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Integration Building Information Modeling and Lean Construction Technologies in the Iraqi Construction Sector: Benefits and Constraints

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ABSTRACT

Building Information Modeling (BIM) and Lean Construction (LC) are two quickly growing applied research areas in construction management. This study focuses on identifying the most essential benefits and analyzing the most affecting constraints on the construction sector that construction players face as they attempt to combine BIM-LC in Iraqi construction. Experts assessed 30 benefits and 28 constraints from examining the previous literature, and a two-round Delphi survey formed the responses. Expert consensus analysis was utilized to elaborate and validate responses after descriptive statistical checks had been used for data processing.

According to the study's findings, the benefits include ensuring the most effective project delivery method and shortening the design project life cycle. The building industry's procedures will incorporate suppliers. In contrast, the main constraints include the government rules and industry standards for BIM and LC are not obligatory, the absence of government funding and participation, and the industry's resistance to changing from customary operating methods. The study strategies and recommendations will enhance BIM-LC-LC implementation. It allows project partners to focus on addressing the challenges identified in this study and understand the benefits of BIM-LC to be an incentive to adopt them.

Keywords: Synergy BIM and lean construction, constraints and benefits, Iraqi construction sector, Delphi method.

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تكامل نمذجة معلومات البناء وتقنيات البناء الخالي من الهدر في قطاع البناء العراقي: الفوائد والقيود

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الخلاصة

نمذجة معلومات البناء(BIM) والبناء القليل الهدر (LC) هما مجالان للبحث التطبيقي سريع النمو في موضوع إلادارة الانشائية. تركز هذه الدراسة على تحديد الفوائد الأساسية وتحليل القيود الأكثر تأثيراً على قطاع الانشاء والتي يواجهها اطراف الانشاء أثناء محاولتهم دمج(BIM-LC) في قطاع البناء العراقي. قام الخبراء بتقييم 30 فائدة و 28 قيودًا من فحص الأدبيات السابقة ، وتم تشكيل الردود من خلال مسح دلفي من جولتين. تم استخدام تحليل إجماع الخبراء لتوضيح والتحقق من صحة الردود بعد استخدام الفحوصات الإحصائية الوصفية لمعالجة البيانات.

وفقًا لنتائج الدراسة ، الفوائد شملت ضمان الطريقة الأكثر فعالية لتسليم المشروع ، وتقليل فترة التصميم للمشروع، وتكامل إجراءات صناعة البناء مع الموردين ، بينما القيود الرئيسية تظمنت عدم الزام القوانين الحكومية ومعايير الصناعة لنماذج BIM وLC , وغياب المشاركة والتمويل الحكومي، ومقاومة الصناعة للتغيير من أساليب التشغيل المعتادة. ستعمل استراتيجيات الدراسة وتوصياتها على تعزيز تنفيذ BIM-LC في المشاريع العراقية ، فهي تسمح لشركاء المشروع بالتركيز على مواجهة التحديات المحددة في هذه الدراسة وفهم فوائد BIM-LC ليكون حافزًا لاعتمادها.

الكلمات المفتاحية: تآزر BIM والبناء الخالي من الهدر، القيود والفوائد، قطاع البناء العراقي، طريقة دلفي.

1. INTRODUCTION

Lean construction (LC) and building information modeling (BIM) have been positioned as two separate but complementary concepts**(Sacks et al., 2010)**. Creating contemporary standards for the use of BIM is crucial **(Joseph Garcia et al., 2018; Olawumi and Chan, 2018; Hasan and Rasheed, 2019; Sampaio, 2021)**, and to obtain the optimal BIM-Lean synergy, BIM and LC must be wholly integrated **(Evans et al., 2021).** When BIM, innovative design-based technology fully integrates with LC will add significant value **(Bui et al., 2016a; Olawumi and Chan, 2018).** The implementation of BIM consists of two key elements: (1) technology, or software that makes modeling easier, and (2) visualization techniques that let users examine the model and get crucial data like costs, timelines, and clash detection **(Sacks et al., 2018).** BIM's fundamental qualities are also consistent with LC concepts **(Zhang et al., 2018; Akbarieh et al., 2020; Tezel et al., 2020).** Despite the benefits of BIM and LC in construction projects, several obstacles remain to attaining the full potential of BIM-Lean synergies. In several studies, the potential, obstacles, dangers, difficulties, crucial success factors, crucial failure factors, and the impact of BIM on the successful completion of construction projects have been extensively discussed **(Hamzeh et al., 2016; Ghaffarianhoseini et al., 2017; Chan et al., 2019a; Olawumi and Chan, 2019; Elhendawi et al., 2020; Evans et al., 2020b).**

This research looked at the benefits and gaps that hinder the implementation of the BIM-LC synergy by consulting experts to understand the most prominent obstacles that prevent their integration into Iraqi construction projects and the advantages that can be obtained from this synergy. The questions that were raised in this research:

Q1: What are the main constraints that might prevent the use of BIM to enhance LC practices?

Q2: How significant are the constraints to using BIM technologies and the primary goal of LC practice?

Q3: What benefits can be obtained from the synergy of BIM with the LC?

Q4: How do the viewpoints of experts vary depending on their fields of expertise?

The research aims to list the benefits and evaluate the constraints of the merger of BIM with LC principles. The aims are first to evaluate the available publications on benefits and implementation hurdles for BIM and LC; second to rank and prioritize constraints reasons according to their levels of relevance; third, to start a comparison of BIM-Lean applications among respondents' groups. By knowing the essential benefits and analyzing the limitations and significant issues obstructing the synergy of BIM and Lean, the outcomes will reinforce and expand the information available in the BIM and LC research field. Additionally, the deliverables will provide recommendations and valuable guidelines for promoting the use of BIM and LC in the project environment.

Numerous studies demonstrate the benefits of applying BIM in developing projects' whole life cycles **(Erzaij and Obaid, 2017; Olawumi et al., 2018a)** The use of BIM by significant players and decision-makers in the building sector has increased **(Evans et al., 2020c)**. BIM and LC might fully use in BIM-Lean synergy and be regarded as multidimensional, or the tenth dimension (10D). Numerous research initiatives have examined the relationships between BIM with LC. Successful factors of BIM and constraints to BIM adoption were all analyzed **(Azhar et al., 2012)**. Researchers looked at the success factors that increased the compatibility between BIM and LC procedures on construction projects and came to a conclusion that the five most important BIM success factors that boosted BIM-Lean synergy are "collaboration in design, engineering management, and construction works," "top organizational management support," "earlier and precise 3D visualization of design," "enhancement application of LC and project delivery," and "coordination construction task" **(Evans et al., 2020b; Ahmed and Altaie, 2021).** The benefits and constraints of BIM in construction were studied **(Hadi, 2018; Chan et al., 2019a).** Other researchers looked into how LC was used in buildings. Contractors, owners, designers, and engineers now have guidelines **(Sacks et al., 2018)**. Other research looked at the advantages, risks, difficulties, and barriers associated with applying BIM **(Hamzeh et al., 2016; Ghaffarianhoseini et al., 2017; Olatunji et al., 2017; Hong et al., 2018; Olawumi and Chan 2019; Shirowzhan et al., 2020)** Ozorhon and Karahan investigated the crucial impediments to BIM adoption **(Ozorhon and Karahan, 2017).** A few research looked at the interactions between BIM and LC **(Sacks et al., 2009; Sacks et al., 2010; Zhang et al., 2018).** The lack of cooperation and coordination in the construction sector has prevented the effective use of BIM-Lean **(Evans et al., 2020a).** Some researchers assert that top-level management support and a collaborative workplace would increase the benefits of BIM in construction practice **(Olatunji et al., 2017; Chan et al., 2019b).**

However, there are several obstacles and problems that the construction sector must overcome to apply BIM technologies and LC concepts **(Hong et al., 2018; Chan et al., 2019a)**. Olawumi and Chan noted resistance to departing from traditional methods **(Olawumi et al., 2018b)**. These difficulties prevented the best use of LC concepts, BIM technology, and their complete integration **(Ozorhon and Karahan, 2017; Olawumi and Chan, 2019)**.

Table 1. The benefits of using BIM-LC synergy in construction projects.

NO	Benefits	References
1	Ensure the most effective project delivery method	**(Sacks et al., 2010; Gamil, 2017; Mollasalehi et al., 2018)**
2	Shortening of the design project life cycle	**(Calderon-Hernandez and Brioso, 2018; Andújar-Montoya et al., 2020; Pedo et al., 2021)**
3	Improving the performance of suppliers in the construction industry	**(Sacks et al., 2010; Gamil, 2017; Koseoglu et al., 2018)**
4	Improved life cycle cost and investment predictability	**(Gamil, 2017; Koseoglu et al., 2018; Andújar-Montoya et al., 2020)**
5	Reduce the volume of needless data.	**(Koseoglu et al., 2018; Andújar-Montoya et al., 2020; Pedo et al., 2021)**
6	Enable information sharing	**(Gamil, 2017; Andújar-Montoya et al., 2019; Pedo et al., 2021)**
7	Strengthen project partnerships	**(Gamil, 2017; Calderon-Hernandez and Brioso, 2018; Pedo et al., 2021)**
8	Significant improvements in legal concerns	**(Koseoglu et al., 2018; Andújar-Montoya et al., 2020)**
9	Ease of forecasting risks	**(Koseoglu et al., 2018; Andújar-Montoya et al., 2020)**
10	Encourage tighter cooperation from the project's earliest phases.	**(Calderon-Hernandez and Brioso, 2018; Koseoglu et al., 2018)**
11	Effectively allow the use of each other for building projects.	**(Calderon-Hernandez and Brioso, 2018; Mollasalehi et al., 2018)**
12	Aiding teams to do their tasks more effectively	**(Gamil, 2017; Koseoglu et al., 2018; Andújar-Montoya et al., 2019)**
13	BIM develops IPD strategies and is an excellent tool for team building.	**(Mollasalehi et al., 2018; Koseoglu et al., 2018)**
14	BIM offers a solution for exchanging data storage.	**(Andújar-Montoya et al., 2020; Pedo et al., 2021)**
15	During the project phases, Solve more of the concerns (constructability, cost, schedule, sustainability, quality, waste, etc.)	**(Calderon-Hernandez and Brioso, 2018; Andújar-Montoya et al., 2020; Pedo et al., 2021)**
16	Effective intent capture and flow down	**(Koseoglu et al., 2018; Andújar-Montoya et al., 2019)**
17	Decreased rework	**(Koseoglu et al., 2018; Pedo et al., 2021)**
18	Increasing iteration to improve the value	**(Gamil, 2017; Mollasalehi et al., 2018; Koseoglu et al., 2018)**
19	Boost output and effectiveness, and create more value for the customer	**(Gamil, 2017; Mollasalehi et al., 2018; Koseoglu et al., 2018; Pedo et al., 2021)**
20	Improved capacity for interaction with stakeholders.	**(Calderon-Hernandez and Brioso, 2018; Koseoglu et al., 2018; Pedo et al., 2021)**
21	Enhanced visualization and information flow	**(Koseoglu et al., 2018; Andújar-Montoya et al., 2019; Pedo et al., 2021)**
22	Higher planning resolution	**(Koseoglu et al., 2018; Andújar-Montoya et al., 2019)**
23	higher quality	**(Gamil, 2017; Andújar-Montoya et al., 2020)**
24	higher safety	**(Kim et al., 2018; Koseoglu et al., 2018; Khan et al., 2020)**
25	A rise in productivity	**(Sun et al., 2017; Mesároš et al., 2020; Wong et al., 2020)**
26	Check the effectiveness of different building techniques.	**(Gamil, 2017; Mollasalehi et al., 2018; Wen et al., 2020)**
27	Precise as-built model	**(Bassier et al., 2017; Koseoglu et al., 2018; Lin et al., 2018)**
28	Planning for operations and maintenance	**(Hu et al., 2018; Chen and Tang, 2019; Gao and Pishdad-Bozorgi 2019)**
29	Efficient facilities management	**(Wong et al., 2018; Matarneh et al., 2019a; Matarneh et al., 2019b)**
30	Enhanced reaction to incidents	**(Koseoglu et al., 2018; Lin, 2022).**

Despite expanding studies and research in BIM-Lean projects, the building industry has concentrated on specific areas without attention to the holistic picture to obtain the maximum BIM-Lean synergy **(Azhar et al., 2012)**. BIM-Lean assessment's present methodology is still in its infancy and needs more study **(Ghaffarianhoseini et al., 2017)**. **Table 1** identifies 30 benefits that can be obtained from the synergy of BIM and LC. **Table 2** summarizes 28 constraints to effectively implementing synergy BIM technology and LC concepts as described in the extant literature.

The main benefits that could be obtained through this synergy are ensuring the most effective project delivery method, shortening the design project life cycle, and the building industry's procedures will incorporate suppliers. In contrast, the main constraints include the government rules and industry standards for BIM and LC are not obligatory, the absence of government funding and participation, and the industry's resistance to changing from customary operating methods. This research seeks experts' opinions on how to analyze, rank, and constraints recognized in the existing literature, to assist leading players in the construction sector in highlighting the most significant constraints impeding the effective adoption of BIM with LC in projects.

Table 2. The constraints to using BIM-LC synergy in construction projects.

Code	Constraints	References
C1	Challenges facing the organization, project strategy, and policy	**(Sacks et al., 2010; Sacks et al., 2018; Akbarieh et al., 2020)**
C2	The negative perception of data sharing	**(Chan and Sciences, 2014; Bradley et al., 2016; Sacks et al., 2018)**
C3	Absence of government funding and participation	**(Sacks et al., 2018; Elhendawi et al., 2020)**
C4	Lack of supporting software and tools for lean construction (LC) analysis	**(Sacks et al., 2009, Hsu et al., 2015; Olatunji et al., 2017)**
C5	Consumer demand and a lack of senior management commitment	**(Rogers et al., 2015; Ozorhon and Karahan, 2017; Elhendawi et al., 2020)**
C6	Lack of communication and cooperation among project stakeholders	**(Azhar et al., 2012; Ghaffarianhoseini et al., 2017)**
C7	BIM software licenses are very expensive.	**(Hamzeh et al., 2016; Sacks et al., 2018)**
C8	lacking well-established BIM processes and LC	**(Ding et al., 2015; Jin et al., 2017; Hong et al., 2018)**
C9	High BIM installation and training costs and times	**(Hsu et al., 2015; Zhang et al., 2018; Olawumi and Chan, 2019)**
C10	Intellectual property rights disputes and dangers are related.	**(Bradley et al., 2016; Sacks et al., 2018; Olawumi and Chan, 2019; Jin et al., 2017)**
C11	Uncertain economic advantages	**(Salleh and Phui Fung, 2014; Olatunji et al., 2017)**
C12	Undeveloped conflict resolution procedures for the implementation of BIM-LC.	**(Olawumi et al., 2018b; Shirowzhan et al., 2020)**
C13	Software for BIM analysis is not user-friendly.	**(Ding et al., 2015; Bradley et al., 2016; Sacks et al., 2018)**
C14	The industry of building is fragmented.	**(Hong et al., 2018; Olawumi et al., 2018b; Tan et al., 2019)**
C15	BIM requires a large initial outlay for personnel training expenses	**(Salleh and Phui Fung, 2014; Olawumi et al., 2018c)**
C16	Having trouble adjusting to BIM techniques and technologies	**(Salleh and Phui Fung, 2014; Rogers et al., 2015)**
C17	Risk allocation and sharing challenges for BIM and LC	**(Ghaffarianhoseini et al., 2017; Zhang et al., 2018; Tan et al., 2019)**
C18	Industry's resistance to changing from customary operating methods	**(Chan and Sciences, 2014; Rogers et al., 2015; Sacks et al., 2018)**
C19	Societal resistance to renouncing conventional beliefs or practices	**(Sacks et al., 2018; Chan et al., 2019b; Azhar et al., 2012)**
C20	Future investment hesitation and a lack of initiative	**(Salleh and Phui Fung, 2014; Chen et al., 2015; Sacks et al., 2018)**

C21	There is no insurance covering the implementation of BIM and LC.	**(Sacks et al., 2018)**
C22	Absence of regulatory framework, BIM, and lean construction (LC) contract uncertainties	**(Abanda et al., 2015; Bradley et al., 2016; Sacks et al., 2018; Olawumi and Chan, 2019)**
C23	More workload for developing models	**(Sacks et al., 2018; Chan et al., 2019b; Olawumi and Chan, 2019)**
C24	Government rules and industry standards for BIM and LC are not obligatory.	**(Salleh and Phui Fung, 2014; Sacks et al., 2018; Elhendawi et al., 2020)**
C25	Lack of cross-field experts in BIM-LC synergy	**(Sacks et al., 2018; Olawumi and Chan, 2019; Elhendawi et al., 2020)**
C26	Low level of academic and industrial research	**(Cao et al., 2015; Ding et al., 2015; Hamzeh et al., 2016)**
C27	Problems with interoperability between different software programs	**(Abanda et al., 2015; Hsu et al., 2015; Bui et al., 2016b; Ghaffarianhoseini et al., 2017; Ozorhon and Karahan, 2017)**
C28	Various levels of market readiness across organizations and regions	**(Chan and Sciences, 2014; Hamzeh et al., 2016; Sacks et al., 2018)**

2. RESEARCH METHODOLOGY

The research aims to list the benefits and evaluate the constraints of the merger of BIM with LC principles. The aims are first to evaluate the available publications on benefits and implementation hurdles for BIM and LC; second to rank and prioritize constraints reasons according to their levels of relevance; third, to start a comparison of BIM-Lean applications among respondents' groups. By knowing the important benefits and analyzing the limitations and significant issues obstructing the synergy of BIM and Lean, the outcomes will reinforce and expand the information available in the BIM and LC research field. The constraints were ranked according to their importance using a two-round of Delphi poll. Farrell and Hasson suggest that using the Delphi approach to help a group of experts reach a consensus is useful **(Hasson et al., 2000; Farrell, 2016)**. Evans et al. used a Delphi approach to examine the success factors that improve the integration between BIM and LC procedures on building projects **(Evans et al., 2020b).** Data was created during two rounds of Delphi questionnaires to analyze, investigate, and prioritize constraints to integrating BIM and LC acquired from the existing literature **(Hsieh and Shannon, 2005; Grisham, 2009).** The expert panel had sixteen (16) members, including “Academics, Consultants, Managers, and Contractors” of the building sector. The experts were chosen based on their expertise in the management and implementation of construction projects, and they have more than fifteen years in the execution of projects. The Delphi survey approach has been used with several previous research projects in the construction sector **(Giel and Issa, 2016)**. A performance monitoring indicator for building projects was devised **(Hasson et al., 2000)**. The basis for defining constraints that prevent the compatibility of BIM technology with the LC concept in the work environment is formed by a thorough analysis of the current literature. Twenty-eight (28) indicators were found after a thorough literature analysis, which was then turned into two rounds of a Delphi survey. Respondents were asked to rank the constraints according to a Likert scale of a 5-point: 5 = strongly agree, 1 = strongly disagree. The reliability testing techniques include the "Shapiro-Wilk" and ''Cronbach's" tests of normalcy and mean score rank. Numerous statistical methods, such as Kendall's coefficient of concordance, ranking with a mean score, analysis of $\chi 2$, Spearman's correlation test, and inter-rater agreement (IRA). IBM (SPSS) Statistics version 26, Microsoft Word, and Microsoft Excel was utilized to complete the study goals.

3. ANALYSIS OF THE RESEARCH

The information compiled from the experts by the two rounds of Delphi was analyzed using a variety of descriptive and inferential statistical approaches, followed by comparisons among the groups of respondents.

3.1 Testing for Reliability

Cronbach's test was used to evaluate the reliability of the questionnaire and validate hypothesis tests and internal consistency evaluations. The value of Cronbach's alpha (α) has ranged from (0 to 1), and Nunnally recommended a minimum value of 0.70 **(Nunnally, 1978)**. The values of (α) for the 1st and 2nd rounds of the Delphi were 0.86 and 0.89, respectively, which is higher than the (0.70) minimum value of Nunnally. The determine if the dataset has a normal distribution, the test of Shapiro-Wilk for normality was performed. The significance level ($p < 0.05$) for the twenty-eight essential elements implies a non-normally distributed dataset; hence nonparametric statistical techniques will be used.

3.2 Mean, SD, Variance, and Ranking of Constraints

The twenty-eight constraints were ranked using mean scores (χ or μ); the respondents' responses were gathered from two rounds of the Delphi when two or more elements in a Delphi survey had the same mean score, the SD (σ) was used to rank the elements. The lower SD value for the element is given an advanced level; however, if they both have the same SD value, the components' ranking remains the same. The (σ^2) for the descriptive study of (variance) was also considered. The 1st round Delphi survey's mean score (μ) values for the twenty-eight constraints that prevent BIM-Lean synergy are shown in **Table 3**, while **Table 4** shows the 2nd round's mean (SD) and ranking. With a variance of (0.69), the mean scores for the (28) constraints specified in the 1st round of Delphi range from [μ_{14} = 4.19, σ_{14} = 0.655, and σ^2_{14} = 0.429] for "C14: The industry of building is fragmented." to [μ_8 = 3.50, σ_8 = 0.632, and σ^2_8 =0.399] for "C8: lacking well-established LBIM processes and LC. While, with a variance of (0.56), which is lower than the variance of the 1st round, the mean score for the (28) constraints specified in the 2nd round of Delphi ranges from [μ_{14} = 4.061, σ_{14} = 0.681, and σ^2_{14} = 0.462] for "C14: The industry of building is fragmented " to [μ_7 = 3.50, σ_7 = 0.727, and σ^2_7= 0.529] for "C7: BIM software licenses are very expensive.

Additionally, an examination of the results from the 2nd round of Delphi showed that the responders, all experts, changed the order in which they prioritized specific constraints with the rankings of other constraints. For instance, in the 1st round of the Delphi, all experts ranked the top five constraints from first to fifth as (C14, C25, C17, C11, and C27), respectively. While in the 2nd round of Delphi, all experts ranked the top five constraints from first to fifth as (C14, C11, C25, C13, and C27), respectively. The last five constraints were ranked (C12, C7, C8, C3, and C18) by experts in the 1st round of the Delphi, and the final five constraints were ranked (C12, C7, C4, C8, and C2) by all experts in the second phase of the Delphi survey. Some constraints have been seen to have increased in ranking following the 2nd round of the Delphi, while others have seen a decrease in ranking. The experts of academics, business professionals, and people with prior building expertise strongly agreed on the top five constraints and the bottom five constraints with an observable degree of concordance.

3.3 The χ^2 Analysis and Kendal Coefficient of Concordance

A “Kendall’s Wis” (W) test was used to assess the degree of agreement among the experts and confirm concord consistency over many Delphi rounds. Kendall's Wise (W) is a number between (0 and 1), The number (0) represents complete inter-rater disagreement, and the number (1) represents perfect inter-rater agreement. After the 2nd round Delphi, the value of (W) increased to (0.764), which was (0.721) in 1st round Delphi, **Tables 3 and 4**. To confirm that changes between the 1st and 2nd rounds of the Delphi are dependent, the chi-square (χ^2) independence test was conducted, and the concordance amongst all members of the experts has improved as a result of the 2nd round of the Delphi. The 1st and 2nd findings of the Delphi are shown in **Tables 3 and 4**. The (χ^2) score for the experts increased from $\chi^2 = 40.332$ in the 1st round of the Delphi to $\chi^2 = 40.651$ in the 2nd round of the Delphi. Furthermore, the values of (χ^2) for two rounds exceeded the (χ^2), the critical value from the statistical table when (P= 0.05) at a degree of freedom (D.F.) of 27, which equals (40.114).
As a result, the significance levels (p) for the 1st and 2nd rounds of Delphi, respectively, are (0.046) and (0.043). The two values are below the 0.05 threshold. Based on these findings, asserting the survey's data and conclusions are correct with a degree of confidence greater than 95% is possible.

3.4 Inter-rater Agreement Analysis and Significance Level

Brown and Hauenstein advised Applying the IRA approach to carry out the agreement analysis among the respondents **(Brown and Hauenstein, 2005)**. The constraints that impact BIM-Lean synergy were determined using IRA analysis. The (μ) from the 2nd round of Delphi was used to rank and prioritize all constraints that prevent BIM-Lean synergy. Using the 5-Likert scale, which Zahoor et al. used **(Zahoor et al., 2017)**, scale intervals were constructed to comprehend the relevance of each factor, were sketched as not important ($\mu < 1.5$), somewhat important ($1.51 \leq \mu \leq 2.5$), important ($2.51 \leq \mu \leq 3.5$), very important ($3.51 \leq \mu \leq 4.5$), and extremely important ($\mu \geq 4.51$).
Other authors advised using the IRA (a_{wg}) approach to assess the degree of agreement among "inter-raters" (LeBreton and Senter, 2008), inter-raters are the respondents for both rounds of the Delphi to confirm the inter-rater agreement discovered by (μ) ranking and (χ^2) analysis. To interpret the IRA assessments, Hauenstein and Brown provided a set of guidelines **(Brown and Hauenstein, 2005)**, such as lack of agreement (0.00–0.30), weak agreement (0.31–0.50), moderate agreement (0.51–0.70), strong agreement (0.71–0.90), and very strong agreement (0.91–1.00).
As shown in **Table 5**, IRA and significance level data were used to assess the respondents' agreement degree at each Delphi round. Eq. (1) gives the formula for calculating the IRA values for each constraint.

$$a_{wg}=1-[(2*SD^2)\backslash[(h+L)\,\mu-\mu^2-(h*L)]*(K(K-1))] \qquad (1)$$

where:
(L) is the scale's lowest possible value equals 1.
(h) the scale's highest potential value equals 5.
(K) represents the respondents' numbers for each round of Delphi which equals 8,

(SD) measures the standard deviation for each element, (μ) represents the respondents' mean versus a factor.

Table 3. The constraints to combining the BIM with LC concepts in building projects (mean, SD, rank), 1st round of Delphi survey.

Code	All experts			Academics			Consultants			Managers			Contractors		
	μ	σ	R	μ	σ	R	μ	σ	R	μ	σ	R	μ	σ	R
C1	3.751	0.577	10	3.88	0.641	9	3.62	0.518	14	3.5	0.535	18	4	0.535	4
C2	3.62	0.806	18	3.88	0.835	9	3.38	0.744	2	3.38	0.916	2	3.88	0.641	8
C3	3.56	0.512	25	3.5	0.535	24	3.63	0.518	11	3.38	0.518	23	3.75	0.463	13
C4	3.56	0.629	22	3.75	0.463	15	3.38	0.744	21	3.63	0.744	14	3.5	0.535	23
C5	3.63	0.619	16	3.63	0.744	20	3.62	0.518	14	3.38	0.744	23	3.87	0.354	11
C6	3.75	0.577	9	3.63	0.518	20	3.87	0.641	6	3.75	0.463	7	3.75	0.707	13
C7	3.44	0.512	27	3.5	0.535	24	3.38	0.518	21	3.25	0.463	28	3.63	0.518	19
C8	3.5	0.632	26	3.5	0.535	24	3.5	0.756	19	3.63	0.744	14	3.38	0.518	27
C9	3.75	0.577	11	3.75	0.463	15	3.75	0.707	7	3.75	0.463	7	3.75	0.707	13
C10	3.69	0.602	14	4	0.535	4	3.38	0.518	21	3.5	0.535	18	3.88	0.641	8
C11	4	0.73	4	4	0.756	4	4	0.756	4	4	0.756	4	4	0.756	4
C12	3.37	0.957	28	3.75	0.886	15	3	0.926	28	3.38	0.916	23	3.38	1.061	27
C13	3.88	0.719	7	4	0.756	4	3.75	0.707	7	3.75	0.886	7	4	0.535	4
C14	4.19	0.655	1	4.13	0.354	1	4.25	0.886	1	4.25	0.707	1	4.13	0.641	1
C15	3.69	0.602	13	3.75	0.463	15	3.62	0.744	14	3.75	0.707	7	3.62	0.518	22
C16	3.63	0.5	15	3.63	0.518	20	3.62	0.518	14	3.38	0.518	23	3.87	0.354	11
C17	4.06	0.772	3	4	0.756	4	4.13	0.835	2	4.25	0.886	1	3.88	0.641	8
C18	3.56	0.512	24	3.5	0.535	24	3.62	0.518	14	3.5	0.535	18	3.63	0.518	19
C19	3.56	0.814	21	3.75	0.707	15	3.38	0.916	21	3.63	0.916	14	3.5	0.756	23
C20	3.56	0.727	20	3.5	0.535	2	3.63	0.916	11	3.5	0.756	18	3.63	0.744	19
C21	3.62	0.806	19	3.88	0.835	9	3.38	0.744	21	3.5	0.926	18	3.75	0.707	13
C22	3.81	0.655	8	3.88	0.835	9	3.75	0.463	7	3.88	0.835	5	3.75	0.463	13
C23	3.75	0.775	12	4	0.535	4	3.5	0.926	19	3.75	0.886	7	3.75	0.707	13
C24	3.62	0.5	17	3.63	0.518	20	3.63	0.518	11	3.75	0.463	7	3.5	0.535	23
C25	4.13	0.619	2	4.13	0.641	1	4.13	0.641	2	4.13	0.641	8	4.13	0.641	1
C26	3.94	0.68	6	3.88	0.641	9	4	0.756	4	3.87	0.641	6	4	0.756	4
C27	3.94	0.68	5	4.13	0.641	1	3.75	0.707	7	3.75	0.707	7	4.13	0.641	1
C28	3.56	0.814	23	3.88	0.835	9	3.25	0.707	27	3.62	0.744	17	3.5	0.926	23

Alpha (α) coefficient = 0.86, No. of respondents (n) =16, Kendall's coefficient (W) = 0.721, Calculated (χ2) = 40.332, (χ2) critical value from table (*P*= 0.05) = 40.114, Degree of freedom, d.f (ν)= 27, Significance level (p)= 0.046.

The following equations can be used to determine the μ-min and μ-max values that the (μ) should fall between them. For the 2nd round, the μ-min and μ-max values were 1.5 and 4.5, respectively:

$$\mu_{min} = [\, h\,(K-1) + L\,]/K \tag{2}$$

$$\mu_{max} = [\, L\,(K-1) + h\,]/K \tag{3}$$

Table 4. The constraints to combining the BIM with LC concepts in building projects (mean, SD, rank), 2nd round of Delphi survey.

Code	**All experts**			**Academics**			**Consultants**			**Managers**			**Contractors**		
	µ	**σ**	**R**	**µ**	**σ**	**R**	**µ**	**σ**	**R**	**µ**	**σ**	**R**	**µ**	**σ**	**R**
C1	3.81	0.655	11	4	0.756	5	3.62	0.518	16	3.5	0.535	19	4.13	0.641	1
C2	3.56	0.727	24	3.75	0.707	16	3.38	0.744	21	3.5	0.926	19	3.62	0.518	23
C3	3.62	0.5	22	3.63	0.518	22	3.63	0.518	12	3.38	0.518	23	3.87	0.354	15
C4	3.5	0.632	26	3.75	0.463	16	3.25	0.707	25	3.63	0.744	14	3.38	0.518	26
C5	3.69	0.602	16	3.75	0.707	16	3.62	0.518	16	3.38	0.744	23	4	0	4
C6	3.81	0.655	9	3.75	0.707	16	3.87	0.641	6	3.75	0.463	7	3.88	0.835	10
C7	3.5	0.516	27	3.63	0.518	22	3.38	0.518	21	3.25	0.463	28	3.75	0.463	16
C8	3.56	0.629	25	3.62	0.518	26	3.5	0.756	19	3.75	0.707	7	3.38	0.518	26
C9	3.75	0.577	13	3.62	0.518	26	3.88	0.641	4	3.75	0.463	7	3.75	0.707	16
C10	3.63	0.719	18	4	0.535	5	3.25	0.707	25	3.38	0.744	23	3.88	0.641	10
C11	4	0.73	2	4	0.756	5	4	0.756	2	4	0.756	2	4	0.756	4
C12	3.37	0.885	28	3.75	0.707	16	3	0.926	28	3.38	0.916	23	3.38	0.916	26
C13	3.94	0.68	4	4.13	0.641	1	3.75	0.707	7	3.88	0.835	4	4	0.535	4
C14	4.061	0.681	1	3.87	0.354	14	4.25	0.886	1	4.13	0.641	1	4	0.756	4
C15	3.81	0.544	8	3.88	0.354	10	3.75	0.707	7	3.75	0.707	7	3.88	0.354	10
C16	3.69	0.704	15	3.75	0.707	16	3.63	0.744	12	3.38	0.518	23	4	0.756	4
C17	3.88	0.719	6	3.88	0.641	10	3.88	0.835	4	4	0.926	2	3.75	0.463	16
C18	3.63	0.5	17	3.63	0.518	22	3.62	0.518	16	3.5	0.535	19	3.75	0.463	16
C19	3.63	0.806	20	3.88	0.641	10	3.38	0.916	21	3.63	0.916	14	3.62	0.744	23
C20	3.63	0.719	19	3.62	0.518	26	3.63	0.916	12	3.5	0.756	19	3.75	0.707	16
C21	3.75	0.856	14	4.13	0.835	1	3.38	0.744	21	3.63	0.916	14	3.88	0.835	10
C22	3.81	0.655	10	3.87	0.835	14	3.75	0.463	7	3.88	0.835	4	3.75	0.463	16
C23	3.81	0.834	12	4.13	0.641	1	3.5	0.926	19	3.75	0.886	7	3.88	0.835	10
C24	3.62	0.5	21	3.63	0.518	22	3.63	0.518	12	3.75	0.463	7	3.5	0.535	25
C25	3.94	0.574	3	3.88	0.641	10	4	0.535	2	3.88	0.354	4	4	0.756	4
C26	3.88	0.719	7	4	0.756	5	3.75	0.707	7	3.62	0.518	17	4.13	0.835	1
C27	3.94	0.68	5	4.13	0.641	1	3.75	0.707	7	3.75	0.707	7	4.13	0.641	1
C28	3.62	0.885	23	4	0.926	5	3.25	0.707	25	3.62	0.744	17	3.63	1.061	22

Alpha (α) coefficient = 0.89, No. of respondents (n) =16, Kendall's coefficient (W) = 0.764, Calculated ($\chi2$) = 40.651, ($\chi2$) critical value from table (P= 0.05) = 40.114, Degree of freedom, d.f (ν) = 27, Significance level (p)= 0.043.

The experts' perspective evolved between the 1st and 2nd rounds of the Delphi. **Table 5** shows that most factors, except for a few factors like "C12, C8, and C4", preserved their significant level after the 2nd round of Delphi. The expert panel downgraded the "C12 and C4" factors from very important to important. While "C8" was raised from important to very important. The Inter-rater agreement (IRA) study of compact between respondents found a moderate to a high degree of consensus between the experts in both the 1st and 2nd rounds of Delphi. Two factors, "C2 and C13" improved their agreement levels based on IRA analysis from "moderate" to "strong" after the 2nd round, while the rest of the constraints remained the same.

In general, experts achieve a high consensus according to the (IRA) analysis and significance level rating. **Table 6** shows the ranking of each factor according to its significance level and IRA analysis. The results after the 2nd round, the (IRA) levels for constraints range from lack of agreement to very strong agreement, while the significance levels range from important to very important. The same table shows the five significant restrictions that received better ratings from the expert panels and strong consensus (C24, C3, C18, C7, C15) and the five least significant factors (C19, C12, C23, C21, C28).

3.5 Consensus Among the Panel of Experts' Replies

Spearman's (ρ) rank-order correlation coefficient was used for additional and more in-depth nonparametric analysis. To measure the degree of agreement between the groups of the Delphi survey, the correlation coefficient of Spearman (γ_s) test was applied. The ranges of value from (+1 to -1). γ_s equal (1) shows an exact positive correlation, while (γ_s) equal (-1), shows an exact negative correlation. The correlation between ranks will be weaker when the (γ_s) is closer to zero.

The results of the analysis showed a small but positive correlation between the academic groups and consultants at a (γ_s) of (0.389), and a moderate but positive correlation between the managers' groups and contractors at a (γ_s) of (0.499).

4. STRATEGIES AND RECOMMENDATIONS FOR OVERCOMING THE CONSTRAINTS

Research has identified several significant obstacles that prevent the implementation and final compatibility of BIM technology and the LC concept in construction projects. Implementing BIM and LC has several important aspects and barriers that differ from one country to another, sometimes inside the same country based on regions. Additionally, the study found that academics and industry professionals had different perspectives on various impediments. According to **Table 6**, the first ten (10) significant constraints are concerned with "legal", "Software and Technology Financing", "Knowledge, Education, and Learning", and "Market and Attitude".

This study seeks to illustrate and explain some strategies and recommendations to overcome these important constraints to improve BIM-Lean synergy in the construction environment, as in **Table 7**.

Table 5. Inter-rater agreement analysis and significance level of the constraints

Code	1st round score of a(wg)	Agreement level	2nd round score of a(wg)	Agreement level	1st round IRA rank	1st round Significance	2nd round Significance
C1	0.818	St.	0.759	St.	11	V. I.	V. I.
C2	0.663	Mo.	0.731	↑St.	15	V. I.	V. I.
C3	0.867	St.	0.87	St.	2	V. I.	V. I.
C4	0.799	St.	0.8	St.	9	V. I.	↓I.
C5	0.801	St.	0.807	St.	7	V. I.	V. I.
C6	0.818	St.	0.759	St.	11	V. I.	↑V. I.
C7	0.871	St.	0.867	St.	4	I.	I.
C8	0.8	St.	0.799	St.	10	I.	↑V. I.
C9	0.818	St.	0.828	St.	6	V. I.	V. I.
C10	0.808	St.	0.731	St.	16	V. I.	V. I.
C11	0.667	Mo.	0.667	Mo.	23	V. I.	V. I.
C12	0.555	Mo.	0.62	Mo.	25	V. I.	↓I.

C13	0.699	Mo.	0.722	↑St.	18	V. I.	V. I.
C14	0.689	Mo.	0.699	Mo.	22	V. I.	V. I.
C15	0.807	St.	0.834	St.	5	V. I.	V. I.
C16	0.87	St.	0.736	St.	14	V. I.	V. I.
C17	0.612	Mo.	0.699	Mo.	20	V. I.	V. I.
C18	0.867	St.	0.87	St.	3	V. I.	V. I.
C19	0.663	Mo.	0.662	Mo.	24	V. I.	V. I.
C20	0.731	St.	0.731	St.	16	V. I.	V. I.
C21	0.663	Mo.	0.6	Mo.	27	V. I.	V. I.
C22	0.759	St.	0.759	St.	11	V. I.	V. I.
C23	0.672	Mo.	0.61	Mo.	26	V. I.	V. I.
C24	0.87	St.	0.87	St.	1	V. I.	V. I.
C25	0.736	St.	0.802	St.	8	V. I.	V. I.
C26	0.722	St.	0.699	St.	20	V. I.	V. I.
C27	0.722	St.	0.723	St.	18	V. I.	V. I.
C28	0.662	Mo.	0.595	Mo.	28	V. I.	V. I.

Nots: -

- IRA: Very Strong agreement (VSt): (0.91–1.00), Strong agreement (St): (0.71–0.90), Moderate agreement (Mo): (0.51–0.70), Weak agreement (W): (0.31–0.50), and Lack of agreement (L): (0.00–0.30).
- Significance: Extremely Important (E.I): ($\mu \geq 4.51$), Very Important (V.I.): ($3.51 \leq \mu \leq 4.5$), Important (I): ($2.51 \leq \mu \leq 3.5$), Some-what important (S): ($1.51 \leq \mu \leq 2.5$), and Not important (N): ($\mu < 1.5$).

Table 6. A list of the key BIM-LC constraints in descending order.

Code	Constraints	Ranking	Significance	Agreement level
C24	Government rules and industry standards for BIM and LC are not obligatory	1	V. I.	St.
C3	Absence of government funding and participation	2	V. I.	St.
C18	Industry's resistance to changing from customary operating methods	3	V. I.	St.
C7	BIM software licenses are very expensive.	4	I.	St.
C15	BIM requires a large initial outlay for personnel training expenses	5	V. I.	St.
C9	High BIM installation and training costs and times	6	V. I.	St.
C5	Consumer demand and a weak high-management commitment	7	V. I.	St.
C25	Lack of experts in the field of BIM-LC synergy	8	V. I.	St.
C4	Lack of software and tools for lean construction (LC) analysis	9	I.	St.
C8	lacking establish well-processes for BIM and LC	10	V. I.	St.
C22	Absence of regulatory framework, BIM and lean construction (LC) contract uncertainties	11	V. I.	St.
C1	Challenges facing the organizational policy, and project strategy.	12	V. I.	St.
C6	Lack of communication and cooperation among project stakeholders	13	V. I.	St.
C16	Having trouble adjusting to BIM techniques and technologies	14	V. I.	St.
C2	The negative perception of data sharing	15	V. I.	St.
C20	Future investment hesitation and a lack of initiative	16	V. I.	St.
C10	Intellectual property rights disputes and dangers are related.	17	V. I.	St.
C27	Problems with interoperability between different software programs	18	V. I.	St.
C13	Software for BIM analysis is not user-friendly.	19	V. I.	St.
C26	Low level of academic and industrial research	20	V. I.	St.
C17	Risk allocation and sharing challenges for BIM and LC	21	V. I.	Mo.
C14	The industry of building is fragmented.	22	V. I.	Mo.
C11	Uncertain economic advantages	23	V. I.	Mo.

C19	Societal resistance to renouncing conventional beliefs or practices	24	V. I.	Mo.
C12	Undeveloped conflict resolution procedures for the implementation of BIM-LC.	25	I.	Mo.
C23	More workload for developing models	26	V. I.	Mo.
C21	There is no insurance covering the working of BIM with LC.	27	V. I.	Mo.
C28	Various levels of market willingness by organizations and regions	28	V. I.	Mo.

Table 7. Strategies and Recommendations for the first ten (10) significant constraints

Constraints	Description of The Problem	Strategies and Recommendations to mitigate constraints
Legal	Government standards and regulations for the BIM and LC industries are not mandatory, and there is a weakness in assistance or involvement by the government.	Government involvement in creating a centralized BIM-Lean leading committee is crucial to successfully managing BIM and LC in construction, issuing appropriate BIM and LC standards, and implementing legal requirements.
Software and Technology Financing	BIM software licenses are expensive, with the large costs of coaching and application and a high investment in personnel traineeship costs.	The government should support investment incentives in technology to help the building sector buy necessary materials and technology licenses to increase (BIM and LC) adoption in construction. Additionally, the construction sector officials are urged to create a variety of BIM and LC software packages for subcontractors to use at discounted prices in projects.
Knowledge, Education, and Learning	Lack of enabling LC analytical tools and software, insufficiency of specialists in the field of (BIM-Lean), and weak established BIM-Lean workflows.	There is a need for professionals and organizations to improve the knowledge, skills, and professionalism of (BIM and LC) practitioners in the building sector. Additionally, creation of programs that provide opportunities for skill development and capacity building, such as workshops, in-depth training, and seminars.
Market and Attitude	weakness of higher management obligation and customer demand, the industry's resistance to transition from established working procedures.	To improve BIM-LC synergy, it is advised that key stakeholders in the construction industry, including top management, engineering firms, and main contractors, reduce their resistance to change and adopt proactive attitudes toward implementing BIM and LC approaches in their projects.

5. CONCLUSIONS

The construction sector is a field that is constantly evolving as new technology, procedures, and government regulations are implemented. It has also embraced the application efforts of (BIM with LC). The study examines the significant benefits and constraints of the application (BIM with LC) that accompany the construction industry to support the successful integration of BIM technology as a tool with LC principles through the whole life cycle of the project. According to a thorough literature auditing, the synergy of BIM with LC concepts in Iraqi construction projects has been shown to have thirty (30) benefits and twenty-eight (28) constraints. A Delphi approach and a range of statistical tools, including the chi-square test, coefficient of concordance by Kendall's, Spearman's correlation, and Inter-rater agreement analysis, were used to analyze the datasets acquired from the sixteen (16) members of Delphi experts for two rounds. Furthermore, a consensus was gotten between two groups of experts following a two-rounds of Delphi. Since a Delphi survey is regarded as a self-validating technique, the experts' consensus t reached on each constraint was validated using the Inter-rater agreement analysis, and obstacles were then graded according to their level of importance.

Integrating building information modeling and lean construction techniques in the Iraqi construction sector needs strategies and recommendations. The strategies and recommendations of the study are:
The government should establish a centralized committee for (BIM-Lean) to manage them in construction, issuing sufficient BIM and LC standards and implementing legal requirements. The government should support investment incentives in technology to help the building sector buy necessary materials and technology licenses. There is a need for professionals and organizations to improve the knowledge, skills, and professionalism of (BIM and LC) practitioners in the building sector. Additionally, the creation of programs that provide opportunities for skill development and capacity building. To improve BIM-LC synergy, it is advised that key stakeholders in the construction industry reduce their resistance to change and adopt proactive attitudes toward implementing BIM and LC approaches in their projects.

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