personnel.

Singh and Holmstrom investigate BIM adopting a hierarchy of needs [6]. The finding shows that not just individuals, organizations also show the hierarchical ordering of innovation-related needs. Gledson researched to acquire an insight into employees' opinions about organizational BIM adoption [63]. A case study was conducted that focused on initial BIM projects conveyed by an early adopter organization. The findings show that organizations often have to utilize hybrid project conveyance methods on initial adopter projects. Mustaffa et al. investigate BIM adoption experiences in various countries, such as USA, UK, and Finland [50]. These countries are known to be early BIM adopters. The authors hope that the experiences explored will be useful for BIM implementation and adoption in Malaysia. Ngowtanasuwan and Hadikusumo proposed a new model to explain and forecast the Thai construction industry's adoption of behaviours. The authors used a system dynamic (SD) approach with four selected companies for a case study [65]. The result illustrates that BIM training is the best way to enhance the performance of a company. Gledson and Greenwood used Rogers' innovation diffusion theory to investigate the adoption of 4D BIM in the UK construction industry [5]. The authors surveyed 97 construction practitioners to assess 4D BIM innovation acceptance in a time. The result shows the advantages of 4D BIM, and also we understand the reason for its adoption and rejection.

Juan et al. examined the existing prominence of BIM adoption in 224 Taiwanese architectural firms. The authors find out the acceptability and readiness of these firms in implementing BIM [79]. The authors also proposed a predictive model which can be utilized by companies that are

Table 6: Publication source.

Publication source	Publishers	Studies	No.	%
Engineering Construction and Architectural Management	Emerald Insight	S1, S29, S30, S31, S44, S45, S49, S50, S51, S52, S55, S74, S76, S77	14	17.28
Construction Innovation	Emerald Insight	S25, S26, S28, S33, S34, S46, S48, S54	8	9.87
Automation in Construction	Elsevier	S2, S17, S59, S66, S67, S81	6	7.41
Construction Management and Economics	Taylor & Francis	S36, S37, S40, S63	4	4.93
Journal of Engineering, Design and Technology	Taylor & Francis	S3, S19, S58	3	3.70
Architectural Engineering and Design Management	Taylor & Francis	S22, S39, S72	3	3.70
International Journal of Construction Management	Taylor & Francis	S5, S35	2	2.46
Built Environment Project and Asset Management	Emerald insight	S20, S47	2	2.46
International Journal of Computer Integrated Manufacturing	Taylor & Francis	S56, S70	2	2.46
International Conference on Research and Innovation in Information Systems	IEEE	S9, S12	2	2.46
International Journal of Sustainable Building Technology and Urban Development	Taylor & Francis	S4	1	1.23
Journal of Cleaner Production	Elsevier	S6	1	1.23
Facilities	Emerald Insight	S8	1	1.23
Journal of Facilities Management	Emerald Insight	S18	1	1.23
Journal of Financial Management of Properties and Construction	Emerald Insight	S21	1	1.23
Structure and Infrastructure Engineering	Taylor & Francis	S23	1	1.23
International Journal of Architectural Research	Emerald Insight	S27	1	1.23
International Journal of Management Projects in Business	Emerald Insight	S32	1	1.23
Production and Planning Control	Taylor & Francis	S38	1	1.23
Journal of Civil Engineering and Management	Taylor & Francis	S43, S64	1	1.23
International Journal of Building Pathology and Adaptation	Emerald Insight	S53	1	1.23
Engineering Project Organization	Taylor & Francis	S57	1	1.23
Procedia Computer Science	Elsevier	S60	1	1.23
Journal of Building Performance Simulation	Taylor & Francis	S61	1	1.23
International Journal of Geographical Information	Taylor & Francis	S71	1	1.23
Intelligent Buildings International	Taylor & Francis	S73	1	1.23
First International Technology Management Conference	IEEE	S10	1	1.23
International Conference on Robots and Intelligent System	IEEE	S15	1	1.23
Workshop on Human-Habitat for Health (H3) : Human-Habitat Multimodal Interaction for Promoting Health and Well-Being in the Internet of Things Era	ACM	S62	1	1.23
International Conference on Information Management	IEEE	S7	1	1.23
Conference on Electrical, Communication, and Computer Engineering	IEEE	S42	1	1.23
Nordic Conference on Construction Economics and Organization	Emerald Insight	S75	1	1.23
International Conference on Virtual Systems and Multimedia	IEEE	S11	1	1.23

Table 6: Continued.

Publication source	Publishers	Studies	No.	%
International Conference on Management of Engineering and Technology	IEEE	S24	1	1.23
International Conference on Applied Systems Innovation	IEEE	S41	1	1.23
Chinese Control and Decision Conference	IEEE	S65	1	1.23
Proceedings of the Winter Simulation Conference	ACM	S14	1	1.23
International Symposium on Instrumentation and Measurement, Sensor Network, and Automation	IEEE	S13	1	1.23
Symposium on Theory of Modelling and Simulation-DEVs Integrative M&S	ACM	S16	1	1.23
International Conference on Research Challenges	IEEE	S68	1	1.23
International Conference on Cloud Computing Technology and Science	IEEE	S69	1	1.23
Sustainability	MDPI	S78	1	1.23
6th International Conference on Communication and Electronics Systems	IEEE	S79	1	1.23
Frontiers of Engineering Management	Springer	S80	1	1.23

Table 7: Research focus in the field of study.

Research focus	Studies	No.	%
BIM adoption	S3, S4, S5, S9, S12, S15, S17, S18, S19, S21, S25, S26, S27, S28, S29, S30, S31, S32, S33, S34, S35, S36, S37, S38, S43, S44, S45, S46, S47, S48, S49, S50, S51, S52, S53, S54, S55, S72, S73, S74, S75	41	50.62
BIM and IoT integration	S1, S2, S6, S7, S8, S10, S11, S13, S14, S16, S20, S22, S23, S24, S39, S40, S41, S42, S56, S57, S58, S59, S60, S61, S62, S63, S64, S65, S66, S67, S68, S69, S70, S71, S76, S77, S78, S79, S80, S81.	40	49.38

considering adopting BIM. The result shows that most of the firms investigated have adopted BIM tools. Ahankoob et al. explore the level of positive association that occurs between BIM adoption and organizational learning [106]. Hence, based on a survey on Australian building contractors, the general effect of BIM maturity couple with years of experience by contractors to embrace new information is examined. The result indicates that the level of organization experience with BIM is a much better forecaster of learning performance than the difficulty of BIM utilization in a given organization. By utilizing the unified theory of acceptance and use of technology (UTAUT), Addy et al. examine the factors facilitating BIM adoption among quantity surveyors in Ghana [57]. Hence, the study's findings give a useful framework in policy development with a clear pathway for BIM implementation in Ghana. Ahmed and Kassem develop a unified BIM adoption Taxonomy (UBAT) and further identify the taxonomy concepts that impact the first three BIM adoption process stages [55]. Hence, the study is mainly planned to enhance the reader's knowledge of the BIM adoption process.

Wang et al. apply BIM technology in construction management [53]. The result shows that BIM application facilitates the integration, visualization, and automation of power engineering construction management. Zhao et al. model the risk routes related to BIM adoption in the Chinese AEC industry [67]. The result confirmed risk categorization with 15 hypothetical risk paths that are statistically important. In the study by Jin et al., the authors show an instructive practice in a task-based appraisal of AEC understudies interdisciplinary structure configuration work receiving BIM [86]. The perception of students with regards to BIM effects in integrated project design is also examined. The result shows that adopting BIM helps motivate students to have a broader design and construction strategy. To know organization differences in BIM adoption speed and its rationale, Ayinla and Adamu investigate the causes of this digital divide and provide some solutions for bridging the gap [108]. Based on a questionnaire conducted to over 240 global respondents, the findings show that organization size is often not significant concerning the speed they adopt BIM. Olapade and Ekemode investigate the general awareness and usage of BIM for facility management (FM) in Nigeria [56]. The findings show that there is a low-level of alertness and adoption of BIM for FM. In a study by Matthews et al., the general insights on how BIM adoption influenced the partnership and change management practices within a project are attained [74]. The finding demonstrates that little knowledge and experience to provide a model for asset management mostly caused the project team to have problems.

Almuntaser et al. proposed a BIM adoption framework in the Saudi Arabia AEC sector [68]. The finding shows that BIM adoption gives several benefits and efficiency. In a study by Oyewole and Dada, the authors examine the gaps in training between the expected and perceived understanding of BIM adoption practice among Nigeria construction professionals [83]. Based on a questionnaire survey conducted, the findings show that there is a substantial gap in training design creation and organization among Nigeria construction professionals. Concerning BIM adoption in the industry, Ahankoob et al. examine the level to which previous BIM experiences influences experts view on BIM prospective advantages [71]. Hence, based on a survey

conducted by the authors, the result shows that BIM familiarity is a key factor in knowing the prospective BIM advantages. In understanding the potential benefits, BIM adoption and implementation by construction organizations will be more comfortable. Ahmed and Suliman proposed an adoption model based on structural equation modeling (SEM). The proposed model analyzes the relationship between key indicators which drives BIM adoption [64]. The result demonstrates that people and the environment are the key indicators facilitating BIM adoption. Shehzad et al. examined the factors that impact BIM adoption in the construction industry [47]. The authors identified 74 factors which were classified into organizational, technology, and environmental dimensions. Therefore, the study will aid researchers in understanding the factors that influence BIM adoption. Ullah et al. conducted a study to study the existing position of BIM adoption, its advantages, and the limitations of BIM adoption in the construction industry globally [7]. The finding shows the BIM adoption rate in several countries' construction companies with eighteen identified obstacles to BIM adoption identified.

Hilal et al. proposed a hybrid conceptual model for BIM adoption in FM. The model incorporates the technology task fit (TTF) and the UTAUT theories [82]. The study is done to help improve the understanding of BIM acceptance and adoption by FM. Marefat et al. examine the effect of BIM for critical safety projects and obstacles to adoption [66]. The authors distributed the questionnaire to 200 construction companies. The result highlights some of the factors that lead to failure in BIM adoption, specifically in Iran. Chen et al. explore the factors influencing BIM adoption in the construction industry and its benefits to research and practice [80]. Given the technology-organization-environment (TOE) framework, the creators built up a research model that consolidates the primary achievement factors associated with BIM innovation implementation. The creators locate that the general preferred position of BIM was a key factor that permitted BIM reception. Hong et al. proposed a model for BIM selection and execution at little and medium-sized development associations [81]. The proposed model accesses BIM adoption benefits, cost, and also its challenges faced by these organizations. Park et al. proposed an acceptance model for BIM. The authors also examined external factors extracted by interviews that facilitate the adoption of BIM technologies [89]. The results show that both compatibility and organizational support play a key part in adopting BIM technologies. Babatunde et al. conducted a study to recognize and analyze the utilization of BIM-based cost estimating software [59]. The study also examines BIM adoption drivers in the Nigerian quantity survey firms. The findings show that most Nigerian quantity survey firms are aware of BIM but have not adopted BIM-based cost estimation software. To promote sustainable policies for enhancing developing countries' economies and environmental performance, Akdag and Maqsood highlight the potential for BIM in such countries, particularly Pakistan [3]. The authors conducted surveys and interviews with BIM users and non-BIM users' architects in Pakistan. The authors highlight strategies that will enhance the adoption and implementation of BIM in Pakistan.

In a study by Rathnasiri and Jayasena, a new framework for adopting green BIM technology for Sri Lankan buildings was developed [107]. The research findings reveal the challenges of green BIM application when building data are not sufficiently available. Babatunde et al. investigate the key drivers of BIM adoption among professionals in the Nigeria construction industry. The authors conducted a preliminary study and a questionnaire survey [41]. The findings recognized 23 key drivers to BIM adoption with the significance of each driver. Vidalakis et al. explore the implementation and adoption of BIM among small- and medium-sized enterprises (SMEs). These SMEs are specifically in the UK AEC industry. Hence, the study tackles the issue of the lack of uniformity in the SME sector regarding BIM adoption [69]. The findings show that SME familiarity with the current BIM software is very low, contributing to the sector's lack of adoption. Saka and Chan develop a hierarchical model for investigating inter-relationships of the obstacles to adopt BIM. The work is intended at examining the main obstacles to BIM adoption [88]. These barriers are analyzed through the viewpoint of SMEs in Nigeria. The finding shows that obstacles are mainly from sociotechnical circumstance; hence, the SMEs can drive BIM adoption by looking to their internal environment. Babatunde et al. investigates BIM implementation barriers and explore means to enhanced BIM adoption in Nigerian construction firms [87]. The authors identified 20 obstacles to BIM implementation with ten ways to enhance BIM adoption in Nigerian construction firms.

3.2.2. BIM and IoT Integration. We found 40 studies that work on BIM and IoT integration from the selected studies (as presented in Table 7). Conversely, from the studies, 2019 was the most active year with the most studies published (S7, S23, S42, S58, S60, S71, and S76), respectively. We followed by 2013, 2017, and 2018 with 6, 4, and 4 studies. Accordingly, studies on BIM-IoT integration will be presented.

Ghosh et al. try to integrate the BIM and enterprise resource planning (ERP) system to help in the sustainable governance process [48]. Dore and Murphy proposed an approach for the maintenance of cultural heritage places [49]. The findings expose some enhancement. In another study by Ren et al., a framework for integrating BIM and e-commerce in a material procurement process was proposed [98]. The framework is designed to improve design-construction integration. The result shows some promise. Melzner et al. present a customizable automatic rule-based checking system for BIM models [97]. The system is built to be an add-on to current BIM software and can check models for safety threats in the early stages of design and preparation processes. The result shows that BIM can play a significant role in safety design and planning. Juan proposed a framework for innovative cloud-based building information interaction [51]. The proposed framework shows some improvement. Wang et al. integrate BIM and Discrete Event Systems Specification (DEV) [54]. The work helps designers in understanding different building properties. Hwang et al. conducted a study to implement a prototype for BIM and GIS (Geographic Information System) interoperability

[102]. The result shows that the prototype shows some promise.

Mahamadu et al. highlight the existing challenges to BIM-cloud integration [103]. Hence, the study focuses on privacy and security concerns as key issues that hinder technology integration. Grilo et al. introduced a model that uses an interdisciplinary way to gather significant components answerable for joint effort execution [90]. The proposed model is incorporated with a multimeasure dynamic apparatus, named Analytical Network Process (ANP). A case study shows the application of the proposed model and ANP; the result shows that the relationship between business interoperability needs to be improved. Zhang et al. integrate BIM with the rule-based system to assess the design and building performance [52]. The authors get data by utilizing a Real-Time Location System (RTLS). The result shows some promise. Love et al. investigate BIM value and the issues stopping its adoption in FM applications [58]. The findings demonstrate a lack of methodologies that illustrate the key advantages of BIM in FM.

Korpela et al. conducted an investigative study by asking three key questions: what sort of information tools is utilized for FM, how to design data are handled, and how facility managers integrate BIM models with maintenance information systems [76]. The result shows the possible steps to the integration of the two systems. With the current hope that BIM tools can increase process integration and support multidisciplinary planning practices, Kovacic and Filzmoser move to test this assumption using various BIM tools [91]. The authors conducted an experimental study. The result demonstrates that BIM tools are perceived as very valuable, but they are not interoperable. Shengyi and Jia explore the research studies on the mix of BIM innovation and computer-generated reality innovation [99]. This coordination makes the use of VR innovation in the development extends much better. Jeong et al. proposed a structure for the reconciliation of BIM, and the article arranged actual demonstrating based on building energy modeling (BEM) [95]. The proposed system is centred on warm reproduction that helps dynamic in the planning cycle. Given a contextual investigation, the proposed system was approved. Golabchi et al. proposed a robotized approach that shows the chance of using BIM to create calculations that computerize dynamic for FM applications [46]. These calculations are to computerize the way toward recognizing failing warming ventilation and cooling (HVAC) hardware. The outcome exhibits that the proposed approach can be valuable in FM rehearse by improving efficiency and cost reduction with regards to decision-making.

In a Larsen study, the author presents a change management process with the Change Control System (CCS) to manage changes in detail, and also to access BIM utilization in identifying the consequences of changes [75]. The finding shows that CCS combined with BIM can help in keeping control of alterations in detailed design. Tsai et al. explore BIM and GIS spatial technology integration in managing pipelines of building [77]. The result shows that the management of such a pipeline with integrated technologies will enhance building maintenance effectiveness. Arslan et al. build up a framework that uses BIM programming and a remote sensor innovation, fundamentally to build up proactive well-being, the board framework [62]. The proposed system indicated to be suitable by decreasing safety hazards during FM phase of a building. Li et al. developed a Radio Frequency Identification Device (RFID) integrated into a BIM platform that encapsulates many stakeholders, data flow, and so on [44]. The result shows that the developed platform improves the achievement of everyday operations and decision-making. Bueno et al. develop an integration interface of manufacturer-based life cycle assessment (LCA) data into a BIM platform [60]. The result shows some promise. Louis and Rashid introduced BIM as an operating system for the smart house application [96]. The investigation of the proposed application demonstrates some potential.

Davtalab et al. proposed a product stage for the assortment and investigation of information from BIM models [101]. The outcome shows some guarantee. To tackle transportation issues, wasteful administration of assets and wasteful creation, and on-location get together of pre-assembled components, Chen et al. build up another framework, named Physical Internet-empowered BIM System (PI-BIMS) [104]. This framework incorporates BIM, auto-ID advancements, and distributed computing, giving constant correspondence, assortment, and representation of data. The outcome shows some guarantee. Usmani et al. build up output to as-fabricated BIM work process. This device will use a 3D laser scanner to review and create as-fabricated structure data models for Malaysian offices dependent on a contextual investigation [92]. The outcome demonstrates that the instrument can be valuable. Lokshina et al. proposed a framework that utilized a blockchain innovation to make sure about and control the system that incorporates coordinated IoT and BIM advances [94]. The proposed incorporated framework displays some guarantee. In an examination by Tariq et al., the creators research the usage of Virtual Reality (VR) innovation through the reconciliation with BIM in the Pakistan development industry [78]. The discovering shows that the combination of BIM and VR can help in the fast dynamic and improves correspondence and cooperation between venture members. Xiang et al. proposed another incorporation model [45]. The model guides in changing over BIM models to GIS models capably. The outcome reveals that the proposed coordinated model achieves well. Munir et al. attempt to distinguish the innovations for leveling out Asset Management (AM) frameworks for BIM-based reconciliation. A contextual investigation is utilized to comprehend the execution cycle of incorporating BIM with AM frameworks [109]. The examination traces key methodologies in embracing BIM-based cycles by a resource proprietor, the execution cycle, issues, and the points of interest.

To explore the outlined detection problem in integrating BIM and GIS, Zhou et al. proposed a new algorithm, named OutDet. The calculation picks agent perception, changes and tasks the BIM mathematical information in an organized framework and recognizes the detectable offices [105]. In light of an observational examination directed, the outcome exhibits that the proposed calculation (OutDet) can

Table 8: Contributions proposed by the selected studies.

Contribution	No.	Studies
Investigation study	26	S16, S20, S40, S41, S62, S42, S76, S3, S12, S15, S18, S21, S27, S30, S33, S47, S49, S50, S74, S72, SS53, S51, S77, S78, S80, S81
Evaluation study	13	S69, S14, S57, S4, S5, S9, S19, S29, S35, S34, S36, S37, S38
Model	13	S56, S7, S26, S28, S31, S43, S44, S45, S46, S48, S55, S54, S52
Framework	7	S10, S64, S13, S61, S67, S32, S73
System	7	S63, S39, S24, S6, S70, S60, S1
Approach	4	S11, S68, S8, S59
Tool	3	S22, S58, S23
Exploration study	4	S65, S25, S75, S79
Algorithm	1	S71
Taxonomy	1	S17
Protocol	1	S66
Method	1	S2

Table 9: Adoption theories utilized by the selected studies.

Theories	No.	Studies
Innovation diffusion theory (IDT)	4	S30, S34, S54, and S74
Technology acceptance theory (TAM)	3	S37, S43, and S55
Technology-organization-environment (TOE) framework	2	S44 and S54
Unified theory of acceptance and use of technology (UTAUT)	2	S19 and S46
BIM maturity model	1	S72 and 74
Technology task fit (TTF)	1	S46
Conceptual adoption model	1	S48
Institutional theory (INT)	1	S54
Organizational readiness model	1	S43

adequately call a massive part of unnecessary highlights when delivering BIM models in GIS. In another work by Boddupalli et al., a representation device is suggested that empowers a robotized sensor information stock into BIM climate [61]. The proposed device gives methodical upkeep and danger to the executives. The examination shows that the proposed instrument is conceivably easy to use and a key financial structure. Zhang et al. proposed a method to integrate BIM and 3D web-based GIS to implement micro and macro information in a unified environment [40]. Hence, this method is aimed at addressing the differences in geometric visualization and transformation coordination. The result shows some promise. Tang et al. proposed the use of Building Automation and Control Networks (BACNET) and BIM standard industry establishment class (IFC) [100]. The outcome shows that the convention can help open the planned future brilliant structure data trade and coordination. Mohamed et al. proposed another methodology for existing structure offices [93]. The proposed structure exhibits some guarantee. Yuan et al. proposed a BIM-based Performance Management System (BPMS). The proposed framework joins BIM with web and cloud innovation to accomplish execution estimation, execution observing, and execution-based instalment [39]. The proposed framework shows some guarantee concerning managing partners in improving work capability with BIM and different advances.

3.3. RQ3: What Are the Contributions Proposed by the Selected Studies, and How They Can Be Categorized? To fully know the contributions proposed by the chosen studies, we plan and categorize the existing known proposals from the studies selected and further classified the studies based on which contribution they proposed. In Table 8, the contribution with regards to the studies that proposed it is presented. In totality, we identify 12 contributions. These contributions are Investigation study with 26 studies, followed by Evaluation (13), Model (13), Framework (7), System (7), Approach (4), Tool (3), Exploration study (3), Algorithm (1), Taxonomy (1), Protocol (1), and Method (1).

The result reveals that investigative study is the most conducted in research (as shown in Table 8). Additionally, we observed that 11 out of the 13 studies that proposed Model are studies that work on BIM adoption, while 10 out of the 13 studies that conducted an Evaluation study works on BIM adoption. Also, five out of the seven studies that proposed Framework works on BIM and IoT integration.

3.4. RQ4: What Are the Theories Used to Examine BIM Adoption in the Construction Industry by the Selected Studies? Out of 41 studies that worked on BIM adoption, we identified 12 studies that used adoption theories when studying BIM adoption in the construction industry. Hence, these studies (the 12 studies) amount to 29.27% of the studies that worked on BIM adoption. Furthermore, we identified nine different theories that were adopted from these studies. These theories concerning the studies that used them are presented in Table 9. Some of the most popular theories are innovation diffusion theory (IDT) (S30, S34, S54, and S74),

Table 10: Performance measures utilized by the selected studies.

Performance measures	No.	Studies
Performance	7	S1, S22, S26, S37, S57, S61, S64
Effectiveness	2	S41, S71
Accuracy	1	S2
Efficiency and accuracy	1	S7
Efficiency and effectiveness	1	S28
Efficiency	1	S70
Accuracy and effectiveness	1	S63
Complexity, compatibility, interoperability	1	S54

technology acceptance theory (TAM) (S37, S43, and S55), technology-organization-environment (TOE) framework (S44 and S54), BIM maturity model (S72 and 74), and unified theory of acceptance and use of technology (UTAUT) (S19 and S46).

3.5. RQ5: What Are the Different Performance Measures Used in the Research Domain? In noting this RQ, we distinguished 15 (19.74%) concentrates out of the chosen considers pre-owned execution measure for assessment. The exhibition estimates, for example, adequacy, exactness, productivity, execution, unpredictability, similarity, and interoperability, were found. A portion of these investigations utilizes a blend of more than one execution measures. We further saw that 11 out of the 15 examinations used presentation measure chips away at BIM and IoT incorporation. This is clear since deals with the mix are predominantly arrangement proposition-driven. An analyst needs to propose a new framework, model, or calculation to help mix the two advancements (BIM and IoT). However, this observation is negligible because most of the studies (80.26%) have no performance measure in their studies evaluation process. This is a huge problem, particularly when it comes to proper and factual evaluation to ascertain a specific phenomenon or trend in the field of study. Hence, researchers in this field need to apply more performance measures to evaluate ones work to enhance result credibility and generalization. Table 10 outlines the performance measures utilized by the studies selected.

4. Discussion

In this article, we led an SLR on BIM and IoT coordination and reception in the development business. BIM and IoT reconciliation and reception have increase generous consideration from the exploration network over the most recent 11 years. Of later, the reception and IoT innovations mix with BIM have become a critical and significant issue in the examination area. In this part, the outcomes identified with the RQs are summed up and examined through the introduction of the examination discoveries, research difficulties, and the future work course.

4.1. Research Findings. The key objective of this SLR is to assess the existing literature in the area of research. Hence, 169 papers were rigorously investigated using our IC and EC criteria, together with our quality assessment criteria. Finally, 81 studies were choosing that meet those criteria for further analysis. The key findings concerning the answered RQs are outlined as follows:

(i) BIM and IoT device integration and adoption have been gaining attention from the research community since 2013. We found that 2011 was the minimum active year with a single work published (S10). We found that in high-ranking Journals, such as Engineering Construction and Architectural Management, Construction Innovation, and Automation in Construction, there are no works published in the year 2011. For the studies selected, we observed that 77.78% of the selected studies were published in Journals sources, while 22.22% were published proceedings such as Conferences, Symposium, and Workshops. Therefore, with the research activity in the research area continuing to gain momentum with steady growth, particularly during the last 4 years, we forecast that the research area will gain significant attention in the years to come.

(ii) The results of the QA reveal that all works score more than 1. However, only one study scores 1, which is S16. 40.74% of the selected studies score 6, and 16.04% scores 5.5, which amounts to 56.78% of the total selected paper. This displays the universal quality of the studies selected. With regards to the publication source, we found three more visible sources. These sources are Engineering Construction and Architectural Management, Construction Innovation, and Automation in Construction were the top contributors with 13, 8, and 5 publications, respectively. We also identified five publishers, which are Taylor & Francis, with 13 publication sources, followed by IEEE (12), Emerald Insight (10), ACM (4), and Elsevier (3).

(iii) Concerning the research focus of the studies selected, we found out that BIM adoption in the construction industry is the most conducted. This is because 53.95% of the selected studies focused on this area, while 46.05% focused on BIM and IoT device integration. This is understandable because researchers are working extremely hard in the last decade to make sure that counties are adopting BIM in their construction policies before moving towards its integration with IoT devices. However, looking at the potential of integrating these two

technologies in recent years, researchers in the field of researcher are encouraging their integration and proposing new solutions to ease this transition in a challenging sector such as construction.

(iv) In answering RQ3, we identify 12 contributions. Out of the 12 found contributions, five were observed to be more proposed and conducted by researchers: Investigation, Evaluation, Model, Framework, and System with 32.09%, 16.04%, 16.04%, 8.64%, and 8.64%, respectively. Out of 41 studies that worked on BIM adoption, we identified 29.27% of the studies that used adoption theories when studying BIM adoption in the construction industry. Hence, we identified 9 different theories that were adopted from these studies. Some of the most popular theories are IDT (S30, S34, S54, and S74), TAM (S37, S43, and S55), TOE framework (S44 and S54), BIM maturity model (S72 and 74), and UTAUT (S19 and S46).

(v) Regarding execution measures, we distinguished 15 (19.74%) concentrates out of the chosen examines that preowned execution measure for assessment. We further saw that 11 out of the 15 examinations used presentation measure chips away at BIM and IoT joining. This is evident because taking a shot at joining is overwhelmingly arrangement proposition-driven, where a specialist ordinarily needs to propose a new framework, model, or calculation to help combine the two advances (BIM and IoT). However, this observation is negligible because most of the studies (80.26%) have no performance measure in their study evaluation process.

4.2. Identified Issues. After the rigorous analysis of the PS, this section gives some identified issues from the result obtained. We observed that more than 90% of the studies are not tailored to solution proposals. Both investigative studies and evaluation studies are gaining significant attention from the researchers in this domain. This trend should be tailored to the proposition of new ways (in terms of framework, techniques, and so on) to help construction industries to adopt such technologies rather than just investigations and general evaluations. This problem limits the chances of a solution proposition that will facilitate BIM adoption. Hence, we encourage researchers to proposed new solutions for BIM adoption in the construction industry. Other problems are with regard to the methodology of this study. Important papers can be missed during the paper collection process. This issue can cause important papers to be excluded. However, we mitigate this issue by conducting our search on five key data sources where many Journals and Proceedings in the domain are indexed. Another issue is with respect to bias on data synthesis. Not all papers selected clearly outline the information we needed to extract. Hence, we have to infer this information based on the experience of the authors. The final decision on a data item extracted is finalized by all the authors in this paper to mitigate this. Hence, this issue can be reduced.

4.3. Challenges and Direction for Future Work. In this study, we conducted a broad review of the studies selected. Henceforth, the findings will help researchers understand the current contributions concerning integrating and adopting BIM and IoT in the construction industry. Furthermore, this study will also help researchers identify the most proposed contributions, the most used adoption theories, and the utilized performance measures by the studies selected in the field of study. Hence, in this section, the identified challenges are highlighted regarding the scope of this study. We further provide future research directions as a pathway for researchers to follow.

From the result in Figure 2, we observed that despite the slow start from 2011 to 2016, the research area's research activity continues gaining momentum with steady growth, particularly during the last four years. Nevertheless, despite the steadiness, the research output is not consistent and proportional where year like 2019 has a large share of papers compared to other prominent years. Even though a conclusion cannot be driven for 2020 due to our search cap, we urge the research community to be more active. With 53.95% of the studies selected, BIM adoption works is the most conducted, while works on BIM and IoT integration are less than 50%. We encourage researchers to focus more on BIM and IoT integration in the construction industry in both developed and underdeveloped countries for future works. We observed that a massive chunk of the selected studies, 28.95% investigated their contributions. At this stage, we could have seen many works by researchers proposing new solutions on the technologies integration rather than investigation. Hence, we urge new and experienced researchers to propose new solutions in the research domain.

We further observed that 11 out of the 15 studies that utilized performance measure works on BIM and IoT integration. This is obvious because integration works are dominantly solution proposal-driven, where a researcher usually has to propose a new model, system, or algorithm to help integrate the two technologies (BIM and IoT). However, this observation is negligible because most of the studies (80.26%) have no performance measure in their studies evaluation process. This is a huge problem, particularly when it comes to proper and factual evaluation to ascertain a specific phenomenon or trend in the field of study. Hence, researchers in this field need to apply more performance measures to evaluate one work to enhance result credibility and generalization.

4.4. Threat to Validity. This survey's impediments must be considered to have a general examination of the outcomes gained from this audit. This way, the principal errors to this study's legitimacy are the error of information extraction, predispositions on examination choice, and incorrectness of information extraction. In this segment, every one of these errors is discussed.

4.5. The Incompleteness of the Study Search. Key examinations can be missed during the time spent recovering the investigations. This can influence the overall fulfilment of the

investigation search. Accordingly, to lighten this danger and further ensure that all critical and forthcoming examinations have been covered, the overall pursuit was done on five information bases (see Table 1). This information sources contain countless Journals, Conference, Workshop, and Symposium procedures in this space that are ordered.

The chosen examines in reverse and forward reference looked to ensure that critical examinations are incorporated. Even though we took measures to upgrade the examination search's fulfilment, the investigation can at present experience the missing effects of choice tendency. This is because different libraries, for example, EI Compendex and Citeceerx, were not included in this study.

4.6. Bias on Study Selection. Regarding the examination choice cycle, we figured exceptionally clear and exact IC/EC standards to diminish predisposition by specialists. Every scientist can have an alternate comprehension of the IC/EC models; consequently, every individual analyst's investigation choice consequences are conceivable going to contrast. To ease this inclination, we led a pilot determination to ensure that an arrangement between the analysts is accomplished on the overall comprehension of the measures. The conceivable botch of copy examines another danger too. This error may have gradually changed our outcomes. Three potential duplications were recognized and were surveyed entirely to see whether they are a similar report.

Also, to choose an examination, the conclusion is taking by the two scientists who directed the hunting cycle. In this manner, any difference that emerges between the two scientists will be fixed between them through the conversation until a detailed understanding is build up. Moreover, excess specialists will audit the last chosen examines. For this investigation, we just incorporate companion audited examines. Nonetheless, there is a probability that we may miss some essential non-peer-investigated concentrate in this area.

4.7. The Inaccuracy of Data Extraction. In information extraction, the inclination can occur in this cycle and influence the outcomes classification and examination of the last investigations. The researchers evaluate the data extracted in distinct teams, and agreement on the significance of all the data extracted was reached to reduce this threat. Moreover, a final weight of the most senior researcher in the teams was taking into consideration when there is an issue that cannot be resolved between the researchers. Thus, the information things separated were evaluated by two analysts, where contradictions were thought and fixed. These estimates taken to diminish predisposition will help in improving the precision of the removed information things.

5. Conclusion

This paper presented eleven years (2011–2021) summary of the literature on integrating and adopting BIM and IoT integration in the construction industry. From the initial search conducted, 81 studies were selected based on the defined IC and EC and quality assessment criteria. The findings from this study revealed that the research domain is progressing with stable growth, particularly during the last four years. We see that 77.78% of the selected studies were published in Journals sources, while 22.22% were published proceedings such as Conferences, Symposium, and Workshops. Furthermore, the quality analysis results showed that all the studies have a score greater than 1.40.74% of the selected studies score 6 and 16.04% scores 5.5, which amounts to 56.78% of the total selected paper. This displays the overall quality of the studies selected. With regards to publication sources and publishers, we identified three sources that more visible. These sources are Engineering Construction and Architectural Management, Construction Innovation, and Automation in Construction and were the top contributors with 13, 8, and 5 publications, respectively. We also identified seven publishers, which are Taylor & Francis, with 13 publication sources, followed by IEEE (13), Emerald Insight (12), ACM (4), Elsevier (4), Springer (1), and MDPI (1). Our result also shows that, concerning research focus, 53.95% of the studies selected focused on BIM adoption, while 46.05% focused on BIM and IoT device integration. We further identify 12 contributions. Out of the 12 identified contributions, five were proposed more and conducted by researchers: Investigation, Evaluation, Model, Framework, and System with 32.09%, 16.04%, 16.04%, 8.64%, and 8.64%, respectively. Hence, we identified nine different theories that were adopted from these studies. Some of the most popular theories are innovation diffusion theory (IDT) (S30, S34, S54, and S74), technology acceptance theory (TAM) (S37, S43, and S55), technology-organization-environment (TOE) framework (S44 and S54), BIM maturity model (S72 and 74), and unified theory of acceptance and use of technology (UTAUT) (S19 and S46). Regarding performance measures used, we found 15 (19.74%) studies out of the studies selected that utilized performance measure for evaluation. We further observed that 11 out of the 15 works that utilized performance measure works on BIM and IoT integration. Lastly, this paper shows the research community's interest level in this domain, considering the general consistency in the publication in the last four years. Hence, we anticipate more contributions from both new and veteran researchers in years to come. Furthermore, the challenges and directions identified in this study must be considered by the research community to help tackle the constraints in the area of research.

Data Availability

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Conflicts of Interest

The authors declare no conflicts of interest.

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