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Collaboration and BIM model maturity to produce green buildings as an organizational strategy

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ABSTRACT

Each organization or work team adopts a specific strategy to produce and execute green buildings because there is no reliable strategy by BIM. Although a BIM model includes many disciplines; however, each company relies on an individual tactic in executing this model, which negatively affects the maturity level of the model due to unguided organizational experience and lack of integrating BIM technologies. Therefore, the research sought to regulate and optimize the collaboration and maturity level of a BIM model as a strategic basis to produce and execute green projects. Therefore, the study addressed the BIM concept, the correlation origin between collaboration and BIM model maturity, and the way to optimize collaboration as a system and qualify individuals through it. The potential of attaining the highest maturity level of a BIM model was investigated, besides overcoming the difficulties related to the evaluation of their business value. The study verified the correlation between BIM and green buildings; and, demonstrated the role of collaboration and BIM maturity level within green assessment systems. Accordingly, the study concluded, formulated, and validated a framework based on collaboration and maturity potentials of a BIM model as an organizational strategy to produce green projects by BIM.

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KEYWORDS Building Information Modeling (BIM); collaboration; maturity level; green building; organization; delphi technique

Introduction

Although the benefits and advantages of BIM have been widely recognized in the field of construction [1–3]. However, there are still some problems or barriers and obstacles to implement and apply BIM. As well as the utilization of BIM to develop and design projects and make them green buildings because there is no framework or strategy supported by BIM to achieve it [4–6]. One possible interpretation of the lack of apparent systemic visible effects of BIM that its maturity level is low. Because of

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firms till now possess a little experience in executing BIM, which impedes the efficient and comprehensive utilization of this innovative technology [7]. Because some believe that BIM is difficult to use, and it is not essential; therefore, it was rejected [5,8]. The role of collaboration always absent and it is being depended on individuals separately; also, lack of reviewing and developing the maturity level of a BIM model [7,9,10]. Because BIM is technology, processes, and policies, collaboration should be activated to operate processes and regulate the relationship among stakeholders for integration among them [11–13]. Utilize BIM-related technologies to achieve the highest maturity level of the BIM model and its capabilities for supporting a project to be green [4,14]. Also, there are not apparent and confirmed mechanisms or strategies by BIM to activate collaboration and achieve the highest maturity levels of a BIM model [10,15,16]. Many see such problem affects the benefits and future of BIM and production green projects based on BIM [7,11,17]. Besides, there is not a single BIM platform that can be relied upon to produce green projects [5,6,18].

Research problem

Lack of a clear strategy adopted by BIM to execute the concepts and characteristics of green buildings [4,5,16]. Therefore, each organization or work team adopts its strategy in the BIM model of any project. Because of the traditional practice of green building techniques, which focuses mainly on an individual tactic constitute the most critical obstacles to integrate between BIM and green building characteristics [2,6,18]. Where, a BIM model includes many disciplines as well as all stakeholders, which requires collaboration as a system among them to regulate and operate processes during such model to benefit from it rather than an individual tactic. This individual tactic affects the maturity level of a BIM model due to the unguided regulatory expertise and lack of integrating available BIM technologies and utilizing them. All these finally have a negative impact on the execution and production of green buildings and projects based on BIM. Such buildings and projects will reflect a low-level of maturity of a BIM model, poor collaboration, and reduce the link benefits between them as a business value.

Research aim and objectives

The research aim is to regulate and optimize interrelationship between collaboration and potentials of BIM model maturity as a strategic basis and a framework of firms to produce and execute green projects by BIM. The following objectives can achieve this aim:

(1) To emphasize the interrelationship between collaboration and maturity as an assessment tool to the BIM implementation success and as a business value;
(2) To clarify the effective role of collaboration in operating and managing processes and integrating stockholders' roles;
(3) To achieve the highest maturity levels of a BIM model to take advantage of BIM technologies and progress in the BIM capability stage;
(4) To recognize and understand the correlation between BIM and green buildings; and
(5) To deduce and formulate an organizational framework based on collaboration and the maturity level of a BIM model for producing green buildings by BIM.

Research methodology

The study followed the inductive approach to illuminate the BIM concept from many sources and its three components; gather and identify benchmarks to measure the performance of BIM and parameters to track the progress by BIM; classify risks and limitations to execute BIM for overcoming them. Then, it illustrated the correlation between collaboration and the BIM maturity level; and, confirmed the business value of this relation. The study used the analytical approach to explain and demonstrate the useful role of the collaboration within BIM as a system and its components; and, reveal five perceptive determinants of individuals for forming the events inside the collaborative system. Then, it investigated the ways to attain the highest maturity level to a BIM model to advance through BIM capability phases and the five integral components to measure BIM maturity. It analyzed major BIM applications and their benefits during the project life cycle. Ultimately, it identified and recognized the linkage between BIM and green buildings through seven sustainability domains as features for their integration disciplines for enhancing such buildings throughout their life cycles. It revealed and emphasized collaboration role and BIM maturity level to produce green buildings by BIM platforms and across organizational experiences. Besides, the study investigated the potentials of BIM with the evaluation systems to assist the calculation of credit points. The deductive approach was utilized to infer and propose an organizational framework depends on collaboration and the BIM maturity level for producing green projects; then, the study validated such a framework using the Delphi survey technique.

The concept of Building Information Modeling (BIM)

According to Autodesk (2019), BIM is an integrated tactic that significantly develops project perception and enables expectable results. This vision allows work team individuals to maintain coordination; increase accuracy; decrease losses; and, make conscious decisions early, which helps to guarantee project success. It is an integrated modeling and process technology utilized to build an information model; such a model is a smart and parametric digital reproduction of a project in virtual models [5,11]. Besides, BIM can focus on concepts, through its utilization in the project life cycle and provide gains to stakeholders with elaborately treating risks and barriers to project implementation and future aims and maximizing value before performing a design proposal [9]. BIM divides into processes, technologies, and policies [7,8]. Processes facilitate collaboration and support integrating the roles among stakeholders. Technologies assist stakeholders in visualizing what is to be constructed in a simulated virtual environment to detect any issues, clashes, or conflicts of design, construction, or operational, which are possible, as a sign of maturity of the BIM model [8]. Besides, BIM has policies such as laws, standards, and rules [10]. Using BIM must be assessable. Without benchmarks, project teams and institutions are not going to appraise their progress or failure level continuously, evaluate their competencies of using BIM, and compare with other practitioners [12]. A set of benchmarks that intentionally developed to measure the performance of BIM as in Table 1; and, increase their trustworthiness, flexibility, and usability through parameters track the progress by BIM as in Table 2.

Table 1. Benchmarks to measure the performance of BIM [12].

Benchmark	Description
Accurate	Clear and capable of measuring performance with high levels of accuracy.
Applicable	Able to benefit all stakeholders at the project phases.
Achievable	Achievable if specific actions are taken.
Consistent	Returns on the same outcomes when performed by different evaluators.
Cumulative	Establish as legitimate developments, submissions from one project as preconditions to another.
Flexible	Capable to apply in markets, regulatory metrics, and subclasses.
Informational	Give notes for progression and guidelines for subsequent steps.
Neutral	Does not affect any solutions or schemes that are private, unregistered, closed, open, free, or commercial.
Specific	Service-specific qualifications for the building industry.
Global	To equally apply across businesses and geography.
Usable	Automatic and able to work easily to evaluate BIM performance.

Table 2. Parameters to track the progress by BIM [9].

Parameter	Description
Cost	Change plans as a % of standard costs & anticipation record and related costs.
Contractor	Reconciliations of savings from the designer and contractors by BIM. Save off-site prefabrication working hours from contractors.
Time	Savings % off-site hours. Realism periods as a % of the standard time.
Accuracy	Increasing it during advancing the project life cycles and with stockholders
Quantity	RFI (Request for information) quantities in Non-BIM vs. BIM.

Overcoming risks and limitations to executing BIM

Besides various advantages of BIM; however, there are many risks and barriers as challenges of achieving BIM classified into many indicators, as in Tables 3 and 4 [8].

The most significant barrier to execute and support BIM across the building industries is a balanced framework for accomplishing that considers both financial and managerial outcomes. Clients look to adopt BIM once it has proven its effectiveness [9]. To overcome the shown risks and limitations in Tables 3 and 4, the organization should adopt the following [11]:

(1) Regarding technology, BIM tool providers should accelerate the advancement of information exchange standards and concentrate on producing seamless interoperability using various BIM instruments be compatible, easy to use;
(2) Regarding cost, it must not be the main barrier to use BIM. Like the staff qualifying cost, the long-term benefits of BIM can recompense platforms and hardware;

Table 3. The classification of indicators of risks to execute BIM [8,19].

Indicators related to Technology	Indicators related to Process
No BIM criteria to integrating and managing a model by multidisciplinary partners; There are no criterion protocols possible, each firm adopts its particular rules that may create clashes if not correctly detected, which may lead to an incorrect and inconsistent. The team has to make routine 'Model – audits as a check' to guarantee a lack of any conflicts. Interoperability problems as the lack of (building process models defined completely – integrating essential data between components of BIMs). Thus, the digital design information must be computable and mature.	Operational risks include legal, contractual, and administrative. The lack of determining ownership of BIM, and the requirement to preserve it through copyright laws and other legal channels. Who will control in inserting data to be responsible for any errors and update to ensure its accuracy that is a risk. It needs additional time consumed recording and examining BIM that is a new budget in design and management related to qualifications and schedule profits. Lack of collaboration in processes and modeling criteria.

Table 4. The classification of indicators of limitations to execute BIM [8,19].

Classification	Explanation
Technology	The functionality of BIM tools; and, Accessibility of BIM tools.
Cost	Particular software; time and teaching; and, hardware promotions.
Management	Changes in workflows and inappropriate models; Fragmentation nature of industry; and, Lack of managers' and possessors' recognition and support.
Personnel	Need to educate professionals about BIM; Habitual resistance to change; and, Not familiar enough with BIM capabilities.
Legal	Contractual environment; Responsibility of stakeholders; Safety and trustworthiness of building data; and, Omitting insurance framework for BIM.

(3) Regarding management, the workflow should be altered to adapt to new technologies. Practitioners should deeply investigate how BIM utilizing within a schedule, cost, and project safety management, etc. Consequently, evolving standards, guidelines, and strategies. Through fulfilling the client demands are the most critical determinant in BIM;
(4) Regarding stakeholders, they should contribute further BIM education in the beginning project. More qualification is essential to utilize BIM. The users realize more positive outcomes from BIM, also develop more levels of expertise; and
(5) Regarding legal, the mutual undertakings via governments and industrial corporations required to publish better legislation, laws, and contract systems for utilizing BIM. Governments must support BIM in general.

The origin of the correlation between collaboration and maturity of a BIM model

Therefore, BIM is not only just software or 3D creative models, but also produce meaningful advances in the workflow and delivery procedures of a project. It possesses the ability to foster greater skills and compatibility among individuals who were as antagonists in the past. The maturity of BIM also promotes integrated project delivery (IPD). IPD promotes interoperability during whole life stages of a project that combines building management principles [8]. Interoperability defined as the capability of two or more systems or platforms to exchange and utilize the data prepared to overcome the separation among stakeholders at a presented project stage such as design, build, or operate [11]. The analysis form literature confirms that the nine-core success benchmarks for implementing BIM, as in Figure 1.

Each of them has high priority, and confirms the correlation between the collaboration and BIM maturity level; also, they can be utilized either as an evaluation tool for the implementation of BIM, or do necessary actions. Further, to gain a competing advantage that helps to win bids [1,2]. The difficulties related to the appraisal to the business value of linking collaboration to BIM model maturity can be classified into six fields, as in Table 5.

The role of collaboration within BIM

All of the data related to the stakeholders, construction materials, machines, and planning through integrating them into a BIM model for communicating and collaborating among stakeholders within one harmonious model can be enhanced [11]. Promoting collaboration among participants in the building industry is one of the concept fundamentals of BIM. BIM as a set of interacting tools carries the thought of multidisciplinary collaboration as its fundamental

During all stages from preparation to implementation	To improve the exchange of data and managing knowledge.
	To collaborate all stakeholders.
	To early correct and increase precise to 3D visualization of a project.
	To integrate design validation (Clash Detection).
	To check Models, validation, and revise code.
	To coordinate and plan of work.
	To develop the planning of site layout.
	To maximize site safety.

Figure 1. The nine-core success benchmarks for implementing BIM [1,2].

Table 5. The six fields of the difficulties in appraising the business value [9].

Field	Explanation
1	Some of the work benefits may be qualitative (intangible).
2	Users may feel about emerging technology; and how it will influence work negatively.
3	Organizational modifications may happen because of introducing a novel order.
4	Work gains are evolving across the project life phases.
5	Applied difficulties such as incorrect use, linked platforms, and incapacity to distribute relevant tasks and benefits.
6	Stakeholders will subjectively appraise the work and may have conflicting judgments.

principle to participate among stakeholders at various stages of the building life to add, renew, or adjust data in a BIM model to promote and indicate stakeholder tasks [8]. BIM is shared knowledge tools for data about a building, where data is the basis for making decisions during its life. The emergence of BIM was rooted in altering the objects where such activities are interfered to promote cooperation and interaction. However, the most significant opportunity given by BIM, is to serve as a single reference to the fact for stakeholders in the project life cycle and assets [10]. BIM represents a virtual method that allows whole team parties to collaborate more precisely and efficiently than usual processes, which has the growing positive signs on project results. While creating a model, the team individuals are continually improving and supporting their parts relative to project features and design modifications for guaranteeing the model is precise as possible before implementation. The bases of BIM depend on two pillars (collaboration, and communication) [15]. The succeeded execution of BIM demands the early engagement of all stakeholders. The collaboration methodology nature concentrates on raising the quality and facilitating the adaptation of a work team. The influence of BIM on collaboration appears in solving conflicts that emerge inside the action systems [2]. The BIM success stands on several determinants such as the size of a project, efficiency of the team members of BIM, the communication of a work team, and other organizational external determinants [9]. While working in different fields, there is a trend to utilize either a structuring method or a method based on collaboration. From a process perspective, among other aspects, team-based workflows and practices such as communication and confidence. Fundamentally, collaboration as a system distinguished as the interaction between four essential components, as shown in is Figure 2. They depended on context to produce specific events,

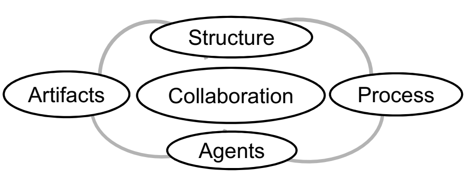

Figure 2. Components of collaboration as a system.

Table 6. Five perceptive determinants of individuals [10].

Determinants	Explanation
Needs	An obliged condition; they compose formal necessities and are hierarchical; and, the lack of precise demands are one of the prime obstacles facing BIM.
Expectations	Both the expected event and its occurrence pronounced about results and their ends restricted by the value related to such results; and, they are the informal or intangible origin of motivations.
Incentives	Financial motivates, personal earnings, and straightforward profits correlate to utilizing (tools – processes -types of profits). They have a negative influence (disincentive – impediment) and assist in fostering responsibility.
Intentions	A prospective plan of activity will be done. It is a forecast of forthcoming developments and a preemptive liability for producing them. Intentions refer to the responsibility for the execution of aims within the progress of plans.
Capabilities	It is an individualized evaluation of the ability to generate a particular result and personal perception of his skill to represent (self-effectiveness).

During collaboration via BIM, these elements (determinants) are reconfigured in novel techniques, which might or no make imbalances among work team members.

outcomes, and shape event patterns that are attempted at accomplishing one or several purposes [12].

Five perceptual determinants of an individual were recognized to form the events inside the collaborative system, as shown in Table 6. These five perceptual determinants reconcile how persons operate and cooperate via BIM similar to the concept of evaluation fields. From the perspective of systems, these five perceptual determinants are inside the operating entity. From the perspective of individuals, they qualify, restrict, and condition of the agent performance to generate and affect particular situation models in these circumstances. The conversions of these event models are examined to realize how BIM influences collaboration [10].

This examination supports the collaborative process among stakeholders, and makes from the measurement of BIM is more effectiveness generally and qualitative. The BIM influence on collaboration is recognized through the transition to BIM that pushes toward a transformation in the five perceptual determinants of individuals. This system gives an equivalent account of BIM-enabled collaboration practitioners via concentrating on individuals as fundamental components to be considered when managing such collaboration. The success of such collaboration demands closer adjustments among individual perceptual determinants of team members to compose the predominant frames of a work team relative to how BIM is utilized and its degree of being expanded and matured [9,10]. Therefore, effective collaboration BIM-enabled gives different benefits heading to enhance the project performance and better value.

The maturity level to a BIM model

With many tangible advantages of BIM as a tool to increase productivity, the slight available direction is for companies wanting to produce new or improve actual BIM projects. Consequently, the perfect application of these advantages needs an appreciation concerning how BIM means as hardware, software, and the technical and management abilities of a team, which requires developing in harmonization among them. Operators possess many and different knowledge about BIM is more composite challenges they experienced [12]. The studies confirm that the high maturity level of BIM depends on the successful BIM implementation by integrating the utilized information modeling technologies with the organizational process of a project. By implementing BIM, organizations seek to raise their performance in the execution of projects in terms of the key performance indicators (KPIs) (Quality -Time – Cost) [7]. Therefore, the organization framework should embrace eight dimensions to success a project, as shown in Table 7.

Particularly the strategic BIM maturity level was determined to be a credible predictor of the KPI concerning a project. It can understand from the viewpoint of technology that a BIM model is a project simulation. It includes the 3D models of the project elements with links to all the necessary information related to planning, programming, design, construction, operation, or demolition. BIM technology was extracted from the technique of object-oriented parametric modeling. The expression 'parametric' illustrates the processing of an object or element can be modified or aligned with a component or a group. e.g. A window attached to a wall is automatically aligned to keep a previously built link [9]. BIM encompasses all data correlated to a building, including its physical, qualitative, and functional features during its life cycle, in a list of 'smart objects.' For instance, air conditioning units within a BIM model also contain data about its supplier, running, flow rates, maintenance procedures, and clearance requirements [8]. Besides, the viewpoint that the maturity level of BIM in an organization will influence its understanding and defining BIM.

The BIM Maturity level defined as the quality, reliability, and degree of distinction inside the BIM capability. BIM capabilities are classified into three phases, as in **Table 8**. They are the extent of the performance level of an

Table 7. The eight dimensions of the framework of an organization [7].

Dimension	Definition
Coordinate	To organize and manage (team- unify – consolidate – articulate – integrate).
Scope	To define and control what is and what is not incorporated in a project.
Time	To complete the project in a timely manner.
Communicate	To perform timely and suitable generate, collect, distribute, store, retrieve, and dispose of project data.
Cost	To plan, estimate, budget, and control cost.
Quality	To plan, control, or assure quality.
Procurement	To obtain or procure a product, services, or outcomes required from external the work team to do work.
Risk	To raise the possibility and influence of affirmative situations and reduce the possibility and influence of opposing circumstances.

Table 8. BIM capability phases [12].

Object-based modeling	Model-based collaboration	Network-based integration
A company demands to expand an object-based modeling platform tool similar to ArchiCAD, Revit, Tekla, or Navisworks.	A company demands to participate in a model-based multidisciplinary collaborative project.	A company requires a network-based solution that connects to external databases, and objects-based models are shared with at least two other disciplines a solution similar to a server.

organization or its ability inside a particular phase, which is measured by defining BIM maturity according to the five levels of maturity, as shown in Figure 3 [9]. Maturity is the degree of ability to execute a mission or submit a BIM service, work, or product, while a capability means a minimum ability or the primary ability to accomplish a task [12].

BIM capability phases determine the least BIM requirements and significant signs, which are achieved by a work team or companies, namely technologies, processes, and policies [12]. For instance, an enterprise makes checks or pilot projects to define BIM benefits may be at the first phase (object-based modeling) and inside this stage, they are at either ad-hoc or defined as a maturity level works to be more improved by increasing check. Moreover, the BIM maturity level of a particular company can be assessed through general purposes within a level similar to Figure 3. Variety to the maturity level of enterprises must be taken into account in comparisons with other BIM works of an enterprise, as in Figure 4 [9]. For instance, in the USA, there is a growing number of large institutional clients now demand object-based three-dimensional models present as a part of tender deliveries. Moreover, in the UK Cabinet Office was published, the building strategy article demands the delivery of a fully collaborative three-dimensional BIM (with all project and original data and documents are electronic) as the lowest limit [12]. Consequently, the study identifies explicitly five integral components to measure BIM maturity, realize BIM performance, and to enable their appraisal and enhancement, as in Table 9.

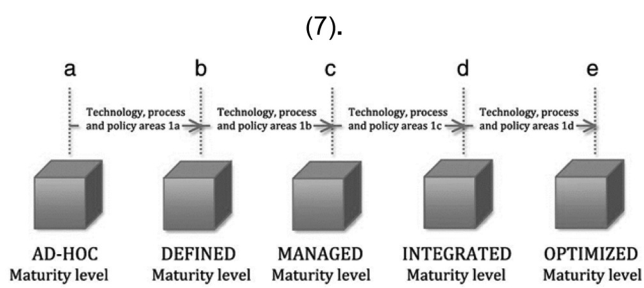

Figure 3. BIM maturity levels in the first phase, 'object-based modeling' [20].

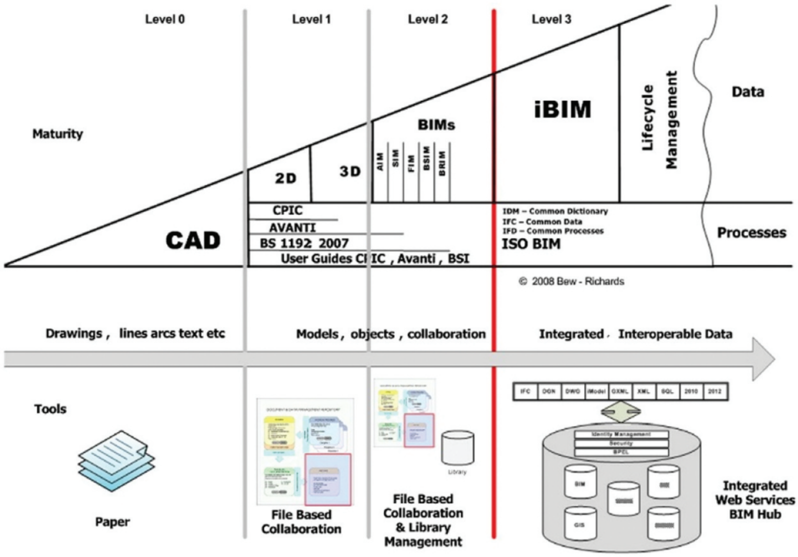

Figure 4. Bew-Richards BIM maturity diagram to assess organization maturity levels [20].

Table 9. Five integral components to measure BIM maturity [12].

Component	Definition
BIM capability phases	Transformational signs along the implementation chain.
BIM maturity levels	The quality, predictability, and variability throughout BIM phases.
BIM competencies	Gradual progress and developments throughout BIM phases.
Organizational scales	The variety of businesses, disciplines and organization volumes.
The level of Granularity	Enables highly flexible analyses that range from informal self-appraisal to high-detail formal audits and clash detection.

Table 10. The three sections of improvement from lower to higher levels of maturity [7].

First section	Second section	Third section
Enhanced control resulting from lower differences between performance objectives and actual outcomes.	Improved predictability and the potential of prediction to access to the cost, time, and performance objectives.	Greater effectiveness to reach specific goals and set new and more ambitious goals.

Metrics of BIM maturity are performance enhancement indications or levels to which work teams and companies aspire or seek. Generally, the improvement from lower to higher levels of maturity shows in three sections, as in Table 10 [12].

One of the benefits of BIM maturity is the clash detection of schemes and plans. Clash detection is considered a crucial responsibility to build processes, particularly when mechanical, electrical, and plumbing schemes are integrated. Clash detection is an example of a contradiction between old and new working techniques. It is supposed that the BIM implementation has potentials to upgrade from the uses of a particular BIM platform by the work team toward collaboration such as clash analysis of a composite and complex model [14]. For example, the design team at the General Motors plant (Flint, Michigan) concludes that the use of BIM, specifically automatic clash detection, preserved 3–5% of the total cost, and the 3D model workflow provided an additional 2–4% in prices and time saving. The Hilton Aquarium in (Atlanta, Georgia) used BIM for coordination, clash detection, and workflow. Most of the savings were from the overcome of clashes, saved massive hours of work [11]. Level Of Development (LOD) is granularity levels as the scale or level of detail present in a set of data or other phenomena used for performance evaluation to improve BIM capability and maturity evaluations and grow their flexibility. Progress from lower to higher levels of granularity shows the advance in items, as in Figure 5 [14].

The practitioners and companies have to learn how to utilize the new technology to realize the exact gains of executing BIM. Therefore, companies must set up their BIM maturity level by depending on the entrenched organizational BIM factors, as in Table 11 [7].

General brief of major BIM applications enhanced by the collaboration and maturity level for a work team and stakeholders during the project life cycle

The successful application of BIM allows a work team to coordinate and simplify its processes depending on collaboration and maturity level during a project, as in Table 12.

Consequently, the BIM application benefits appear to all stakeholders, as in Table 13.

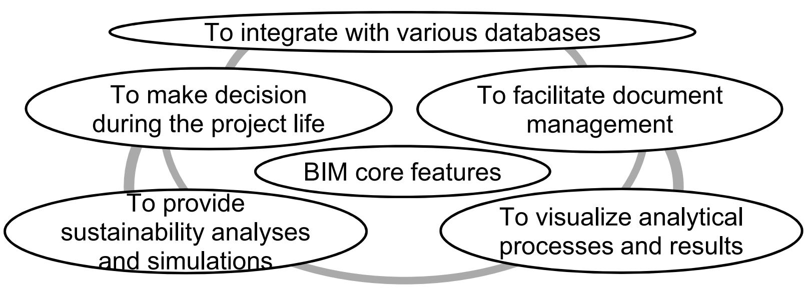

Figure 5. The progression items from lower to higher levels of granularity [8].

Table 11. The entrenched organizational BIM factors [7,17].

Factor	Definition
Strategy	Mission, Vision, Objectives, Management Support, BIM supporters, BIM Planning Committee.
Process	Means to fulfill BIM uses.
Information	Model structure, level of advancement, and data specifications.
BIM uses	Specific internal and external methods or process for executing BIM
Personnel	Roles, responsibilities, education, training, and readiness to change.
Infrastructure	Technological and physical systems and platforms for operating BIM.

Table 12. Major BIM applications of a work team during the project life cycle [8].

Phase		Major BIM applications
Preparation	To investigate and analyze all spaces, understand space criteria, use regulations that save time, and perform more value-added actions.	
Design	**Schematic design**	To analyze Alternatives (to compare various choices); and, merge to unite realistic project images of its actual statuses.
	Detailed design	3D models of outside and inside; Walk-through and Animations; and, analyze design performances (Ventilation, Energy, Material, Lighting, Waste, Emissions, and Structure).
	Building Details	4D stages; scheduling time and tasks; conflicts and clash detections; and, shop or fabrication drawings.
Construction	**Before**	Estimation (precise quantity survey and provide detailed estimates); site coordination (site logistics, elaborate traffic plan, and recognize possible hazards); and constructability analysis (progression plan of site operations).
	During	To monitor project progress by 4D staging plans; coordinate meetings; and, Integrate a request for information, change instructions, and filter list information in BIM models.
Operation & Maintenance	To make operations and maintenance more efficient; run maintenance works and emergency service requests; plan and manage space, and inspections.	

Table 13. BIM application benefits to stakeholders during the project life [8,9,11].

BIM application benefits	Customer	Designer	Constructor	Manager
Visualization	x	x	x	x
Sequencing coordination	x	x	x	x
Preliminary cost	x	x	x	x
Communication and collaboration	x	x	x	x
Analysis of alternatives	x	x	x	
Green building	x	x	x	x
Analyses of Sustainability	x	x		
Survey of quantities		x	x	
Estimation of costs	x	x	x	
Clash Detection		x	x	x
Code Checking		x	x	x
Productivity	x	x	x	x
Fabrication		x	x	
Logistics of site	x		x	
4D scheduling and Phasing		x	x	x
Analysis of the ability to Construction		x	x	
Performance analysis of a building	x	x	x	x
Labor	x	x	x	x
RFI	x	x	x	x
Safety	x	x	x	x
Change orders	x	x	x	x
Quality	x	x	x	x
Management of a building	x			x

Recognize correlation between BIM and green buildings

It can be utilized other platforms of BIM for additional analysis of sustainability domains to accomplish green buildings such as building emissions, human comfort, lighting, energy performance, etc [11,17]. To recognize this correlation; there are seven sustainability domains as features for green buildings that were categorized to analyze BIM disciplines, as in Table 14. These domains were formulated and adjusted based on the concept of the project life cycle. These seven domains were divided according to two attributes, namely the promotion of collaboration and BIM maturity level [6]. The conventional practice of technologies regarding green buildings fundamentally concentrated on an individual tactic in the single discipline, which formed primary obstacles to entering the work market. Therefore, it should be considered the integration of various disciplines that classified into six disciplines to overcome this obstacle.

These six disciplines must associate with the seven sustainability domains in the built environment to support a collaborative work environment for BIM to improve integrating these disciplines, as in Table 14. The attempt of integrating these disciplines will base on [6]:

(1) The disciplines demand to support the BIM advancement that would integrate with other advanced technologies in the direction of green evolution of the total project; and

Table 14. The classification of six BIM integration disciplines under seven sustainability domains to recognize the correlation between BIM and green buildings [6].

Sustainability domains		BIM integration disciplines	Sustainability points (examples)
Based on the concept of the phases of the project life.	Development	Law – Management	Local acts and regulations, appropriate planning and choosing the site, etc.
	Design	Law – Management – Information Communication and Technology (ICT) – Energy – Health Science	Green buildings, contract documents without paper, collaborative work, design for coexistence with natural systems, human comfort and lifestyles, etc.
	Construction	Law – Management – ICT-Engineering – Energy	Sustainable and green building techniques, management of green waste, high production, etc.
	Materials	Law – Management – ICT – Engineering – Energy – Heath Science	Advanced manufacturing techniques, green materials, products, etc.
	Energy consumption	Law – Management – ICT – Engineering – Energy – Health Science	Renewable and new energies, adaptation with natural systems, human comfort, and health, etc.
	Maintenance	Law – Management – ICT – Energy – Health Science	Protective and corrective, automation, sensors, etc.
	Demolition	Law – Management – ICT – Engineering – Energy	Environment-friendly policies and technologies, recycling, etc.

(2) These disciplines must depend on a comprehensive strategy to consolidate the increasingly sophisticated features and policies during planning, designing, constructing, and operating the built environment.

Based on the previous studies that indicated that applying BIM during projects attain many features of a green building, as shown in Table 15:

A process-based on a model to produce coordinated and harmonious building information all over the project life cycle improves energy efficiency performance and promotes attaining specific green objectives [5]. BIM can provide a chance to make the best utilization of accessible design information to sustainable design. Because BIM and green buildings continuously gain growing interest, organizations adopt green practices via BIM that promote buildings to be green [5]. Therefore, BIM enhances green features via its five core features, as in Figure 6.

Consequently, Current BIM platforms and its green characteristics are not limited to one stage of the project life cycle. More types of BIM platforms have been developed the analytical capacity throughout project life cycles. For instance, eQUEST as a BIM platform began to promote comprehensive energy performance analyses throughout the stages of building documentation, commissioning, post-occupancy, renovation, and demolition [3]. BIM supports and accomplishes green buildings within nine analyzes by which can assess the BIM maturity level, as in Table 16.

The role of collaboration and BIM maturity level to produce green buildings

There is still debate over the comprehensive BIM use in green buildings. Here the role of collaboration and BIM maturity levels appear. In the conviction of a group of professionals that the sustainability concept is not only the prime application of BIM; but also is project coordination and visualization. During construction, many consider BIM as a means to improve quality management

Table 15. Many features of a green building that applying BIM attains [11].

	Features		
Based on the concept of project life phases.	Facilitating the simulation and visualization.	Guaranteeing lower whole-life costs by green design	Promoting coordination.
	Reducing costs, increasing precision, and quick estimating cost.	Avoiding clashes up to 10% of the contract value is conserved by clashes detection.	Reducing the time (up to 7% shrinkage in time).
	Reducing requests for information and changing orders (up to 40% removal of unbudgeted difference).	Enabling the production of the building documents.	Perform analysis of green features to be green buildings.

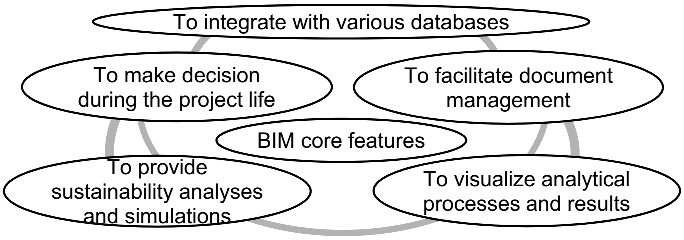

Figure 6. BIM core features [5].

Table 16. The main Functions of BIM for analysis of green buildings [21–23].

No.	Analysis	Main Functions
1	**Energy Consumption**	Total building energy analysis; Appraisals of diverse energy conservation measures; Feasibility assessments for renewable energy; and, Detect error and diagnose power systems.
2	**Carbon Emissions**	Carbon emission calculations; Carbon emission control; and, Design alternatives to reduce carbon emissions.
3	**Natural Ventilation**	Determination of natural ventilation capacity; and, Evaluation of different natural or mixed patterns of ventilation strategies.
4	**Solar and Daylighting**	Solar radiation analyzes of the outside of buildings; Analysis of the lighting condition; and, Simulation of lighting with a point.
5	**Acoustics**	Sound performance simulation; and, Improved visual and audio effects of simulated sound.
6	**Water usage**	Estimate water use; and, Maximize the water distribution system.
7	**User Performance**	Simulation, retrofit, and improvement during the design stage; and, Monitor comfort levels by incorporating sensors.
8	**Materials**	BIM integration and life cycle assessments to evaluate materials that are raw material extraction, manufacturing, packaging, transportation to site, building, installation, operation, even demolition, and recycling.
9	**Waste Management**	It is more important than minimizing its causes (design errors and rework). To reduce waste is to eliminate the causes, focus on waste minimization than reuse and recycle; so, clash detection, design review, quantitative take-off, and pre-fabrication can minimize it.

and scheduling as a begin sustainability. Furthermore, the surveys were concluded that most BIM projects are highly technologically integrated but divided organizationally. This organizational part may be complicated by some technical problems of BIM platforms such as the inadequate or low interoperability between different BIM platforms and across organizational borders [14]. However, many BIM platforms are mainly designed for one type of these analysis functions of BIM. Consequently, work teams may take advantage of their capability to utilize BIM platforms based on collaboration and the level of BIM maturity that rooted in organizational experience to employ this new BIM concept. Although, still there a demand for a comprehensive and integrated BIM platform for all green analysis that allows methodical analysis to attain a green building according to standard evaluation systems [5].

Potentials of BIM within the evaluation systems supported by collaboration and maturity levels

The previous studies have developed a model to distinguish different specifications of green buildings and they have supported analysis by BIM. Accordingly, BIM can present data to calculate many credit points to access the aim of green buildings by rating systems [4,24]. Collaboration and BIM maturity levels can facilitate the evaluation by systems [13,15,17,25]:

(1) BIM platforms assist stakeholders in determining the effective and more suitability framework to accomplish a green certification of a building. For example, BIM can support stakeholders to define the number of LEED or Green Star scores and certification level;
(2) BIM platforms can explain and account points to standard evaluation systems; and
(3) BIM platforms promote documentation management is required to get green certificates.

Consequently, BIM platforms can develop the performance and operation of these evaluation systems and support a building to be a green building. The gaps and obstacles must be overcome during taking advantage of BIM in executing features of green buildings [18,26,27]:

(1) The inadequate interoperability between multiple BIM platforms;
(2) The limited ability of BIM platforms in supporting the building and operation stages;
(3) Lack of codes or standards for typical integration of BIM platforms for different aspects of environment and management through multidisciplinary teams and stakeholders;
(4) Low industrial acceptance of green BIM applications, although a large number of BIM studies conducted on its importance;
(5) Low precision for prediction models based on BIM. For example, most certificates of evaluation systems such as LEED, rely on expected rather than real performance; and
(6) Lack of proper ways to the delivery of a green project to benefit from BIM platforms.

The framework to interrelationship between collaboration and the maturity level of a BIM model as an organizational strategy to produce green projects

The research deduces and proposes a framework to regulate and optimize the potentials of the collaboration and maturity level of a BIM model to take advantage of BIM in executing the concepts and features of green buildings as a strategic basis of a work team and an organization for producing green projects, as shown in Figure 7.

The inferred frame consists of two stages

The first stage is the qualification stage in which the firm or organization adopts BIM as Strategy through the following:

(1) Collaboration as a system has components, as in Figure 2 to operate and manage processes as the fundamental component of BIM. Therefore, the individual should be qualified as a unit that interacts with the components of the collaboration system through five perceptual determinants, as in Table 6, which enhance the interaction among stakeholders;

(2) Maturity level to take advantage of technology as the fundamental component of BIM on which processes depend as the second component to achieve the highest maturity level of the BIM model based on:

- Organizational experience of the organization or work team, which has:

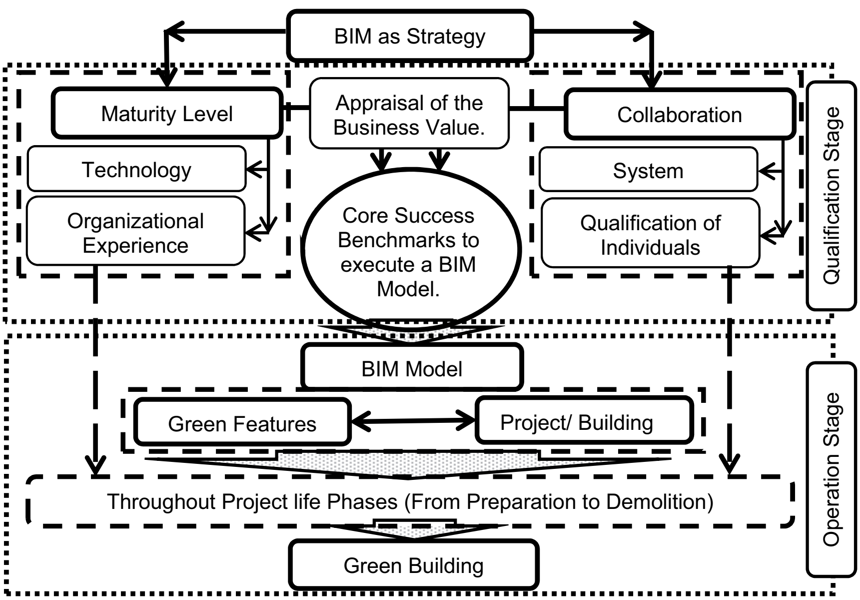

Figure 7. The organizational framework based on collaboration and BIM model maturity to produce green projects by BIM.

An institutional framework, as in Table 7, includes eight dimensions of the success of a project that have KPIs (Quality -Time – Cost) as a reliable predictor of project success; and, the organization establishes and consolidates its BIM maturity level Figure 4 and its ability inside a particular phase Figure 3 through six entrenched factors, as in Table 11.

- Technologies for determining the BIM capability phase, as in Table 8, then measuring the maturity level and achieving BIM performance during all project phases, as in Table 9.

(3) Difficulties in appraising the business value of the relationship between collaboration and maturity of a BIM model must be overcome in the six fields, as in Table 5; and

(4) During the qualification stage, the correlation success between collaboration and BIM maturity level should be reviewed by the nine factors, as in Figure 1, which confirm their linkage. They will be utilized as an evaluation tool for executing BIM successfully, predicting the success of the project to do necessary actions, and gaining a competing advantage to win bids.

The second stage is the operation phase in which the company or organization depends on

(1) The proposed framework comes out of its first phase to enter the operation stage as a second phase. Where the organization as a team is qualified and equipped to build and generate a BIM model for any project, such a model:

- It meets the detail levels (LOD) that were previously determined and attaining the possible progress according to the items, as in Figure 5.
- It has five BIM core features, as in Figure 6;
- It achieves a set of benchmarks that purposely developed to measure the performance of BIM as in Table 1, and to increase their trustworthiness, flexibility, and usability; also, parameters to track the progress by BIM, as in Table 2; and
- It measures the maturity model improvements for the project through the three sections for improvement from the lower to upper maturity levels of the BIM model, as in Table 10.

(2) This good model of the BIM-based project will facilitate and support the role of a work team (especially) and stakeholder to achieve the required project objective during the project life cycle, as in Tables 12 and 13, respectively;

(3) Moreover, try to overcome the risks and limitations of BIM execution, as shown in Tables 3 and 4, respectively;

(4) To utilize of BIM-related technologies to achieve the highest maturity level of such a BIM model and its capabilities stages to support

a project to be green. There are seven domains of sustainability as features of green buildings that were categorized to analyze BIM six disciplines, also classifying BIM integration disciplines under these domains, as in Table 14;

(5) Consequently, solving the problem of conventional practice in producing green buildings because of depending on an individual tactic within the single discipline while the production process, which forms the greatest obstacles to produce green buildings and the work market entry; and

(6) In addition, the execution of BIM during the project life phases after confirming the integration, as mentioned earlier, will achieve many features of green buildings, as in Table 15. The BIM support potentials will emerge during the life phases of green buildings to help work teams (especially) and stakeholders, as in Tables 12 and 13. These potentials can be used continuously throughout the project life phases to conduct the analysis of green buildings, as in Table 16. Their results and the potentialities of treating and development within the project will reflect the maturity level of the BIM model and the benefits of linking collaboration and BIM maturity as a business value. This business value the organizations are seeking to achieve at the beginning of the proposed and devised framework as a strategy for producing and executing green buildings, even if new green analyzes or new features of BIM have emerged.

Using the Delphi survey technique to validate the framework as an organizational strategy

With the aim of accrediting and verifying the validity of this practical framework as an effective and applicable strategy, and it is useful in the field of producing green buildings. A quantitative investigation procedure that included a three-round Delphi survey was utilized to capture agreeing on the effectiveness of the inferred framework. Delphi survey method is a technique that enables utilizing a series of questionnaires regularly with feedback or reviews (report summaries) for each round. To collect the judgment of a panel of experts on a specific topic in the field of BIM and sustainability to attain consensus among them. It is also beneficial when it is crucial to investigate areas of disagreement among specialists [28]. Forty-five specialists were invited. Finally, only 25 specialists (consisting of 9 academics and 16 practitioners) participated in the survey. The choice of the participants based their work in the field of the design and construction where they utilized or benefited BIM in the segment of the environmental design or green buildings or sustainability on the academic or practice levels. The investigation adopted the Likert Scale to judge, namely: 1 = Strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree and 5 = Strongly agree [29]. In beginning round two, the participants in the first round were

Table 17. The results of using the Delphi survey technique via three-rounds to validate and agree on the framework as an organizational strategy to produce green buildings.

Test Statistics	Rounds		
Kendall's (W) Test	First	Second	Third
N (No. of questionnaires)	25	25	25
(W)	0.45	0.552	0.768
Chi-Square	89.907	110.371	153.649
df (degrees of freedom = n-1)	8	8	8
Asymp. Sig.	0.000	0.000	0.000

(W): Kendall's coefficient of concordance. In nonparametric statistical tests, a strong agreement or consensus exists for $W \geq 0.7$; a moderate agreement for $W = 0.5$; and a weak agreement for $W < 0.3$.
n: The number of questions of the Survey questionnaire.
Asymp. Sig.: The p-value is less than 5% (significance level).

supplied individual feedback on the unified results or a nameless summary of the judgments obtained in the previous round, and the reasons they provided for their judgments. Furthermore, they are asked again to review or adjust their original judgments given the mean rating for each point. The same procedures were undertaken during round three [28]. The three rounds were analyzed statistically applying Kendall's coefficient of concordance (W), mean and standard deviation by using the SPSS software, version 16. Kendall's concordance analysis is used to measure the level of agreement among the experts and to determine whether the respondents respond consistently or not. In fact, it is always the case that $0 \leq W \leq 1$. If $W = 0$ then there is no agreement among judgments or $W = 1$ complete agreement and consensus exists. The value of W is recognized jointly the p-value of the analysis. If the p-value is less than 5% (significance level), it indicates that there is a considerable degree of agreement among the participators, as in Table 17.

The framework was developed and optimized to reach its current structure during the survey from the feedback during each round.

Discussions

(1) The reasons for agreeing on the importance of the inferred framework were, as follows:

- It changes the framework of the institutions or firms toward a better level of collaboration and the maturity of the BIM model that is produced to uptake, realize, and achieve the concepts and features of green buildings during all stages of the life of the project that they are working on.
- The strategy also optimized, uptake, and embraced all or the vast majority of the potential available to the maximum extent and extent possible. It cannot provide more than that although it can incorporate

new ways, means, and new capabilities. Being achieved in its current state is the best that can be achieved and accomplished.

- It is considered an effective strategy because it needs a duration of six months to a year, especially the qualification stage.
- The operation stage depends entirely on the qualification stage; this is what many specialists consider positive in the interest in qualification; but, some qualified individuals may leave the team and another enters his place needs a qualification period, which negatively delays and impedes producing and delivering the BIM model of a project.
- The effectiveness of the methodology or strategy appear in large and medium projects, but small projects may not make a notable difference.
- It reflects and is an indication of the capabilities and the ability of the firms or teams to achieve all possible features of green buildings in all project life stages.

(2) The maturity of any additional BIM elements is assuredly associated with each performance indicator. Investments to improve BIM strategy maturity must prove an acceptable return in performance, cost, and time.

(3) BIM strategy was often formulated as the group of the other six entrenched organizational BIM factors Table 11.

(4) Given the rapid pace of the development of BIM technology, the tool may not represent the latest technology to allow a balanced measurement of BIM maturity level [7].

(5) There is still a lack of agreement among researchers and practitioners about BIM applications for developing and attaining green buildings.

(6) The most management challenges to apply BIM until now, there is no explicit agreement by BIM on how to utilize BIM to produce green buildings.

(7) Many platform companies take advantage of BIM's 'buzz' and have programs to treat some quantitative aspects of it, but they do not deal with processes as a combination.

(8) To improve BIM performance, organizations or vendors must find a way to reduce the learning curve of BIM learners.

(9) Platform vendors face a greater obstacle in providing a high-quality product to get Clients on reliable and manageable, and meet expectations set by the announcements.

(10) The BIM industry should develop adequate processes and policies that support the use of BIM and control current ownership and risk management issues [8].

(11) The lack of a clear strategy by BIM in the field of green buildings and the lack of organizational expertise in any firm that many see will negatively affect the future of BIM. However, others see it as an opportunity for companies and organizations to differentiate in the business market

and as a commercial value whenever they have a mature strategy that accommodates collaboration and stages of BIM capability to produce green projects.

Conclusions

The main conclusion is the deduced organizational framework to regulate and optimize collaboration and maturity potentials of a BIM model as a strategic basis of firms to produce green buildings. This framework depended on the effective role of collaboration and increasing BIM maturity level to take advantage of BIM in executing the concepts and features of green buildings. This framework will treat and solve the problem of individual tactics and lack of a clear strategy adopted by BIM to execute green buildings through a BIM model of any project. This BIM model involves many disciplines as well as all stakeholders. Accordingly, it is required that collaboration is as a system between them to regulate and operate processes as well as interoperability during this model to benefit from it. Therefore, this collaboration supports and increases the maturity level of the BIM model and the progress in the BIM capability phases. This maturity level depends on benefiting from the provided technologies by BIM, improving, and supporting the level of organizational expertise of an organization, a company, or a team. Thus, it will have a strong positive impact on the successful production and execution of green projects by BIM. These projects will reflect the maturity level of BIM and the extent of true collaboration and the benefits of integrating BIM with the concepts and principles of green buildings as business value and will seek all partners and companies to adopt them in the future or from now. This proposed framework as a practical strategy can be developed and modified depending on the policy of each company or agency. Besides, the possibility of supporting and improving this framework after its execution and application throughout the life of projects to be the beginning of other strategies more advanced with the advances in BIM technologies.

Disclosure statement

No potential conflict of interest was reported by the author.

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